

**PAEDIATRIC REGIONAL ANAESTHETIC PROCEDURES:
CLINICAL ANATOMY COMPETENCE, PITFALLS AND
COMPLICATIONS.**

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Abstract

Paediatric regional anaesthetic procedures: clinical anatomy competence, pitfalls and complications.

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Clinical procedures are an important part of the daily work of doctors of various specialities, including the practice of regional anaesthetic procedures on paediatric patients. The competency that a doctor displays in clinical procedures is an important aspect of their overall clinical competence and the successful performance of regional blocks demands a working and yet specific knowledge of the anatomy underlying each procedure, especially knowledge regarding the relative depth or specific positions of certain key structures in paediatric patients, as it is known that the anatomy of children differ to a greater or lesser degree from that of adults.

Precise information on epidemiology and morbidity of paediatric regional anaesthesia, especially from a clinical anatomy perspective, remains scarce. The aim of this study was therefore: (1) to determine, through means of a questionnaire, the scope of regional anaesthetic techniques performed on paediatric patients in South Africa, as well as, determine the competence of anaesthesiologists to perform these procedures based on their clinical anatomy knowledge regarding each nerve block; (2) select 5 problem procedures based on the anatomical competence that anaesthesiologists display when performing each nerve block; and (3) develop an extensive, referenced clinical anatomy knowledge base regarding each of the 5 problem procedures.

A list of 18 regional anaesthetic procedures common in paediatric practice was compiled and a detailed questionnaire was completed by a randomly selected sample of anaesthesiologists (n=80) working in both government institutions and in private practice.

The problem procedures chosen were those that were performed most often; ranked important; encountered most difficulties and complications; where anaesthesiologists felt uncomfortable performing the procedures and where the influence of clinical anatomy knowledge on the safe and successful performance of the procedure was ranked highest. The 5 problem procedures selected are the following: caudal epidural block, lumbar epidural block, the axillary approach to the brachial plexus, femoral nerve block and the ilioinguinal/ iliohypogastric nerve block. A referenced clinical anatomy knowledge base was developed by an extensive literature review of the selected procedures under the following headings: Indications, contraindications, step-by-step technique, anatomical pitfalls, anatomically related complications and references.

Opsomming

Pediatriese regionale narkoseprosedures: kliniese anatomie vaardigheid, slaggate en komplikasies.

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Kliniese prosedures vorm 'n belangrike deel van die daaglikse werk wat dokters, van verskillende spesialiteits velde, verrig. Dit sluit ook regionale narkose, wat op pediatriese pasiënte uitgevoer word, in. Die vaardigheid van 'n dokter tydens die verrigting van kliniese prosedures bly 'n belangrike aspek van sy algehele kliniese vaardighede en die suksesvolle uitvoering van regionale senuweeblokke verreis 'n aktiewe, en tog spesifieke, kennis van anatomie onderliggend aan elk van die regionale prosedures is. Dit is veral belangrik wanneer dit by die relatiewe dieptes of spesifieke posisies van sekere belangrike strukture in pediatriese pasiënte kom, siende dat dit algemeen herken word dat die anatomie tussen volwassenes en kinders, tot 'n groter of kleiner mate, wel verskil.

Daar is 'n definitiewe tekort aan noukeurige informasie wat oor epidemiologie en morbiditeit, wat met pediatriese regionale narkose geassosieer word, handel, veral vanaf 'n klinies-anatomiese perspektief. Die doel van die studie was dus om die volgende vas te stel: (1) deur middel van 'n vraelys 'n oorsig te verkry oor pediatriese regionale prosedures wat deur Suid-Afrikaanse narkotiseurs verrig word, sowel as die vaardighede waarvoor die narkotiseur beskik om die prosedures suksesvol uit te voer. Laasgenoemde is op die anatomiese vaardighede wat hy of sy tydens die uitvoering van elke prosedure toon, gebaseer; (2) om 5 probleemprosedures te selekteer, wat weereens op die anatomiese vaardigheid wat die narkotiseur tydens die uitvoering van elke prosedure toon, gebaseer is; en laastens (3) om 'n ekstensiewe literatuurstudie van elk van die geselekteerde probleemprosedures te doen.

'n Lys van 18 regionale narkose prosedures, wat algemeen deur narkotiseurs op pediatriese pasiënte uitgevoer word, was saamgevat in die vraelys wat aan 'n lukraak gekose groep narkotiseurs (n=80), van beide staatsinstansies en privaatpraktyk, gegee is om in te vul.

Die gekose probleem prosedures, was die prosedures wat die algemeenste deur die groep narkotiseurs verrig word; wat as belangrik beskou word; waar tydens die meeste probleme en komplikasies teëgekomp is; die prosedures waar narkotiseurs ongemaklik was tydens verrigting van die prosedure; en waar die invloed van anatomiekennis, om die prosedure veilig en suksesvol te kan verrig, die hoogste geklassifiseer is. Die 5 probleemprosedures wat gekies was, was: kaudale epidurale blok, lumbale epidurale blok, bragiale pleksusblok (aksillêre toegang), femorale senuweeblok en die ilioïnguinaal/ iliohipogastriese senuweeblok. 'n Ekstensiewe literatuurstudie oor die 5 geselekteerde probleemprosedures was uitgevoer met die volgende hoofopskrifte: indikasies, kontra-indikasies, stap-vir-stap tegniek, anatomiese slaggate, anatomies- verwante komplikasies en bibliografie.

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1. Introduction

1.1 Importance of clinical anatomy

The safe and successful performance of any clinical procedure demands a working and yet specific knowledge of the anatomy associated with that procedure ¹.

Often doctors who lack the appropriate anatomy knowledge to perform the procedure successfully are responsible for prolonging the specific procedure. This may be accompanied by complications of various degrees ², as well as, increased morbidity and mortality ³.

The primary importance of a sound understanding of the anatomy underlying clinical procedures is therefore to the benefit of patients.

With this in mind, clinical anatomy remains one of the most valuable subjects to any medical practitioner ⁴, however in recent years the teaching of anatomy in medical schools has changed dramatically. Decrease in dissection time or complete abolishment of dissection of human cadavers has been adopted in certain medical schools ^{2,4}.

However, anatomy forms a very important part of medical practice and clinically applied anatomy is usually defined as anatomy applied to patient care ⁴. An advanced knowledge of the anatomy associated with clinical procedures is doubly important for doctors in developing countries where high technology is often lacking. Therefore, doctors of all specialities are often dependent on their anatomical knowledge for the successful performance of clinical procedures ⁵.

Despite the almost limitless possibilities in medical research today as well as the rapidly expanding possibilities in medical technology, the effective performance of clinical procedures still rests on a solid anatomical basis. This includes the performance of all clinical procedures, which depend heavily on a sound knowledge of human anatomy ⁵.

A medical speciality that relies especially on sound clinical anatomy knowledge is the practice of regional anaesthetic nerve blocks. This is especially true for anaesthesiologists who perform regional nerve blocks on paediatric patients ⁶. Clinical procedures, such as regional nerve blocks, which either fail to achieve their objective or that result in complications, can often be linked to a lack of understanding or misunderstanding of the anatomy relevant for the specific procedure ¹. This is also true for regional anaesthetic procedures for paediatric patients ⁷, as many complications that occur during regional anaesthesia in paediatric patients are often anatomically related and could have been avoided had certain precautions been taken, or if the anatomical knowledge of the doctor performing the procedure had been sufficient.

Winnie and co-workers ⁸ states that no technique could truly be called simple, safe and consistent until the anatomy has been closely examined. This is very true, for as one can see in the literature, many anatomically based studies regarding certain regional techniques have resulted in the improvement of known techniques, as well as the creation of safer and more efficient techniques and the renouncement of outdated and clinically difficult or dangerous techniques. This constant advancement of regional anaesthetic techniques ensure that nerve blocks will well remain, and in future prove to be a dominant aspect of any anaesthesiologist's clinical practice.

1.2 Clinical competence

Clinical procedures are an important part of the daily work of doctors of various specialities. This also includes performing regional anaesthetic procedures on paediatric patients by anaesthesiologists. The competency that a doctor displays in clinical procedures can be seen as an important aspect of their overall clinical competence. Furthermore, an important part of this competency is a sound knowledge of the anatomy relevant to the specific procedure. The most important elements of competence according to Wigton⁹ are the cognitive aspects: knowing indications and contraindications, managing complications, and interpreting results.

It is important to focus on the competency of doctors to perform clinical procedures, especially the underlying anatomical knowledge of the procedure, such as a regional nerve block, safely and successfully. The performance of any clinical procedure needs a certain level of competency in order to be performed safely and effectively, fewer complications should occur¹⁰. Competency exists when a practitioner has sufficient knowledge and manual skill, such that a procedure can be performed to obtain the intended outcomes and without harm to the patient. Competency is especially important when failure of the procedure could result in complications or cause patient discomfort¹¹.

An important part of competency is therefore a sufficient and updated knowledge base, which is necessary to perform a safe and successful procedure. Recognition of the relevant anatomy to any specific procedure remains the important basis of this knowledge.

1.3 Role of paediatric regional anaesthetic techniques

Over the last thirty years there has been a renewed interest in the practice of paediatric regional anaesthetic procedures, as many procedures have been extensively evaluated and researched and as there are an abundance of data available on many of the techniques and for nearly all paediatric age groups. As Clergue and co-workers¹² stated: “the practice of anaesthesia has both increased and changed over the last 16 years”. Along with more aggressive administration of parenteral medications, the use of regional nerve block techniques have become more prevalent in recent years, the number of cases of regional anaesthetic procedures increased from 4% to 23% between 1980-1996¹³.

However, accurate information on the epidemiology and morbidity of paediatric regional anaesthesia remains relatively scarce¹³⁻¹⁸.

An extensive literature search regarding regional anaesthetic procedures revealed them to be safe and efficient, increase postoperative pain control, and decrease side effects that a patient might experience such as nausea, sedation and hyperventilation¹⁹⁻²⁶.

However, studies of anaesthetic morbidity and mortality have suggested that children might be at greater risk when compared to adults²⁶⁻²⁹. From 1985 to 1992 Morray and co-workers³⁰ collected 2400 closed malpractice claims of which 28% of all paediatric claims involved children younger than 1 year of age (55% involved children of 3 years and younger).

It is with this knowledge, or lack thereof, that this study was undertaken. The goal of the initial survey was to shed light on the situation in which South African anaesthesiologists find themselves, especially those that perform, or those that would prefer to perform, regional nerve blocks on paediatric patients. The only way that this can be accomplished is to find out which procedures are currently being performed by anaesthesiologists in the diverse setting that South African doctors find themselves in everyday.

In an Internet database ³¹, compiled in January of 2004, it showed that per capita, South Africa has the 15th highest mortality rate in the world (0.02 deaths per 1 million people) due to anaesthesiology related incidents. This does not however discriminate between adult and paediatric anaesthesiology or general or regional anaesthesiological complications.

It does however show that knowledge of regional anaesthesia, although more than a century old, may still be improved through scientific study and research.

1.4 Anatomical differences between adults and children

Even though, it is obvious that regional anaesthetic procedures can benefit children by improving operating conditions and postoperative analgesia. The anaesthesiologists performing these procedures must have a clear understanding of (1) the anatomy, (2) the influence of age and size, and (3) the potential complications and hazards of each procedure, if good results are to be achieved and morbidity avoided³². Ellis and Feldman³³ stated that anaesthesiologists required a particularly specialised knowledge of anatomy, which in some cases should even rival that of a surgeon.

Using regional anaesthetic procedures on paediatric patients brings forth even more complications. First, the fact that those not working regularly with children might not be used to working on a dose/ weight basis. Secondly, and most importantly, the lack of knowledge of relative depth or specific positions of certain key structures in paediatric patients, as it is known that the anatomy of children differ to a greater or lesser degree from that of adults^{6, 32, 34, 35}.

A thorough knowledge of the regional anatomy and its specific anatomical landmarks is an essential prerequisite to successful nerve blocks and it cannot be substituted by probing with a needle attached to a nerve stimulator. The anatomy described in adults is not always, and in most instances not applicable to children as anatomical landmarks in children vary with growth. Bony landmarks, (e.g. the greater trochanter of the femur) are poorly developed in infants prior to weight bearing. Muscular and tendinous landmarks, commonly used in adults tend to lack definition in young children partly because of poorer muscle development⁶, but also because they require patient cooperation to locate them and most children are under a light general anaesthesia when the nerve block is being performed^{6, 36}. The advantages of combining both regional and a light general anaesthesia are that it reduces the requirements for intravenous and inhaled agents, therefore decreasing the risk of complications and also decreasing the recovery time³⁷. Finally,

classical anatomical landmarks are absent or difficult to define in children with congenital anatomical deformities ⁶.

It is important to realise this fact, especially when performing a nerve blockade on a paediatric patient. Sound knowledge and understanding of anatomy is vitally important for successful nerve blocks. Extrapolation of anatomical findings from adult studies and simply downscaling these findings in order to apply them to infants and children is inappropriate ³⁸.

There is therefore a need to study the paediatric anatomy specifically applied to regional anaesthetic procedures.

1.5 Techniques: Anatomy knowledge and nerve stimulation

Accurate placement of the needle in close proximity to the nerve is essential for a successful block³⁹, and correct placement requires a familiarity with regional anatomy and landmarks³². Difficulty arises when there is anatomical variation as seen in the growing child and when landmarks are difficult to identify. Techniques based on measurements from a fixed anatomical point clearly have limitations when applied to all age groups.

Seeking *paresthesia* as a sign of accurate needle placement requires both patient understanding on the part of the anaesthesiologist as well as cooperation from the patient, which is often unlikely to be forthcoming in a neonate or young infant, frightened child or a child under light general anaesthesia⁴⁰.

A *nerve stimulator* allows for the localisation of a nerve by the electrical stimulation of its motor component and is particularly useful when the patient is under general anaesthesia, which is often the case in children undergoing regional anaesthetic procedures³⁶. A study conducted by Bosenberg⁴¹ revealed that a relatively cheap, unsheathed needle could be successfully used to locate peripheral nerves with the aid of a nerve stimulator in anaesthetised children. Although a slightly larger current is required to produce a motor response when compared to sheathed needles, a success rate of greater than 98% underlines its value as a cost-effective teaching tool, and the ease with which a technique can be mastered when using a nerve stimulator.

Surface nerve mapping is a modification of the standard nerve stimulator technique and can be used to trace the path of a nerve prior to skin penetration. Surface nerve mapping could prove to be most useful in paediatric patients since anatomical landmarks are least precisely defined⁶, and paediatric patients are at the greatest risk for complications of regional anaesthesia.¹⁴ Nerve mapping offers a further dimension for localisation of

superficial peripheral nerves prior to skin penetration in both infants and children ⁶

Peripheral nerve stimulation should not be a substitute for sound anatomical knowledge and careful technique ⁶. In a study conducted by Bosenberg and co-workers ⁶ they did however show that using a nerve stimulator does provide a greater degree of reliability and accuracy in finding the correct needle insertion site than when using purely anatomical landmarks or paresthesias to perform nerve blocks. It is also a safer technique for getting in close proximity to the actual nerve.

A combination of using a nerve stimulator/ surface nerve mapping device and anatomical landmarks seem to be the best recipe for accurate, safe and successful blockade ⁴¹.

Ultrasonography may offer significant advantages in regional anaesthesia of the upper and lower limbs. Recent studies have shown non-invasive technique to be effective in successfully locating the nerves. Marhofer and co-workers ⁴² performed a prospective, randomised study comparing ultrasound visualisation to conventional nerve stimulation for infraclavicular brachial plexus anaesthesia in children. Forty children scheduled for arm and forearm surgery underwent infraclavicular brachial plexus blocks guided by either nerve stimulation or ultrasound visualisation. In their study, direct ultrasound visualisation was successful in all cases and was associated with significant improvements when compared with the use of nerve stimulation. They therefore concluded that ultrasound visualisation offers faster sensory and motor responses and a longer duration of sensory blockade than nerve stimulation in children undergoing infraclavicular brachial plexus blocks. In addition, the pain associated with nerve stimulation due to muscle contractions at the time of insertion is eliminated.

1.6 Complications during paediatric regional anaesthesia

Although regional anaesthesia avoids many of the complications associated with general anaesthesia, there are certain complications, often associated with the local anaesthetic solution, which should be considered. These include:

- Central nervous system toxicity, which could lead to:
 - Tonic-clonic seizures, which is a very serious complication, provided that it is treated immediately, it should not lead to cerebral injury or death;
 - Nystagmus;
 - Sudden vertigo;
 - Brief blackouts;
 - Inability to move or respond to external stimuli.
- Cardiovascular toxicity.
- Allergic reactions.

These complications can occur due to either an overdose of local anaesthetic solution, when the safe amount of anaesthetic indicated for the procedure is exceeded or, more commonly, by an accidental intravenous injection⁴³.

With epidurals, incidents of total spinal anaesthesia after accidental dural puncture have been described in the literature⁴⁴, as well as, convulsions that can be ascribed to intravascular injection of the local anaesthetic solution^{25, 26}.

In spinal anaesthesia, ventilatory depression or apnoea have occurred due to an undesirably high level of blockade⁴⁵. Post-spinal headache also occur in paediatric patients following spinal anaesthesia⁴⁶.

Along with general complications that may accompany the performance of regional anaesthetic techniques some complications are specific for each procedure. Complications often cause damage to certain key

anatomical structures, thereby resulting in anything ranging from patient discomfort, a failed block, or even to serious morbidity or death.

An example of this is dural puncture during the performance of a caudal epidural block. Complications that could result from dural puncture ranges from postdural headaches, which although rare, have been described in children where the dura was punctured ⁴⁶ to a total spinal block, which could lead to the patient becoming rapidly apnoeic and profoundly hypotensive. Management includes control of the airway and breathing, and treatment of the blood pressure with intravenous fluids and vasopressors such as ephedrine ⁴⁷. This could be fatal in high-risk infants.

1.7 Role of regional anaesthesia in developing countries

South Africa finds itself in a somewhat unique situation, having to cater for both first and third world patients in a host of different clinical settings. From private hospitals with state-of-the-art equipment and a full quota of experienced staff members to poorly kept clinics in rural areas with only the bare minimum of equipment and a shortage of staff.

This appears to be the two extremes of the spectrum in which medical professionals find themselves. It is because of the overwhelming need for cost-effective treatment and the lack of expensive medication and equipment found in some of these rural areas, and even in some of the larger hospitals, which have lead to the emergence of some of the most experienced anaesthesiologists in the world.

Regional anaesthesiology appears to be flourishing in South Africa. Albeit because of the lack of equipment, the high frequency of emergency procedures that anaesthesiologists are exposed to, or the need for analgesia amongst both rural and urban patients, anaesthesiologists in South Africa still have to contend with all these difficulties and be able to provide effective pain management for patients. Exposure to such harsh conditions stresses the need for the equipment of anaesthesiologists with an extensive arsenal of techniques to enable them to deal with all but the most severe cases, even in the absence of more sophisticated medical equipment.

Regional nerve blocks provide South African anaesthesiologists with a safe and effective method of managing pain in paediatric patients. It is because of practicing in rural areas with a lack of proper equipment that it is even more essential for South African anaesthesiologists to understand the importance of a reliable knowledge of each regional anaesthetic technique, i.e., indications, contraindications, the technique, and possible complications; to posses adequate practical skill to perform the procedure; experience, and very importantly, a sound knowledge of the anatomy surrounding the procedure ^{1, 6, 9, 32}.

Regional nerve blocks therefore play a pivotal role in the developing countries like South Africa. Proper knowledge of these techniques is therefore essential for the anaesthesiologist. This in turn will allow them to be able to cope in any situation with minimal assistance and with the most basic equipment.

Incidence of conditions that are ideally suited for the use of regional anaesthetic procedures in South Africa, and which are predominantly prevalent in the rural settings include ^{6, 19, 41, 48, 49-59.}

- Repair of (strangulated) inguinal hernias;
- Repair of umbilical hernias;
- Repair of hydrocele;
- Repair of hypospadias;
- Performance of orchidopexy;
- Anorectal surgery;
- Genitourinary surgery in both males and females;
- Pelvic surgery;
- Surgery on the hip and the lower extremities;
- Surgery of the area of the coccyx;
- Testicular torsion;
- Repair of omphalocele;
- Treatment of unstable fractures of the upper extremity;
- Reduction of dislocations;
- Reduction of fractures;
- Amputations; and
- Procedures of the upper extremities, especially when the lesions involve the forearm and/ or the hand.

Regional anaesthetic procedures are ideal in the ambulatory or day-case setting for a range of minor and emergency procedures, i.e., circumcision and inguinal hernia repair, where the parents of the paediatric patient can ill afford the time and money necessary to have their child stay unnecessary periods of time in a medical clinic.

1.8 General indications of regional anaesthesia

Regional anaesthesia has more indications than general anaesthesia since it covers not only the intra-operative but also the postoperative period, it can be used to treat both acute and chronic pain, and in addition it also provides both sympathetic and motor blockade³⁷.

Patients often have certain conditions, which make them ideal candidates indicated for regional nerve blocks, e.g.:

1. *Disorders of the respiratory tract:* The presence of respiratory diseases is in most cases (except the interscalene block, which has a high incidence of phrenic nerve blockade) an indication for the use of regional anaesthetic techniques. A regional nerve block can safely be performed on paediatric patients with respiratory distress, provided that the needle insertion, as well as the surgical site, is easily accessible. In certain cases, regional anaesthesia can be performed under mild general anaesthesia, after the patient has been intubated. In these cases peripheral blocks may be more preferable than central blocks. The advantages of combining both regional and general anaesthesia are that it reduces the requirements for intravenous and inhaled agents, thus decreasing the risk of complications and also decreasing the recovery time. The patient should be extubated only when fully awake and with the effect of anaesthetic inhalant worn off. This will allow the anaesthesiologist to effectively avoid aspiration³⁷.

2. *Disorders of the central nervous system:* This is often considered to be a contraindication for performing regional nerve blocks. It is however more likely that an anaesthesiologist would refrain from performing regional nerve blocks on these patients more from the fact that there is a concern that the regional nerve block might worsen the disease state. The only true contraindications for performing regional nerve blocks on these patients are mechanical (neuropathy) and infectious conditions (infections in the vicinity of the block). Nevertheless, all children with disorders of the central nervous system should undergo careful evaluation before performing any regional

nerve block on them. A neurologist should preferably do the evaluation, and as always the risk versus benefit ratio should be carefully examined.³⁷

3 *Myopathy and myasthenia*: Regional anaesthesia is especially indicated for patients with muscular dystrophy because it avoids the complications of general anaesthesia, particularly malignant hyperthermia. Unfortunately, due to the various anatomical deformities often found in these patients, certain regional nerve blocks might be more difficult to perform³⁷.

Like all clinical procedures, the indications for a regional anaesthetic is based on well established criteria, such as patient safety, quality of analgesia, duration of surgery, and whether the surgical procedure can be termed as a minor or a major procedure^{36, 37, 60-63}.

Indications should not be decided by the subjective preferences of the anaesthesiologists about to perform the procedure or on the basis of mastery of the specific technique, although this is vital when the procedure is actually performed, but solely on whether the technique is required by careful examination of the indications³⁷.

In order to select the best anaesthetic technique available, the benefits and risks of the regional nerve block should first be weighed against the advantages and disadvantages of all other available techniques of analgesia, i.e., general anaesthesia⁶⁰.

1.9 Skills required for paediatric anaesthesia

Other than the cognitive aspects of competency, experience and skills play a large role in the clinical competence of practicing anaesthesiologists, as regional nerve blocks requires particular skills on the part of the anaesthesiologist⁶⁴.

Fear of failure, as well as, complications remain an important deterrent for those anaesthesiologists who have had little opportunity during his/ her training to develop expertise in performing regional nerve blocks, especially on high-risk neonates.

Kopacz and co-workers⁶⁵, they aimed to determine the minimum amount of blocks that a new anaesthesiologist trainee must undertake before becoming clinically competent to perform these blocks. Clinical competence was achieved where there was a 90% or greater success rate for the procedure. They found that it takes approximately twenty-five epidural blocks before improvement in the technique is demonstrated and about sixty successful cases to be deemed competent. This study only looked at the technical aspects regarding regional blocks, i.e., the correct placement of the needle, and not other aspects such as choosing the correct anaesthetic solution or determining the correct dose per individual patients. The authors further conclude that a thorough knowledge of indications, contraindications, possible complications and side-effects, as well as, variations present in the anatomy is essential before proficiency in any regional nerve block technique can be gained.

Bosenberg and co-workers⁶ noticed that trainees or those who are inexperienced in nerve blocks seem more willing to attempt different nerve blocks when using the “nerve mapping” technique and they stated that: “Successful blockade inspires confidence and generates enthusiasm. In the process practical experience is gained and, as the individual becomes more familiar with the anatomical landmarks, they may become less reliant on the nerve mapping technique.” However, peripheral nerve stimulation should not be a substitute for sound anatomical knowledge and careful technique.

Therefore, this research focuses on determining which regional anaesthetic procedures are performed on paediatric patients, by anaesthesiologists, in South Africa. It also aims to determine the competency of anaesthesiologists to perform a range of paediatric regional anaesthetic procedures. This especially refers to the underlying anatomical knowledge necessary to perform these procedures safely and successfully.

2. Aims and Objectives

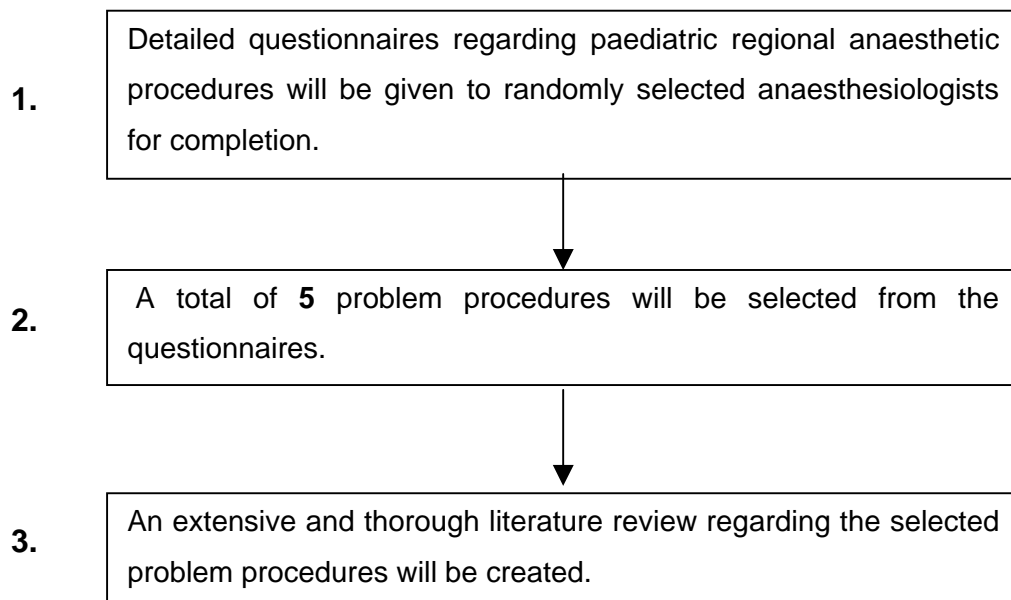
The aims of the research (indicated schematically in Figure 1) are:

- 2.1 To develop a survey in order to reach the following objectives by means of a questionnaire:
 - 2.1.1 Determine which paediatric regional nerve block procedures are performed by anaesthesiologists or anaesthesiologists in training practicing in South Africa.
 - 2.1.2 Determine the frequency of performance of these procedures.
 - 2.1.3 Determine the importance rating of the procedures by anaesthesiologists or anaesthesiologists in training.
 - 2.1.4 Determine the comfort levels of anaesthesiologists or anaesthesiologists in training to perform these procedures.
 - 2.1.5 Determine the difficulties that might be associated with these procedures.
 - 2.1.6 Determine the anatomically related complications encountered whilst performing the procedures.
 - 2.1.7 Evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the role of clinical anatomy competency in reducing difficulties and complications.
 - 2.1.8 Evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the role of clinical anatomy in improving confidence in the performance of clinical procedures.
- 2.2 To select a total of **5 problem procedures** from a list of paediatric regional anaesthetic procedures (see Table 1 on page 29) using the selection criteria stated in 3.2, where the main area of focus is on the anatomically relevant difficulties and complications which might be found when performing one of these procedures.

- 2.3 To develop a clinical anatomy knowledge base for selected problem procedures, identified in the second aim, to increase the cognitive competence of anaesthesiologists performing regional nerve blocks on paediatric patients.

Together with the development of the anatomy knowledge base, identify “gaps” with regards to the role of anatomy, in a paediatric/neonatal population group, for each problem procedure selected.

Figure 1: Schematic diagram illustrating the research process in a flow diagram.



3. Material and methods

3.1 Development and survey

A qualitative research method was employed, by means of a detailed questionnaire (see appendix A), to determine the scope of paediatric regional anaesthetic procedures performed by anaesthesiologists practicing in South Africa.

This research on *paediatric* regional nerve blocks. This includes neonates (less than 1 month old), infants (between 1 month and 1 year old), toddlers (between 1 and 3 years old), and children (between 3 and 12 years old).

The questionnaire was developed after an extensive literature review and also by means of feedback obtained from anaesthesiologists who completed a pilot questionnaire (see appendix B) while attending a regional anaesthesia workshop at the Department of Anatomy, University of Pretoria. This pilot study provided useful information on shaping the questionnaire. It also allowed for the identification of problems that might have been present in the questionnaire.

Furthermore, discussions were conducted with an anaesthesiologist ^a performing paediatric regional anaesthetic procedures on a daily basis.

After an extensive search of the literature, a total of 18 paediatric regional anaesthetic procedures were selected for this study (see Table 1 on page 29). Furthermore a blank form was also attached to the questionnaire where anaesthesiologists could, if they felt inclined to do so, add any procedures that they might also perform, other than the ones indicated on the questionnaire.

^a Prof. AT Bosenberg. Department of Anaesthesiology, Faculty of Health Science, University of Cape Town.

The questionnaire was developed to identify: (1) which paediatric regional anaesthetic procedures are performed by a reliable sample of anaesthesiologists; (2) the frequency of performance of the procedures; (3) the importance of regional anaesthetic procedures in anaesthesiological practice; (4) the comfort levels of the anaesthesiologists to perform the specific regional anaesthetic procedures in paediatric patients; the (5) difficulties and (6) anatomically related complications that the anaesthesiologists might experience during the performance of the specific regional anaesthetic procedure and finally the role that a solid knowledge of clinical anatomy play in (7) reducing these difficulties and complications and (8) in improving the confidence levels of performance.

A significant sample (n=80) of anaesthesiologists was randomly selected to participate in the study by completing a detailed questionnaire. Informed consent was first obtained from the anaesthesiologists that partook in the study with the guarantee that no participants would be identified during the survey and anonymity would be maintained. Each anaesthesiologist participating in the study also completed a section relating to the demographic profile of the participant.

Statements or questions were developed to reflect the specific aims and objectives and determine the response(s) of the anaesthesiologists. This is summarised in Table 2a.

A literature review was performed to determine the most common complications for every procedure, which are directly related to clinical anatomy knowledge. These were included in the questionnaire. The participants had to tick those complications that they have experienced before. They were able to tick more than one box if multiple complications have been experienced. When they did not tick any box, it was assumed that they have not experience any complications during the performance of the procedures. This is summarised in Table 2b.

Demographic data for every practitioner was also obtained. This included years in practice (experience), highest qualification, and type of practice.

Table 1: List of procedures

Paediatric Regional Anaesthetic Procedures	
Central Nerve Blockade	
1.	Caudal block
2.	Spinal block
3.	Lumbar epidural block
4.	Thoracic epidural block
Peripheral Nerve Blockade	
1.	Infraclavicular brachial plexus block: Axillary approach
2.	Supraclavicular brachial plexus block: Interscalene approach
3.	Femoral nerve block
4.	Lateral cutaneous nerve of the thigh block
5.	“3-in-1” block
6.	Fascia iliaca compartment block
7.	Psoas compartment block
8.	Sciatic nerve block: Anterior approach
9.	Sciatic nerve block: Posterior approach
10.	Sciatic nerve block: Lateral approach
11.	Ilioinguinal and iliohypogastric nerve block
12.	Penile block
13.	Intercostal nerve block

Table 2a. Questionnaire development of aims and objectives, statements or questions and responses for every procedure

<i>Aim</i>	<i>Statement/ Question</i>	<i>Response</i>				
2.1.1 To determine which paediatric regional anaesthetic procedures are performed.	I perform this procedure in my practice.	Yes/ No				
2.1.2 To determine the frequency of performance of these procedures.	How many times did you perform this procedure in the past year?	<table border="1"> <tr> <td>More than 20</td> <td>10-20</td> <td>5-10</td> <td>Less than 5</td> </tr> </table>	More than 20	10-20	5-10	Less than 5
More than 20	10-20	5-10	Less than 5			
2.1.3 To determine the importance rating of the procedures.	How important is the performance of this procedure to my practice?	<table border="1"> <tr> <td>Essential</td> <td>Desirable but not essential</td> <td>Useful</td> <td>Not necessary</td> </tr> </table>	Essential	Desirable but not essential	Useful	Not necessary
Essential	Desirable but not essential	Useful	Not necessary			
2.1.4 To determine the comfort rating of anaesthesiologists in performing the procedures.	How comfortable do I feel to perform this procedure?	<table border="1"> <tr> <td>Very comfortable</td> <td>Fairly comfortable</td> <td>Uncomfortable</td> <td>Very uncomfortable</td> </tr> </table>	Very comfortable	Fairly comfortable	Uncomfortable	Very uncomfortable
Very comfortable	Fairly comfortable	Uncomfortable	Very uncomfortable			
2.1.5 To determine the difficulties associated with the procedures.	I find difficulty to perform this procedure due to the following reason(s):	<table border="1"> <tr> <td>Knowledge of the procedure itself</td> <td>Equipment necessary for the procedure</td> <td>Practical skills to perform the procedure</td> <td>Regional anatomy knowledge</td> </tr> </table>	Knowledge of the procedure itself	Equipment necessary for the procedure	Practical skills to perform the procedure	Regional anatomy knowledge
Knowledge of the procedure itself	Equipment necessary for the procedure	Practical skills to perform the procedure	Regional anatomy knowledge			
2.1.6 To determine the complications encountered whilst performing the procedures.	I met the following complication(s) after performing this procedure: ^b	Femoral nerve block is given as an example: <table border="1"> <tr> <td>Difficulty locating needle insertion site</td> <td>Femoral artery penetration</td> <td>Nerve trauma</td> </tr> </table>	Difficulty locating needle insertion site	Femoral artery penetration	Nerve trauma	
Difficulty locating needle insertion site	Femoral artery penetration	Nerve trauma				
2.1.7 To evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the role of clinical anatomy competency in reducing difficulties and complications.	The improvement of critical anatomy knowledge necessary to perform this procedure will reduce difficulties and complications.	<table border="1"> <tr> <td>Strongly agree</td> <td>Agree</td> <td>Disagree</td> <td>Strongly disagree</td> </tr> </table>	Strongly agree	Agree	Disagree	Strongly disagree
Strongly agree	Agree	Disagree	Strongly disagree			
2.1.8 To evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the role of clinical anatomy in improving confidence in the performance of clinical procedures.	Improvement of anatomy knowledge necessary for the procedure will increase my confidence in performing the procedure.	<table border="1"> <tr> <td>Strongly agree</td> <td>Agree</td> <td>Disagree</td> <td>Strongly disagree</td> </tr> </table>	Strongly agree	Agree	Disagree	Strongly disagree
Strongly agree	Agree	Disagree	Strongly disagree			

^b The complications differ for every procedure. These complications were determined by an extensive literature review and by selecting those that are specifically anatomically relevant and are illustrated in Table 2b.

Table 2b: Anatomically relevant complications selected for each procedure.

Procedure	Complications						
Caudal Epidural Block	Difficulty palpating landmarks for needle insertion	Injection of local anaesthesia into sacral bone marrow	Difficulty piercing the sacrococcygeal ligament	Penetration of vascular structures	Dural puncture	Subarachnoid injection	Misplacement into soft tissue or rectum (pelvic viscera)
Spinal Anaesthesia	Difficulty locating needle insertion site	Penetration of vascular structures					
Thoracic Epidural	Difficulty locating needle insertion site	Dural puncture	Lesions to intervertebral disks and ligaments	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Misplacement of epidural catheter	
Lumbar Epidural	Difficulty locating needle insertion site	Dural puncture	Lesions to intervertebral disks and ligaments	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Misplacement of epidural catheter	
Axillary Block	Difficulty locating axillary artery	Axillary artery puncture	Nerve trauma	Pneumothorax			
Interscalene Block	Difficulty locating interscalene groove	External jugular vein puncture	Vertebral artery puncture	Blocked phrenic nerve	Blocked vagus nerve	Epidural anaesthesia	Subarachnoid penetration
Femoral Nerve Block	Difficulty locating needle insertion site	Femoral artery penetration	Nerve trauma				
Lateral Cutaneous Nerve Block	Difficulty locating needle insertion site	Difficulty locating position of the nerve					
“3-in-1” Block	Difficulty locating needle insertion site	Penetration of vascular structures	Nerve trauma				
Fascia iliaca Block	Difficulty locating needle insertion site	Penetration of vascular structures	Nerve trauma				
Psoas Compartment Block	Difficulty locating needle insertion site	Penetration of vascular structures	Nerve trauma				
Anterior Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	Sciatic nerve trauma	Femoral artery or vein penetration	Occurrence of a compression haematoma			
Posterior Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	Sciatic nerve trauma					
Lateral Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	Sciatic nerve trauma					
Ilioinguinal/ Iliohypogastric Nerve Block	Difficulty in visualizing position of ilioinguinal and iliohypogastric nerves	Nerve trauma	Blocking of femoral nerve	Incomplete blocking of ilioinguinal and iliohypogastric nerves			
Penile Block	Difficulty locating needle insertion site	Penetration of vascular structures	Penetration of corpora cavernosa				
Intercostal Nerve Block	Difficulty locating needle insertion site	Penetration of peritoneum and viscera	Penetration of intercostal vessels	Failure to block intercostal nerves	Pneumothorax	Respiratory failure	
Digital Nerve Block	Difficulty locating needle insertion site	Penetration of vascular structures	Nerve trauma				

3.1.1 Conduction of survey

Two groups of anaesthesiologists were randomly selected to complete the questionnaire:

The first group was anaesthesiologists attending anaesthesiology workshops at the University of Pretoria and the South African Society of Anaesthesiologists Congress held at Sun City, South Africa in 2003. All anaesthesiologists were randomly approached and asked to fill in the questionnaire and thus had an equal chance of being selected to participate in the study. All participants were approached without prior knowledge of the anaesthesiologist. All anaesthesiologists in South Africa had an equal chance of attending the conference/ workshops as both private and public sector anaesthesiologists attend such conferences/ workshops.

The second group of anaesthesiologists was those working in hospitals in the Gauteng area. Hospitals were visited in accordance with a pharmaceutical representative of the Gauteng area. There was no prior knowledge of which hospitals were to be visited and therefore any hospital within the Gauteng area could have been visited. Visitations were at any time during the morning or afternoon and all anaesthesiologists on duty were approached and asked to fill in the questionnaire.

No previous experience or lack of experience in regional anaesthetic techniques were known beforehand or required for an anaesthesiologist to participate in this study.

The aim was to reach at least a sample size of 80 fully completed questionnaires. A total of 80 anaesthesiologists were approached. Approximately 40% of the sample was from the first group of anaesthesiologists and 60% from the second group of anaesthesiologists.

The 8 page descriptive cross sectional questionnaire was completed in the anaesthesiologist's own time and took between 15 and 30 minutes for the

participant to complete. Because the questionnaire was structured in a way that certain choices had to be made (see appendix A), anaesthesiologists had to tick the appropriate box. This way of answering the questionnaire facilitated the participant's choice, eases the evaluation process and provides a means to compare the data obtained for various calculations. The questionnaires were subsequently analysed as categorical data.

No interviews were performed. A completed questionnaire was placed in a box supplied for the collection of completed questionnaires. The researcher was available at all times to answer any questions that may arise, although the questionnaire was self-explanatory.

There was, however, a slight theoretical chance for the researcher to identify a specific respondent's completed questionnaire and therefore abridge anonymity, although the respondent was assured of staying anonymous due to above-mentioned measures. The researcher however protected anonymity at all times and refrained from transgressing good ethical conduct.

Only doctors with postgraduate degrees or diplomas in anaesthesiology or who were at the time busy studying anaesthesiology were included in the study.

The anaesthesiologists participating in the study included no other procedures. Analysis of only the original 18 procedures was therefore conducted.

3.1.2 Analysis of data produced by the survey

Every data-item on the questionnaire was given a numerical value for all eight questions. The data for every procedure was then entered into the Excel® statistical program.

Incidence of performance was calculated as being either yes **(0)** or no **(1)**. The values were added by simple summation, mean values were

determined and percentages for each procedure were also determined for all 80 questionnaires.

The following categories of the questionnaire were only analysed if the anaesthesiologist or anaesthesiologist in training performed the specific procedure:

For **frequency of performance** analysis, the responses were quantified as follows: More than 20 **(0)**; 10-20 **(1)**; 5-10 **(2)**; Less than 5 **(3)**; No response **(4)**. A simple count function was performed (COUNTIF) to determine how many times anaesthesiologists or anaesthesiologists in training performed the procedures in the past year.

For the **importance rating** of the various procedures, the different categories were quantified as follows and then summated by a simple count function (COUNTIF) to determine the result of hits in every category: Essential **(0)**; Desirable but not essential **(1)**; Useful **(2)**; Very uncomfortable **(3)**.

Regarding the **determination of measure of comfort**, the different categories were quantified as follows and then summated by a simple count function (COUNTIF) to determine the result of hits in every category: Very comfortable **(0)**; Fairly comfortable **(1)**; Uncomfortable **(2)**; Very uncomfortable **(3)**.

Regarding analysing the **difficulties encountered**, the different categories were quantified as follows and then summated by a simple count function (COUNTIF) to determine the result of hits in every category: Knowledge of the procedure itself **(0)**; Equipment necessary for the procedure **(1)**; Practical skills to perform the procedure **(2)**; Regional anatomy knowledge **(3)**. Anaesthesiologists could, in this case, tick more than one box if appropriate.

The various **complications** encountered were analysed by quantifying every choice with a numerical value for each procedure and then summating the various categories.

For the following two categories all 80 questionnaires were used for analysis, because even if an anaesthesiologist or anaesthesiologist in training does not perform the procedure, he/ she can still appreciate and assess the need of clinical anatomy competence in performing the specific procedure.

To evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the **role of clinical anatomy competency in reducing difficulties and complications**, the different categories were quantified as follows and then summated by a simple count function (COUNTIF) to determine the result of hits in every category: Strongly agree **(0)**; Agree **(1)**; Disagree **(2)**; Strongly disagree **(3)**.

To evaluate the assessment of anaesthesiologists and anaesthesiologists in training on the **role of clinical anatomy in improving confidence in the performance of clinical procedures**, the different categories were quantified as follows and then summated by a simple count function (COUNTIF) to determine the result of hits in every category: Strongly agree **(0)**; Agree **(1)**; Disagree **(2)**; Strongly disagree **(3)**.

3.1.3 Statistical analysis of demographic data

Every data-item on the demographic data was given a numerical value for performance of procedure, years in practice, and highest qualification. The data for every procedure was then entered into the statistical program, Statistix® for Windows version 8.

A simple cross-tabulation was performed (see Table 3 on page 42) to summarise the distribution of the participating anaesthesiologists according to *qualification and years in practice (experience)*.

A *logistic regression* was also performed with *incidence of performance* as the dependant variable and *qualification and years in practice (experience)* as the independent variables.

Incidence of performance was calculated as being either yes **(0)** or no **(1)**.

Categories for qualification were determined as being either doctors who have a post-graduate qualification degree or diploma in anaesthesiology **(0)** or doctors who are currently undergoing specialist training in anaesthesiology **(1)**.

Categories for years in practice (experience) were determined as anaesthesiologists or anaesthesiologists in training with 5 or less years of anaesthesiological experience **(0)**, anaesthesiologists or anaesthesiologists in training with 6-10 years of experience **(1)**, and anaesthesiologists or anaesthesiologists in training with more than 10 years of experience **(2)**.

Logistic regression is a technique for making predictions when the dependent variable can be divided into two, usually opposing, parts or opinions, i.e., performance: **Yes** or **No** (also known as binary opposition or dichotomy), and the independent variables are continuous and/ or discrete ⁶⁶.

This is often used to analyse the relationship between probabilities of variables, and this is also used to determine the *odds ratio* of the sample of variables, which can be either dependant or independent variables ⁶⁷.

The ratio of the odds of an event in the experimental (intervention) group to the odds of an event in the control group. The odds ratio is therefore the ratio of the number of people in a group with an event to the number without an event ⁶⁸.

For example, the odds ratio (see Table 7 on pages 51-52) is represented by a figure relative to the demographic category, which is indicated in both categories (both *qualification* and *experience*) with a **(0)**, i.e., doctors who has a post-graduate qualification in anaesthesiology for the *qualification* category and anaesthesiologists or anaesthesiologists in training

with 5 or less years of anaesthesiological experience for the *experience* category.

The *odds ratios* were determined for each procedure. This allowed for determining what the odds of certain anaesthesiologists or anaesthesiologists in training with specific demographic criteria, such as *qualification* or *experience*, are to **not perform** the specific procedure. For example odds ratios indicate the likelihood or odds of a doctor *without* a postgraduate degree or diploma in anaesthesiology to **not perform** the procedure compared to a doctor *with* a postgraduate degree or diploma in anaesthesiology. This is also true for the reverse, as it could therefore also indicate the odds or likelihood of a doctor *with* a postgraduate degree or diploma in anaesthesiology to **perform** a procedure when compared to a doctor *without* a postgraduate degree or diploma in anaesthesiology. This is also true for *experience*.

In the case of this study, because only a small representative sample of South African anaesthesiologists were approached to participate in this study, and through multiple discussions with a statistician, it was decided to determine the likelihood (*odds*) of anaesthesiologists, to perform a certain procedure based on the demographic profile of the participating anaesthesiologist, i.e., *qualification* and *years in practice*. Therefore instead of absolute values of performance for each procedure, determining the *odds ratios* allowed for determining the ratio of performance of a procedure.

This method allows for better extrapolation of the results to the rest of the anaesthesiologists in South Africa. For example with caudal epidural blocks, rather than saying **63.75%** of anaesthesiologists or anaesthesiologists in training perform this procedure out of a sample of 80, this study can now determine that the likelihood of a doctor with a postgraduate degree or diploma in anaesthesiology to perform caudal epidural blocks is **2.78** times higher when compared to an anaesthesiologist in training.

3.1.4 Ethical concerns

1. Ethical clearance to conduct the survey was obtained from the Ethics and Research Committee of the Faculty of Health Sciences at the University of Pretoria.
2. Participation in the study was voluntary and anonymous.
3. All questionnaires were accompanied by an informed consent form, which was signed after full information on the project was given.

3.2 Selection of procedures and criteria for selection

Various selection models were developed to select the **5 problem procedures**. The various selection models were developed because no other means of selection criteria are available in the literature.

Scoring options A, B, C and D were developed (see appendix C)

Scoring option B was selected to best represent the selection criteria of the study portraying a block that is performed, has anatomically related difficulties and complications associated with it, and where improvement of anatomical knowledge will make a difference in reducing difficulties and complications and increase confidence of performance. Scoring option B is as follows:

Scoring option B

1.	Incidence of performance	20%-25%	1 point
		26%-30%	2 points
		>30%	3 points
2.	Essentiality	60-79%	1 point
		80-100%	2 points
3.	Comfortability	uncomfortable > comfortable	2 points
		uncomfortable > 10%	1 point
4.	Difficulty or complications related to anatomy, experienced by	25-35%	1 point
		>35%	2 points
5.	More than 80% thought that improvement of critical anatomical knowledge necessary to perform the procedure would reduce difficulties and complications.	80-90%	1 point
		91-100%	2 points
6.	More than 80% thought that improvement of anatomical knowledge necessary for the procedure would increase confidence in performing the procedure.	80-90%	1 point
		91-100%	2 points

		Total:	12 points

The procedures that were performed by 5 or less anaesthesiologists or anaesthesiologists in training were excluded from being analysed using Scoring option B. Because so few anaesthesiologists performed a procedure, the percentages were adversely high and thereby does not accurately portray a global perspective regarding the procedure in question. These were the following:

- Interscalene block
- Lateral cutaneous nerve of the thigh block
- Fascia iliaca compartment block
- Psoas compartment block
- Anterior approach of the sciatic block
- Posterior approach of the sciatic block and
- Lateral approach of the sciatic block

The remaining procedures (of which more than 5 respondents indicated to perform the block) that scored highest in every section were subjected to the selection criteria and the 5 procedures with the highest score were selected as the problem procedures where anatomical knowledge plays a particularly important role.

Due to the fact that the focus of this study is on the influence of clinical anatomy on the performance of procedures, procedures were scored in a way by giving aspects of difficulties and complications met and the assessment of the influence of clinical anatomy on performance, more weight than for instance frequency of performance alone. The fact whether the procedure was regarded as essential in the specific practice situation was regarded as important as well, because of its reflection on the need in the practical situation.

Scoring option B was therefore eventually chosen to select the procedures which anaesthesiologists ranked important, where most difficulties and complications were met, and where the influence of clinical anatomy knowledge on the safe and successful performance of the procedure, was ranked highest.

3.3 Development of a clinical anatomy knowledge base for each selected problem procedure

After selecting the **5 problem procedures** according to the criteria in Scoring option B, the clinical anatomy content for every procedure was developed in the form of a clinical anatomy knowledge base.

The clinical anatomy knowledge base for each selected procedures was developed by an extensive literature review of the most recent and relevant publications, both in the basic medical and clinical sciences. The following standard pattern was followed for every procedure:

1. Indications
2. Contraindications/ Precautions
3. Step-by-step procedure
4. Anatomical pitfalls
5. Complications (anatomically relevant)
6. References

Emphasis was placed on the anatomical pitfalls and anatomically relevant complications that may be experienced during the performance of the regional anaesthetic procedure. The Medline database was studied via an interactive windows-based search engine OVID WEB via the online services of the Academic Information Service of the University of Pretoria.

Results of this study are found in Sections **5.1-5.5**

In the process of creating the anatomy knowledge base for each of the selected problem procedures, certain “gaps” in the knowledge regarding the anatomy surrounding the problem procedures were identified and indicated in the **Future studies** section of the anatomy knowledge base.

4. Results

4.1 Development and conduction of survey

A total of 80 anaesthesiologists were approached during the conduction of the survey. Seven of the anaesthesiologists failed to complete the demographic section of the questionnaire and could therefore not be included in the demographic analysis. Table 3 illustrates the demographic data through means of **cross tabulation** between experience and qualification of the sample population.

Table 3: Cross tabulations for demographic data

Years in practice (Experience)	Qualification		
	Postgraduate qualification in anaesthesiology obtained	Currently undergoing postgraduate training in anaesthesiology	
5 yrs or less	16 29.1%	12 66.7%	28
6-10 yrs	12 21.8%	3 16.7%	15
>10 yrs	27 49.1%	3 16.7%	30
	55 75.3%	18 24.7%	73 100%

The results obtained from the questionnaire analysis are summarised in Table 4. The percentages given are the response to the questions stated in the questionnaire to answer questions 1 (percentage that performs the block), 3 (percentage that believes the block to be important), 4 (percentages that feel comfortable when performing the block), and 5 (percentage that feel that difficulties and complications occur due to problems with knowledge of the procedure, necessary equipment, practical skill and/ or clinical anatomy knowledge).

Question 2 (frequency of performance) is summarised separately in Table 5 on page 45, while question 6 (complications that have occurred

during the performance of the block) is summarised in Table 7 on pages 51-52.

Questions 7 (percentage that believe that anatomy knowledge reduces the occurrence of complications) and 8 (percentage that believe that anatomy knowledge increases comfort levels) are summarised in Table 6 on page 47 and also graphically represented in the form of a bar graph in figures 2 and 3, respectively.

4.1.1 Incidence, frequency, importance, measure of comfort and difficulties of performance

Table 4: Results obtained from analysis of the questionnaires

Procedure	% That performs the block (Question 1)	% That believe block to be important (Question 3)	% That feel comfortable performing the block (Question 4)	% That has difficulties with... (Question 5)			
				Knowledge of Procedure	Necessary Equipment	Practical Skill	Clinical Anatomy Knowledge
Caudal Epidural Block	63.75% (51/80)	80.4% (41/51)	90.2% (46/51)	9.8% (5/51)	21.6% (11/51)	15.7% (8/51)	15.7% (8/51)
Spinal Anaesthesia	8.75% (7/80)	42.9% (3/7)	71.5% (5/7)	0	28.6% (2/7)	0	0
Thoracic Epidural	11.25% (9/80)	66.6% (6/9)	55.5% (5/9)	11.1 (1/9)	33.3% (3/9)	33.3% (3/9)	11.1% (1/9)
Lumbar Epidural	20 % (16/80)	43.8% (7/16)	75% (12/16)	0	37.6% (6/16)	18.8% (3/16)	18.8% (3/16)
Axillary Block	22.5% (18/80)	44.4% (8/18)	72.3% (13/18)	27.8 (5/18)	22.3% (4/18)	50% (9/18)	33.3% (6/18)
Interscalene Block	6.25% (5/80)	40% (2/5)	60% (3/5)	0	0	60% (3/5)	20% (1/5)
Femoral Nerve Block	22.5% (18/80)	72.2% (13/18)	77.8% (14/18)	22.3% (4/18)	22.3% (4/18)	27.8% (5/18)	22.3% (4/18)
Lateral Cutaneous Nerve of the Thigh Block	5% (4/80)	50% (2/4)	50% (2/4)	25% (1/4)	0	25% (1/4)	0
“3-in-1” Block	11.25% (9/80)	44.4% (4/9)	88.9% (8/9)	22.2% (2/9)	33.3% (3/9)	11.1% (1/9)	22.2% (2/9)
Fascia Iliaca Compartment Block	3.75% (3/80)	33.3% (1/3)	33.3% (1/3)	33.3% (1/3)	33.3% (1/3)	33.3% (1/3)	0
Psoas Compartment Block	2.5% (2/80)	100% (2/2)	50% (1/2)	50% (1/2)	50% (1/2)	50% (1/2)	50% (1/2)
Anterior Sciatic Block	3.75% (3/80)	33.3% (1/3)	100% (3/3)	33.3% (1/3)	66.6% (2/3)	33.3% (1/3)	33.3% (1/3)
Posterior Sciatic Block	6.25% (5/80)	40% (2/5)	80% (4/5)	40% (2/5)	60% (3/5)	40% (2/5)	40% (2/5)
Lateral Sciatic Block	0	0	0	0	0	0	0
Ilioinguinal/ Iliohypogastric Nerve Block	26.25% (21/80)	66.7% (14/21)	80.9% (17/21)	19.1% (4/21)	9.5% (2/21)	14.3% (3/21)	19.1% (4/21)
Penile Block	46.25% (37/80)	62.1% (23/37)	89.2% (33/37)	18.9% (7/37)	8.1% (3/37)	9.8% (4/37)	16.2% (6/37)
Intercostal Block	11.25% (9/80)	55.6% (5/9)	66.7% (6/9)	44.4% (4/9)	22.2% (2/9)	22.2% (2/9)	11.1% (1/9)
Digital Nerve Block	30% (24/80)	62.5% (15/24)	91.7% (22/24)	16.7% (4/24)	16.7% (4/24)	16.7% (4/24)	16.7% (4/24)

As can be seen from Table 4, the most commonly performed regional anaesthetic procedures is caudal epidural block, which is performed by 63.75% (51/80) of the participating anaesthesiologists. Penile blocks are performed by 46.25% (37/80), digital nerve blocks are performed by 30% (24/80) of the anaesthesiologists, while 26.25% (21/66) of the anaesthesiologists perform the ilioinguinal/ iliohypogastric nerve blocks. The axillary approach to the brachial plexus blockade, as well as the femoral nerve blocks is performed

by 22.5% (18/80) of the anaesthesiologists and lumbar epidural blocks are performed by 20% (16/80) of the anaesthesiologists who participated in the survey.

Table 5: Frequency of performance of paediatric regional anaesthetic procedures.

Procedure	Frequency of performance per annum (Question 2)				
	> 20	10-20	5-10	< 5	No Response
Caudal Epidural Block	33.33%	27.45%	25.49%	13.73%	0%
Spinal Anaesthesia	0%	42.86%	14.29%	42.86%	0%
Thoracic Epidural	0%	11.11%	11.11%	66.67%	11.11%
Lumbar Epidural	0%	6.25%	37.5%	56.25%	0%
Axillary Block	27.78%	5.56%	22.22%	44.4%	0%
Interscalene Block	20%	0%	0%	60%	20%
Femoral Nerve Block	22.22%	16.67%	22.22%	33.33%	5.56%
Lateral Cutaneous Nerve of the Thigh Block	50%	0%	0%	25%	25%
“3-in-1” Block	22.22%	0%	44.44%	33.33%	0%
Fascia Iliaca Compartment Block	0%	33.3%	0%	33.33%	33.33%
Psoas Compartment Block	0%	0%	50%	50%	0%
Anterior Sciatic Block	33.33%	0%	0%	66.67%	0%
Posterior Sciatic Block	0%	0%	20%	60%	20%
Lateral Sciatic Block	0%	0%	0%	0%	0%
Ilioinguinal/ Iliohypogastric Nerve Block	14.29%	23.81%	14.29%	38.1%	9.52%
Penile Block	21.62%	16.22%	35.14%	16.22%	10.81%
Intercostal Nerve Block	11.11%	0%	22.22%	44.44%	22.22%
Digital Nerve Block	19.17%	20.83%	20.83%	20.83%	8.33%

Apart from simply determining whether a procedure has been performed by the sample of anaesthesiologists who participated in the study, the frequency of performance allows for ascertaining the exact amounts that the procedure was performed.

From Table 5 it is obvious that not only is a caudal epidural block performed by the most anaesthesiologists participating in this study, it also performed the most frequently. A third of the participants who performs this procedure do so more than 20 times per annum. A further 27.45% and 25.49% of the participants perform a caudal epidural block between 12-20 and between 5-10 times per annum, respectively.

The majority of participants perform paediatric spinal anaesthesia between 10-20 and less than 5 times per annum, making it an infrequently performed procedure.

This is the same for both thoracic and lumbar epidural blocks where the majority of the participants perform these two procedures less than 5 times per annum.

The axillary approach to the brachial plexus, as well as, the femoral nerve block can both be regarded as frequently performed procedure as 27.78% and 22.22% of the participating anaesthesiologists perform these two procedures more than 20 times per annum. The majority of participants performing this procedure do however perform these procedures less than 5 times per annum. This is also true for the interscalene approach to the brachial plexus.

Although the lateral cutaneous nerve of the thigh block, “3-in-1” block and the sciatic nerve block via the anterior approach are only performed by a small number of participating anaesthesiologists, 50%, 22.22% and 33.33% perform these procedures more than 20 times per annum.

More anaesthesiologists perform the ilioinguinal/ iliohypogastric nerve block, penile block and digital nerve block. It would appear that the anaesthesiologists performing these blocks do so relatively frequently.

4.1.2 Importance of anatomy knowledge

Table 6: Results of statement: "Increased clinical anatomy knowledge decrease complications" and "Increased clinical anatomy knowledge increase confidence".

Procedure	Increased clinical anatomy knowledge will decrease complications (Question 7)				Increased clinical anatomy knowledge will increase confidence (Question 8)			
	Strongly agree	Agree	Disagree	Strongly disagree	Strongly agree	Agree	Disagree	Strongly disagree
Caudal Epidural Block	59.26%	35.19%	5.56%	0%	54.90%	41.18%	3.92%	0%
Spinal Anaesthesia	40%	60%	0%	0%	36.84%	63.16%	0%	0%
Thoracic Epidural	50%	45.45%	0%	4.55%	40%	60%	0%	0%
Lumbar Epidural	54.17%	45.83%	0%	0%	50%	45.83%	4.17%	0%
Axillary Block	51.85%	40.74%	3.70%	3.7%	48.15%	44.44%	3.7%	3.7%
Interscalene Block	27.78%	61.11%	5.56%	5.56%	27.78%	61.11%	5.56%	5.56%
Femoral Nerve Block	52%	48%	0%	0%	56%	44%	0%	0%
Lateral Cutaneous Nerve of the Thigh Block	61.54%	38.46%	0%	0%	61.54%	38.46%	0%	0%
"3-in-1" Block	50%	50%	0%	0%	50%	50%	0%	0%
Fascia Iliaca Compartment Block	42.86%	57.14%	0%	0%	46.67%	53.33%	0%	0%
Psoas Compartment Block	30%	70%	0%	0%	36.36%	63.64%	0%	0%
Anterior Sciatic Block	35.29%	64.71%	0%	0%	38.89%	61.11%	0%	0%
Posterior Sciatic Block	41.18%	58.82%	0%	0%	43.75%	56.25%	0%	0%
Lateral Sciatic Block	37.5%	62.5%	0%	0%	41.18%	58.82%	0%	0%
Ilioinguinal/ Iliohypogastric Nerve Block	48.15%	51.85%	0%	0%	53.57%	46.43%	0%	0%
Penile Block	51.35%	37.84%	8.11%	2.7%	53.85%	35.9%	7.69%	2.56%
Intercostal Nerve Block	47.37%	52.63%	0%	0%	47.37%	52.63%	0%	0%
Digital Nerve Block	45.83%	50%	4.17%	0%	48%	48%	4%	0%

Figure 2: Results of statement: "Increased clinical anatomy knowledge will decrease complications" (Question 7).

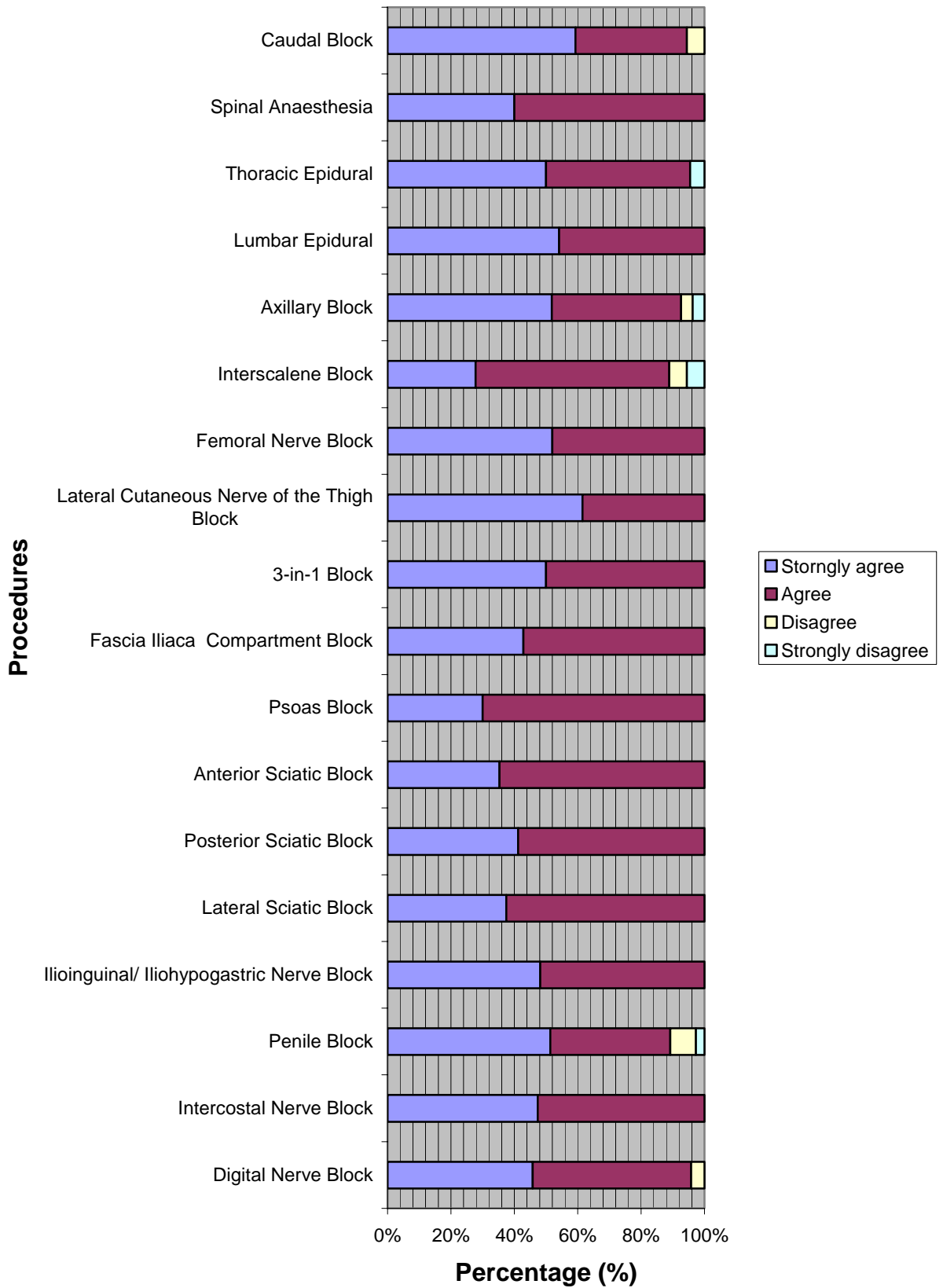
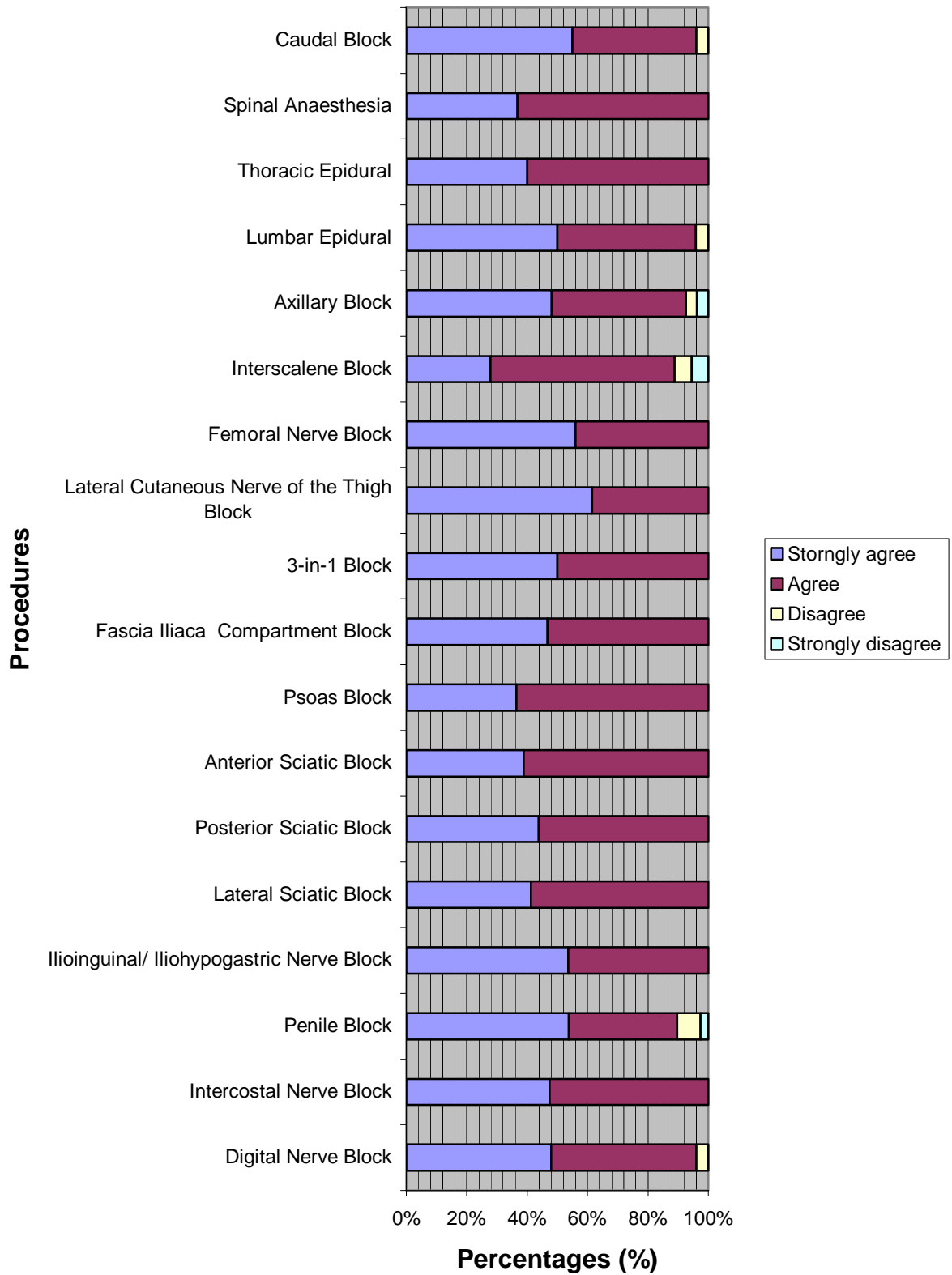


Figure 3: Results of statement: “Increased clinical anatomy knowledge will increase confidence” (Question 8).



In the case of questions 7 and 8 of the questionnaire, which is summarised in Table 6 and also schematically illustrated in figures 2 and 3, all the anaesthesiologists that answered these questions were included in the results. This is because, as was mentioned before, an anaesthesiologist does not necessarily need to perform the procedure in order to realise the value that anatomy knowledge has in the successful performance of the procedure.

Anaesthesiologists almost unanimously feel that a solid knowledge of clinical anatomy will both increase confidence and decrease difficulties and complications for the specific procedures. This coincides with what Bosenberg and co-workers⁶ stated when they said that many complications that occur during regional anaesthesia in paediatric patients are often anatomically linked and could have been avoided had certain precautions been taken or if the anatomical knowledge of the anaesthesiologist or anaesthesiologist in training, performing the procedure, had been sufficient. This is a very strong message and certainly a challenge to take up and identify the relevant anatomy necessary to perform the listed blocks safely and successfully.

The fact that practicing anaesthesiologists accept the necessity of a sound knowledge in anatomy supports the need for an extensive anatomical knowledge base regarding the paediatric regional anaesthetic procedures, as well as realising the differences in the anatomy between adults and children.

4.1.3 Complications

Table 7: Complications experienced during the performance of regional nerve blocks

Procedure	Complications (Question 6)													
Caudal Epidural Block	Difficulty palpating landmarks for needle insertion	47.1% (24/51)	Injection of local anaesthesia into sacral bone marrow	29.4% (15/51)	Difficulty piercing the sacro - coccygeal ligament	33.3% (17/51)	Penetration of vascular structures	25.5% (13/51)	Dural puncture	17.7% (9/51)	Sub - arachnoid injection	11.8% (6/51)	Misplacement into soft tissue or rectum (pelvic viscera)	23.5% (12/51)
Spinal Anaesthesia	Difficulty locating needle insertion site	0	Penetration of vascular structures	0										
Thoracic Epidural	Difficulty locating needle insertion site	11.1% (1/9)	Dural puncture	11.1% (1/9)	Lesions to intervertebral disks and ligaments	0	Trauma of the spinal cord and nerve roots	11.1% (1/9)	Penetration of vascular structures	0	Misplacement of epidural catheter	11.1% (1/9)		
Lumbar Epidural	Difficulty locating needle insertion site	12.5% (2/16)	Dural puncture	37.5% (6/16)	Lesions to intervertebral disks and ligaments	6.3% (1/16)	Trauma of the spinal cord and nerve roots	12.5% (2/16)	Penetration of vascular structures	6.3% (1/16)	Misplacement of epidural catheter	18.8% (3/16)		
Axillary Block	Difficulty locating axillary artery	22.3% (4/18)	Axillary artery puncture	44.4% (8/18)	Nerve trauma	11.2% (2/18)	Pneumothorax	5.6% (1/18)						
Interscalene Block	Difficulty locating interscalene groove	20% (1/5)	External jugular vein puncture	0	Vertebral artery puncture	20% (1/5)	Blocked phrenic nerve	0	Blocked vagus nerve	0	Epidural anaesthesia	0	Sub-arachnoid penetration	0
Femoral Nerve Block	Difficulty locating needle insertion site	39% (7/18)	Femoral artery penetration	44.4 (8/18)	Nerve trauma	10.2% (2/18)								
Lateral Cutaneous Nerve Block	Difficulty locating needle insertion site	25% (1/4)	Difficulty locating position of lateral cutaneous nerve of the thigh	0										
“3-in-1” Block	Difficulty locating needle insertion site	44.4% (4/9)	Penetration of vascular structures	33.3% (3/9)	Nerve trauma	22.2% (2/9)								

Table 7 (cont.):

Procedure	Complications (Question 6)													
	Difficulty locating needle insertion site		Penetration of vascular structures		Nerve trauma									
Fascia Iliaca Block	Difficulty locating needle insertion site	0	Penetration of vascular structures	33.3% (1/3)	Nerve trauma	33.3% (1/3)								
Psoas Compartment Block	Difficulty locating needle insertion site	50% (1/2)	Penetration of vascular structures	50% (1/2)	Nerve trauma	50% (1/2)								
Anterior Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	33.3% (1/3)	Sciatic nerve trauma	33.3% (1/3)	Femoral artery or vein penetration	33.3% (1/3)	Occurrence of a compression haematoma	33.3% (1/3)						
Posterior Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	40% (2/5)	Sciatic nerve trauma	40% (2/5)										
Lateral Sciatic Block	Difficulty finding landmarks necessary for correct needle insertion site	0	Sciatic nerve trauma	0										
Ilioinguinal/ Iliohypogastric Nerve Block	Difficulty in visualizing position of ilioinguinal and iliohypogastric nerves	33.4% (7/21)	Nerve trauma	23.8% (5/21)	Blocking of femoral nerve	14.1% (3/21)	Incomplete blocking of ilioinguinal and iliohypogastric nerves	61.9% (13/21)						
Penile Block	Difficulty locating needle insertion site	29.7% (11/37)	Penetration of vascular structures	13.5% (5/37)	Penetration of corpora cavernosa	16.2% (6/37)								
Intercostal Nerve Block	Difficulty locating needle insertion site	11.1% (1/9)	Penetration of peritoneum and viscera	0	Penetration of intercostal vessels	22.2% (2/9)	Failure to block intercostal nerves	0	Pneumo-thorax	33.3% (3/9)	Respiratory failure	0		
Digital Nerve Block	Difficulty locating needle insertion site	25% (6/24)	Penetration of vascular structures	20.8% (5/24)	Nerve trauma	12.5% (3/24)								

When looking at Table 7 it is interesting to see that difficulty to locate the point of needle insertion was often the most common complication reported by most anaesthesiologists. This can directly be related to anatomical knowledge of the region in which the procedure is to be performed. This was especially prominent in the 5 problem procedures, 47.1% for caudal epidural blocks, 39% for femoral nerve blocks, 33.4% for the ilioinguinal/ iliohypogastric nerve block and 22.3% for axillary approach to the brachial plexus. This does not appear to be the case for lumbar epidural blocks, where difficulty locating the needle insertion site doesn't appear to be a major problem, however 37.5% of the anaesthesiologists have indicated dural puncture to be a prominent complication, and considering the severity of dural puncture in paediatric patients, this is an important finding.

Other complications that stands out for caudal epidural blocks are: Injection of local anaesthesia into sacral bone marrow (29.4%) and difficulty piercing the sacrococcygeal ligament (33.3%).

Another complication, which occurs frequently during axillary approach to the brachial plexus, is axillary artery puncture (44.4%), which is considered to be a major complication in paediatric patients, due to the possibility of haematoma formation and subsequent possible impairment of blood flow to the upper limb if not attended to immediately.

It would also appear that puncturing of the femoral artery during femoral nerve blocks (44.4%) is a prominent complication. This is clinically seen as a major threat to paediatric patients as there is a high risk of thrombosis in the femoral artery after an accidental puncture with subsequent possible impairment of blood flow to the lower limb. Vascular penetration is also prominent in the "3-in-1" block (33.3%).

The most common occurring complication during an ilioinguinal/ iliohypogastric nerve block is an incomplete block, which 61.9% of the anaesthesiologists, in this study, have frequently experienced.

All these complications regarding each nerve block could be due to a lack of understanding or misunderstanding of the anatomy in paediatric patients. By creating the clinical anatomy knowledge base for the **5 problem procedures** this study hopes to enlighten anaesthesiologists to the importance of a sound paediatric anatomy knowledge

surrounding paediatric regional anaesthetic techniques, as well as, indicate possible anatomical pitfalls with associated complications, which may occur when performing these procedures. No matter how experienced an anaesthesiologist might be in regional nerve blocks in adult patients, most of the rules are changed when performing these blocks on paediatric patients, and even more specifically neonates or infants, as the anatomy most definitely differs dramatically from that of an adult⁶.

During the conduction of this survey most of the anaesthesiologists also commented on the inability to perform certain desired paediatric regional anaesthetic procedures due to a number of limiting factors such as: (a) lack of sufficient preoperative consulting time with parent(s) or guardian(s); (b) insufficient preoperative time allowed for anaesthesiologists to perform regional anaesthetic procedures; (c) lack of procedural and (d) regional anatomical knowledge, (e) practical skills and (f) inadequate confidence to perform the procedure safely and successfully.

4.1.4 Analysis of individual blocks (in order of appearance in the questionnaire)

4.1.4.1 Caudal epidural blocks

It is clear that caudal epidural blocks are the most commonly performed procedure in paediatric anaesthetic practice. Of the 80 anaesthesiologists who participated in the study, 63.75% (51/80) perform caudal epidural blocks on paediatric patients.

Of the 51 anaesthesiologists who perform caudal epidural blocks, 41 (80.4%) stated that the procedure is of great importance in their everyday practice, while almost all of the participating anaesthesiologists 46 (90.2%) are comfortable performing caudal epidural blocks on paediatric patients, however as can be seen in Table 7, 24 (47.1%) have difficulty palpating the landmarks necessary for identification of the needle insertion site.

Other complications that also occur during caudal epidural blocks included: difficulty piercing the sacrococcygeal ligament (33.3%), injection of local anaesthetic into the sacral bone marrow (29.4%), penetration of vascular structures (25.5%) and misplacement of the needle into the surrounding soft tissue or pelvic viscera (rectum) (23.5%).

Anatomical knowledge of the caudal area is essential for successful performance of caudal epidural blocks in paediatric patients, as 94.5% (51/54) agreed that improved anatomical knowledge would reduce complications from occurring and 96.1% (49/51) agreed it would increase comfort levels.

4.1.4.2 Spinal anaesthesia

The anaesthesiologists participating in the survey rarely perform spinal anaesthesia. Only 8.75% (7/80) perform spinal anaesthesia on paediatric patients even though 71.5% (5/7) feel comfortable performing the block.

However, even amongst those who perform the block it is considered to be important by only 42.9% (3/7) of the anaesthesiologists.

All of the anaesthesiologists agree that anatomical knowledge is essential for decreasing complications and increasing confidence levels when performing spinal anaesthesia.

4.1.4.3 Thoracic epidural block

As with spinal anaesthesia, only 11.25% (9/80) anaesthesiologists perform thoracic epidural blocks. As can be seen in Table 7, severe complications such as dural punctures, spinal cord and nerve root trauma, and vascular puncture are fortunately rare.

The low frequency of performance could, however, be due to the fact that only 55.5% (5/9) of the anaesthesiologists feel comfortable performing thoracic epidurals on paediatric patients. This is obviously due to the associated risks.

As could have been expected, anatomy was considered to play an important role, as 95.5% (21/22) agreed that clinical anatomy knowledge decreases complications and 100% (20/20) agreed that it increases confidence levels.

4.1.4.4 Lumbar epidural block

Interestingly enough, lumbar epidural blocks are performed by only 20% (16/80) of the anaesthesiologists and 43.8% (7/16) feel that lumbar epidural are important in their practice.

Of those performing the procedure, 75% (12/16) feel comfortable performing the block.

Dural puncture is the most frequent complication to occur, as 37.5% (6/16) of the anaesthesiologists have punctured the dura before. Extreme care must be taken to avoid puncturing the dura, as a total spinal block will occur if the dose for a lumbar epidural block is injected into the subarachnoid space. Reflux of spinal fluid through the needle must be verified and, if this occurs, the needle should be withdrawn.

This high frequency could be linked to the fact that 37.6% (6/16) of anaesthesiologists have a problem with the equipment necessary to perform lumbar epidural blocks. Dalens and Hasnaoui⁶⁹ believe that, to some degree, complications are directly related to the equipment used.

4.1.4.5 Axillary approach to the brachial plexus (an infraclavicular brachial plexus block)

Of the 22.5% (18/80) who perform the axillary approach to block the brachial plexus, only 44.4% (8/18) regarded the block as being important for their practice.

72.3% (13/18) of the anaesthesiologists feel comfortable performing this procedure on paediatric patients, however as can be seen in Table 4, 50% (9/18) have problems regarding

the practical skills necessary in order to safely perform the block, 33.3% (6/18) have problems with the clinical anatomy knowledge regarding the procedure, and 27.8% (5/18) with knowledge of the procedure itself.

Puncture of the axillary artery is the most commonly occurring complication during the performance of this procedure. Approximately 44.4% (8/18) of anaesthesiologists have punctured the axillary artery before. Difficulty locating the axillary artery, which is an important landmark during the procedure is experienced by 22.3% (4/18) of the anaesthesiologists.

Of the participating anaesthesiologists, 92.6% (25/27) agree that anatomy knowledge is essential for preventing complications and increasing confidence levels.

4.1.4.6 Interscalene approach to the brachial plexus (supraclavicular brachial plexus block)

Only 6.25% (5/80) anaesthesiologists perform this procedure on paediatric patients and only 40% (2/5) of these anaesthesiologist feel that this procedure is important.

Of those performing this block 60% (3/5) feel comfortable performing the procedure and 60% (3/5) stated that they have difficulty with the practical skill required to successfully perform the block.

Although complications are fortunately rare, 20% (1/5) of the anaesthesiologists have inadvertently punctured the vertebral artery, which could lead to severe complications if not attended to immediately.

As many as 88.9% (16/18) of the anaesthesiologists agree that better anatomical knowledge would decrease complications and increase confidence levels when performing the interscalene approach.

4.1.4.7 Femoral nerve block

The femoral nerve block is performed by 22.5% (18/80) of the anaesthesiologists. It is the most commonly performed regional nerve block of the lower extremity in children and is also considered to be the most important as 72.2% (13/18) anaesthesiologists consider it to be an important procedure and 77.8% (14/18) feel comfortable performing the block, however there is a high frequency of the occurrence of femoral artery penetration. Of those performing femoral nerve blocks in children, 44.4% (8/18) have punctured the femoral artery. This is a serious complication, especially in paediatric patients, as penetration of the femoral artery is a common cause for thrombosis in the femoral artery ⁷⁰. Also, 39% (7/18) of the

anaesthesiologists performing this procedure have difficulty in locating the needle insertion site.

This could also be due to a lack of specific anatomical knowledge of the femoral triangle in paediatric patients. 27.8% (5/18) of the anaesthesiologists have problems with practical skills required to perform the procedure and 22.3% (4/18) have problems with the knowledge of the procedure itself and clinical anatomy knowledge regarding the procedure.

4.1.4.8 Lateral cutaneous nerve of the thigh block

The lateral cutaneous nerve of the thigh block is only performed by 5% (4/80) of the anaesthesiologists, although 50% (2/4) indicated to consider the block important to their practice situation

Knowledge (25%) and practical skill (25%) seem to be difficulties associated with this block.

4.1.4.9 “3-in-1” block

When “3-in-1” block is indicated, anaesthesiologists prefer to block the femoral nerve, lateral cutaneous nerve of the thigh and the obturator nerve with a single injection rather than blocking each nerve individually.

Only 11.25% (9/80) anaesthesiologists performs the “3-in-1” block on paediatric patients. Of those, 44.4% (4/9) consider the block important and 88.9% (8/9) are comfortable with the performance of the block.

Complications appear to be relatively common as 44.4% (4/9) have difficulty locating the needle insertion site and 33.3% (3/9) have punctured vascular structures, i.e., the femoral artery, and 22.2% (2/9) report nerve trauma.

4.1.4.10 Fascia iliaca compartment block

This procedure was first introduced by Dalens and co-workers in 1989 ⁷¹ as an alternative to “3-in-1” block of Winnie and co-workers ⁸. However, it is only performed by 3.75% (3/80) of anaesthesiologists who participated in the survey.

Of the three anaesthesiologists, only one (33.3%) considered the block to be important and felt comfortable with its performance.

4.1.4.11 Psoas compartment block

Even fewer anaesthesiologists, only 2.5% (2/80), perform the psoas block on paediatric patients.

4.1.4.12 Anterior sciatic nerve block

Only 3.75% (3/80) of the participating anaesthesiologists perform the sciatic nerve block via the anterior approach.

4.1.4.13 Posterior sciatic nerve block

The posterior sciatic nerve block technique, although not overall popular amongst the anaesthesiologists participating in the survey, is the most commonly used approach to the sciatic nerve. Only 6.25% (5/80) anaesthesiologists block the sciatic nerve using the posterior approach.

For both the anterior and the posterior approach, all of the anaesthesiologists that anatomy knowledge will decrease complications and increase confidence of performance.

4.1.4.14 Lateral sciatic nerve block

The lateral approach to the sciatic nerve blockade wasn't performed by any of the anaesthesiologists who participated in the survey.

4.1.4.15 Ilioinguinal/ iliohypogastric nerve block

The ilioinguinal/ iliohypogastric nerve block is performed by 26.25% (21/80) of anaesthesiologists.

Of these, 66.7% (14/21) believe it to be an important procedure and 80.9% (17/21) feel comfortable performing this block. However, 61.9% (13/21) of anaesthesiologists performing this procedure have experienced a partial or complete failure to block the ilioinguinal and iliohypogastric nerves in paediatric patients.

In the literature, it is estimated that complete failure could occur in about 10% of procedures, even in experienced hands. Partial failure may be even more frequent in the order of 10 and 25%⁷². The failure rate is higher in children under 2 years of age, even when the nerve is exposed at surgery⁷³. The failure rate was higher even when the local anaesthetic was injected in two sites –“double shot technique”⁷².

A lack of spatial knowledge regarding the position of these nerves in paediatric patients could be the reason for this high failure rate, as 33.4% (7/21) of the anaesthesiologists have difficulty in visualising the position of the ilioinguinal and iliohypogastric nerves together with the fact that 19.1% (4/21) have problems with the knowledge of the procedure itself, as well as, with the clinical anatomy knowledge regarding the ilioinguinal/ iliohypogastric nerve block.

Further complications that could result from lack of either anatomical or procedural knowledge include nerve trauma, as well as, inadvertently blocking the femoral nerve during the performance of an ilioinguinal/ iliohypogastric nerve block, which occurs when the needle is advanced to deeply⁷⁴.

All participants agreed that improved clinical anatomy knowledge would decrease complications and improve confidence of performance.

4.1.4.16 Penile block

Penile blocks are the second most performed regional block in paediatric anaesthetic practice as 46.25% (37/80) of anaesthesiologists perform the block.

Of the anaesthesiologists who perform this block, 62.1% (23/37) believe it to be an important block for their practice and 89.2% (33/37) feel comfortable performing this block.

There are however still a significant number (29.7%) who are experiencing difficulty locating the needle insertion site.

4.1.4.17 Intercostal nerve block

Intercostal nerve blocks are only performed by 11.25% (9/80) of the anaesthesiologists participating in the study.

Only 55.5% (5/9) of those performing the block feel that it is important in their practice while 66.6% (6/9) feel comfortable performing the block and 44.4% (4/9) have difficulty with the block due to lack of knowledge of the procedure itself.

Of the complications that are experienced, the occurrence of a pneumothorax is the most prevalent, as 33.3% (3/9) of the participants have caused a pneumothorax while performing an intercostal block. One anaesthesiologist experienced difficulty in locating the needle insertion site.

As would be expected, all of the anaesthesiologists agreed that anatomy knowledge decreases the frequency of complications and increases confidence levels.

4.1.4.18 Digital nerve block

Digital nerve blocks in paediatric patients are the third most common procedure as 30% (24/66) of anaesthesiologists perform this regional block.

62.5% (15/24) of the anaesthesiologists believe the procedure to be important for their practice and 91.7% (22/24) feel comfortable performing the procedure.

It appears that 25% (6/24) of anaesthesiologists have difficulty locating the needle insertion site in paediatric patients for digital nerve blocks.

4.2 Statistical analysis of the demographic data

Too few anaesthesiologists performed certain procedures in order to obtain accurate *odds ratios* for the various demographic categories. This accounts for the empty spaces found in Table 8. These procedures are: spinal anaesthesia, interscalene approach to the brachial plexus, lateral cutaneous nerve of the thigh block, fascia iliaca compartment block, and anterior and lateral approaches of the sciatic nerve blocks.

The first column in Table 8 indicates the odds of anaesthesiologists to perform certain regional nerve blocks based on their *qualification*. In this case the dependant variable was whether anaesthesiologists (with a postgraduate degree or diploma in anaesthesiology) perform a certain nerve block. A value over 1 indicates that the procedure is more likely to be performed by anaesthesiologists when compared to anaesthesiologists in training.

A value of less than 1 indicates that the reverse is true. Anaesthesiologists in training have a better chance of performing the block when compared to anaesthesiologists (with a postgraduate degree or diploma in anaesthesiology).

The second and third columns indicates the odds of anaesthesiologists to perform certain regional nerve blocks based on the amount of years in practice, i.e., *experience*. Again a value over 1 in the second column indicates that the specific procedure has better chance of being performed by anaesthesiologists or anaesthesiologists in training with 5 years or less experience when compared to anaesthesiologists or anaesthesiologists in training with between 6 and 10 years of experience. A value of more than 1 in the third column indicate that the anaesthesiologists or anaesthesiologists in training with 5 years or less experience have a better chance of performing the specific procedure when compared to anaesthesiologists or anaesthesiologists in training with more than 10 years of experience.

A value of less than 1 in either of the second or third columns indicates that those anaesthesiologists or anaesthesiologists in training with between 6 and 10 years experience (in the second column) and the anaesthesiologists or anaesthesiologists in training with more than 10 years experience (in the third column) have a better chance of performing the block when compared to anaesthesiologists or anaesthesiologists in training with 5 or less years experience.

Table 8: Odds ratios for each procedure

	Odds of anaesthesiologists to perform a procedure compared to anaesthesiologists in training	Odds of anaesthesiologists or anaesthesiologists in training, with 5 years or less experience to perform a procedure compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience	Odds of anaesthesiologists or anaesthesiologists in training, with 5 years or less experience to perform a procedure compared to anaesthesiologists or anaesthesiologists in training with 10 years or more experience
Caudal Epidural Block	2.78	1.98	14.00
Spinal Anaesthesia	-	-	-
Thoracic Epidural	1.87	0.11	0.40
Lumbar Epidural	2.63	0.72	0.93
Axillary Block	1.34	1.71	1.76
Interscalene Block	-	-	1.14
Femoral Nerve Block	1.82	2.56	4.39
Lateral Cutaneous Nerve of the Thigh Block	-	-	1.79
3-in-1 Block	1.96	4.44	9.70
Fascia Iliaca Compartment Block	-	-	3.71
Psoas Block	0.27		0.64
Anterior Sciatic Block	0.44	-	0.38
Posterior Sciatic Block	0.33	0.81	1.45
Lateral Sciatic Block	-	-	-
Ilioinguinal/ Iliohypogastric Nerve Block	3.26	0.90	3.40
Penile Block	1.85	1.74	1.07
Intercostal Nerve Block	0.28	0.77	0.22
Digital Nerve Block	0.52	0.95	1.04

4.3 Selection of problem procedures and criteria for selection

After the exclusion of procedures that are performed by 5 or less anaesthesiologists or anaesthesiologists in training, the procedures shown in Table 9 scored the highest points after Scoring option B was applied.

Table 9: Procedures that scored the highest points, according to Scoring option B.

Procedure	Score	Incidence of Performance
Femoral Nerve Block	9/12	22.5% (18/80)
Axillary Approach to the Brachial Plexus	9/12	22.5% (18/80)
Caudal Epidural Block	8/12	63.75% (51/80)
Ilioinguinal/iliohypogastric Nerve Block	8/12	26.25% (21/80)
Lumbar Epidural Block	8/12	20% (16/80)
“3-in-1” Block	8/12	11.25% (9/80)

The 6 procedures that scored the highest were revised and it was decided that because of the lower incidence of performance than the other procedures the “3-in-1” block should not be identified as a problem procedure. However, because of the close relationship with the femoral nerve block, a section of the anatomical knowledge base regarding the paediatric femoral nerve block was dedicated to the “3-in-1” block.

The problem procedures identified in this study therefore consist of 2 central blocks, the caudal epidural block and lumbar epidural block, and 3 peripheral nerve blocks, axillary approach to the brachial plexus, femoral nerve block and ilioinguinal/ iliohypogastric nerve block.

4.4 Development of a clinical anatomy knowledge base for each selected problem procedure

A detailed referenced library was developed for every problem procedure selected by Scoring option B. This was done in a standard way by means of the following headings:

1. Indications
2. Contraindications/ Precautions
3. Step by step procedure
4. Anatomical pitfalls
5. Complications (anatomically relevant)
6. References

The most recent and relevant literature was studied extensively to compile a referenced clinical anatomy synopsis for each of the 5 problem procedure.

One significant change was however made with the creation of the anatomy knowledge base. In the questionnaire, the most frequently used brachial plexus blockade performed below the clavicle, the “axillary approach”, was used. This approach does have its limits for anatomical study, as the main landmark for determining the correct site of needle insertion is in fact the pulse of the axillary artery, which is logically absent from a cadaver population. Therefore, in order to validate future anatomical studies, to be done on a sample of neonatal cadavers, it was decided to use another brachial plexus blockade, one that is aptly named the “infraclavicular approach”.

Recent studies have shown this technique to be, although somewhat unused, just as safe and effective as the axillary approach with the same, if not more, indications for surgery of the upper extremities in paediatric patients

75-80

Recent modifications made to the original technique described by Raj and co-workers⁸¹ have also eliminated many of the complications, such as pneumothorax, associated with the original technique, which made anaesthesiologists wary of performing the procedure on paediatric patients^{77, 79, 80}.

The infraclavicular approach uses multiple, easily identifiable and constant bony landmarks to determine the site of needle insertion, which allows for cadaver studies.

5. Problem procedures

5.1 Paediatric Caudal Epidural Block

1. Indications
2. Contraindications
3. Block procedure
4. Anatomical pitfalls
5. Complications
6. References

1. Indications

- Caudal epidural blocks are the most widely used regional anaesthetic procedure. The popularity of this procedure seems to be due to the presence of clearly defined anatomic landmarks, simplicity, safety, ease of performance, and availability of data on doses and pharmacokinetics of local anaesthetics in infants and older children ¹⁻¹⁷.

1.1 Advantages over the adult caudal epidural block

- Better anatomical relationships and easier orientation, thereby decreasing time required for puncture ¹⁸.
- Perforation of the sacrococcygeal ligament is more clearly palpable ^{18, 19}.
- Better distribution of the injected local anaesthetic solution ²⁰.
- Easier to advance the epidural catheter, as well as, higher positioning of the catheter is possible ²¹.
- Very rapid recovery phase after anaesthesia due to the shallow supplementary of light general anaesthesia and avoidance of muscle relaxants ²².

- Quiet postoperative phase, thus reducing the need for opioids and thereby reducing the occurrence of side effects such as nausea, vomiting and/ or urinary retention ²².
- With experience, technically much simpler in anaesthetised children and the blockade produced is much more predictable ²³.

1.2 Surgical indications

- The caudal epidural block provides excellent intra- and postoperative analgesia for almost all types of interventions on the lower part of the abdomen and lower limbs, especially in neonates, infants, and certain high risk children ^{1-4, 7, 11, 13, 15, 17, 19, 23-31}.
- In high-risk neonates caudal epidural blocks are a useful procedure for lower extremity, anorectal, and inguinal procedures and obviates the need for general anaesthesia and endotracheal intubation, in order to reduce risk of postoperative apnoea ^{7, 32}.
- Elective procedures that caudal epidural blocks are indicated for include ^{1-8, 10-13, 15-17, 23-26, 29, 30, 33, 34}:
 - Repair of inguinal hernias;
 - Repair of umbilical hernias;
 - Repair of hydrocele;
 - Orchidopexy;
 - Repair of hypospadias;
 - Anorectal surgery;
 - Treatment of early onset myotonic dystrophy in children ³⁴;
 - Genitourinary surgery in both males and females;
 - Pelvic surgery;
 - Surgery on the hip and the lower extremities;
 - Surgery of the area of the coccyx.
- Anaesthesia can be provided for superficial operations on the lower limb such as
 - Skin grafting;

- Improving blood flow and reversing ischemia in the lower limbs³⁵.
- Caudal epidural blocks can also be used for emergency procedures, such as^{1, 2, 7, 18}:
 - Testicular torsion;
 - Repair of omphalocele;
 - Strangulated hernia repair;
 - Repositioning of incarcerated hernias.
- Caudal epidural blocks can also be performed in an ambulatory or day-case setting for a range of minor and emergency procedures, i.e., circumcision and inguinal hernia repair^{9, 11, 36-38}.
- Caudal epidural blocks have been recommended for upper abdominal surgery in children for which, however, higher doses of local anaesthetic solution is necessary to attain a higher level of analgesia, thereby increasing the risk of local anaesthetic toxicity, morbidity, or even mortality^{7, 23}.
- Bosenberg and co-workers²¹ have successfully threaded a catheter to thoracic levels via the caudal route for children undergoing biliary duct surgery. They believe that this technique could be used as a safe alternative route of access to the upper lumbar and thoracic epidural spaces in small infants. This procedure can also be used to provide long-term postoperative analgesia in the appropriate circumstances.
- Some authors recommend caudal epidural blocks for correction of phimosis and for circumcision^{9, 11, 27, 39-41}. Performing caudal epidural blocks for minor surgery are, however not recommended if an alternative peripheral anaesthetic procedure can provide effective analgesia, i.e., a penile block for circumcision^{37, 41-44}. Martin⁴² believes, that caudal epidural blocks are not worth the time, risk and expense involved to perform on infants and neonates for circumcision and other minor surgical procedures.
- For elective surgery caudal epidural blocks may be the sole anaesthetic or it might be combined with general anaesthesia. This is advised since paediatric patients do not generally tolerate surgery

under regional anaesthesia alone. However in the very young a caudal epidural block may be adequate to carry out urgent procedures such as reduction of incarcerated hernias, allowing return of normal bowel function prior to surgical repair ^{1, 2, 7, 30}.

1.3 Continuous caudal epidural block indications

- In combination with light general anaesthesia, continuous caudal epidural blocks can be used on longer lasting operations in the
 - Upper and lower abdominal areas;
 - Urogenital area;
 - Lower extremities.
- Whether it is safe to use continuous caudal catheters in neonates and infants, however remains controversial ¹.

2. Contraindications

2.1 General contraindications

2.1.1 Patient refusal

- Patient refusal is an absolute contraindication to regional anaesthesia. Appropriate information should be given to the patient regarding the technique, on its advantages and potential drawbacks and complications. Informed consent must be obtained ⁴⁴.

2.1.2 Local infections

- Skin infections at the needle insertion site are an absolute contraindication to regional anaesthesia ^{1, 2, 7, 18, 45}.
- Inflammation of the lymph nodes near the site of needle insertion is a contraindication.

2.1.3 Septicaemia (presence of pathogens in the blood) ^{1, 2, 18, 45}

2.1.4 Coagulation disorders

- Coagulation disorders, as well as patients who are undergoing antithrombotic or anticoagulant treatment are contraindications to a regional block ^{1, 2, 7, 18, 45}.
- Most of the complications have been described with epidural anaesthesia due to multiple traumatic vascular punctures and needle placement difficulties ^{1, 2}.

2.1.5 Neurological diseases involving the peripheral nerves (neuropathy)

- Although neuropathy (due to neurological or metabolic diseases) is not an absolute contraindication to perform a regional block, a clear distinction to benefit over general anaesthesia should be made ^{1, 2, 7, 18, 45}.

2.1.6 Allergy to the local anaesthetic ^{1, 2, 18, 45}

2.1.7 Lack of training

- Adequate skills regarding a specific technique are essential for a successful procedure and to avoid complications and malpractice. With experience and careful attention to landmarks, a failed caudal epidural block is rare ²⁴.
- Skills and expertise are key points to success in regional anaesthesia ⁴⁴.
- Caudal epidural blocks should not be performed unless the anaesthesiologist has had considerable experience with regional methods and an acquaintance with the techniques of resuscitation is necessary before performing caudal epidural blocks on infants ⁷.

2.1.8 Knowledge of Anatomy

- Winnie and co-workers ⁴⁶ believes that good anatomy knowledge is essential to performing regional anaesthesia, he said: "regional anaesthesia is nothing more than applied anatomy".
- Ellis and Feldman ⁴⁷ stated that anaesthesiologists required a peculiarly specialized knowledge of anatomy, which in some cases should even rival that of a surgeon.

2.2 Specific contraindications ^{1, 2, 4, 6}

2.2.1 Increased intracranial pressure (ICP)

- A careful neurological examination should always precede caudal epidural blocks to check for the possibility of increase ICP. When the pressure in the spinal compartment is lowered due to piercing the dura mater, as in a lumbar puncture, transtentorial and foramen magnum herniation may occur, resulting in immediate loss of consciousness, permanent neurological sequelae and may even result in death ⁴⁸.
- In the presence of intracranial lesions and hydrocephalus and taking the problems of raised ICP in consideration, it is preferable to avoid an epidural block and rather rely on peripheral blocks instead ⁴⁹.

- During a caudal epidural block an accidental dural puncture will have the same effect, therefore caudal epidural blocks should be contraindicated in children with increased ICP¹⁸.

2.2.2 Major malformations of the lower spine or meninges

- Major malformations of the lower spine are total contraindications for caudal epidural blocks, because of the unclear or impalpable anatomy^{1, 2, 7, 50}.
- Spina bifida occulta, which is not a major sacral malformation, is a relative contraindication for caudal epidural blocks, as anatomical landmarks must be clearly defined before the procedure commences.^{1, 50}.
- Myelomeningocele^{1, 2, 50}.
- Patients with sacral or lumbosacral agenesis⁵¹.

2.2.3 Active disease of the central nervous system¹⁸

- Meningitis.
- Poliomyelitis.

2.2.4 Cardiovascular diseases

- Specific cardiovascular diseases of myocardial, ischemic or valvular origin are a specific contraindication if the planned procedure requires higher sensory spread of the anaesthetic solution¹⁸.

2.2.5 Presence of a pilonidal cyst

- A pilonidal cyst is a cyst at the bottom of the coccyx that can become infected and filled with pus. At this point it is technically called a pilonidal abscess and looks like a large pimple at the bottom of the coccyx, just above the intergluteal fold^{1, 2, 18, 52}.

2.2.6 Continuous caudal catheter for postoperative pain control

- Although the catheter can be placed intra-operatively for long surgical intervention, it should be withdrawn after the surgery is complete¹,

because of a potential risk of infection due to the proximity of the catheter to the anus (especially in children lacking sphincter control).

- Thus the retention of a caudal catheter for postoperative analgesia is contraindicated in children.

2.2.7 Minor surgical procedures

- Even though caudal epidural blocks have several advantages, it is vital that one should not forget the risk. Before performing any central block it is important that the benefits should be weighed against the risks for each individual patient. Minor surgery may not be an indication for caudal epidural blocks. These surgical procedures may instead preferably be performed under a peripheral nerve block, which is safer and easier to perform ¹.

2.2.8 Intra-abdominal surgery above the 10th thoracic dermatome

- According to Fortuna ⁷, any intra-abdominal surgery above the 10th thoracic dermatome should be considered a contraindication for performing a caudal epidural block on an infant because of the problems offered by active phrenic and vagal reflexes, which are not blocked by a caudal epidural block.

3. Block procedure

3.1 Technique as described by Dalens ^{1,2}

3.1.1 Objective

- The aim is to enter the epidural space at a level not only well below the spinal cord (L3), but also below the dural sac (S3 or S4).

3.1.2 Patient position

- The choice of position depends on the preference of the anaesthesiologist and the degree of sedation of the patient.
- There are two main approaches ^{1,2}
 - Ventral decubitus position (prone), with the pelvis elevated with the help of a pillow or a rolled towel placed under the hips.
 - Lateral decubitus position, with the child lying on the side of the operation table with the hips and knees flexed at right angles. An assistant can hold the child in place and a pillow can be placed beneath its head to increase stability. This position is preferred in children under general anaesthesia.

3.1.3 Anatomical landmarks

1. Line of sacral spinous processes
 2. Sacrococcygeal joint
 3. Sacral cornua
- The intergluteal fold is not an ideal landmark since it is not necessarily in the midline, especially if the patient is lying in the lateral decubitus position.
 - Palpation of the sacrococcygeal membrane, which covers the sacral hiatus, gives a characteristic feeling of a membrane under tension similar to that of a fontanelle ².

3.1.4 Technique: Single-shot

I. *Preparation*

- Check that all emergency equipment is present, complete and in working order:
 - ECG monitor;
 - Intubation kit;
 - Ventilation facilities;
 - Emergency medication;
 - Sterile precaution;
 - Intravenous access;
 - Pulse oximetry;
 - Anaesthetic machine.
- An intravenous cannula should always be inserted in either the upper or lower limb, in case of accidental intravenous injection, or profound sympathetic blockade from a high epidural block.
- Normally light general anaesthesia is given to the paediatric patient.
- The procedure must be carried out with a strict aseptic technique. The skin should be thoroughly prepared and sterile gloves must be worn. Infection in the caudal space is extremely serious.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The sacral hiatus and the posterior superior iliac spines form an equilateral triangle pointing inferiorly. The sacral hiatus can be located by first palpating the coccyx, and then sliding the palpating finger in a cephalad direction (towards the base of the equilateral triangle) until a depression in the skin (the sacral membrane) is felt.

III. *Insertion of needle*

- As there can be a considerable degree of anatomical variation in this region confirmation of bony landmarks is the key to success. The needle can penetrate a number of different structures mimicking the feel of entering the sacral hiatus. It is important to establish the midline of the sacrum as considerable variability occurs in the prominence of the cornua, causing problems unless care is taken.
- The needle is inserted in a cephalad direction at an angle of about 60°-70°, towards the dorsum of the sacrum with the bevel parallel with the longitudinal fibres of the sacrococcygeal membrane. A characteristic “give” will be felt as the needle pierces the membrane, a few millimetres before the needle comes into contact with the periosteum of the sacral canal, which is not ideal and should be avoided.
- The needle is carefully redirected in a cephalad direction at an angle of approximately 20°-30° to the skin, approaching the long axis of the spinal canal. There are, however, many different insertion routes available in the literature ⁸.
- The thumb and index finger remain on the sacral cornua throughout the whole of the location and insertion procedure.
- Care should be taken not to insert the needle too far as the dural sac may extend as far inferior as S3 or S4 in children ^{1, 18, 53}.

IV. *Tests to confirm the correct placement of the needle*

- The needle should be aspirated looking for either cerebrospinal fluid (CSF) (dural puncture) or blood (vascular puncture).
- A small volume of local anaesthetic should be injected as a test dose ¹.
². It should not produce:
 - A lump in the subcutaneous tissues;
 - A feeling of resistance while injecting;
 - Systemic effects such as arrhythmias, peri-oral tingling, numbness or hypotension.

- If the test dose does not produce any side effects then the rest of the volume is injected, the needle removed and the patient positioned for surgery.
- Schwartz and Eisenkraft⁵⁴ disagrees with the use of air during loss of resistance identification to locate the epidural space in children and suggests that it should be avoided as reports indicate that children may develop a life-threatening venous air embolism from small quantities of air used during loss of resistance identification.
- Saberski and co-workers⁵⁵ searched the Medline scientific data bank from 1966 to 1995 for case reports of epidural complications following the loss of resistance technique using air. They believe that the potential complications associated with the use of air for identifying the epidural space with the loss of resistance technique may outweigh the benefits. Therefore use of saline to identify the epidural space may help to reduce the incidence of complications, however this may lead to a misinterpreted loss of resistance, especially in infants whose tissues have fewer connective fibres¹⁴.
- In the post-operative period, motor function must be checked and the patient should not be allowed to try and walk until complete return of motor function is assured. The patient should not be discharged from hospital until he/she has passed urine, as urinary retention is a recognised complication^{1,2}.

V. *Correlation between dosage of anaesthetic and age or weight*

- Busoni and Andreuccetti²⁰ aimed to determine the best mathematical model correlating the spread of analgesia to two predictor variables: the dose of local anaesthetic solution and the age or body weight of the patient. They found that age and weight are equally good predictors to determine dosage of anaesthetic solution for a desired level of analgesia in children. They do however feel that weight is a more useful guide in newborns and infants, while age is better in older children.

- Similar studies have also been conducted on children by Bromage in 1969⁵⁶ who found a linear relationship between age and dose requirements of 2% lignocaine in lumbar epidural blocks in patients between the ages of 4 and 18; and Schulte-Steinberg and Rahlfs in 1970⁵⁷ who developed a similar model for caudal epidural blocks in children. They found that the dose-response is highly correlated to age, as well as, weight and height.

3.1.5 Technique: Continuous caudal epidural block¹⁸

I. *Preparation*

- Same as for single-shot technique.

II. *Determine needle insertion site*

- Same as for single-shot technique.

III. *Insertion of needle*

- The skin is pierced using a large-diameter needle.
- A plastic indwelling catheter needle is advanced at an angle of 60°-70° to the skin, in the direction of the sacrococcygeal ligament. After perforation of the ligament the needle is further advanced for about 10mm into the sacral canal.
- The stylet is then removed and the plastic part is advanced a further 5mm.
- The catheter can be measured, as to advance the catheter the correct distance within the epidural space, to allow the desired dermatome to be blocked.
- Advance the catheter to the desired dermatome. In neonates, infants and small children the catheter meets hardly any resistance, so that it is easy to advance to the upper lumbar or thoracic levels²¹.

IV. *Checking the catheter position*

- Firstly remove the plastic indwelling catheter needle.
- Aspiration test.
- The syringe can be disconnected and the open end of the catheter placed on a sterile drape below the level of the puncture and any escaping fluid (CSF or blood) is noted.

4. Anatomical pitfalls

4.1 Sacrum^{1, 2, 45, 53}

- The sacrum is a triangular bone, consisting of five fused vertebrae, with a concave anterior surface and a convex posterior surface. In the centre and on the posterior surface of the sacrum is the sacral canal, which is a continuation of the spinal canal.
- The dorsal aspect of the sacrum presents with several protuberances resulting from the fusion of the sacral vertebrae (S1-S5):
 - A median sacral crest, which is a remnant of the spinous processes of the sacral vertebrae.
 - Two sacral articular crests, lateral to the median sacral crest, which consist of a series of tubercles almost parallel to the median sacral crest, from which they are separated by the left and right sacral grooves. The two sacral crests originate from the fusion of the articular processes of the sacral vertebrae.
 - Two sacral cornua, which are derived from the inferior articular processes of the fifth sacral vertebra. They form the triangle shaped hiatus.

4.2 Abnormalities of the sacrum

Spina Bifida

- Spina bifida occulta is a limited defect of the vertebral arch, which does not involve protrusion of the cord or membrane. It is seen as an incidental radiograph finding in up to 10% of the healthy population, mostly at the lumbosacral junction⁵⁸.
- Myelomeningocele is the severest form of spina bifida, and is characterised by complex malformation of the spinal cord, nerve roots, meninges, vertebral bodies, and skin^{1, 2, 50}.

Sacral or lumbosacral agenesis⁵¹

- Sacral agenesis is a very rare disorder, which is characterised by the absence of variable portions of the sacrum.
- Patients with sacral agenesis lack motor function below the level of the normal remaining spine, while sensory function is impaired below the level of the affected vertebrae.
- In more severe cases of sacral agenesis, part or all of the lumbar spine and even the lower thoracic spine may be absent. The term lumbosacral agenesis is used in these severe cases.
- The exact aetiology of sacral agenesis is unknown. In the human embryo, differentiation of the lumbar spine, sacrum, and coccyx occurs between the fourth and seventh postovulatory weeks⁵⁸.
- In 1959, Blumel and co-workers⁵⁹ found that in mothers with diabetes mellitus, the incidence of sacral agenesis in their children was 16%.
- Although maternal diabetes mellitus is most commonly associated with sacral agenesis, other less common risk factors such as genetic mutation, teratogens and vascular anomalies also occur⁵¹. Reports have also suggested that exposure to organic solvents in early pregnancy may increase the incidence of sacral agenesis⁶⁰.

Classification

- Renshaw⁶¹ classified patients according to the remaining sacrum and according to characteristics of the articulation between the spine and the pelvis:
 - Type I is either partial or total unilateral sacral agenesis.
 - Type II is partial sacral agenesis with a bilaterally symmetrical defect, a normal or hypoplastic sacral vertebra, and a stable articulation between the ilea and the first sacral vertebra.
 - Type III is variable lumbar and total sacral agenesis, with the ilea articulating with the sides of the lowest vertebra present.
 - Type IV is variable lumbar and total sacral agenesis, with the caudal endplate of the lowest vertebra resting above either fused ilea or an iliac amphiarthrosis.

4.3 Sacral hiatus^{1, 2, 45, 53}

- The sacral hiatus is a triangular and obliquely placed defect on the lower aspect of the posterior surface of the sacrum formed by the failure of the laminae of S5 (and/ or S4 in some individuals) to meet and fuse in the midline. There is a considerable variation in the anatomy of the tissues near the sacral hiatus, in particular, the bony sacrum^{53, 62}.
- The sacral hiatus is of considerable clinical importance. It is here that the extradural space terminates and the hiatus thus forms a portal of entry into this compartment⁵³.
- In adults, the sacral hiatus usually lies about 5cm from the tip of the coccyx and directly beneath the uppermost limit of the intergluteal fold. In clinical practice, it is best to locate the sacral hiatus by means of palpation of the depression, which it forms between the two sacral cornua¹.

4.4. End of the spinal cord

- In the third month of development the spinal cord extends the entire length of the embryo, and spinal nerves pass through the intervertebral foramina at the level of origin⁵⁸.
- With increasing age the vertebral column and the dura lengthen more rapidly than the neural tube, and the terminal end of the spinal cord gradually shifts to a higher level⁵⁸.
- Sadler⁵⁸ stated that at six months of foetal life, the lowest limit of the spinal cord lies at the level of S1.
- At birth the spinal cord ends at L3^{1, 3, 58, 63} and reaches its definitive position at the L1 level at the age of one year¹⁻³.
- Hawass and co-workers⁶³ assessed the length of the spinal cord relative to the vertebral column during foetal development by performing translumbar myelograms on 146 spontaneously aborted

foetuses. (76 males and 70 females, foetal age between 7-33 weeks). Significant variation in the level of spinal cord termination was found in foetuses between 12-25 weeks gestational age. In foetuses between 25-33 weeks gestational age, the cord ended at or above L3.

4.5 Dural sac^{1, 2, 45, 53}

- Along with the upward migration of the spinal cord, the dural sac also migrates from its S3-S4 level in a newborn to the S1-S2 level of the adult by the age of one year¹.
- Adewale *et al.*⁶⁴ studied the caudal (sacral extradural) space in 41 patients, weighing between 8 - 80kg, with ages of 10 months to 18 years, using magnetic resonance imaging (MRI). They determined: (a) the distance from the upper margin of the sacrococcygeal membrane to the dural sac, (b) the length of the sacrococcygeal membrane, and (c) the anterior-posterior distance of the sacral canal.
- Their results showed that there are great variations in the anatomy of the caudal space in children.
 - The distance of (a) was 27.9mm ± 8.0mm (mean ± SD) in males and 33.2mm ± 11.5mm in females.
 - The distance of (b) was 23.5mm ± 6.4mm in males and 24.7mm ± 6.9mm in females.
 - The distance of (c) was 4.7mm ± 1.9mm in males and 5.0mm ± 1.7 in females.

4.6 Sacral canal and caudal epidural space^{1, 2, 45, 53}

- The caudal epidural space is the lowest portion of the epidural system and a continuation of the lumbar epidural space, below the termination of the epidural sac. The caudal epidural space can be entered via the sacral hiatus that is found on the lower portion of the sacrum.
- The sacral canal contains the cauda equina, which is formed by the roots supplying the lumbar, sacral, and coccygeal plexuses. The sacral

canal ends caudally at the sacrococcygeal ligament (or membrane), which covers the sacral hiatus and to which the filum terminale is tightly attached. The sacrococcygeal ligament may only partially cover the sacral hiatus in some individuals.

- The volume of the sacral canal can vary greatly ¹.
- The sacral canal contains:
 - The terminal part of the dural sac, projecting at S3-S4 levels at birth and at S1-S2 level (adult level) at one year of age ¹.
 - The five sacral nerves and coccygeal nerves, which form part of the cauda equina.
 - The filum terminale, the final part of the spinal cord does not contain nerve exits through the sacral hiatus and is attached to the sacrococcygeal membrane or ligament.
 - Epidural fat, the character of which changes from a loose texture in children to a more fibrous close-meshed texture in adults. This transition occurs round about 6 or 7 years of age. This may significantly reduce the spread of the local anaesthetic solution ^{25, 57}. It is this difference that gives rise to the predictability of caudal local anaesthetic spread in children and its unpredictability in adults.

4.7 Vasculature of the spinal cord

Arterial blood supply ^{1, 18, 53}

- The arterial blood supply of the spinal cord is dependant upon three continuous, longitudinal arterial trunks extending from the medulla oblongata to the conus medullaris ⁶⁵.
- The spinal cord is supplied by numerous radicular arteries, which branches off from the cervical vertebral arteries, the thoracic intercostal arteries and the lumbar vertebral arteries, to form the *anterior spinal artery* and *posterior spinal arteries*.
- Branches of the lumbar, iliolumbar and lateral or median sacral arteries supply the cauda equina. These also supply the medullary cone.

- Thin pial branches run from the spinal arteries, forming a network on the surface of the spinal cord known as the *arterial pial network*.

Variations of spinal blood supply¹

- The blood supply of the spinal cord shows considerable individual and segmental variations, particularly in the areas called the *transitional zones*.
- If even one of the segmental arteries that arise from the radicular arteries is injured, that particular spinal segment is very likely to undergo ischemic necrosis.

Venous blood drainage^{1, 18, 53}

- The caudal epidural space has considerable venous drainage, thereby increasing the risk of vascular puncture during a caudal epidural block.
- Two venous plexuses, the *internal* and *external vertebral venous plexus*, traverse the entire spinal canal.
- Together these form a ring around each vertebra, freely anastomosing with one another and receiving tributary flow from the vertebrae, ligaments and spinal cord.
- The extradural vertebral venous plexus or Batson's plexus occupies the epidural space and is described as a characteristically plexiform network of vessels, "a large venous lake or reservoir", which extends from the cranium to the coccyx. There are many communications with the veins found in the spinal canal, as well as the veins surrounding the spinal cord⁶⁵.
- Like the upper epidural veins, the caudal epidural veins have no valvular system: thus, inadvertent injections into the epidural veins result in almost instantaneous systemic distribution.
- The sacral epidural veins generally end at S4, but may extend throughout the canal⁵³.

4.8 Future studies

- Determine the level of termination of the spinal dural sac in a neonatal population.
- Measure the distance from the upper margin of the sacrococcygeal membrane to the dural sac in (a) neonatal cadavers and (b) axial MRI of paediatric patients.
- Determine the surface anatomical position of the sacral hiatus in relation to easily identifiable bony landmarks, such as the coccyx.
- Describe the morphology of the sacral canal including its structure, contents and blood supply.

5. Complications

5.1 Dural puncture

- Extreme care must be taken to avoid puncturing the dura, as a total spinal block will occur if the dose for a caudal epidural block is injected into the subarachnoid space. If this occurs the patient will become rapidly apnoeic and profoundly hypotensive. Management includes control of the airway and breathing, and treatment of the blood pressure with intravenous fluids and vasopressors such as ephedrine¹⁸.
- It usually results from inserting the needle too deeply into the sacral canal. This could be due to an inappropriate technique or anatomical variations of the sacral hiatus or the dural sac.
- In a series of 170 infants, ages ranging between 1 day and 10 years, undergoing caudal epidural blocks, Fortuna⁷ states that the dura was pierced in only 2 patients.
- In a study to determine the spread of caudal analgesia in children, Busoni and Andreuccetti²⁰ conducted 763 caudal epidural blocks on children, ages 1 day to 12 years. In this sample there were no dural punctures that occurred.
- Bramwell and co-workers²⁷ performed a series of 181 caudal epidural blocks on children between 1 and 12 years of age. In 1 case a suspected dural puncture occurred.
- Trotter⁶⁶ showed in 53 adult cadavers that the distance between the sacral hiatus and the dura mater varies from 16-75mm. In the presence of certain sacral malformations this distance might be less and the dural sac can project even up to the sacral hiatus. Further studies for neonatal measurements are required.
- Adewale and co-workers⁶⁴ demonstrated in 41 children, using MRI, that there is great variation in the distance from the upper margin of the sacrococcygeal membrane to the dural sac. The distance is 27.9mm ± 8.0mm in males and 33.2mm ± 11.5mm in females.

- If a dural puncture occurs the needle must be withdrawn, but another trial may be attempted, giving special attention to the cardiorespiratory tracings and to the speed of the injection. If a dural puncture occurs for the second time, the needle must again be withdrawn and the use of an alternative technique should strongly be considered ^{1,2}.
- Desparment ⁶⁷ described a case for right-sided hernia repair where a caudal epidural block was performed on a male neonate born at 27 weeks gestational age and weighing 1070g at birth. The caudal epidural block failed. Total spinal anaesthesia occurred due to what the author describes as leakage of anaesthetic solution from the epidural space through the puncture site into the dura in the spinal canal thereby causing a total spinal block. Therefore he believes that if a dural puncture occurred it would be wiser to abandon any attempts of a second trial, as he believes the risk of total spinal anaesthesia is too great.

5.2 Vascular puncture

- Vascular penetration into the epidural veins is by no means uncommon. This accidental puncture is of no consequence if no injection was performed. The needle should simply be removed and reinserted properly before administering the local anaesthetic solution ^{1,2}.
- The frequency of vascular punctures varies greatly. It has been reported by McGown ²³ to occur in 10%-15% of caudal epidural blocks performed on adults and in 7%-10% performed on children.
- Bramwell and co-workers ²⁷ performed a series of 181 caudal epidural blocks on children between 1 and 12 years of age. In 2 cases the attempt to perform the caudal epidural block had to be abandoned due to a bloody tap.
- Dalens ²⁹ stated that they reduced this frequency from 10% to 1.5% by replacing a long bevelled needle with a short bevelled one. This

strongly suggests that the frequency of vascular puncture is related to some degree to the equipment used.

- Intravascular administration, overdose and/ or rapid vascular uptake of local anaesthetic solution, can lead to toxic CNS reactions like:
 - Tonic-clonic seizures (a very serious complication), but provided that it is treated immediately, it does not lead to cerebral injury or death;
 - Nystagmus;
 - Sudden vertigo;
 - Brief blackouts;
 - Inability to move or respond to external stimuli.

5.3 Misplacement of needle into soft tissue^{1, 2, 68}

- Misplacement of the needle into the soft tissue superficial to or surrounding the caudal hiatus results in subcutaneous injection rather than an epidural injection of local anaesthetic solution. The main complication is a failure of the block, which occurred in 4% of paediatric patients during a study done by Dalens and Hasnaoui²⁹. This will result in complete or partial failure of the block.
- Such misplacements decrease with experience, but cannot be completely prevented due to the frequency of malformations of the sacrum. Another puncture can be attempted provided that the total dose should not exceed safety limits.

5.4 Puncture of sacral foramen

- Dalens¹ describes how one can puncture one of the sacral foraminae. This occurs when the needle enters the 3rd or 4th sacral foramen due to improper identification of the anatomical landmarks or due to incorrect needle direction.

- This would result in a block of the sacral root involved and would not be accompanied by subcutaneous swelling. A second caudal may be attempted after the anatomical landmarks are clearly identified ¹.

5.5 Partial or complete failure of block

- Partial or complete failure of caudal epidural anaesthesia most often occurs due to misplacement of the needle or due to “low resistance” wrongly identified as “loss of resistance”. Especially when attempting epidural blockade in patients with abnormalities of the vertebral column ⁶⁹.
- In a series of 170 infants, ages ranging between 1 day and 10 years, undergoing caudal epidural blocks, Fortuna ⁷ reports 9 complete failures and 5 partial failures. He did not elaborate on the possible causes for these failures.

5.6 Lateralisation

- A peculiarity of caudal epidural blocks is lateralisation of the block. When caudal epidural blocks are performed on patients in the lateral decubitus position, 50% have a level of anaesthesia 2 dermatomes higher on the side on which they are lying. This might be more (up to 4 dermatomes higher) if the local anaesthetic solution is injected at a very slow rate ¹.
- The incidence of a unilateral block is always a probability even when the procedure is correctly performed, even though this incidence can be as little as 1 in every 1000 cases. Dalens ¹ however states that this incidence may be as high as 1.2% of all caudal epidural blocks performed on paediatric patients.
- The reason why a unilateral block occurs is not fully understood but the occurrence can be very distressing if the unanaesthetised side is about to be operated on ⁷⁰⁻⁷².

- Lateralisation may occur due to the presence of adhesions that developed following previous surgery, or due to inflammation or infection. Most often complete lateralisation is due to the presence of a complete plica mediana dorsalis, which divides the posterior epidural space into two halves⁷⁰⁻⁷⁴.

5.7 Other complications

- Other rare complications have been described in the literature. There are many due to incorrect placement of the needle and would not have occurred if the correct technique and/ or precautions were followed. They include:
 - Intraosseous injection, which may lead to symptoms similar to that of intravascular injections^{68, 75, 76}.
 - Perforation of the pelvic viscera (rectum) or vessels by a needle that has penetrated through the anterior surface of the sacrum into the pelvic cavity^{73, 75}. While simple needle puncture is not of grave concern, contamination of the needle is extremely dangerous if it is then inserted into the epidural space^{1, 2}.
 - Bone marrow injection or sampling during aspiration. Injection of local anaesthetic solution into the bone marrow may result in systemic toxicity and should therefore be avoided⁶⁸.

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5.2 Paediatric Lumbar Epidural Anaesthesia

1. Indications
2. Contraindications
3. Block procedure
4. Anatomical pitfalls
5. Complications
6. References

1. Indications

1.1 Advantages over adult lumbar epidural anaesthesia

- Reduced need for muscle relaxants, opioid analgesics and postoperative ventilatory support ¹.
- Quiet postoperative phase, thus reducing the need for opioids and thereby reducing the occurrence of side effects such as nausea, vomiting and/ or urinary retention ¹.
- Better anatomical relationships and thus easier to orientate oneself, thereby decreasing the time required for puncture ².
- Better distribution of the injected local anaesthetic solution ³⁻⁵.
- Easier to advance the epidural catheter, as well as, higher positioning of the catheter is possible ⁶.
- Due to immaturity of the sympathetic nervous system, circulatory problems are very rare, particularly in children younger than 8 years old ⁵.
- Reduce subsequent postoperative intensive care ⁵.
- Can be the sole anaesthetic in the following groups of patients:
 - Those with a full stomach ^{3, 5, 7};
 - Those in whom intubation difficulties are expected ⁵;
 - Those with a history or suspicion of malignant hyperthermia ^{5, 7};
 - Muscle disease ⁸;
 - Cardiopulmonary disease ⁹;

- Metabolic disease ⁵;
 - Renal and hepatic failure ^{5, 7};
 - Neurological disease with a stable course ⁵;
 - Where general anaesthesia has been contraindicated ³⁻⁵;
 - When the patient's family has refused general anaesthesia ¹⁰.
-
- An advantage of paediatric lumbar epidural anaesthesia over spinal anaesthesia is the ability to maintain continuous anaesthesia after placement of an epidural catheter, thus making it suitable for procedures of long duration. The use of continuous epidural analgesia has been proven to be safe in both newborn and ex-premature infants ¹¹. This feature also enables the use of this technique into the postoperative period for analgesia, using lower concentrations of local anaesthetic drugs or in combination with different agents ^{9, 12-14}.

1.2 Anaesthetic indications

- Lumbar epidural anaesthesia can be used as sole anaesthetic for all urologic, orthopaedic and/ or general surgical procedures in the region of dermatomes T5-S5 involving operating times of up to 90 minutes, i.e., all procedures on the lower limbs, pelvis, perineum and lower abdomen ^{3-5, 8, 12-23}.
- It can also be used for surgical procedures on high-risk infants who are more prone to postoperative complications than other patients. Especially patients who are susceptible to malignant hyperthermia ^{5, 7}, patients with respiratory disabilities ^{9, 13}, and myopathy ⁸.

1.3 Analgesic indications

- The versatility of a lumbar epidural block means that it can be used as an anaesthetic, as an analgesic adjuvant to general anaesthesia, and for postoperative analgesia in procedures involving the lower limbs, perineum, pelvis, abdomen and thorax^{3, 4, 9, 12, 14}.
- Wee and Stokes²⁴ describe how they combined a lumbar epidural block and general anaesthesia, with remifentanil supplementation, on a 2 day old infant who had to undergo emergency closure of bladder extrophy. The advantage of this anaesthetic combination allowed them to avoid unnecessary neuromuscular blocking drugs and prolonged intensive care.
- Williams and co-workers¹³ report successful management of postoperative pain, using a continuous lumbar epidural catheter, in 17 infants (1.52kg - 7.84kg) who underwent upper and lower abdominal surgery.

2. Contraindications

2.1 General contraindications

2.1.1 Patient refusal

- Patient refusal is an absolute contraindication to regional anaesthesia. Appropriate information should be given to the patient regarding the technique, on its advantages and potential drawbacks and complications. Informed consent must be obtained ¹⁰.

2.1.2 Local infections

- Skin infections at the needle insertion site are an absolute contraindication to regional anaesthesia ^{3, 4, 15}.
- Insertion of the epidural needle through an area of skin infection may introduce pathogenic bacteria into the epidural space, leading to serious complications such as meningitis or epidural abscess ^{3, 4}.

2.1.3 Septicaemia (presence of pathogens in the blood) ^{3, 4, 15}

2.1.4 Coagulation disorders

- Coagulation disorders, as well as patients who are undergoing antithrombotic or anticoagulant treatment are contraindications to a regional block ^{3, 4, 8, 15, 25, 26}.
- Most of the complications have been described with lumbar epidural anaesthesia due to the possibility of multiple traumatic punctures and needle placement difficulties ^{3, 4}.

2.1.5 Neurological diseases involving the peripheral nerves (neuropathy)

- Although neuropathy (neurological or metabolic diseases) is not an absolute contraindication to perform a regional block, a clear distinction to benefit over general anaesthesia should be made ^{3, 4, 15}.

2.1.6 Allergy to the local anaesthetic ^{3, 4, 15}

2.1.7 Lack of training

- Adequate skills regarding a specific technique are essential for a successful procedure and to avoid complications and malpractice.
- Skills and expertise are key points to success in regional anaesthesia¹⁰.

2.1.8 Anatomical knowledge

- Winnie and co-workers²⁷ stated that regional anaesthesia is nothing more than applied anatomy.
- Ellis and Feldman²⁸ stated that anaesthesiologists required a peculiarly specialized knowledge of anatomy, which in some cases should even rival that of a surgeon.

2.1.9 Unresponsive patient

- Unresponsive patients may be impossible to position correctly without help, and may be unable to remain still long enough to safely insert an epidural needle^{3, 4}.

2.2 Specific contraindications

2.2.1 Patients with increased intracranial pressure (ICP)

- Transient increases in the ICP have been reported in the literature and lumbar epidural anaesthesia should therefore not be performed on patients with a reduced intracranial compliance and increased ICP²⁹⁻³².
- A careful neurological examination should always precede lumbar epidural blocks to check for the possibility of increased ICP. When the pressure in the spinal compartment is lowered due to piercing the dura mater, as in a lumbar puncture, transtentorial and foramen magnum herniation may occur, resulting in immediate loss of consciousness, permanent neurological sequelae and may even result in death³¹.

- In the presence of intracranial lesions and hydrocephalus and taking the problems of raised ICP in consideration, it is preferable to avoid an epidural block and rather rely on peripheral blocks instead³³.
- Accidental dural puncture in a child with increased ICP (as with a space occupying lesion) could therefore result in herniation, immediate loss of consciousness, permanent neurological damage and even death³¹.

2.2.2 Abnormalities of the vertebral column

- Anatomical abnormalities of vertebral column (see 4.1) may make the placement of an epidural needle technically impossible, and the risk versus benefit should be weighed before a lumbar epidural block is attempted^{3, 4, 28, 34}.

2.2.3 Minor surgical procedures

- Even though lumbar epidural anaesthesia has several advantages, it is vital that one should not forget the risk. Before performing a lumbar epidural block it is important that the benefits should be weighed against the risks for each individual patient. Minor surgery may not be an indication for lumbar epidural anaesthesia. These surgical procedures may be easily performed under a peripheral nerve block that might be safer and easier to perform³.

3. Block procedure

3.1 Technique for a lumbar epidural anaesthesia^{3, 4, 8, 15, 34}

3.1.1 Objective

- The objective of the lumbar epidural block is to approach the lumbar epidural space from posteriorly and to insert the tip of the needle into the posterior part of the epidural space, following the midline insertion route.
- The oblique paramedian insertion route is suitable for a lumbar epidural block when a midline insertion was unsuccessful^{4, 17, 35}.

3.1.2 Patient position

- *Sitting position*: This position is mostly used in adults or anaesthetised children older than 7 years of age.
- *Lateral position*: This is the most common position for performing a lumbar epidural block on anaesthetised and unanaesthetised infants.
 - The patient lies on the side of the operating table with the hips and knees flexed by 90°.
 - The ipsilateral arm lies at right angle with the table and the contralateral arm across the chest.
 - A pillow is placed underneath the patient's head for stability and to keep the vertebral spinous processes in the same horizontal plane.
 - The spinal column should be adequately flexed to open the angle between the consecutive spinous processes and the vertebral laminae. This allows the ligamentum flavum to be more easily penetrated with the midline insertion route³⁴.
- This position reduces the cerebrospinal fluid (CSF) pressure and increases the width of the posterior epidural space³.
- *Prone position*: This position is rarely used to approach the lumbar epidural space in children. In rare circumstances, especially in orthopaedic procedures (patients with large plaster casts), the lateral or

sitting position is impossible; therefore the prone position is the only other available position.

3.1.3 Anatomical landmarks

1. Spinous process of the vertebral column.
2. Iliac crests.

3.1.4 Technique: *Single-shot midline approach*

I. *Preparation*

- Check that all emergency equipment is present, complete and in working order:
 - ECG monitor;
 - Intubation kit;
 - Ventilation facilities;
 - Emergency medication;
 - Sterile precaution;
 - Intravenous access;
 - Pulse oximetry;
 - Anaesthetic machine.
- An intravenous cannula should always be inserted in either the upper or lower limb, in case of accidental intravenous injection, or profound sympathetic blockade from a high epidural block.
- Normally light general anaesthesia is given to the paediatric patient.
- The procedure must be carried out with a strict aseptic technique. The skin should be thoroughly prepared and sterile gloves must be worn. Infection in the epidural space is extremely serious.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- A line joining the most superior part of both iliac crests (Tuffier's line) will intersect the midline at the L4 spinous process or L4-L5 interspaces in adults^{28, 36}.

- The spinal cord ends at L3 in neonates, therefore the needle is inserted at the L4-L5 or L5-S1 interspaces^{3, 5, 7}.
- Over 1 year of age the needle can be inserted at L3-L4 or L4-L5 interspaces. Both these spaces are below the termination of the spinal cord at L1-L2^{5, 7, 14, 28, 34}.
- Dalens³ feels that it would be safer to use the lower needle insertion levels in children up to an age of 10 years, i.e., L4-L5 or L5-S1 interspaces.

III. *Insertion of needle*

- The needle is inserted in the midline of the patient.
- As the needle passes through the supraspinous ligament, which connects the two adjacent spinous processes (felt as an increase in resistance), the stylet is removed and a syringe containing either air or saline (for detecting loss of resistance) is attached (see 5.7).
- The epidural needle is then slowly advanced through the interspinous ligaments, which connect adjacent borders of the spinous processes.
- As the needle pass through ligamentum flavum the anaesthesiologist will feel a distinctive “give”. If a second “give” is experienced, it means that the needle has penetrated the dura mater and has traversed into the subarachnoidal space. Care should be taken to avoid this.
- If bone is encountered, withdraw the needle partially to the subcutaneous tissue. Re-palpate the back to make sure the needle is in the midline, and try again.

IV. *Tests to confirm the correct placement of the needle*

- Loss of resistance indicates that the epidural space has been reached.
- The needle should be aspirated looking for either CSF or blood.
- Care should always be taken to look for signs of acute toxicity during the injection, which should never be at a rate of more than 10 ml/ 30 seconds.

3.1.4 Technique: Continuous catheter epidural placement

I. *Preparation*

- The preparation is the same as the single-shot technique.
- The length of the puncture needle should be compared with the marking points on the catheter, for better identification of the depth of the catheter after it has been introduced. The ability of the catheter to pass the puncture needle is tested at the same time (see 5.6).

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- A median line puncture in the L5-S1 region has proved particularly favourable for placing a catheter in the lumbar region ⁵.

III. *Insertion of needle*

- Inserting the epidural needle is the same as for the single-shot technique.
- Once the epidural space has been identified, and loss of resistance has been confirmed, an aspiration test is carried out.
- Once aspiration is satisfactory (no blood or CSF) and tests suggest that the needle is placed correctly in the epidural space, the needle is rotated so that the bevel of the needle faces upwards so that the catheter can be placed cranially. According to Meikeljohn ³⁷, rotating the needle increases the risk of dural puncture, however if care is taken that the needle isn't advanced further during the rotation, this risk is minimised.
- The catheter is then passed through the needle up to its tip. The catheter is then advanced a short distance passed the tip of the needle provided that no resistance is experienced at any time.
- Once the catheter is beyond the tip of the needle, the catheter should at no time be withdrawn through the needle. If it is necessary to withdraw the catheter, then it is done together with the needle. This is to avoid the complication of cutting off a piece of the catheter with the

bevel of the needle, resulting in a piece of catheter left in the epidural space.

- Once the desired length of the catheter has been inserted into the epidural space, the guide wire is withdrawn with extreme care, making sure that no resistance is felt. If resistance is encountered, the catheter, together with the guide wire and needle, should be withdrawn (preferably with dominant hand) while firm pressure must be placed on the insertion site.
- Once the guide wire has been removed, the epidural needle is withdrawn while the catheter is firmly held in place, and subsequently securely fixed to the patients back, preferably in a straight line along the vertebral column.
- In neonates, infants and small children the catheter meets hardly any resistance, so that it is easy to advance the catheter to the upper lumbar or thoracic levels ⁶.

4. Anatomical pitfalls

4.1 Course of the epidural needle

- The epidural needle pierces several structures before reaching the epidural space. These are the:
 - Skin;
 - Subcutaneous tissue;
 - Supraspinous ligament;
 - Interspinous ligament;
 - Ligamentum flavum.
- Hasan and co-workers³⁸ studied the depth of the epidural space from the skin in 586 children amongst which 29 were neonates and 139 were infants. He found that the skin to epidural distance in neonates, with a mean weight of $3.8\text{kg} \pm 1.1\text{kg}$ (mean \pm SD), was $0.9\text{cm} \pm 0.2\text{cm}$ and in infants, with a mean weight of $6.4\text{kg} \pm 1.8\text{kg}$, it was $1.1\text{cm} \pm 0.3\text{cm}$.
- In 1995, Bosenberg and Gouws³⁹ measured the skin-epidural distance in 274 children (range 2kg – 43kg), who underwent lumbar epidural anaesthesia. When “loss of resistance” to air was detected, the needle was marked as it emerges from the skin. Distance from this point to the needle aperture, and not the tip, was then measured. Between the ages of 6 months and 10 years (n=233) there was a good correlation between skin-epidural distance and both weight and age. This relationship between skin-epidural distance and body weight is described by the regression equation: **skin-epidural distance (mm) = 0.80 weight (kg) + 3.93**. In the 22 children under 6 months of age the distance varied between 5mm and 12mm and bore poor correlation to the weight of the patient. In children over 10 years of age (n=19) there were a poor correlation and the data from these patients were not used for further analysis.
- In a more recent study, Bosenberg¹ performed a series of 211 successful lumbar epidural blocks on infants and neonates, weighing

between 0.9kg – 5.8kg, undergoing major abdominal surgery, i.e., intestinal atresia, omphalocele, gastroschisis, and malrotation. He found that the skin-epidural distance ranged between 3mm and 12mm (mean; 6.0mm \pm 1.7mm).

4.2 Abnormalities of the vertebral column ⁴⁰

- Congenital deformities of the vertebral column are caused by anomalous development in the embryo.
- Minor malformations of the spine are seldom apparent, while more severe congenital malformations resulting in progressive scoliosis could have major clinical implications in children undergoing lumbar epidural anaesthesia.
- These abnormalities may be simple and benign, causing no spinal deformity, or they may be complex, causing severe spinal deformity or even paraplegia.
- The 3 major patterns of congenital vertebral column deformities are;
 - Scoliosis.
 - Kyphosis.
 - Lordosis.
- Anatomically there is a normal cervical and lumbar lordosis and a normal thoracic kyphosis.

Classification

- Congenital vertebral deformities can be classified as follows ⁴⁰:
 1. Failure of formation:
 - Partial failure of formation (e.g. wedge vertebra)
 - Complete failure of formation (e.g. hemivertebra)
 2. Failure of segmentation:
 - Unilateral failure of segmentation (e.g. unilateral unsegmented bar)
 - Bilateral failure of segmentation (e.g. block vertebra)

3. Mixed:
 - Elements of both failure of formation and failure of segmentation
- Defects of formation may be classified as follows:
 1. Anterior formation failure (resulting in kyphosis, which is sharply angulated).
 2. Posterior formation failure (rare but can produce a lordotic curve).
 3. Lateral formation failure (occurs frequently and produces the classic hemivertebrae of congenital scoliosis).
- The scoliosis that develops may occur with kyphosis or lordosis, depending on the precise location of the defects. Specific defects of segmentation may be classified as follows:
 1. Anterior segmentation failure with anterior unsegmented bar (leads to progressive kyphosis owing to the absence of anterior vertebral growth).
 2. Posterior segmentation failure (if symmetrical, results in lordotic deformities).
 3. Lateral segmentation failure with unilateral unsegmented bar (often produces some of the worst and most unrelenting scoliotic curves).
 4. Total segmentation failure (produces block vertebrae, which results in shortening of the spine).
 5. Posterolateral and anterolateral segmentation failures (rare but produce lordoscoliosis and kyphoscoliosis, respectively, when they do occur).

Scoliosis

- Congenital scoliosis is a lateral curvature of the spine caused by congenital anomalies of vertebral development.
- The vertebral abnormalities are present at birth, but clinical deformity may not be evident until later in childhood, when progressive scoliosis is evident.

- Adolescent idiopathic scoliosis (AIS) may present in children before puberty and progress until skeletal growth ceases. Further deterioration is slight. Although the cause of AIS is unknown, it has been shown that any extension deformity of the normal kyphotic spine (thoracic vertebrae) will in time force the spinal column to swivel and produce the appearance of a lateral curvature⁴¹.

Kyphosis

- Kyphosis is defined by an outward (to posterior) curve of the vertebral column.
- There are 2 causes for congenital kyphosis:
 - Defects of segmentation
 - Defects of formation
- Defects of segmentation occur most often in the mid-thoracic or thoracolumbar regions and may involve 2-8 vertebral levels. This tends to produce a round kyphosis rather than a sharp angular gibbous. Therefore, paraplegia rarely is a problem. The main clinical symptom is low back pain caused by the necessary compensatory lumbar hyperlordosis. Commonly, the kyphosis caused by the defect of segmentation starts in the late juvenile years with the progressive ossification of the disk spaces anteriorly.
- Defects of formation are more common and may involve only one vertebral level, but multiple defects are possible.
- The failure of the formation can be purely anterior, resulting in kyphosis, or can be anterolateral with a posterior corner hemivertebra, resulting in kyphoscoliosis. The more severe the anterior defects, the more progressive the deformity.

Lordosis

- Lordosis is defined by an inward (to anterior) curve of the vertebral column.
- Hyperlordosis is the excessive inward curvature of the lumbar vertebrae and is caused by a failure of posterior segmentation in the

presence of active growth anteriorly. Asymmetrical defects of segmentation, like a posterolateral unsegmented bar leading to lordoscoliosis, are more common.

Sacral or lumbosacral agenesis

- Renshaw ⁴² classified patients with sacral or lumbosacral agenesis according to the amount of sacrum remaining and according to characteristics of the articulation between the spine and the pelvis.
- Type I and II are characterised by variable amounts of agenesis of the sacrum.
- Types III and IV are far more severe:
 - Type III is characterised by variable lumbar and total sacral agenesis, with the ilea articulating with the sides of the lowest vertebra present.
 - Type IV is characterised by variable lumbar and total sacral agenesis, with the caudal endplate of the lowest vertebra resting above either fused ilea or an iliac amphiarthrosis.
- This condition drastically distorts the anatomy of the lumbar area making finding of the correct needle insertion site and actual placement of the needle almost impossible. Lumbar epidural blocks should therefore be avoided in patients with advanced types of lumbosacral agenesis.

Age related changes of the vertebral column

- In young patients the vertebral anatomy is well defined, consistent and amenable to easy localization of the epidural and subarachnoid space ².
- In a study conducted by Boon and co-workers ³⁵, the placement of epidural needles in 36 adult cadavers was evaluated, using the alternative paramedian approach. Radiographic measurements on anteroposterior lumbar spine X-rays in different age groups were used to determine the dimensions of the interlaminar area. The results showed that with age, the interlaminar area decreases in height and

width. This study however focused on adults and the dimensions of the interlaminar space has yet to be measured in children, especially in neonates.

4.3 Development of the spine

- Molecular and cellular tissue interaction and increasing organ complexity characterise the fundamental features of the embryonic developmental process during axial embryogenesis. Alteration in the molecular and macromolecular process may lead to structural defects involving the vertebral column and spinal cord.
- Such defects may occur prenatally and/ or postnatally and are divided into 3 categories:
 - Malformation;
 - Disruption;
 - Deformation.

Malformation

- Malformation is a failure of embryological differentiation and/ or development of a specific anatomical structure, causing it to be absent or improperly formed before the foetal period commences, e.g., hemivertebrae.
- Once it is anatomically established, the defect may continue to adversely affect vertebral column development throughout the subsequent foetal and postnatal periods. The eventual type of malformation and its severity depend on the stage of the developmental or maturational cycle that is specifically affected.

Disruption

- Disruption is a structural defect resulting from destruction of a part that formed normally during the embryonic period.
- This mechanism involves the limbs (amniotic band syndrome) more frequently than the vertebral column during the foetal stage.

Deformation

- Deformation is an alteration in the shape or structure of individual vertebrae or of the entire vertebral column during the foetal and/ or postnatal periods, with the involved region having initially differentiated normally.
- Deformation may be divided into those that are intrinsically derived and those that are extrinsically derived.
- Intrinsic deformation results from the reduced ability of the foetus or child to move away from normal imposed forces and depends on the integrity of the neuromuscular system to respond effectively.
- Extrinsic prenatal deformations are the result of reduction in the available space in which a developing foetus may move. Such reduction may be either physiologic or pathologic.

4.4 The epidural space ^{4, 28, 43-47}

- The epidural space lies within the spinal canal of the vertebral column, between the periosteum of the spinal canal and the outer surface of the dural sac and extends from the foramen magnum to the sacral hiatus.
- Due to the triangular shape of the epidural space, and the ellipsoid shape of the spinal cord, the widest part of the epidural space is found in the midline. Therefore, the safest approach to the epidural space is via the midline insertion route.
- Several studies have been conducted to describe the anatomy of the epidural space. The presence of a median epidural band, which divides the epidural space into an anterior and two dorsolateral spaces, has been described in the literature and could very well play a major role in the lateralisation of a lumbar epidural block ⁴⁴⁻⁴⁷.
- Hogan ⁴⁸ reports findings from cryomicrotome sections of 38 adult cadaver lumbar spines. He states that the epidural space is less uniform and more complex than previously thought. He believes that further studies of the structural detail of the spinal soft tissue anatomy could lead to improved epidural techniques and a better understanding

regarding the spread and distribution of local anaesthetic solution administered into the lumbar epidural space.

- When the epidural needle is inserted at an angle, the skin-epidural distance will be increased. This distance will be increased by up to 1.5mm for every 10mm perpendicular distance, if the angle of insertion is at 30° to the skin⁴⁹.

4.5 Contents of the epidural space^{3, 4, 28, 43, 44}

- The epidural space is filled with loose areolar tissue, fat, blood vessels, and lymphatics.
- Between the dura mater and the spinal canal is a layer of areolar tissue. This contains the *internal vertebral venous plexus* and the posterior deposit of fat, which lies in a recess between ligamentum flavum⁴⁴.
- The fat is very fluid in infants and becomes more packed, and thus less permeable to local anaesthetic solutions in children over 7 years of age⁵⁰.

4.6 End of spinal cord

- In the third month of development the spinal cord extends the entire length of the embryo, and spinal nerves pass through the intervertebral foramina at the level of origin⁵¹.
- With increasing age the vertebral column and the dura lengthen more rapidly than the neural tube, and the terminal end of the spinal cord gradually shifts to a higher level.
- At six months of foetal life, the lowest limit of the spinal cord lies at the level of S1^{22, 51}.
- At birth the spinal cord ends at L3^{3, 14, 22, 51, 52} and reaches its definitive position at the level of L1 at the age of one year^{3, 22}.
- Hawass *et al.*⁵² assessed the length of the spinal cord relative to the vertebral column during foetal development by performing translumbar

myelograms on 146 spontaneously aborted fetuses. (76 males and 70 females, foetal age between 7-33 weeks). Significant variation in the level of spinal cord termination was found in fetuses between 12-25 weeks gestational age. In fetuses between 25-33 weeks gestational age, the cord ended at or above L3.

4.7 Vasculature of the spinal cord

Arterial blood supply^{3, 5, 43}

- The arterial blood supply of the spinal cord is dependant upon three, continuous, longitudinal arterial trunks extending from the medulla oblongata to the conus medullaris⁵³.
- The spinal cord is supplied by numerous radicular arteries, which branches off from the cervical vertebral arteries, the thoracic intercostal arteries and the lumbar vertebral arteries, to form the *anterior spinal artery* and *posterior spinal arteries*.
- The thoracolumbar region of the spinal cord (T8 to the medullary cone) is supplied mainly by the great radicular artery (artery of Adamkiewicz), which arises from an intercostal artery on the left side⁴³.
- Branches of the lumbar, iliolumbar and lateral or median sacral arteries supply the cauda equina. These also supply the medullary cone.
- Thin pial branches run from the spinal arteries, forming a network on the surface of the spinal cord known as the *arterial pial network*.

Variations of spinal blood supply³

- The blood supply of the spinal cord shows considerable individual and segmental variations, particularly in the areas called the *transitional zones*.
- If even one of the segmental arteries that arise from the radicular arteries is injured, that particular spinal segment is very likely to undergo ischemic necrosis.

Venous blood drainage^{3, 5, 43}

- The epidural space has considerable venous drainage. Therefore the epidural space must be entered with considerable caution.
- Two venous plexuses, the *internal* and *external vertebral venous plexuses*, traverse the entire spinal canal. The *internal vertebral venous plexus* can be found in a thin layer of areolar tissue between the dura mater and the vertebral canal⁴⁴.
- Together these form a ring around each vertebra, freely anastomosing with one another and receiving tributary flow from the vertebrae, ligaments and spinal cord.
- The extradural or internal vertebral venous plexus or Batson's plexus occupies the epidural space and is described as a characteristically plexiform network of vessels (a large venous lake or reservoir), which extends from the cranium to the coccyx. There are many communications with the veins found in the spinal canal, as well as the veins surrounding the spinal cord⁵³.
- The lumbar epidural veins have no valvular system: thus, inadvertent injections into the epidural veins result in almost instantaneous systemic distribution.
- The epidural veins generally end at S4, but may extend throughout the canal^{3, 5, 43}.

4.8 Ligamentum flavum^{28, 44, 48, 54}

- Ligamentum flavum is an essential landmark for identifying the epidural space. It consists of strong yellow elastic fibres that are densely packed and can be up to 1 cm thick in the lumbar region and spans the interlaminar space between adjacent vertebrae.
- Fibres are stretched in the flexed position and can be more easily penetrated with lumbar puncture. If the needle is exactly in the midline, it may pass through the gap between the right and left ligamentum flavum⁴⁸.

- Through means of dissection of 10 adult cadavers, Zarzur⁵⁴ described the anatomy of ligamentum flavum. He described how he found ligamentum flavum to be between 3mm to 5mm thick at levels L2 - L3 and 12mm to 22mm wide. The anterior surface forms an acute angle with its vertex in contact with the interspinous ligament.

4.9 Meninges^{22, 28, 43}

- *Dura mater*: The dura mater lines the spinal canal to the level of S3-S4 in neonates and S1-S2 (adult level) in infants older than one year.
- *Arachnoid mater*: The arachnoid mater lines the dural sac to the level of the middle one-third of S3-S4 in neonates and S1-S2 (adult level) in infants older than one year. The subarachnoid thus continues down to level S3-S4.
- *Pia mater*: The pia mater leaves the spinal cord at the conus medullaris to form the filum terminale which traverses the subarachnoid space and terminates on the periosteum of the coccyx, after penetrating the dura and arachnoid at the level of S3-S4 in neonates and S1-S2 (adult level) in infants older than one year.

4.10 Iliac crests as bony landmarks

- Due to the lower termination of the spinal cord in children (L3) it is safer to choose L4-L5 or L5-S1 interspace in patients younger than 1 year of age. The L3-L4 interspace is used in patients over one year of age, as the spinal cord terminates at the adult level of L1.
- In the adult, identification of the correct level of needle insertion is in a line drawn between the iliac crests (Tuffier's line); it crosses the spinous line at a level ranging from the 4th lumbar spinous process to the lower part of the interspace between the 4th and the 5th lumbar vertebrae, depending on the degree of flexion of the vertebral column

- Reynolds⁵⁵ describes seven cases in which neurological damage followed spinal or combined spinal-epidural anaesthesia in adult women. Reynolds⁵⁵ therefore believes that Tuffier's line is unreliable in determining the lumbar interspaces. Anaesthesiologists, for example, often select a space of insertion one or two segments higher than they estimated using Tuffier's line.
- Because of the variability of Tuffier's line in adults, Reynolds⁵⁵, as well as, Boon and co-workers³⁴ recommends to rather go for one space lower, as the identified space is likely to be at least one interspace too high.
- In infants a line drawn between the 2 iliac crests crosses the midline in the area of about L5 and at about L5-S1 in neonates⁵. Identifying the correct interspace is essential before even contemplating a lumbar epidural block in children.
- A search of the Medline database did not reveal any studies to validate the value of Tuffier's line in children.

4.11 Future studies

- Measure the distance from the skin to the epidural space in neonatal cadavers.
- Determine at which level the dural sac terminates in neonates.
- Determine the value of Tuffier's line in children.
- Study the dimensions of the neonatal ligamentum flavum.
- Using spiral CT scan, study the dimensions of the interlaminar space in neonates.
- Determine the presence of plica mediana dorsalis in paediatric patients.

5. Complications

- Many authors feel that only experienced anaesthesiologists should perform lumbar epidural aesthesia on neonates and small infants as to avoid the occurrence of disastrous complications. The less experienced anaesthesiologists should alternatively consider a single shot lumbar epidural block for minor surgery or the lumbar catheter technique for more prolonged surgery ^{1, 11, 23}.
- Wood and co-workers ¹² conducted a study to determine the incidence of side effects and complications with the use of epidural analgesia for 190 patients with a mean age of 5.6 years (range 1 month – 18 years) and a mean weight of 22 kg (range 4kg – 88kg). Minor complications (e.g., nausea and vomiting, urinary retention, jitteriness) occurred in 67% of the population (127/190) while major complications (e.g. seizure, respiratory depression, and severe insertion site infection) occurred in 3 patients (1.6%).

5.1 Dural puncture

- Extreme care must be taken to avoid puncturing the dura, as a total spinal block will occur if the dose for a lumbar epidural block is injected into the subarachnoid space. Reflux of spinal fluid through the needle must be verified and, if this occurs, the needle should be withdrawn.
- The frequency of dural puncture, in a study conducted by Dawkins ⁵⁶ in 1969, occurred in 2.5% of the patients.
- Bosenberg ⁽¹⁾ performed a series of 211 lumbar epidural blocks on infants, weighing between 0.9kg and 5.8kg. In that study dural puncture occurred in only one patient (0.5%). He therefore concluded that lumbar epidural anaesthesia is a safe and effective procedure to perform on neonates for major abdominal surgery if the correct technique is followed and the anaesthesiologist is careful not to puncture the dura.

- If a dural puncture occurs, the needle must be withdrawn. Another attempt is allowed, giving special attention to the cardiorespiratory tracings and to the speed of the injection. If a dural puncture occurs for the second time, the needle must again be withdrawn and the use of an alternative technique should strongly be considered^{3,4}.
- Desparment⁵⁷ states that if a dural puncture occurs it would be wiser to abandon any second attempt, as he believes the risk of total spinal anaesthesia is too high due to leakage of local anaesthetic through the first puncture hole in the dura, into the subarachnoid space.

5.2 Vascular puncture

- Vascular penetration into the epidural veins is by no means uncommon. This accidental puncture is of no consequence if no injection is performed. The needle should simply be removed and reinserted properly before administering the local anaesthetic solution^{3,4}.
- Although formation of a haematoma following a lumbar epidural block is rare, it is still a possible complication that has been reported in the literature^{25,26}, and the anaesthesiologist should be extremely aware of this medical emergency as the presence of a space-occupying lesion may compress the spinal cord or nerve roots.
- Bosenberg¹ performed a series of 211 lumbar epidural blocks on infants, weighing between 0.9kg and 5.8kg, and vascular puncture occurred in only one patient (0.5%).

5.3 CNS toxicity⁵

- Intravascular administration, overdose and/ or rapid vascular uptake of local anaesthetic solution, can lead to toxic CNS reactions like:
 - Tonic-clonic seizures (a very serious complication), but provided that it is treated immediately, it does not lead to cerebral injury or death;

- Nystagmus;
- Sudden vertigo;
- Brief blackouts;
- Inability to move or respond to external stimuli.

5.4 Trauma of the spinal cord and roots

- Direct trauma to the spinal cord or spinal roots may occur during a lumbar epidural block.
- This is a rare complication, as most punctures are carried out inferior to the medullary cone ⁵.
- Neurological disorders may result from the insertion of the tip of the needle into the perineural sheath or within nerve fibres of the spinal root. Injecting local anaesthetic solution into the spinal root could tear the nerve fibres and/ or produce a compression lesion of the root ⁴.

Prevention of trauma ⁵

- Advance the needle with the utmost care.
- The procedure should be interrupted if pain occurs during the puncture, while introducing the catheter and/ or during the injection (intraneural positioning).

5.5 Partial or complete failure of block

- Partial or complete failure of lumbar epidural anaesthesia most often occurs due to misplacement of the needle or due to “low resistance” wrongly identified as “loss of resistance”. Especially when attempting epidural blockade in patients with abnormalities of the vertebral column ⁵⁸.

5.6 Lateralisation

- A lateralised block is a rare occurrence during lumbar epidural anaesthesia. The cause of a unilateral block occur, is not clearly understood but the occurrence can be very distressing if the unanaesthetised side is about to be operated on⁵⁹⁻⁶¹.
- Lateralisation may also occur due to the presence of adhesions that developed following previous surgery, or due to inflammation or infection. Most often complete lateralisation is due to the presence of a complete plica mediana dorsalis, which divides the posterior epidural space into two halves^{46, 47, 59-61}.

5.7 Complications related to epidural catheters

- Complications with epidural catheters include misplacement, kinking, or partial removal (either while the epidural needle is withdrawn or due to the patient moving).
- Bosenberg⁶² described how the catheter of certain needles could actually bend within the cuvette, so that the force required to push the catheter is not transmitted down the catheter. According to him this might lead to a false impression that the catheter is entering the epidural space when it is in fact being curled up in the cuvette. If this remains undetected it could lead to failure of the block.
- According to Wood and co-workers¹², technical problems associated with catheters include: the size, flexibility, and tensile strength of the catheter. Leakage of anaesthetic solution at the catheter site was the most frequent complication and presented as bubbles of solution under the patient's dressing. Therefore the catheter should be frequently inspected for premature failure of the epidural infusion.
- A catheter should never be withdrawn through an epidural needle. If it is necessary to withdraw the catheter, it is done together with the needle, preferably with the dominant hand, while firm pressure must be placed on the insertion site. This is to avoid the complication of cutting

the catheter with the bevel of the needle, possibly resulting in a piece of catheter remaining in the epidural space.

5.8 Complications due to “loss of resistance” with air.

- Although testing for “loss of resistance” using air is a reliable method to test whether the needle is placed correctly, Swartz and Eisenkraft⁶³, as well as, Flandin-Bléty and Barrier⁶⁴ disagrees with the use of air to test for loss of resistance in order to locate the epidural space in children. They suggest that it should be avoided as reports indicate that children may develop a life-threatening venous air embolism from small quantities of air used during loss of resistance identification. The authors recommend the use of a small dose of saline.
- Injection of air into the epidural space during lumbar epidural anaesthesia may cause complications such as a patchy block or nerve root pain due to an air lock around the nerve root⁶⁵⁻⁶⁷.
- Too much air injected into the epidural space may cause subcutaneous emphysema as the air migrates^{68, 69}.
- Saberski and co-workers⁷⁰ searched the Medline scientific data bank from 1966 to 1995 for case reports of epidural complications following the loss of resistance technique using air. They believe that the potential complications associated with the use of air for identifying the epidural space with the loss of resistance technique may outweigh the benefits. Therefore use of saline to identify the epidural space may help to reduce the incidence of complications.

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5.3 Paediatric Infraclavicular Approach to the Brachial Plexus

1. Indications
2. Contraindications
3. Block procedure
4. Anatomical pitfalls
5. Complications
6. References

1. Indications

1.1 Anaesthetic indications

- The infraclavicular approach is yet another addition to the multitude of different approaches, techniques, and variations on the brachial plexus block.
- Like the interscalene, supraclavicular, coracoid and axillary approaches, the infraclavicular block is designed to inject the local anaesthetic solution inside the brachial plexus sheath, effectively blocking the cords and branches of the brachial plexus above and below the formation of the musculocutaneous and axillary nerves ¹⁻⁶.
- Indications are therefore much the same as for the axillary approach to the brachial plexus, which can be used during elective surgical procedures for:
 - Relief of intra- and postoperative pain ⁷;
 - Prevention of inappropriate movements of the upper limb following plastic surgery ³, and
 - Tendon and tendon sheath operations ⁸.
- During emergency procedures it can be used for:
 - Treatment of unstable fractures of the upper extremity ⁹;
 - Reduction of dislocations ^{8, 9};
 - Reduction of fractures ^{8, 9};

- Amputations⁸; and
- Procedures of the upper extremities, especially when the lesions involve the forearm and/or the hand^{3,5}.
- The infraclavicular technique also allows for the easy blocking of the ulnar segment of the medial cord and intercostobrachial nerve, thus preventing tourniquet pain without the need for additional infiltration².
- This block can be considered an alternative to the axillary approach in instances where abduction of the arm is uncomfortable or difficult, or when infection is located in the axilla^{2,3,5,6,10}.

1.2 Analgesic indications

- Can be used in combination with a light general anaesthetic, especially in smaller infants¹⁰.
- It is especially effective for continuous analgesia for patients experiencing complex regional pain syndromes, where a catheter needs to be left in place for a few days³. When an indwelling catheter technique is indicated, the infraclavicular approach allows suture fixation of the catheter to the relatively clean, immobile infraclavicular region (in contrast to the axilla or neck). This may provide patients with greater comfort and freedom of movement with less risk of catheter dislodgement and entry site infection⁷.
- The infraclavicular block is indicated for patients where general anaesthesia is contraindicated or patients with decreased respiratory function or pulmonary diseases, as the occurrence of an accidental phrenic nerve block¹¹, as well as, the occurrence of a pneumothorax is rare although still a possibility^{4,11,12}.

2. Contraindications

2.1 General contraindications

2.1.1 Patient refusal

- Patient refusal is an absolute contraindication to regional anaesthesia. Appropriate information should be given to the patient regarding the technique, on its advantages and potential drawbacks and complications. Informed consent must be obtained^{2, 13}.

2.1.2 Local infections

- Skin infections at the needle insertion site are an absolute contraindication to regional anaesthesia^{2, 3, 14}.

2.1.3 Septicaemia (presence of pathogens in the blood)^{2, 3, 14}

2.1.4 Coagulation disorders

- Coagulation disorders, as well as patients who are undergoing antithrombotic or anticoagulant treatment are contraindications to the infraclavicular block due to the possibility of vascular puncture^{2, 3, 13, 14}.

2.1.5 Neurological diseases involving the peripheral nerves (neuropathy)

- Although neuropathy (due to neurological or metabolic diseases) is not an absolute contraindication to perform a regional block, a clear distinction to benefit over general anaesthesia should be made however^{2, 3, 14}.

2.1.6 Allergy to the local anaesthetic^{2, 3, 14}

2.1.7 Lack of training

- Adequate skills regarding a specific technique are essential for a successful procedure and to avoid complications and malpractice.

- Skills and expertise are key points to success in regional anaesthesia¹³.
- Whiffler¹¹ stated that, “careful identification of landmarks and strict attention to the technique described are important to avoid failure.”

2.1.8 Anatomical knowledge

- Winnie and co-workers¹⁵ stated that regional anaesthesia is nothing more than applied anatomy.
- Ellis and Feldman¹⁶ stated that anaesthesiologists required a peculiarly specialized knowledge of anatomy, which in some cases should even rival that of a surgeon.

2.2 Specific contraindication

2.2.1 Ankylosing spondylitis¹⁷

2.2.2 Neuromuscular diseases¹⁷

2.2.3 Unavailability of a nerve stimulator

- Although not an absolute contraindication, the use of a nerve stimulator and an insulated needle improves the reliability of the technique and the success rate of the block as well as prevents injury to the nerves of the brachial plexus and is therefore highly recommended^{2, 7, 18, 19}.

3. Block procedure

3.1 Infraclavicular approach according to Raj and co-workers in 1973⁴

3.1.1 Objective

- The aim of this procedure is to penetrate the brachial plexus sheath below the emergence of the brachial plexus under the clavicle and above the site of emergence of the musculocutaneous nerve.

3.1.2 Patient position

- Optimally the patient should lie supine in a dorsal recumbent position with the head turned contralaterally and the arm abducted to a 90° angle with the body ⁴. The main advantage of the infraclavicular block is that, unlike the axillary block, the arm and head can actually be in any position to successfully palpate the landmarks necessary for a successful block ^{2, 4, 5}.

3.1.3 Anatomical landmarks and needle insertion site

1. The entire length of the clavicle.
 2. The subclavian artery located by palpation above the clavicle, or if the pulse of the subclavian artery cannot be located; the midpoint of the clavicle can be used.
 3. Pulse of axillary artery located in the axilla.
 4. Transverse process of the 6th cervical vertebra (Chassaignac's tubercle).
 - A line is drawn from Chassaignac's tubercle to the axillary artery (this line should pass over the midpoint of the clavicle).
 - These landmarks can be simplified by drawing a straight line perpendicular to the midpoint of the clavicle. The site of puncture should lie on this line immediately lateral to the axillary artery, i.e., approximately 10mm - 30mm below the clavicle, depending on the age of the child.
- Sims ²⁰ reported improved landmarks consisting of:
 1. The coracoid process of the scapula
 2. The inferior border of the clavicle

3. The palpable depression in the groove between the coracoid process, the clavicle, and the superior portion of pectoralis major.
 - The index finger is placed in the groove between the coracoid process and the inferior border of the clavicle.
 - The fingertip is advanced inferiorly and medially with moderate pressure of the skin.
 - It will fall into a depression bordered inferiorly and medially by the superior portion of pectoralis major laterally by the coracoid process, and superiorly by the clavicle.
 - The site of puncture is marked on the skin at the level where the depression is palpated.
- Borgeat and co-workers¹² further improved the landmarks first proposed by Raj and co-workers⁴. They are:
 1. Ventral acromion process of the scapula (lateral landmark).
 2. Jugular notch (medial landmark).
- An infraclavicular line is drawn between the lateral and medial landmarks. The point where the axillary artery can be palpated as it emerges inferior of the clavicle and bisects the above-mentioned infraclavicular line is marked as the needle insertion site.
- Borgeat and co-workers¹² concludes that this modification increases the success rate of the infraclavicular block as it is based on reliable and relatively constant landmarks, offer good conditions for catheter placement, and decreases complications such as pneumothorax.

3.1.4 Technique

I. *Preparation*

- Check that all emergency equipment is present, complete and in working order:
 - ECG monitor;
 - Intubation kit;
 - Ventilation facilities;
 - Emergency medication;
 - Sterile precaution;
 - Intravenous access;
 - Pulse oximetry;
 - Anaesthetic machine.
- An intravenous cannula should always be inserted in either the upper or lower limb, in case of accidental intravenous injection.
- Normally mild light general anaesthesia is given to the paediatric patient.
- The procedure must be carried out with a strict aseptic technique. The skin of the pectoral region should be thoroughly prepared and sterile gloves must be worn.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- Respective needle insertion sites are described in 3.1.3.

III. *Insertion of the needle and administration of local anaesthetic solution*

- For this procedure the use of a nerve stimulator is essential, as it will effectively increase the success rate of the block and prevent the possibility of nerve damage^{2, 10, 18, 19}.
- The needle is advanced dorsally in a slightly lateral and caudal direction, until twitches are elicited in the limb.

- The first visible twitches will be those of pectoralis major and minor as the needle traverses through them. This only represents the shallow placement of the needle.
- As the needle is advanced deeper and once the twitches of pectoralis major and minor cease, the stimulation of the brachial plexus (hand twitches) is obtained.
- The ideal twitch response with this block is that of the median nerve (wrist and finger flexion). While twitches of the radial, ulnar, musculocutaneous and axillary nerves all indicate brachial plexus stimulation, wrist twitches (due to the innervation of the median nerve) are the most reliable indicator of correct needle placement².
- After negative aspiration for blood, the local anaesthetic solution is injected with intermittent aspiration to rule out inadvertent intravascular injection.
- Using the same technique, Whiffler¹¹ described a needle insertion site that is medial and inferior to the coracoid process determined by palpation of vascular landmarks with the affected arm abducted and the relevant shoulder depressed. This position moves the neurovascular bundle closer to the coracoid process.
- The needle direction is directly posterior to avoid the occurrence of a pneumothorax.
- Twitches from biceps brachi (flexion of the elbow) should not be accepted, since the musculocutaneous nerve may be outside the brachial plexus sheath. If twitching of biceps brachi does occur, the needle orientation should be re-directed inferiorly and slightly medially to obtain median nerve stimulation.
- Twitches from the deltoid (shoulder) should not be accepted, since the axillary nerve is often outside the brachial plexus sheath at this level. When a deltoid response is obtained, the needle orientation should be directed more superiorly.

3.2 Technique described by Wilson and co-workers in 1998 ⁵

3.2.1 Objective

- The same as in the infraclavicular approach according to Raj and co-workers in 1973 ⁴.

3.2.2 Patient position

- The patient lies supine with the arm in any position, i.e., abducted to 90° or parallel to the body ⁵.

3.2.3 Anatomical landmarks

1. The coracoid process.

3.2.4 Technique

I. *Preparation*

- Preparation is the same as the technique described by Raj and co-workers ⁴.

II. *Determine needle insertion site*

- The coracoid process is identified and marked on the skin.
- In the adult patient the needle insertion site is found 20mm medial and 20mm inferior from the tip of the coracoid process.
- These measurements are obviously different for neonates, and the measurements should be changed if used on a neonatal patient. It is not known how this will differ in neonates.

III. *Insertion of the needle and administration of local anaesthetic solution*

- For this procedure the use of a nerve stimulator is essential, as it will effectively increase the success rate of the block and prevent the possibility of nerve damage ^{2, 10, 18, 19}.
- The needle is inserted directly posterior, perpendicular to the table and not the skin of the patient. This effectively decreases the risk of a pneumothorax occurring while performing this block as was seen in a

preliminary cadaver study conducted by Wilson and co-workers⁵, where there was no occurrence of penetrating the thoracic cavity even if the entire needle was inserted.

- Wilson and co-workers⁵ further studied the Magnetic Resonance Images (MRI) of the brachial plexus of 20 adult males and 20 adult females. They found that the mean depth from the skin to the anterior wall of the axillary artery was $4.24\text{cm} \pm 1.49\text{cm}$ in males and $4.01\text{cm} \pm 1.29\text{cm}$ in females.
- Hand stabilization and precision is crucial with this block as the brachial plexus is very thin at this location and small movements of the needle may result in the injection of local anaesthetic outside the sheath (weak block with slow onset). This is the most common cause for a failed block²¹.

Children

- No study determining the correct distances of the brachial plexus from the coracoid process in paediatric patients has been described in the literature.

3.3 Lateral infraclavicular technique as described by Kapral and co-workers, in 1996⁶

3.3.1 Objective

- The same as in the infraclavicular approach according to Raj and co-workers in 1973⁴.

3.3.2 Patient position

- Patient lies supine with the arm adducted to the trunk and the elbow flexed at 90° with the forearm placed on the abdomen⁶.

3.3.3 Anatomical landmarks

1. The coracoid process.
 - Ask the patient to shrug his/her shoulders. This results in the anterior movement of the coracoid process, facilitating easy identification of the coracoid process.
 - This may not always be possible in the very young patient with extensive upper extremity damage, or in patients under general anaesthesia. The anaesthesiologist should therefore accurately palpate the coracoid process before continuing with the procedure.

3.3.4 Technique

I. *Preparation*

- Preparation is the same as the technique described by Raj and co-workers⁴.

II. *Determine needle insertion site*

- The coracoid process is identified and marked on the skin.

III. *Insertion of the needle and administration of local anaesthetic solution*

- For this procedure the use of a nerve stimulator is essential, as it will effectively increase the success rate of the block and prevent the possibility of nerve damage^{2, 10, 18, 19}.
- The needle is inserted directly posterior (perpendicular to the table) until the needle comes into contact with the coracoid process.
- After bone contact the needle is withdrawn about 2mm-3mm and, with a parallel shift inferior, the needle is reinserted inferior to the coracoid process until the needle comes into contact with the brachial plexus.
- Fleischmann and co-workers²² performed the lateral infraclavicular block on 20 children (ages 1-10 years). He described a needle puncture site 5mm inferior of the coracoid process.

Comparison of the infraclavicular approach compared to the axillary approach

- Shortcomings of the axillary approach to the brachial plexus, according to Fleischmann and co-workers²², include painful arm positioning during puncture, ineffective analgesia of the upper arm, and inconsistent action of the musculocutaneous nerve.
- Tobias²³ also list the shortcomings as:
 - Painful arm position during puncture,
 - Ineffective analgesia of the upper arm²⁴, and
 - Inconsistent block of the musculocutaneous nerve as it frequently branches from the lateral cord higher up in the axilla and are not encased in the fascia surrounding the three cords.
- In a recent paper, Kapral and co-workers²⁵ compared the lateral infraclavicular block with the axillary block for hand and forearm surgery in 40 adult patients. The lateral infraclavicular approach provided a high success rate and a greater extent of blockade when it was compared to the axillary block.
- Fleischmann and co-workers²² investigated the quality and spectrum of the lateral infraclavicular block as compared to the axillary block for

brachial plexus analgesia in 40 children (ages 1-10) undergoing hand or forearm surgery. Based on all assessable children, sensory blockade in the primary sensory regions of various nerves was significantly more effective in patients who had a lateral infraclavicular block (axillary nerve: $P < 0.0001$; musculocutaneous nerve: $P=0.002$; medial brachial cutaneous nerve; $P=0.008$). Motor blockade was also significantly more effective (axillary nerve: $P < 0.0001$; musculocutaneous nerve: $P=0.003$). No major complications were observed in either group. Therefore they believe that the lateral infraclavicular block can be safely performed in children and that they add to the spectrum of sensory and motor blockade seen with the axillary approach.

- Unlike the supraclavicular and interscalene approaches, the infraclavicular block carries no risk of accidental intrathecal, epidural, or intravertebral injection, stellate ganglion block, paralysis of the hemidiaphragm, and was a very low incidence of a pneumothorax^{2, 3, 5, 11, 12}.

4. Anatomical pitfalls

4.1 Roots of the brachial plexus^{16, 26, 27}

- The brachial plexus is formed by the ventral roots of the spinal nerves C5 to T1 with some contributions from C4 and T2. It extends from the lower part of the side of the neck to the axilla.
- The brachial plexus presents as a broad plexiform arrangement at its commencement between the anterior and middle scalene muscles, it becomes narrower opposite the clavicle, and again presenting as a broad, dense interlacement of nerves in the axilla, dividing opposite the coracoid process into its numerous branches that supply the upper extremity²⁶.

4.2 Trunks of the brachial plexus^{16, 26, 27}

- The roots of C5 and C6 unite near their exit from the spine, between the anterior and middle scalene muscles to form the *superior trunk*. Variably C7 joins this trunk near the outer border of the middle scalene muscle to form one large single cord, or remains separate to form the *middle trunk* of the brachial plexus. C8 and T1 unite beneath the anterior scalene muscle to form *inferior trunk*.
- These trunks lie posterior to the subclavian artery (supraclavicularly) and vein (which lies anterior and inferior to the artery) as the trunks accompany the vessels into the axilla.

4.3 Divisions of the brachial plexus^{16, 26, 27}

- Posterior to the clavicle, at the lateral border of the first rib, each of these trunks divides into an *anterior* and *posterior division* thereby forming 6 divisions.

4.4 Cords of the brachial plexus^{16, 26, 27}

- The 6 divisions continue into the axilla and unite to form 3 cords; a *lateral*, *medial* and *posterior cord* (named after their relationship to the axillary artery), upon emerging from the inferior border of the clavicle.
- The cords are formed as follows:
- *Lateral cord* is formed by anterior divisions of the superior and middle trunks
- *Medial cord* is formed by the continuation of the anterior division of the inferior trunk
- *Posterior cord* is formed by all three of the posterior divisions.
- Using the modified technique described by Wilson and co-workers⁵ in 1998, the direct posterior placement of the needle should touch the cords of the brachial plexus where they surround the second part of the axillary artery (posterior cord posterior to the artery; medial cord medial to the artery and lateral cord lateral to the artery).

4.5 Terminal branches of the brachial plexus^{16, 26, 27}

- The terminal branches of the brachial plexus form the peripheral nerves that supply the upper extremity. These terminal branches are:
 - The *musculocutaneous nerve* (C5-C7), which originates from the lateral cord;
 - The *median nerve* (C5-T1), originating from both the lateral and medial cords and has a relation with the axillary and brachial arteries;
 - The *ulnar nerve* (C7-T1), which originates from by the medial cord;
 - The *radial* (C5-T1) and the *axillary* (C5, C6) nerves, which both originate from the posterior cord.

4.6 The axilla^{16, 26, 27}

- The axilla can be thought of as a pyramid shaped space between the lateral chest wall and the medial proximal part of the arm. This space has a triangular apex, a square base and four walls.
- The borders of the apex are:
 - Anterior: Posterior surface of the clavicle
 - Posterior: Anterior border of the superior part of the scapula
 - Medial: Lateral border of the first rib
- The base is the armpit, which is formed by skin and soft tissue.
- Walls of the axilla:
 - The anterior wall is formed by pectoralis major and minor.
 - The posterior wall is formed by subscapularis, teres major and latissimus dorsi.
 - The medial wall is formed serratus anterior, which partly covers ribs 2-8.
 - The medial aspect of the proximal humerus forms the lateral wall.
- The contents of the axilla consist of:
 - Axillary blood vessels,
 - The brachial plexus,
 - Lymph nodes,
 - Adipose and areolar tissue,
 - Fascia, and
 - Muscles (coracobrachialis and the short head of biceps brachialis).

4.7 Axillary artery/ vein^{16, 26, 27}

- The subclavian arteries arise from the brachiocephalic trunk on the right and the aortic arch on the left. They both enter the root of the neck at the medial aspect of the anterior scalene muscle and then pass posterior to this muscle. Thereafter they descend inferiorly, posterior to

the midpoint of the clavicle. The subclavian artery becomes the axillary artery at the lateral border of the first rib.

- An important landmark in the infraclavicular region is pectoralis minor, which divides the axillary artery into three parts. The first part lies between the lateral border of the first rib and the medial border of pectoralis minor. The second part lies posterior to pectoralis minor, while the third part lies between the lateral border of pectoralis minor and the inferior border of teres major, where the artery continues as the brachial artery.
- The first part of the axillary artery is related to the three trunks of the brachial plexus. The second part is surrounded by the cords of the brachial plexus, which divide into terminal branches at the level of the third part of the axillary artery.
- The relationship of the terminal branches of the brachial plexus to the axillary artery is by no means constant. Theoretically the ulnar nerve is situated medially, the median nerve medially and the radial nerve posteriorly.
- In a study done by Partridge and co-workers²⁸ on 36 adult cadavers, they found that:
 - The median nerve was situated posterior and superior to the axillary artery, the ulnar nerve slightly inferior and anterior to the artery while the radial nerve was positioned directly posterior and slightly inferior to the axillary artery in 28 cases.
 - The radial nerve passed anterior to the artery and adjacent to the ulnar nerve in 4 cases.
 - All the nerves passed anterior to the artery in 2 cases.
 - The axillary vein was outside the neurovascular sheath (2/36)
 - The subclavian vein passed slightly inferior and more anterior than the subclavian artery. The subclavian vein is the continuation of the axillary vein and, together with the internal jugular vein, forms the brachiocephalic vein.

4.8 Pleura

- The lungs are covered by a very delicate serous membrane, which encloses the lungs and is then reflected upon the inner surface of the thorax. There are two layers:
 - The parietal pleura, which is on the inner surface of the chest wall, pericardium and mediastinum.
 - The visceral pleura, which is intimately related to the surface of the lungs.
- The apex of the *cervical part* of the parietal pleura extends above the clavicle.
- The lines of pleural reflexion pass from behind the sternoclavicular joint on each side to join in the midline at the angle of Louis (T4/5). The right pleural edge then passes vertically downwards to the 6th costal cartilage and then crosses:
 - The 8th rib (midclavicular).
 - The 10th rib (midaxillary).
 - The 12th rib (lateral border of the erector spinae).
- On the left side the pleural edge arches laterally at the 4th costal cartilage and descends lateral to the border of the sternum; apart from this the relationships are those described on the right side.
- The inferior border of the lungs are:
 - The 6th rib (midclavicular).
 - The 8th rib (midaxillary).
 - The 10th rib (lateral border of the erector spinae).
- The two pleural layers are in close apposition and the space between them is only a potential one. It may, however, fill with air when punctured, resulting in a pneumothorax.
- During the infraclavicular approach, if the needle is placed perpendicular to the table, keeping it in the sagittal plane, as was described by Wilson and co-workers⁵, there is very small if any risk to enter the thoracic cavity and injure the parietal pleura causing a pneumothorax. This risk is increased if the needle is aimed medially.

Children

- Except for the absence of subcutaneous fat in children, the anatomy of the neurovascular bundle in the infraclavicular and axillary regions are presumed to be essentially the same as in adults. The depth of the brachial plexus is shallower in children ²⁹. There is a lack of studies describing the anatomy of the brachial plexus in relation to bony landmarks and the axillary artery in the paediatric/ neonatal patient population.

4.9 Future studies

- Wilson and co-workers ⁵ described an effective infraclavicular approach to block the brachial plexus in an adult sample. The technique uses the coracoid process as landmark. From it the needle is inserted 2cm medial and 2cm inferior. These measurements cannot be applied to a neonatal sample. The distance of the brachial plexus from the coracoid process should be examined in a neonatal cadaver population.
- The distance of the inserted needle from the parietal pleura when performing the infraclavicular approach on a neonatal cadaver population can also be determined.
- Another possibility is to study the relationship between the brachial plexus and the axillary artery.

5. Complications

5.1 Vascular puncture

- As with any regional anaesthetic procedure there is the risk of puncturing blood vessels in the region of the needle insertion³⁰.
- Puncturing the axillary artery is undesirable, even though it has no major consequence in most patients, and occasionally it might lead to transient vascular insufficiency^{3, 14, 31}.
- Puncturing of the axillary vein could lead to the formation of a haematoma if pressure isn't applied to the punctured vessel^{31, 32}.
- Compression of vascular structures, due to the local anaesthetic solution injected into the perineurovascular sheath, may also occur³.

5.2 CNS toxicity³²

- Intravascular administration, overdose and/or rapid vascular uptake of local anaesthetic solution, may lead to toxic CNS reactions like:
 - Tonic-clonic seizures (a very serious complication), but provided it is treated immediately, does not lead to cerebral injury or death;
 - Nystagmus;
 - Sudden vertigo;
 - Brief blackouts;
 - Inability to move or respond to external stimuli.

5.3 Pneumothorax

- Pneumothorax is the presence of air within the pleural space. This can be caused when a needle pierces the parietal pleura.
- Although extremely rare, a pneumothorax may occur during an infraclavicular block when inappropriate insertion routes are chosen³, especially if the needle is aimed medially instead of staying in the sagittal plane.

- Whiffler¹¹ purposely attempted in a cadaver study, without success, to penetrate the thoracic cavity using the infraclavicular block.
- Recent modifications to the infraclavicular block have lead to the decrease in the occurrence of a pneumothorax when performing the procedure. There was a 0% occurrence of pneumothorax during the clinical application of the procedures described by each author^{4-6, 11, 12, 20}.

5.4 Nerve injury

- Like any regional anaesthetic procedure there is always the risk of complications, which include the probability of inserting the needle into the brachial plexus³.
- Clinical indications of nerve damage include paresthesia, shooting or sharp stinging sensations, and excessive pain during needle insertion.

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5.4 Paediatric Femoral Nerve Block

1. Indications
2. Contraindications
3. Block procedure
4. Anatomical pitfalls
5. Complications
6. References

1. Indications

Advantages

- The femoral nerve block is a quick, safe and easy block to perform with the minimum of equipment necessary¹⁻⁷. It is also the most commonly used peripheral nerve block of the lower limb in children according to Dalens^{2, 3}, as it is believed that the most painful operations in paediatric practice are performed on the lower extremities^{5, 8}.
- Femoral nerve blocks provide more rapid recovery and lower incidence of complications when compared with spinal anaesthesia for outpatient procedures⁹.
- When there are other injuries that contraindicate general anaesthesia, a femoral nerve block is regarded as the quickest and most effective method of pain relief for femoral shaft fractures, as there are negligible systemic reactions to the block procedure¹.
- When epidural blocks cannot be used due to either infection at the site of injection, anatomical deformities of the vertebral column (i.e., sacral agenesis and spina bifida), or due to the inability to position the patient for the approach to the epidural space, the femoral nerve block in combination with other peripheral nerve blocks, i.e., lateral cutaneous nerve of the thigh block and sciatic nerve block may pose as a reliable alternative technique^{2, 3}. Larger volumes of local anaesthetic solution

is required, therefore caution must be taken not to give more than the required dose of local anaesthetic in order to prevent local anaesthetic toxicity¹⁰.

1.1 Surgical indications

- Pre- or postoperative analgesia for femoral shaft fractures. With femoral shaft fractures, a femoral nerve block should be performed as soon as possible after the incident to improve the clinical status of the patient during transport of the patient, physical examinations, radiological examinations, application of wound dressings and orthopaedic procedures^{2-5, 7, 11-16}.
- Muscle spasm relieve around a fractured femur^{1, 7, 11, 13, 17}.
- Superficial surgical anaesthesia for wound care¹⁰, skin transplantation¹⁰ and muscle biopsies on the lower extremities. Analgesia for these types of procedures is often performed in conjunction with a block of the genital branch of the genitofemoral nerve to provide for analgesia of the groin near the area of the incision⁹. For vastus medialis biopsies, a femoral nerve block alone will suffice, however, the lateral cutaneous nerve of the thigh should also be anaesthetised if a vastus lateralis biopsy is intended^{10, 18}.
- Anaesthesia for outpatient knee arthroscopy¹⁹.
- Surgical anaesthesia of the entire lower extremity can be obtained when the “3-in-1” block or the fascia iliaca compartment block is combined with the sciatic nerve block¹⁷. This is due to the complexity of the sensory supply of the lower limb²⁰. **Caution: Local anaesthetic toxicity.**

1.2 Therapeutic indications

- Postoperative pain management in children in combination with other peripheral nerve blocks of the lower limb, i.e., sciatic-, obturator-, and lateral cutaneous nerve of the thigh block^{5, 10, 21, 22}.
- Postoperative analgesia for procedures performed on the hip, knee and femoral shaft^{2, 6, 10}.
- Post traumatic pain management in children¹⁰.
- Early mobilisation after hip or knee joint operations^{6, 10, 22}.
- Treatment of arterial occlusion disease and poor perfusion in the lower extremities¹⁰.
- Post-amputation pain relief and treatment of phantom limb pain¹⁰.

1.3 Continuous femoral nerve block indications

- Postoperative analgesia can be continued for days with a local anaesthetic infusion when a catheter is placed within the connective tissue "sheath" of the femoral nerve. This technique has been shown to significantly reduce systemic opioid requirements with a minimum of complications following lower limb procedures, i.e., knee procedures^{23, 24}.
- The technique could also be used after thigh surgery, thigh skin grafting, and, as in adults, knee trauma or surgery, e.g., ligamentoplasty in children²¹.

2. Contraindications

2.1 General contraindications

2.1.1 Patient refusal

- Patient refusal is an absolute contraindication to regional anaesthesia. Appropriate information should be given to the patient regarding the technique, its advantages and potential drawbacks and complications. Informed consent must be obtained.

2.1.2 Infections

- Skin infections at the needle insertion site are an absolute contraindication to regional anaesthesia^{2, 3, 25}.
- Inflammation of the femoral lymph nodes and infection of the leg is a contraindication to perform a femoral nerve block⁴.
- Osteomyelitis, pyoderma or malignant diseases of the inguinal region also acts as a contraindication to perform a femoral nerve block¹⁰.

2.1.3 Septicaemia (presence of pathogens in the blood)^{2, 3, 25}

2.1.4 Coagulation disorders

- Coagulation disorders, antithrombotic or anticoagulant treatment are contraindications to regional block techniques. This is mainly due to the probability of puncturing the femoral artery during a femoral nerve block^{2-4, 10, 25, 26}.

2.1.5 Neurological diseases involving the peripheral nerves (neuropathy)

- Although neuropathy (due to neurological or metabolic diseases) is not an absolute contraindication to perform a regional block, a clear distinction to benefit over general anaesthesia should be made.^{2, 3, 25}

2.1.6 Allergy to the local anaesthetic^{2, 3, 25}

2.1.7 Lack of training

- Adequate skills and expertise regarding a specific technique are essential for a successful procedure and to avoid complications and malpractice²⁶.
- Since vital structures are not significantly threatened by this procedure, there is no specific, anatomically based contraindication^{2, 3, 25}, as long as proper caution is taken during the performance of this block.

2.1.8 Anatomical knowledge

- Winnie and co-workers²⁷ stated that regional anaesthesia is nothing more than applied anatomy.
- Ellis and Feldman²⁸ stated that anaesthesiologists required a peculiarly specialized knowledge of anatomy, which in some cases should even rival that of a surgeon.

2.2 Specific contraindications

2.2.1 Lower extremity compartment syndrome

- In combination with a sciatic nerve block, a dense sensory block could mask the onset of lower extremity compartment syndrome²⁹ (e.g., fresh fractures of the tibia and fibula, or especially traumatic and extensive elective orthopaedic procedures of the tibia and fibula). The above-mentioned contraindication is not specific for the femoral nerve block but rather applies to regional anaesthesia of the lower extremity in general. The surgeon should be consulted as to the likelihood of the development of compartment syndrome and his own preferences of postoperative analgesic technique when considering the risks and benefits of performing regional anaesthesia³⁰.

2.2.2 Local haematoma¹⁰

2.2.3 Distorted anatomy

- This can be due to prior surgical interventions and trauma to the inguinal and thigh regions ¹⁰.

2.2.4 Risk vs. benefit

- An informed decision regarding the risks and benefits should be taken in patients with the following clinical presentations ¹⁰:
 - Haemorrhagic diathesis;
 - Stable central nervous system (CNS) disorders;
 - Local neural injury;
 - Contralateral neural paresis.

3. Block procedures

3.1 Femoral Nerve Block Technique

- Fenwick, who performed this procedure on adult patients at Sydney Hospital, first introduced the femoral nerve block in 1957. Since then it gradually gained popularity by means of word of mouth only, as it appears that the procedure was never documented in anaesthetic or orthopaedic journals. Since then many authors have described the exact technique for the performance of a femoral nerve block ^{1-3, 5, 15, 20}.
- In the literature the femoral nerve block has been described with a needle insertion site at the level of the inguinal ligament ^{15, 31, 32} and at the level of the inguinal crease ^{2, 10, 18, 33}.

3.1.1 Objective

- This technique consists of approaching the femoral nerve below the inguinal ligament as it enters the thigh and divides into its terminal branches either at the level of the inguinal ligament or inguinal crease.

3.1.2 Patient position

- Ideally the patient lies supine in a dorsal recumbent position with the lower limb slightly abducted (10°-20°) and the foot laterally rotated.
- If the femoral shaft or neck is fractured the limb should then, under no circumstances, be moved. The femoral nerve block can be performed in almost any position provided that the femoral artery can be palpated and the inguinal ligament or crease can be located.
- The anaesthesiologist performing the procedure should preferably stand on the side being blocked.

3.1.3 Anatomical landmarks

1. The inguinal ligament (extending from the anterior superior iliac spine to the pubic tubercle).
2. Pulse of the femoral either at the inguinal ligament or inguinal crease.

3.1.4 Technique

I. *Preparation*

- Check that all emergency equipment is present, complete and in working order:
 - ECG monitor;
 - Intubation kit;
 - Ventilation facilities;
 - Emergency medication;
 - Sterile precaution;
 - Intravenous access;
 - Pulse oximetry;
 - Anaesthetic machine.
- An intravenous cannula should always be inserted in either the upper or lower limb, in case of accidental intravenous injection.
- Normally mild light general anaesthesia is given to the paediatric patient.
- The procedure must be carried out with a strict aseptic technique. The skin of the inguinal region should be thoroughly prepared and sterile gloves must be worn.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The femoral artery is located by means of palpation and marked.
- According to Dalens ², needle insertion is between 5mm-10mm lateral of the pulse of the femoral artery and between 5mm-10mm inferior of the inguinal ligament.
- In a study conducted by Vloka and co-workers ³³, on 9 adult cadavers and with a subsequent follow-up clinical study on 100 adult patients undergoing a femoral nerve block, it was found that the femoral nerve is most accurately and easily located at the level of the inguinal crease. This study was however conducted on both adult cadavers and adult

patients and its relevance in paediatric femoral nerve block procedures is a question that remains to be answered.

- Denton and Manning ¹⁵ suggests a needle insertion site in children just lateral to the pulse of the femoral artery at the level of the inguinal ligament.
- An injection just lateral to the femoral artery may actually spread along the sheath around the artery and therefore not reach the femoral nerve with subsequent failure to block this nerve. It is therefore important to inject some distance lateral to the femoral artery.

III. *Insertion of the needle*

- The needle is inserted either perpendicularly to the skin, or slightly cephalic, until muscle twitches or paresthesia are elicited in the quadriceps femoris.
- The depth at which the nerve is located depends on the patient's age, but also on the presence and size of haematomata after a fracture of the femoral shaft. The use of a nerve stimulator will greatly increase the safety and effectiveness of the block ^{31, 34}.
- The needle pierces the skin, fascia lata, and both layers of the femoral sheath, i.e., fascia transversalis (anterior layer), which is a continuation of the intra-abdominal wall fascia and the fascia iliaca (posterior layer), which covers iliaca ²⁸.

IV. *Administration of local anaesthetic solution*

- After an aspiration test and administration of a test dose, incremental injection of local anaesthetic solution is administered.
- If no paresthesia is produced, some of the local anaesthetic is injected in a fan-shaped manner just lateral of the artery. The onset of the block will be slow ¹⁰.
- A successful block is indicated if the patient is unable to extend the knee.

3.2 “3-in-1” Block Technique as described by Winnie and co-workers in 1973³²

- The femoral nerve block should be distinguished from the "3-in-1" block, as this technique blocks the lateral cutaneous nerve of the thigh, the obturator nerve as well as the femoral nerve³².

3.2.1 Objective

- The technique consists of injecting the local anaesthetic solution close to the femoral nerve, at the level of the inguinal ligament, and then to force the solution cephalad towards the lumbar plexus, within the perineural envelope, which is formed by the fasciae of the psoas major, iliacus, and transverse abdominis.

3.2.2 Patient position

- As with the femoral nerve block, the patient ideally lies supine in a dorsal recumbent position with the lower limb slightly abducted (10°-20°) and the foot lying on its lateral border (lateral rotation).
- If the femoral shaft or neck is fractured the limb should not be moved. The "3-in-1" block can also be performed in almost any position provided that the femoral artery can be palpated and the inguinal ligament located.

3.2.3 Anatomical landmarks

- Anatomical landmarks for the "3-in-1" block are essentially the same as with a femoral nerve block, i.e.:
 1. The inguinal ligament (extending from the anterior superior iliac spine to the pubic tubercle).
 2. Pulse of the femoral artery.

3.2.4 Technique: Single injection

I. *Preparation*

- Preparation is the same as the femoral nerve block.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The femoral artery is located by means of palpation and marked.
- The needle insertion site is directly lateral to the pulse of the femoral artery at the level of the inguinal ligament.

III. *Insertion of the needle*

- Instead of inserting the needle perpendicularly to the skin, the needle is inserted in a cephalad direction at an angle of 30°-40° to the skin, almost parallel to the course of the femoral artery.
- The use of a nerve stimulator will greatly increase the safety and effectiveness of the block³⁴.
- Application of finger pressure on the femoral artery while the needle is inserted is recommended^{32, 35}.
- The needle is advanced until muscle twitches of quadriceps femoris are elicited and movement of the patella (“dancing patella”) becomes visible¹⁰. **The needle should not be advanced further!**
- The needle pierces the skin, fascia lata, and both layers of the femoral sheath, i.e., fascia transversalis (anterior layer), which is a continuation of the intra-abdominal wall fascia and the fascia iliaca (posterior layer), which covers iliacus²⁸.

IV. *Administration of local anaesthetic solution*

- After an aspiration test and administration of a test dose, incremental injection of local anaesthetic solution is administered.
- During injection, the twitching slowly disappears and the finger is firmly placed just distal to the needlepoint to force the local anaesthetic solution to move in a cephalad direction³².

- The needle is then removed, but finger pressure should be maintained for a few minutes while the area is gently massaged to favour the upwards spread of the local anaesthetic^{2, 10}, and then the thigh should be flexed for about 1 minute¹⁰.
- If the patient's condition allows it, the placement of a tourniquet at the upper part of the thigh will significantly improve the procedure by favouring the upward diffusion of the local anaesthetic solution².

3.2.5 Technique: Continuous technique³⁶

I. *Preparation*

- Preparation is the same as the femoral nerve block.

II. *Determine needle insertion site*

- Determining the needle insertion site is the same as the femoral nerve block.

III. *Insertion of the needle*

- The needle is inserted in a cephalad direction at an angle of 30°-40° to the skin, almost parallel to the course of the femoral artery.
- The needle pierces the skin, fascia lata, and both layers of the femoral sheath, i.e., fascia transversalis (anterior layer), which is a continuation of the intra-abdominal wall fascia and the fascia iliaca (posterior layer), which iliacus²⁸.
- The needle tip location can be further adjusted using a peripheral nerve stimulator to achieve good quadriceps contractions.
- The needle is advanced deep into the fascia iliaca compartment.
- Through this needle cannula, the catheter can be threaded, between 5cm-8cm, cranially, into the fascia iliaca sheath.

IV. *Administration of local anaesthetic solution*

- After an aspiration test and administration of a test dose, the catheter is secured and a bacterial filter is put into place.

- After another aspiration test, a local anaesthetic solution can then be administered on an incremental basis.

Alternative Technique

- Dalens and co-workers²⁰ developed the fascia iliaca compartment block after they re-evaluated the gross anatomy of the lumbar plexus nerves and fasciae of the groin and thigh in children. The authors then went and compared their new technique with the “3-in-1” block described by Winnie and co-workers in 1973³².
- It was found that the hypothesis Winnie and co-workers³² stated in their article was not supported by their own data, as Dalens and co-workers²⁰ did not observe any spread of anaesthetic solution from within the psoas compartment, where the solution was directly introduced, towards either the femoral or obturator nerves or the lateral cutaneous nerve of the thigh. The psoas compartment is described as a space, which is delineated by the dorsal muscles attached to the transverse processes of the lumbar vertebrae (transversospinalis and erector spinae), the ventral muscles attached to the vertebral bodies and intervertebral discs (psoas major and quadratus lumborum), and lastly the bodies and transverse processes of the lumbar vertebrae³⁷.
- Furthermore adequate analgesia of all three target nerves was only obtained in 20% of the patients given the “3-in-1” block, whereas the fascia iliaca compartment block yielded a 90% success rate²⁰.
- The fascia iliaca compartment block can therefore be considered as an easy, reliable and safe alternative to the femoral nerve block²⁰.
- Dalens and Mansoor³⁸ believe that the fascia iliaca compartment block is a more preferred procedure for lower limb surgery in neonates as all the lumbar plexus nerves supplying the lower limb are block with a single injection with the least risk involved.

3.3 Fascia Iliaca Compartment Block as described by Dalens and co-workers in 1989²⁰

3.3.1 Objective

- This procedure is based on the fact that the obturator and femoral nerves, as well as the lateral cutaneous nerve of the thigh run anterior to iliacus. Thus injecting sufficient amounts of local anaesthetic solution beneath the fascia iliaca should result in blocking these nerves due to diffusion of the solution over the surface of iliacus.

3.3.2 Patient position

- Ideally the patient should lie in a supine position, as for a “classical” femoral nerve block. However, any position that allows for the palpation of the femoral artery may be suitable.

3.3.3 Anatomical landmarks

1. The ipsilateral ASIS.
2. The spine of the pubic tubercle.
 - A line is drawn between the two above-mentioned landmarks (i.e., the inguinal ligament), which is subsequently divided into three equal parts.

3.3.4 Technique

I. *Preparation*

- Preparation is the same as the femoral nerve block.

II. *Determine needle insertion site*

- The site of puncture is marked about 5mm caudal to the point where the lateral one third joins the medial two thirds. The needle should be inserted perpendicular to the skin.

III. *Insertion of the needle*

- The needle is then inserted at right angles to the skin while gentle pressure is exerted on the barrel of a syringe filled with local anaesthetic²⁰.
- A first “give” and another loss of resistance is felt when the needle pierces the fascia lata. The needle should then be inserted deeper until another “give” and another loss of resistance is felt as the needle pierces the fascia iliaca²⁰.
- The use of a nerve stimulator will greatly increase the safety and effectiveness of the block³⁴.
- The needle is advanced until muscle twitches of quadriceps femoris is elicited and movement of the patella (“dancing patella”) becomes visible¹⁰. **The needle should not be advanced further!**

IV. *Administration of local anaesthetic solution*

- After an aspiration test and administration of a test dose, incremental injection of local anaesthetic solution is then administered.
- If the needle is inserted too medially, the tip of the needle may enter the perineural sheath, resulting in a pure femoral nerve block. Therefore, the occurrence of paresthesia (in alert patients) or muscle twitches (when a nerve stimulator has been used) requires the needle to be removed and inserted more laterally².
- However, if this occurs it might be beneficial to inject a small measure of local anaesthetic solution to produce a consistent femoral nerve block before the needle is withdrawn and reinserted more laterally².
- If the patient’s condition allows it, the placement of a tourniquet at the upper part of the thigh will significantly improve the procedure by favouring the upward diffusion of the local anaesthetic solution at the surface of the muscles covered by the fascia iliaca².

4. Anatomical pitfalls

4.1 The lumbar plexus^{28, 39, 40}

- The lumbar plexus is formed by fusion of the ventral rami of the first four lumbar spinal nerves (L1-L4). It usually receives a branch from the 12th thoracic nerve. The 4th lumbar spinal nerve subsequently gives a branch to the sacral plexus, i.e., the lumbosacral trunk.
- The lumbar plexus lies posterior to psoas major, in a fascial plane called the “psoas compartment”. This term was first used by Chayan and co-workers³⁷ and is delineated by the dorsal muscles attached to the transverse processes of the lumbar vertebrae (transversospinalis and erector spinae), the ventral muscles attached to the vertebral bodies and intervertebral discs (psoas major and quadratus lumborum), and lastly the bodies and transverse processes of the lumbar vertebrae.
- The upper parts of the lumbar plexus (T12-L1 spinal nerves) give rise to the iliohypogastric and ilioinguinal nerves (fibres from L1 spinal nerve), the genitofemoral nerve (L1-L2), and the branches supplying motor innervation to quadratus lumborum (T12-L4), psoas minor (L1), and psoas major (L2-L4).
- The remaining lumbar plexus nerves divide into ventral and dorsal branches.
 - The ventral branches originate from L1-L3 spinal nerves and the femoral nerve (L2-L4).
 - The dorsal branches unite to form the obturator nerve (L2-L4) and the inconstant accessory obturator nerve (L3-L4).

4.2 Femoral nerve (L2-L4)^{28, 39, 40}

- The femoral nerve is the largest branch of the lumbar plexus, and is found lateral to the femoral artery and vein.

- It runs within the substance of psoas major and emerges in the groove formed by psoas major and iliacus. The femoral nerve passes posterior to the inguinal ligament, and enters into the femoral triangle, lateral to the femoral artery. The femoral nerve supplies sartorius, rectus femoris, vastus medialis, vastus intermedius and vastus lateralis.
- The femoral nerve runs outside the femoral sheath, which contains both the femoral artery and the vein. As it passes the inguinal ligament it is situated deep to the femoral sheath and is therefore covered by both fascia transversalis (anterior layer of femoral sheath) and fascia iliaca (posterior layer of femoral sheath) ²⁸.

4.3 Divisions of the femoral nerve ^{28, 39, 40}

- The nerve divides into two divisions:
- An anterior division with two branches
 - The intermediate cutaneous nerve of the thigh. This nerve supplies the skin of the thigh down to the knee.
 - The medial cutaneous nerve of the thigh, which further divides into two branches:
 - An anterior branch, which supplies the skin down to the knee;
 - A posterior branch, which runs along the posterior border of sartorius, reaches the knee where it gives off a branch to the saphenous nerve, and supplies sensory innervation to the medial aspect of the thigh.
- A posterior division with:
 - Motor branches to quadriceps femoris;
 - Articular branches, supplying the hip joint and the knee joint;
 - The posterior division also gives off the saphenous nerve. This is the largest terminal branch of the femoral nerve and runs within the adductor canal and descends along the tibia where it ends at the medial aspect of the ankle. The branches of the

saphenous nerve give rise to the subsartorial plexus as well as infrapatellar branches forming the patellar plexus.

- The femoral nerve also supplies sensory innervation to the periosteum of the femur³⁹.

4.4 The femoral triangle^{28, 39, 40}

- The borders of the femoral triangle are as follow⁴⁰:
 - The lateral border of adductor longus forms the medial border;
 - The medial border of sartorius forms the lateral border;
 - The inguinal ligament forms the superior border;
 - Pectineus forms the floor of the femoral triangle, medially, and iliopsoas, laterally;
 - The roof is formed by the fascia lata, which covers the triangle.

4.5 Femoral blood vessels^{28, 39, 40}

- The femoral vessels are bundled by the femoral sheath and lie immediately below fascia lata. The femoral nerve is lateral to the femoral artery, but deep to fascia iliaca, not bundled with the vessels within the femoral sheath²⁰.
- The femoral nerve lies in close relationship to the femoral artery. Therefore femoral artery puncture could possibly occur if the correct technique is not followed or the landmarks are not properly determined.

4.6 Future studies

- Measure the distance of femoral nerve and artery from easily identifiable bony landmarks (anterior superior iliac spine, pubic tubercle) in neonates.
- Study the relationship between the femoral artery and nerve.

5. Complications

- Very few complications have been reported during the performance of the femoral nerve block, “3-in-1” block or fascia iliaca compartment block^{5, 13, 20, 32, 35, 38}.
- Lynch and co-workers²⁴ placed a continuous catheter for femoral nerve analgesia in 208 adult patients (ages 18-65 years) who underwent explorative knee surgery and anterior cruciate ligament repair. In their study the incidence of complications were as follows: arterial puncture (5.3%), redness of puncture site (4.3%), inguinal pain (1%), intravascular catheter placement (1%), arterial bleeding after catheter placement (1%), paresthesia on injection (0.5%), prolonged motor block for up to 36 hours (0.5%), and temporary femoral nerve palsy for up to 12 weeks (0.5%).

5.1 Vascular puncture

- Vascular puncture is the most common occurring complication stated in the literature^{5, 13, 15, 20, 38, 41}. In case of a vascular puncture, the procedure should be halted while pressure is applied to the injured vessel for about 5-10 minutes in order to prevent haematoma formation. Another, more careful, attempt may be made^{2,3}.
- Smith and Greene⁴² conducted a review on cases of paediatric vascular injuries and found that deliberate penetration of the femoral artery (for diagnostic purposes, i.e., blood gas sampling) was a common cause for thrombosis in the femoral artery, which is especially hazardous in infants and children⁴³.
- In children there is a higher risk of thrombosis in the femoral artery after an accidental puncture than in adults⁴³.
- In small children, iatrogenic injury does not have to be penetrating as mobilisation of the femoral artery alone has been shown to produce angiographically proven thrombosis requiring thrombectomy in 3 patients⁴³.

- McNicol ⁵ performed femoral and lateral cutaneous nerve of the thigh blocks on 50 paediatric patients. They weighed between 7 - 51.2kg and were aged between 6 months – 15 years. Blood was aspirated from the femoral artery on 3 occasions without the development of a haematoma. He believes that this could have been due to the narrow gauge needle that was used for the block.
- Dalens and co-workers ²⁰ compared the “3-in-1” block with the fascia iliaca compartment block in a sample (n=60) aged between 8 months and 17 years of age. In the group who underwent the “3-in-1” block, 9 had to undergo a second attempt due to reflux of blood into the syringe (arterial in 3 and venous in 2) and due to misplacement of the needle (absence of muscle twitches in 4). No complications occurred in the group who underwent the fascia iliaca compartment block.

5.2 CNS toxicity ¹⁰

- Intravascular administration, overdose and/ or rapid vascular uptake of local anaesthetic solution, can lead to toxic CNS reactions like:
 - Tonic-clonic seizures (a very serious complication), but provided that it is treated immediately, it does not lead to cerebral injury or death;
 - Nystagmus;
 - Sudden vertigo;
 - Brief blackouts;
 - Inability to move or respond to external stimuli.

5.3 Nerve trauma

- Another possible complication that might occur is direct neural injury, which is indicated by postoperative weakness of quadriceps femoris.
- The mechanism of nerve injury following a peripheral nerve block includes direct nerve trauma from the needle, injury from intraneural

injection, and compressive-ischemic injury caused by local haematoma formation ⁴¹.

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5.5 Paediatric Ilioinguinal/ Iliohypogastric Nerve Block

1. Indications
2. Contraindications
3. Block procedure
4. Anatomical pitfalls
5. Complications
6. References

1. Indications

1.1 Anaesthetic indications

- The ilioinguinal/ iliohypogastric nerve block is a technique that is safe, effective and easy to perform on neonatal or paediatric patients, for a range of surgical procedures in many different clinical scenarios¹⁻¹². These include:
 - Elective procedures of the inguinal region like:
 - Inguinal hernia repair (inguinal herniorrhaphy)^{4, 5, 8-11, 13-15}.
 - Varicocele^{4-6, 16}.
 - Orchidopexy^{2, 4, 5, 8}.
 - Hydrocele surgery^{4, 5, 15}.
 - Emergency procedures:
 - Strangulated hernia with intestinal obstruction^{4, 5, 17}.
 - Ambulatory or day-care procedures:
 - The ilioinguinal/ iliohypogastric nerve block has been shown to be safe and effective for a range of surgical procedures, i.e., orchidopexy, inguinal hernia repair, in an ambulatory setting^{2, 9-11, 15, 16}.

1.2 Therapeutic indications

- Postoperative pain relief after surgical procedures on the inguinal region ¹⁸.
- Treatment of post-herpetic neuralgia ¹⁸.
- Intra- and postoperative pain management ^{2, 4, 5, 7-11}.
- Incisional pain management after hernia repair or orchidopexy ^{4, 5, 10, 11}.

1.3 Analgesic indications

- The ilioinguinal/ iliohypogastric nerve block can safely be combined with a light general anaesthesia in younger patients ^{2, 11}.
- Cross and Barrett ⁸ believe that the use of longer-acting local anaesthetic agents, can last well into the postoperative period and reduce the need for either conventional intramuscular injections or oral analgesics.

2. Contraindications

2.1 General contraindications

2.1.1 Patient refusal

- Patient refusal is an absolute contraindication to regional anaesthesia. Appropriate information should be given to the patient regarding the technique, on its advantages and potential drawbacks and complications and informed consent must be obtained^{19,20}.

2.1.2 Local infections

- Skin infections at the needle insertion site are an absolute contraindication to regional anaesthesia^{4,5,19}.

2.1.3 Septicaemia (presence of pathogens in the blood)^{4,5,19}

2.1.4 Coagulation disorders

- Coagulation disorders, as well as patients who are undergoing antithrombotic or anticoagulant treatment are contraindications to regional anaesthesia^{4-6,19}.

2.1.5 Neurological diseases involving the peripheral nerves (neuropathy)

- Although neuropathy (due to neurological or metabolic diseases) is not an absolute contraindication to perform a regional anaesthesia, a clear distinction to benefit over general anaesthesia should be made however^{4,5,19}.

2.1.6 Allergy to the local anaesthetic^{4,5,19}

2.1.7 Lack of training

- Adequate skills regarding a specific technique are essential for a successful procedure and to avoid complications and malpractice.

- Skills and expertise are key points to success in regional anaesthesia²⁰.

2.1.8 Knowledge of Anatomy

- Winnie and co-workers²¹ believe that a solid knowledge of anatomy is essential to performing regional anaesthesia. They stated that: "regional anaesthesia is nothing more than applied anatomy".
- Ellis and Feldman²² stated that anaesthesiologists required a peculiarly specialized knowledge of anatomy, which in some cases should even rival that of a surgeon.

2.2 Specific contraindications^{4, 5}

2.2.1 Obese patients

- This is not a specific contraindication of the ilioinguinal/ iliohypogastric nerve block. However, there may be difficulty in the uniform spread of the anaesthetic solution due to difficulty in determining the various anatomical landmarks in obese patients^{4, 5}.

Alternative regional technique

- The main alternative to the ilioinguinal/ iliohypogastric nerve block is a caudal epidural block, which is a very effective block to perform^{2, 7, 8, 23}.
- Many papers have compared caudal epidural blocks with the ilioinguinal/ iliohypogastric nerve block and many have found that there is no significant proof indicating that the one technique is better than the other^{2, 7, 8, 17}.
- Martin²⁴ however believes that caudal epidural blocks are not worth the time, risk and expense involved to perform on children undergoing minor surgical procedures.
- Hannallah and co-workers² compared caudal epidural blocks with the ilioinguinal/ iliohypogastric nerve block for postoperative pain management in 44 boys (ages 18 months – 12 years), for elective

repair of an unilateral undescended testicle. The study did not show the caudal epidural block to be more effective than the ilioinguinal/iliohypogastric nerve block, and therefore both techniques can be used for effective post-orchidopexy pain management in children.

- Markham and co-workers ⁷ compared the ilioinguinal/iliohypogastric nerve block with the caudal epidural block using a sample of 52 boys, ages 1 to 12 years, and found that a decreased delay in time to micturate in the group who underwent the ilioinguinal/iliohypogastric nerve block, was the only significant advantage over the caudal epidural block, even though more complications were experienced during the caudal epidural block.
- Cross and Barrett ⁸ compared the ilioinguinal/iliohypogastric nerve block and caudal epidural block for postoperative analgesia in children following hernia repair and orchidopexy. They found that:
 - Both procedures had a similar duration of action and half of the patients were free of pain for at least 6 hours postoperatively.
 - Both techniques are relatively convenient and technically easy to perform.
 - Preparation time for the ilioinguinal/iliohypogastric nerve block was much less than for a caudal epidural block.
 - Both techniques required a second anaesthesiology to control the airway. This however is not essential when performing an ilioinguinal/iliohypogastric nerve block.
 - The morbidity associated with the ilioinguinal/iliohypogastric nerve block is less than for the caudal epidural block.
 - The total dose of local anaesthetic solution was also less than the dose required for a caudal epidural block.
- In 1988, Stow and co-workers ²³ did a study on the plasma bupivacaine concentrations during a caudal epidural block and an ilioinguinal/iliohypogastric nerve block in children and found that the uptake of bupivacaine is more rapid after an ilioinguinal/iliohypogastric nerve block than during a caudal epidural block. They related this higher rate of absorption to 4 factors:

- The vascularity of the injection site.
- The ratio of the injected volume of local anaesthetic solution to the volume of the space into which the injection is made.
- The concentration of local anaesthetic used.
- The total dose of local anaesthetic solution injected.

3. Block procedures

3.1 Technique described by Von Bahr, in 1979¹³

3.1.1 Objective

- This technique consists of multiple injections of local anaesthetic solution both subcutaneously and below the aponeurosis of the external oblique in order for the solution to reach the ilioinguinal and iliohypogastric nerves.

3.1.2 Patient position

- The patient lies supine during the injection.

3.1.3 Anatomical landmarks

1. The umbilicus
2. The ipsilateral anterior superior iliac spine (ASIS)

3.1.4 Technique

I. *Preparation*

- Check that all emergency equipment is present, complete and in working order:
 - ECG monitor;
 - Intubation kit;
 - Ventilation facilities;
 - Emergency medication;
 - Sterile precaution;
 - Intravenous access;
 - Pulse oximetry;
 - Anaesthetic machine.
- An intravenous cannula should always be inserted in either the upper or lower limb, in case of accidental intravenous injection.
- Normally mild light general anaesthesia is given to the paediatric patient.

- The procedure must be carried out with a strict aseptic technique. The skin of the inguinal region should be thoroughly prepared and sterile gloves must be worn.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The insertion site is on a line drawn from the ASIS to the umbilicus and is subsequently divided equally into four parts. The point of insertion is at the junction of the lateral one-fourth or medial three-fourths of this line.

III. *Insertion of the needle and administration of local anaesthetic solution*

- Aspiration should precede every injection of local anaesthetic solution.
- The needle is introduced into the subcutaneous tissue; a quarter of the total dose (as determined by a dose to weight ratio) is injected at this site in a fan-like manner from lateral to medial.
- The needle is then advanced through the external oblique where another quarter of local anaesthetic solution is injected in a fan-shaped manner.
- A second point of insertion is on a line drawn between the ASIS and the pubic tubercle, immediately proximal to the tubercle.
- The needle is advanced through the skin and the third quarter of the anaesthetic solution is injected, in a fan-like manner from lateral to medial, subcutaneously.
- As before, the needle is further advanced through the aponeurosis of the external oblique and the remaining anaesthetic solution is injected with the same technique as described above.

Alternative technique described by Nolte in 1990²⁵

- This technique is essentially the same as described by Von Bahr¹³ except that there is no second needle insertion site (just superior to the pubic tubercle).
- A single dose of anaesthetic solution is injected between the external and internal oblique in a fan-like manner.

3.2 Technique described by Sethna and Berde in 1989 ¹

3.2.1 Objective

- This technique consists of a singular insertion site, where the local anaesthetic solution is injected in a fan-shaped manner, at a level between the transverse abdominis and the internal oblique to block the nerves before they perforate the muscles of the anterior abdominal wall.

3.2.2 Patient position

- The patient lies supine during the injection.

3.2.3 Anatomical landmark

1. Ipsilateral ASIS

3.2.4 Technique

I. *Preparation*

- Preparation is the same as the ilioinguinal/ iliohypogastric nerve block described by Von Bahr ¹³.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The needle insertion site is at a point 10mm medial and 10mm inferior to the ASIS.

III. *Insertion of the needle and administration of local anaesthetic solution*

- The needle is slowly advanced through the skin, subcutaneous tissue, as well as the external and internal oblique. A distinct “pop” can be felt as the needle transverses through each layer.
- After aspiration, the local anaesthetic solution is injected in a fan-like manner at a right angle to the two nerves (medial to lateral).

3.3 Technique described by Schulte-Steinberg in 1990⁶

3.3.1 Objective

- This technique consists of a single injection at a level between the internal and external oblique.

3.3.2 Patient position

- The patient lies supine during the injection.

3.3.3 Anatomical landmarks

1. Ipsilateral ASIS

3.3.4 Technique

I. *Preparation*

- Preparation is the same as the ilioinguinal/ iliohypogastric nerve block described by Von Bahr¹³.

II. *Determine needle insertion site*

- The specific anatomical landmarks are palpated and marked on the skin.
- The needle insertion site is at a point just medial and inferior of the ASIS.
- The distance medial depends on the age of the patient (between 5mm and 10mm in infants and 20mm adolescents).

III. *Insertion of the needle and administration of local anaesthetic solution*

- The needle is slowly advanced until there is a loss of resistance, which occurs as the aponeurosis of the external oblique is pierced.
- After aspiration, the local anaesthetic solution is injected between the internal and external oblique.

4. Anatomical pitfalls

4.1 Origin – L1^{22, 26, 27}

- The ilioinguinal and iliohypogastric nerves are branches of the primary ventral ramus of L1, which in turn stems from the lumbar plexus and receives a branch from the 12th thoracic spinal nerve. They run in series with the intercostal (T1-T11) and subcostal (T12) nerves, which in turn are located in the intercostal spaces and below the 12th rib respectively.
- The L1 primary ventral ramus enters the upper part of psoas major where it branches into the ilioinguinal and iliohypogastric nerves and emerges at the lateral border of psoas major, anterior to quadratus lumborum and posterior to the kidneys.
- At the lateral border of quadratus lumborum, the two nerves pierce the lumbar fascia to reach a plane between the internal oblique and transverse abdominis.

4.2 Iliohypogastric nerve^{22, 26, 27}

- The iliohypogastric nerve is situated more superiorly than the ilioinguinal nerve and continues ventrally between the internal and external oblique. At the level of the iliac crest the iliohypogastric nerve divides into two terminal branches:
 - A *lateral cutaneous branch*, which perforates the internal and external oblique and supplies the skin over the ventral part of the buttocks.
 - The *medial cutaneous branch* continues ventrally until it gradually pierces the internal oblique and later the aponeurosis of the external oblique and supplies the skin covering the abdominal wall, above the pubis (L1 dermatome).

4.3 Ilioinguinal nerve^{22, 26, 27}

- The ilioinguinal nerve runs ventrally, inferior to and in a deeper plane than the iliohypogastric nerve. It perforates the transverse abdominis at the level of the iliac crest and continues ventrally deep to the internal oblique. Gradually it pierces both internal and external oblique to reach the lower border of either the spermatic cord (in males) or the round ligament of the uterus (in females) where it finally reaches the inguinal canal.
- It contributes fibres to the internal oblique, the skin of the upper medial part of the thigh, and either the skin of the upper part of the scrotum and the root of the penis or the skin covering the labium majus and the mons pubis.

4.4 Children

- The anatomy, in children, is essentially the same as in adults with the exception that the distance of the ilioinguinal and iliohypogastric nerves are only about 5mm – 15mm medial of the ASIS in children³.
- It is believed that this distance is much closer to the ASIS than previously thought in the literature²⁸.

4.5 Future studies

- Determination of the exact position of the neonatal ilioinguinal and iliohypogastric nerves in relation to an easily identifiable bony landmark, the ASIS.

5. Complications

- Complications are rare ^{4, 5, 7-10, 14, 25}.

5.1 Partial or complete failure of block

- The main disadvantage of this block is either a complete or partial failure ^{1, 4, 5}. It is estimated that complete failure could occur in about 10% of procedures, even in experienced hands. Partial failure to block these nerves occurs even more frequently, between 10 and 15%, and as high as 25%, of procedures ^{4, 5, 29, 30}.
- The failure rate is higher in children under 2 years of age, even when the nerve is exposed at surgery ³¹. The failure rate was higher even when the local anaesthetic was injected in two sites – “double shot technique” ³⁰.
- A lack of spatial knowledge regarding these nerves could be the reason for this high failure rate. It was found in a recent study that the ilioinguinal and iliohypogastric nerves were located much closer to the ASIS than was previously thought ²⁸.

5.2 Intravascular injection

- Like with any regional anaesthetic procedure there is always a chance of injecting the local anaesthetic intravascularly. In this highly vascular area, haematoma formation is common, but of little lasting consequence ³². Aspiration before injecting local anaesthetic solution is therefore recommended.

5.3 CNS toxicity ¹⁸

- Intravascular administration, overdose and/ or rapid vascular uptake of local anaesthetic solution, can lead to toxic CNS reactions like:

- Tonic-clonic seizures (a very serious complication), but provided that it is treated immediately, it does not lead to cerebral injury or death;
- Nystagmus;
- Sudden vertigo;
- Brief blackouts;
- Inability to move or respond to external stimuli.

5.4 Intraperitoneal injection

- If the needle is too long or is inserted too deeply, an intraperitoneal injection may accidentally be given. Jöhr and Sossai³³ described a case of an accidental colonic puncture after an ilioinguinal/iliohypogastric nerve block was performed on a patient.

5.5 Nerve damage

- Nerve damage is always a possibility when the correct equipment for the technique is not available or if there is a lack of spatial anatomy knowledge of the ilioinguinal and iliohypogastric nerves⁴.
- Clinical indications of nerve damage include paresthesia, shooting or sharp stinging sensations, and excessive pain during needle insertion.

5.6 Transient femoral nerve block

- Reports of the occurrence of a transient femoral nerve block after the performance of an ilioinguinal/iliohypogastric nerve block has been described in the literature^{9, 11, 34-36}.
- Rosario and co-workers³⁷ found, by injecting methylene blue in a sample of adult cadavers, that when the solution was injected deep to the internal oblique the bony and fascial attachments of the iliacus fascia caused the injected media to track medially and collect around the femoral nerve, which lies in a natural gutter between psoas major and iliacus within the fascia iliaca.

- It is therefore considered that the space between the internal oblique and transverse abdominis is continuous with the fascia iliaca within which the femoral nerve is situated. This in turn could result in a transient femoral nerve block during the performance of an ilioinguinal/iliohypogastric nerve block if the needle is advanced to deeply ³⁷.

5.7 Inadequacy to abolish visceral pain

- Complement anaesthesia is sometimes needed for hernia orifice and spermatic cord infiltration. This nerve block is not adequate to abolish the visceral pain produced from peritoneal traction, and exploration and manipulation of the spermatic cord and testicles ^{4, 5}.
- Within the spermatic cord there are sympathetic fibres accompanying the arteries as well as sympathetic (from T7 spinal segment) and parasympathetic (from the vagus nerve) fibres accompanying the ductus deferens to form the testicular nerve plexus. These autonomic sensory nerves carry the impulses that produce deep visceral pain when the testis is squeezed or injured, producing excruciating visceral pain and a sickening sensation ²⁶.
- Hannallah and co-workers ² believe that testicular innervation can be traced up to the 10th thoracic segment and therefore a T10 level block, i.e., a caudal epidural block, may be required to prevent visceral pain if the procedure requires for testicular traction and/ or manipulation.

6. References

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6. Discussion

6.1 Development and conduction of survey

The questionnaire used in this study consisted of a list of regional anaesthetic procedures important for anaesthesiologists to be able to perform in South Africa. The list was compiled by an extensive literature research review, as well as, from comments given by and discussions with anaesthesiologists attending regional anaesthesiology workshops in the Department of Anatomy, University of Pretoria. A list of 18 procedures was compiled and a questionnaire developed to assess various aspects of the procedures performed including the role of the underlying anatomy regarding each block.

A total of 80 questionnaires were analysed in this study. All the questionnaires were filled out by anaesthesiologists or anaesthesiologists in training, either at anaesthesiology conferences or in the various hospital practices visited during the conduction of this survey.

All anaesthesiologists where randomly approached and filled in the questionnaire voluntarily and anonymously. Anaesthesiologists approached at either the anaesthesiology conferences or workshops practiced in all parts of South Africa. Only anaesthesiologists practicing in either rural or urban hospitals situated in Gauteng in South Africa were approached their various hospital practices, although the scenario for regional anaesthetic procedures in other parts of South Africa may be somewhat different. This study may therefore not be geographically generalisable. It is thought however, that the data presented reflect a general picture due to the representative number of anaesthesiologists that took part in the study.

A limitation of the study is the fact that the different hospitals were not randomly selected in the sense that each hospital had an equal chance to be selected by the pharmaceutical representative. Also the fact that only hospitals in Gauteng were visited limited the diversity of the participating sample of anaesthesiologists, this means that a percentage of the sample population was in fact only anaesthesiologists in Gauteng. This probably signifies the greatest limitation of this study. A future survey can be conducted to include a larger sample size with a better distribution across all parts of South Africa. Nonetheless this study presents findings of a representative number of anaesthesiologists and anaesthesiologists in training on paediatric regional anaesthetic techniques that has never been done before.

Importantly, the role of anatomy in safely and successfully performing paediatric regional anaesthetic techniques has been illustrated by studying the evidence for this in the field, while reducing complications and difficulties and improving confidence of performance are major challenges to address.

The main focus of this study was to identify the problems as illustrated by the evidence from the field and addressed by an extensive knowledge base.

The critical outcomes of specialised training programmes remains an absolutely essential component for designing valid and effective courses that remains up to date with current technologies, knowledge and skills. It is therefore import for the content of such courses to be essentially **outcomes based**. This means that outcomes regarding the course content must be researched thoroughly and revised regularly from evidence in the field.

De Villiers ⁸² indicated that there is a need for assessing real, perceived and expressed educational needs in South Africa. This study addresses the need for better understanding of the anatomy behind regional nerve blocks in paediatric patients as well as realising the importance of a sound anatomical knowledge base that acts as the foundation on which successful clinical procedures, such as regional nerve blocks, rest.

This study, also, embarked on gaining better understanding regarding the state of paediatric regional anaesthesia in South Africa. It may serve as a basis on which regional nerve blocks could be taught in residency programs to prepare anaesthesiologists for cases where general anaesthesia may not be indicated in paediatric patients or where regional techniques form a useful supplement to general anaesthesia during surgery or postoperative pain management.

Similar studies have been conducted on the importance of clinical anatomy knowledge for general practitioners or family physicians performing clinical procedures in both rural and urban hospitals. Boon⁸³ evaluated the clinical anatomy competence of family physicians performing clinical procedures in hospital practice in South Africa. He further developed a comprehensive clinical knowledge base regarding a range of clinical procedures, which were identified as problem procedures.

In a study conducted by Abrahams⁸⁴, the focus was not specifically on the clinical anatomy of procedures; instead it was a broad evaluation of the applications of anatomy in general practice. In this study, three levels of anatomical knowledge were considered: (1) no anatomy needed during the consultation, (2) routine physical examination and (3) surface anatomy and detailed specific anatomical knowledge required for specific diagnosis and clinical reasoning. It was found that especially in the second group, anatomy was essential in 62.5% of 4131 consultations.

The evidence base that both these studies revealed has great implications for clinical training of general practitioners.

It was the goal of this study to impress the need for a sound and well researched content base used for training of anaesthesiologists who aim to perform paediatric regional anaesthetic procedures.

6.1.1 Analysis of individual blocks (in order of appearance in the questionnaire)

6.1.1.1 Caudal epidural block

It is clear that the caudal epidural block is a widely practiced procedure, which is regarded by the majority of anaesthesiologists or anaesthesiologists in training to be of great importance in their practice situation. This is not amazing as the caudal epidural block provides excellent intra- and postoperative analgesia for almost all types of interventions on the lower part of the abdomen and lower limbs, especially in neonates, infants, and certain high risk children^{24, 50, 52, 61, 63, 69, 85-97}. Although the majority feels comfortable with the procedure, a significant minority does experience difficulties and complications that are closely associated to anatomical understanding of the technique. The challenge is to address the need of this minority in an effective way. These include difficulty to palpate landmarks which is a unique problem associated to the paediatric population where bony landmarks are not always easily palpated in comparison to that of the adult⁶. This was confirmed by the assessment of anaesthesiologists or anaesthesiologists in training regarding the role of anatomy in the performance of this block. Participants strongly expressed the need for the role of anatomy in decreasing complications and difficulties and increasing confidence in performing caudal epidural blocks.

This study addressed this hiatus in anatomical knowledge by developing a comprehensive review on the anatomical pitfalls of the technique. This will aid anaesthesiologists or anaesthesiologists in training in performing the caudal epidural block with more confidence, safely and successfully.

The complications that were experienced during the performance of this block can be divided into two categories, namely:

1. *Blocks where actual morbidity resulted:*

- Dural puncture, i.e., total spinal block will occur if the dose for a caudal epidural block is injected into the subarachnoid space.
- Vascular puncture, i.e., intravascular administration, overdose and/or rapid vascular uptake of local anaesthetic solution, can quickly lead to toxic CNS reactions⁴⁷.
- Intraosseous injection, which may lead to symptoms similar to that of intravascular injections⁹⁸⁻¹⁰⁰.

2. *Blocks that failed without resulting complications:*

- Complete or partial failure of lumbar epidural anaesthesia most often occurs due to misplacement of the needle or due to “low resistance” wrongly identified as “loss of resistance”. Especially when attempting epidural blockade in patients with abnormalities of the vertebral column¹⁰¹.
- A peculiarity of caudal epidural blocks is lateralisation of the block. When caudal epidural blocks are performed on patients in the lateral decubitus position, 50% have a level of anaesthesia two dermatomes higher on the side on which they are lying. This might be more (up to 4 dermatomes higher) if the local anaesthetic solution is injected at a very slow rate⁸⁵. Various plicae and bands found in the epidural space may be responsible for this.

When considering the results of the logistic regression and odds ratio analysis on qualification and years experience on the performance of the block, it is clear that for caudal epidural blocks the postgraduate training and particularly the years experience play a significant role in whether the block is performed or not. The presence of a higher qualification increases the chances of anaesthesiologists performing the block **2.78** fold, whereas the likelihood of anaesthesiologists or anaesthesiologists in training with 5 or less years experience to perform caudal epidural blocks is **1.98** fold and **14** fold more than anaesthesiologists or anaesthesiologists in training with 6-10 years

experience and more than 10 years experience, respectively. This gives a vivid indication of how paediatric regional anaesthesia appears to be an emerging entity in the South African context. It would appear that young anaesthesiologists show a remarkable willingness to perform regional blocks on children, most probably due to more emphasis on regional techniques in their training programme. The review of the anatomy background of caudal epidural blocks as well as its pitfalls and complications can therefore be used to assist training of registrars and junior doctors and thereby increasing their experience.

6.1.1.2 Spinal anaesthesia

Although spinal anaesthesia has been performed on paediatric patients since the beginning of the 20th century, it was never as popular as in adult patients. However since 1975 new research on the benefit of spinal anaesthesia in high-risk infants provided a new look at this technique^{63, 102}. It would seem that the practice of spinal anaesthesia on paediatric patients in South Africa is less prevalent. According to the results presented, it is also not regarded as a very important block by those that perform it, when compared to other central blocks. This could in part be due to having much the same indications when compared to for instance caudal epidural blocks; possibly because of the requirement of more precautionary measures; and the fact that it provides less possibility for postoperative pain relief¹⁰³.

The demographic profile of the anaesthesiologists performing spinal anaesthesiology on paediatric patients definitely plays a significant role in whether the block is performed or not. However, because of the small number of anaesthesiologists that actually perform these blocks, accurate analysis of the demographic data was unfortunately not possible.

6.1.1.3 Thoracic epidural block

Like spinal anaesthesia, only a few anaesthesiologists perform thoracic epidural blocks, however unlike spinal anaesthesia, the anaesthesiologists that do perform this block consider it to be important in their practice. This could be because of the indications, which include almost any procedures involving the lower extremities, pelvis, perineum and abdomen. Additionally, it is also possible to perform upper abdominal and thoracic procedures. However, because of the height of the block required, the risk of possible complications increases, as well as, patient discomfort and risk ¹⁰⁴. More specific indications as reported by the Anesthésie Loco Régionale Francophone (2004) include patients with respiratory and cardiac problems; neurovascular problems; and patients with a history of a complicated postoperative period in the past ¹⁰⁵.

Interestingly enough, only about half of the anaesthesiologists who perform this block feel sufficiently comfortable to perform this block. This is in line with the literature: the thoracic epidural block is technically a more difficult block to perform, especially in children. This is due to the fact that both the dural sac and spinal cord is in danger, because of the oblique shape of the thoracic spinous processes and slope of the thoracic vertebrae making needle insertion difficult in any position other than the lateral position. Furthermore, the ligamentum flavum is thinner in the thoracic spine; therefore, loss of resistance is more difficult to perceive ^{20, 23, 106}.

Although the occurrence of complications appeared to be scarce in the sample of anaesthesiologists performing this block, common difficulties that were well experienced were problems with or lack of the equipment vital to performing a successful block and a lack of practical skills and experience needed to perform the block.

The complications that were experienced during the performance of this block can be divided into two distinct categories, namely:

1. *Blocks where actual morbidity resulted:*

- Trauma to spinal cord or spinal nerve roots.
- When the dura is punctured it would be wiser to abandon any attempts of a second trial, as Desparment⁴⁴ believes the risk of total spinal anaesthesia is too great because of the anaesthetic solution leaking through the puncture site into the spinal canal with a resultant total spinal block.
- Vascular penetration into the epidural veins is by no means uncommon. This accidental puncture is of no consequence if no injection was performed. The needle should simply be removed and reinserted properly before administering the local anaesthetic solution^{106, 107}. Total spinal anaesthesia will be elicited in the patient if the solution is injected intravascularly. Aspiration before injection is therefore important.

2. *Blocks that fail without any morbidity*

- Lack of knowledge regarding the correct needle insertion site or anatomy of the area could lead to a failed block, or to more serious complications.
- Misplacement into soft tissue could lead to a failed block⁶⁹.
- Misplacement of the needle or due to “low resistance” wrongly identified as “loss of resistance” could also be a reason for a failed block¹⁰¹.
- Lateralisation of a block may occur due to the presence of adhesions that developed following previous surgery or due to the presence of a complete plica mediana dorsalis, which divides the posterior epidural space into two halves¹⁰⁸⁻¹¹⁰.

When considering the results of the logistic regression and odds ratio analysis on qualification and years experience on the performance of the block, it would appear that anaesthesiologists with a postgraduate degree or diploma perform thoracic epidural blocks more often. Qualification therefore

plays a role whether the block is performed and in the case of thoracic epidural blocks the chances of it being performed by a more qualified doctor is slightly more (**1.82** fold) than doctors currently in specialist training. This is no doubt because of the technical difficulty associated with this block. This is reaffirmed when looking at *experience*. Results show that anaesthesiologists or anaesthesiologists in training, with 6-10 years and anaesthesiologists or anaesthesiologists in training, with more than 10 years of experience have a higher likelihood of performing this block when compared to less experienced anaesthesiologists or anaesthesiologists in training.

6.1.1.4 Lumbar epidural block

Lumbar epidural block is the second procedure that was selected according to the selection criteria used in this study and it is also the second most performed central block next to a caudal epidural block. The safety and effectiveness of a lumbar epidural block make it suitable to act as the sole anaesthetic for all urologic, orthopaedic and/ or general surgical procedures in the region of dermatomes T5-S5 involving operating times of up to 90 minutes, e.g., all procedures on the lower extremities, pelvis, perineum and lower abdomen^{21, 23, 24, 36, 61, 63, 75, 87, 97, 106, 111-116}.

It can also be used for surgical procedures on high-risk infants who are more prone to postoperative complications than other patients. Especially patients who are susceptible to malignant hyperthermia^{95, 114}, patients with respiratory disabilities^{20, 116}, and myopathy¹¹².

Because of the clear landmarks and easy access to the epidural space via the lumbar vertebrae, the lumbar epidural block remains a favourite alternative to both caudal epidural blocks and spinal anaesthesia, as well as, in procedures where general anaesthesia is contraindicated.

According to the results of the present survey, lumbar epidural blocks are not indicated to be very important to the anaesthesiologists or anaesthesiologists in training who perform them. This could be due to a number of reasons, most possibly because of the ease of performing either caudal epidural blocks on paediatric patients or using general anaesthesia.

Problems with necessary equipment appear to be a cause of concern for many of the participants, more so than practical skills and knowledge of clinical anatomy. This could also be the reason for the high incidence of dural punctures experienced by the anaesthesiologists or anaesthesiologists in training performing this block. Dural punctures may result in total spinal anaesthesia, which, if not urgently attended to, may result in tragic consequences for the patient. Dalens and Hasnaoui ⁶⁹ believe that, to some degree, complications are directly related to the equipment used.

Difficulty with equipment can however not be addressed in this study and understandably many hospitals cannot afford certain specialised equipment needed for optimally performing a safe procedure. This study can however address the need for a sound anatomical knowledge that goes hand-in-hand with this procedure even with the most state-of-the-art equipment, especially considering how the anatomy of children differ to that of adults, anaesthesiologists still require a unwavering anatomical knowledge and steady hand to successfully perform this block. This was confirmed by their perception that increased anatomical knowledge could both decrease the occurrence of complications and difficulties, as well as, increase confidence in performing this procedure.

Qualification understandably plays an important role in the performance of this block as anaesthesiologists with a postgraduate degree or diploma are **2.63** times more likely to perform lumbar epidural blocks. Like with thoracic epidural blocks it appears that anaesthesiologists with more experience have a slightly better chance of performing this procedure. This is a healthy situation, for real morbidity is associated with this technique as has been illustrated by complications and difficulties described in this study. The

present review of the anatomy background of lumbar epidural blockade as well as its pitfalls and complications can be fruitfully used to assist in training registrars and junior doctors with inferior qualification and experience.

6.1.1.5 Axillary approach to the brachial plexus (an infraclavicular brachial plexus block)

The axillary approach to the brachial plexus appears to be the frequently performed upper extremity block and this is due to both its wide variety of indications in paediatric patients, as well as, the effectiveness of the block. Although not regarded as being absolutely essential to those who perform the procedure, almost three quarters of the sample of anaesthesiologists or anaesthesiologists in training performing this block feel comfortable performing it when the need arises.

However, a significant number appear to experience difficulty during the performance of the block due to lack of knowledge of the procedure, necessary equipment and clinical anatomy knowledge and more commonly, due to a lack of practical skills required. This could in fact be due to a large number of different techniques for determining the needle insertion site⁷⁶, all of which lack easily identifiable and constant bony landmarks to orientate inexperienced anaesthesiologists.

The complications that were experience during the performance of this block can be divided into two categories, namely:

1. Blocks where actual morbidity resulted:

- Puncturing the axillary artery is undesirable, even though it has no major consequence in most patients, and occasionally it might lead to transient vascular insufficiency or in more serious circumstances haematoma formation if pressure isn't applied to the punctured vessel^{76, 117, 118}. This risk of thrombosis is higher in the paediatric population.
- There is always the risk of inserting the needle into the brachial plexus when performing this procedure. Clinical indications of nerve

damage include paresthesias, shooting or sharp stinging sensations, and excessive pain during needle insertion⁷⁶.

2. *Blocks that fail without any morbidity:*

- Partial or complete failure to block the terminal branches of the brachial plexus could occur if there is difficulty locating the needle insertion site due to a lack of adequate anatomical knowledge associated with this block.

When looking at the demographic analysis for the axillary approach to the brachial plexus block, it would seem that this procedure is only slightly more likely to be performed by anaesthesiologists with a postgraduate degree or diploma in anaesthesiology. The likelihood of less experienced anaesthesiologists or anaesthesiologists in training to perform this block is **1.71** and **1.76** more when compared to anaesthesiologists or anaesthesiologists in training with between 6 and 10 years experience and anaesthesiologists or anaesthesiologists in training with more than 10 years experience. This may be due to more emphasis placed on regional anaesthetic techniques in registrar training programmes.

This study concentrated on the infraclavicular approach, with an insertion site below the clavicle. This obviates the need to move the arm unnecessarily and it relies mainly on constant and easily identifiable bony landmarks to determine the needle insertion site, enabling even inexperienced anaesthesiologists or anaesthesiologists in training to perform the procedure. It is often difficult to palpate the pulse of the axillary artery in neonates. With the recent improvements in this technique^{77, 79, 80}, commonly occurring complications such as pneumothorax, which had previously caused even experienced anaesthesiologists to be cautious performing this block, have been minimised, making this technique safe, effective and easy to perform.

6.1.1.6 Interscalene approach to the brachial plexus (a supraclavicular brachial plexus block)

The interscalene approach is rarely performed on paediatric patients by the anaesthesiologists participating in this study. Although the indications for an interscalene block are different to those of the other brachial plexus block (axillary or infraclavicular block) there are substantially more complications associated with the interscalene approach, including: vertebral artery puncture, external jugular vein puncture, blocking of the stellate ganglion, phrenic nerve, recurrent laryngeal nerve and vagus nerve, epidural anaesthesia, and subarachnoid anaesthesia ⁷⁶.

These complications can be divided into three categories, namely:

1. *Blocks where actual morbidity resulted:*
 - Puncturing the vertebral artery
 - Puncturing the external jugular vein.
2. *Blocks that fail without any morbidity:*
 - Partial or complete failure to block the terminal branches of the brachial plexus could occur if there is difficulty locating the needle insertion site due to a lack of adequate anatomical knowledge associated with this block.
3. *Blocks that fail due to undesired spread of the anaesthetic solution:*
 - During this block, the anaesthetic solution may spread to structures situated close to the needle insertion site. These structures include; the phrenic nerve, vagus nerve, epidural space, and even the subarachnoid space ¹¹⁷.

Because of the few anaesthesiologists or anaesthesiologists in training who performed this procedure, an accurate demographic analysis was not possible.

6.1.1.7 Femoral nerve block

The femoral nerve block is the most commonly performed lumbar plexus block according to the results of this survey. This is consistent with what is found in the literature ¹¹⁹.

The femoral nerve block has come a long way since Fenwick first introduced it in adults in 1957 ¹²⁰. For years it has shown remarkable effectiveness and safety in adult patients and more recently this procedure has been put to good use in paediatric patients for pre- or postoperative analgesia for femoral shaft fractures. With femoral shaft fractures, a femoral nerve block should be performed as soon as possible after the incident to improve the clinical status of the patient during transport of the patient, physical examinations, radiological examinations, application of wound dressings and orthopaedic procedures ^{24, 61, 87, 90, 121-126}). The femoral nerve block is also indicated to relieve muscle spasm of the quadriceps around a fractured femur ^{35, 87, 90, 120, 122}.

Because of the complex nerve supply of the lower extremities (nerve supply from both lumbar and sacral plexuses), in combination with other nerve blocks of the lower limb, the femoral nerve block can provide complete anaesthesia of the lower limb where central blocks are contraindicated ^{123, 124}.

It is therefore not surprising that the anaesthesiologists or anaesthesiologists in training participating in this study believe this block to be important in the setting in which they practice anaesthesiology. The majority of anaesthesiologists also feel very comfortable performing this procedure on paediatric patients, although almost a third of the participants have difficulty performing femoral nerve blocks due to lack of practical skills or experience required to perform the procedure comfortably. Nearly a quarter of the anaesthesiologists or anaesthesiologists in training find that complications occur or difficulties arise during the performance of the block due to lack of knowledge regarding the procedure and clinical anatomy knowledge. When analysing the complications that were experienced during the performance of

a femoral nerve block (Table 7), although most anaesthesiologists or anaesthesiologists in training feel that they can perform the procedure comfortably, more than a third had difficulty locating the needle insertion site for blocking the femoral nerve.

Also, and more alarming is the fact that nearly halve of the anaesthesiologists or anaesthesiologists in training have penetrated the femoral artery during a femoral nerve block. This has serious implications for paediatric patients as femoral artery puncture can easily cause thrombosis in the femoral artery⁷⁰, which is especially hazardous in infants and children¹²⁷.

The complications that were experience during the performance of this block can be divided into two categories, namely:

1. *Blocks where actual morbidity resulted:*

- Smith and Green⁷⁰ conducted a review on cases of paediatric vascular injuries and found that deliberate penetration of the femoral artery (for diagnostic purposes, i.e., blood gas sampling) was a common cause for thrombosis in the femoral artery, which is especially hazardous in infants and children¹²⁷. In the literature, vascular puncture is the most common occurring complication for a femoral nerve block in a paediatric patient^{60, 71, 90, 125, 126, 128}.
- Nerve trauma.

2. *Blocks that fail without any morbidity:*

- Partial or complete failure to block the femoral nerve could occur if there is difficulty locating the needle insertion site due to a lack of adequate anatomical knowledge associated with this block.

A sound knowledge of the exact position of the femoral artery in paediatric patients is therefore essential. An anaesthesiologist should determine the site of the femoral artery either by the pulse of the artery or conversely, in the absence of a pulse, with a solid knowledge of the relevant anatomy and through meticulous examination. There are no studies to illustrate the relation of the femoral nerve to a bony landmark such as the anterior superior iliac spine, which may be of great value in determining the position of the nerve in the absence of a femoral artery pulse.

It is important to note, however, that the knowledge base was designed to make anaesthesiologists aware of the importance of a sound anatomy knowledge that is embedded in the field of regional anaesthesia. It can only be stressed that even with vast amounts of theoretical knowledge, experience still plays a vital role in the performance of this block. This appears to be the case when looking at the demographic analysis for femoral nerve blocks. Young anaesthesiologists or anaesthesiologists in training are actively performing femoral nerves blocks, more so than the older anaesthesiologists. Anaesthesiologists or anaesthesiologists in training with 5 years or less experience are performing femoral nerve blocks approximately **2.56** times and **4.39** more than anaesthesiologists or anaesthesiologists in training with between 6 and 10 years experience and anaesthesiologists or anaesthesiologists in training with more than 10 years experience, respectively. When looking at qualification, qualified anaesthesiologists perform femoral nerve blocks only slightly more so than anaesthesiologists in training. This could mean that there is ample opportunity for anaesthesiologists in training to gain valuable experience from performing femoral nerve blocks with the expert guidance of more experienced anaesthesiologists.

6.1.1.8 Lateral cutaneous nerve of the thigh block

The lateral cutaneous nerve of the thigh has very few specific indications, other than muscle biopsies for the diagnosis of malignant hyperthermia¹²⁴, for performance in paediatric patients. It is often used, however, as a complementary block to the femoral nerve block, especially when a tourniquet must be placed on the thigh⁸⁷.

From the few anaesthesiologists or anaesthesiologists in training that actually perform this block it could be presumed that most prefer performing a “3-in1” block as opposed to a femoral nerve block and lateral cutaneous nerve of the thigh block, separately.

Again, because of the few who perform this procedure, accurate demographic analysis was not possible.

6.1.1.9 “3-in-1” block

As was mentioned before, it would appear that most anaesthesiologists or anaesthesiologists in training would prefer to perform the “3-in-1” block when it calls for blocking the femoral nerve, obturator nerve and lateral cutaneous nerve of the thigh. A high failure to block the latter two nerves is however often associated with the “3-in-1” block in children. The success rate does not appear to increase even with the placement of a tourniquet and injection of large volumes of local anaesthetic solution ¹²⁴.

Dalens and co-workers ¹²⁹ prospectively evaluated the “3-in-1” block and the psoas compartment block in 50 children (weight range: 8kg-52kg) undergoing surgery of the hip region. In this study they concluded that the “3-in-1” block was more suitable for providing a unilateral blockade of the lower extremity than the psoas compartment block.

Furthermore, difficulties and complications are common amongst the participating anaesthesiologists or anaesthesiologists in training who perform this procedure suggesting that both the femoral nerve block and the “3-in-1” block to be a problem. Although classically they share the same insertion site, both are difficult to perform, even more so due to lack of knowledge regarding the correct performance of this procedure, practical skills necessary or due to a lack of clinical anatomy knowledge, which is indicated by the anaesthesiologists or anaesthesiologists in training who perform this procedure.

Like the femoral block, the complications that were experienced during the performance of the “3-in-1” block and the fascia iliaca compartment block, can also be divided into two categories, which are the same.

As with the axillary approach to the brachial plexus the main landmark remains the pulse of the artery, which is often faint or even lacking in certain paediatric patients and locating the femoral nerve can be difficult for inexperienced anaesthesiologists or anaesthesiologists in training attempting to perform the procedure. Therefore, as was indicated before it would be prudent to determine the position of the femoral nerve in the absence of a femoral artery pulse or if only for reaffirming the position of the femoral nerve in the presence of the femoral artery pulse.

6.1.1.10 Fascia iliaca compartment block

With the high incidence of performance of both the femoral nerve block and the “3-in-1” block, it is no wonder that the fascia iliaca compartment block is so infrequently performed by the anaesthesiologists approached for this study. This procedure should however not be discarded just because of this. Dalens and co-workers⁷¹ in 1989, after they re-evaluated the gross anatomy of the lumbar plexus nerves and fasciae of the groin and thigh in children, introduced this procedure. Clinical trials in this study also indicate a remarkable success rate of 90%.

Dalens and Mansoor⁶⁰ believe that the fascia iliaca compartment block is a more preferred procedure for lower limb surgery in neonates as all the lumbar plexus nerves supplying the lower limb are blocked with a single injection with the least amount of risk involved. This doesn't however appear to be the case amongst the anaesthesiologists in South Africa.

Because of the few anaesthesiologists or anaesthesiologists in training performing this procedure, accurate information regarding the difficulties and complications, as well as the demographic analysis of this procedure, could not be obtained. The likelihood of a anaesthesiologist or anaesthesiologist in training with 5 or less years experience to do this procedure is almost four times higher than the likelihood of a anaesthesiologist or anaesthesiologist in training with more than 10 years experience. It would seem that younger

anaesthesiologists are only now trying out this procedure on paediatric patients.

6.1.1.11 Psoas compartment block

The psoas compartment block is the last of the lumbar plexus blocks performed on paediatric patients and it is also performed the least. This was also the case in a survey conducted by Buist in 1990¹¹⁹ where only 15% of the anaesthesiologists, who participated in that study, perform the psoas compartment block.

In a comparative study conducted by Dalens and co-workers¹²⁹ they evaluated the effectiveness of the “3-in-1” block and the psoas compartment block in 50 children (weight range: 8kg-52kg) undergoing surgery of the hip region. Although they concluded that the “3-in-1” block was more suitable for providing a unilateral blockade of the lower extremity, they did state that the psoas compartment block could serve as an alternative regional procedure where a lumbar epidural block is contraindicated.

Dalens¹²³ also feels that the psoas compartment block is rarely indicated for children and is only performed when a central block is contraindicated. The possibility for complications such as damage to visceral structures is also increased when performing the psoas compartment block and therefore should not be performed by an inexperienced anaesthesiologist. Basically, according to Dalens¹²³, and this is reflected in the results of this survey, the psoas compartment block occupy a secondary position when compared to other blocks of the lumbar plexus and has a low benefit versus risk ratio.

The demographic analysis for this procedure indicate that when it comes to paediatric patients, only the most experienced anaesthesiologists perform the psoas compartment block.

6.1.1.12 Anterior sciatic nerve block

Very few participants perform the anterior approach to the sciatic nerve block in paediatric patients. Dalens¹³⁰ even went as far as saying that because of the difficulty and impracticality of this procedure in paediatric patients, it has to a greater extent become obsolete. This is evident in this survey, and is also reflected in the study conducted by Buist in 1990¹¹⁹, where only 19% of the participating anaesthesiologists (n=211) perform the procedure in their practice.

The few that do perform the procedure does however feel comfortable performing the blockade. While difficulties experienced are mostly isolated to a lack of equipment needed for the procedure, complications include:

1. *Lack of anatomical knowledge:*

- Difficulty in identifying the correct anatomical landmarks in order to determine the correct needle insertion site. This in turn could lead to a failed block or more serious complications.

2. *Blocks where actual morbidity resulted:*

- Sciatic nerve trauma.
- Vascular penetration.
- Occurrence of a compression haematoma.

The demographic analysis indicate that it is much more likely for an anaesthesiologist with a vast amount of experience to perform this procedure, even though in combination with a femoral nerve block, it could virtually provide analgesia of the entire lower limb¹³⁰.

6.1.1.13 Posterior sciatic nerve block

The anaesthesiologists or anaesthesiologists in training participating in this study appear to be more partial to blocking the sciatic nerve via the posterior approach. In the study conducted by Buist in 1990¹¹⁹, the posterior approach to the sciatic nerve was only performed by 20% of the participating

anaesthesiologists (n=211). As was stated in the anterior approach to the sciatic nerve, blocking the sciatic nerve can give analgesia for a large number of surgical procedures of the tibia and foot ¹³⁰.

Of those performing this approach, most of them appear to be confident performing the procedure on a paediatric patient; however, lack of the necessary equipment, knowledge of the procedure and the anatomy, as well as a lack of practical skills can cause difficulties and complications when performing this procedure.

The lack of knowledge and practical skills is confirmed by the difficulty for anaesthesiologists or anaesthesiologists in training to locate the correct position of needle insertion from the various landmarks, which first need to be identified correctly.

Damage to the sciatic nerve is also a complication experienced by the anaesthesiologists or anaesthesiologists in training performing this procedure. This can easily have been avoided if a nerve stimulator is used ⁴¹. Dalens ¹³⁰ stated that there has been no case of sciatic nerve injury in children when a nerve stimulator was used to identify the nerve. This refers back to the lack of necessary equipment that the participants of the survey indicated to be a cause of difficulties and complications.

Like the anterior approach, the complications that were experienced during the performance of this procedure can also be divided into two categories where actual morbidity resulted and those that fail without any morbidity.

Bosenberg and co-workers ⁶ stated that the use of a nerve stimulator should not be a substitute for sound anatomical knowledge and careful technique, and even with the help of a nerve stimulator, this procedure, and any regional nerve block in general should not be performed when the anatomy of the region is in doubt. The anaesthesiologists or anaesthesiologists in training who regarded sound clinical anatomy

knowledge to be essential for decreasing complications and difficulties, and increasing confidence levels of this approach confirm this statement.

The demographic analysis for this procedure indicate that the posterior approach to the sciatic nerve is more likely to be performed by anaesthesiologists in training when compared to anaesthesiologists. When looking at experience it would appear that anaesthesiologists or anaesthesiologists in training with less than 5 years experience and those with between 6 and 10 years experience are more likely to perform this procedure than anaesthesiologists or anaesthesiologists in training with more than 10 years experience.

6.1.1.14 Lateral sciatic nerve block

According to the survey conducted in this study, none of the participating anaesthesiologists or anaesthesiologists in training block the sciatic nerve via the lateral approach. This may not be reflective to the whole of South Africa. Because of the simplicity of the technique, the multitude of indications of the sciatic nerve block especially for procedures of the foot, and due to the fact that the lateral approach hardly has any risk associated with it¹³⁰, a new look at this approach is recommended.

6.1.1.15 Ilioinguinal/ iliohypogastric nerve block

The ease in which this block can be performed, together with its safety and effectiveness in a multitude of procedures; such as inguinal hernia repair (inguinal herniorraphy)¹³¹⁻¹³³, varicocele surgery^{78, 131, 132, 134}, orchidopexy^{51, 53, 131, 132}, hydrocele surgery¹³¹⁻¹³³, as well as, for emergency procedures such as strangulated hernia with intestinal obstruction^{131, 132, 135}, makes the ilioinguinal/ iliohypogastric nerve block one of the most frequently performed procedures on paediatric patients. This is supported from the data of this survey, as well as that from a survey conducted in the UK where 74% of anaesthesiologists perform the ilioinguinal/ iliohypogastric nerve block¹¹⁹.

This high frequency of performance coincide with the fact that more than two thirds of the participating anaesthesiologists believe this procedure to be an important procedure to be able to perform and most of the participants do so, comfortably and with the minimum amount of difficulty.

Complications with this procedure however include:

1. *Lack of anatomical knowledge:*

- Difficulty in identifying the correct anatomical landmarks in order to determine the correct needle insertion site.

2. *Blocks where actual morbidity resulted:*

- Nerve trauma;
- Intravascular injection and
- Puncture of the peritoneum and underlying visceral structures.

3. *Partial or complete failure to block the ilioinguinal and iliohypogastric nerves:*

- The main disadvantage of this block is either a complete or partial failure^{61, 87, 131, 132}. It is estimated that complete failure could occur in about 10% of procedures, even in experienced hands. Partial failure to block these nerves occurs even more frequently, between 10 and 15% of procedures^{131, 132}.
- Another cause for failure is a transient femoral nerve block, which could occur if the needle is advanced too deeply into the space between the internal oblique and transverse abdominis, which is continuous with the fascia iliaca within which the femoral nerve is situated⁷⁴.

Complications were abundant amongst the participants. Nearly two thirds have experienced partial or complete failure to block these nerves. This could possibly be due to a lack of knowledge regarding the actual positions of the ilioinguinal and iliohypogastric nerves in paediatric patients, as anatomical studies describing the exact position in the above mentioned population, remains scarce. The mistake to apply adult data to the paediatric/ neonatal group of patients may explain, at least partly why these blocks often fail.

From the demographic analysis it would appear that anaesthesiologists have only recently, perhaps within the past 10 years, actively performed this procedure. Looking at qualification, qualified anaesthesiologists are three times more likely to perform this procedure when compared to registrars. Anaesthesiologists or anaesthesiologists in training with 5 years or less years experience and anaesthesiologists or anaesthesiologists in training with between 6-10 years experience, appear to have about the same chance of performing this procedure as opposed to anaesthesiologists or anaesthesiologists in training with more than 10 years experience. Anaesthesiologists or anaesthesiologists in training with 5 or less years of experience are **3.4** times more likely to perform this procedure when compared to the latter group.

6.1.1.16 Penile block

In this survey, penile blocks are the second most performed procedure. The participants, who perform this block, also believe it to be an important procedure to be able to perform.

Only some participants find a lack of knowledge of the procedure and also clinical anatomy knowledge regarding the procedure itself, to be a cause for difficulties and complications, as most anaesthesiologists or anaesthesiologists in training seem to be comfortable to perform this procedure on a paediatric population.

The complications that occur, and most likely due to the lack of knowledge regarding this block, are difficulties in locating the correct needle insertion site, which in turn account for the penetration and injury to other structures within the penis, such as vascular structures and the corpus cavernosum. These complications are very rare when the correct technique is carefully performed, making this procedure very safe and effective for procedures such as circumcision, correction of phimosis or paraphimosis and hypospadias repair¹³⁶. The lack of knowledge of both the anatomy and the

procedure itself will most certainly lead to complications. The need for a better understanding of both these factors are expressed in that the participating anaesthesiologists or anaesthesiologists in training understand that an increased clinical anatomy knowledge will lead to an increase in the comfort levels when performing this procedure, as well as, a decrease in complications.

Looking at the demographic analysis for this procedure it seems that anaesthesiologists, as opposed to anaesthesiologists in training, are more likely to perform penile blocks. Also anaesthesiologists or anaesthesiologists in training with 5 years or less experience are more likely to perform this procedure when compared to anaesthesiologists or anaesthesiologists in training with between 6 and 10 years experience. They, in turn, also have an almost equal chance of performing this procedure compared to anaesthesiologists or anaesthesiologists in training with more than 10 years experience.

6.1.1.17 Intercostal nerve block

The anaesthesiologists or anaesthesiologists in training who participated in this survey perform this block infrequently. Although, easy to perform, it has a high failure rate, (which has not yet been determined in paediatric patients but quoted as being between 12 and 22% in adults), with a high risk of complications associated with this block, this procedure has a very poor benefit versus risk ratio, especially in children younger than 10 years old¹³¹. Even with this grim statement in mind, more than half of the anaesthesiologists or anaesthesiologists in training who perform this procedure feel that it is important and two thirds feel comfortable to perform intercostal blocks on paediatric patients. Knowledge of the procedure however seems lacking, as nearly half of the anaesthesiologists or anaesthesiologists in training who perform this procedure feel that a lack of proper knowledge regarding this procedure contribute to the morbidity following an intercostal block.

In this study, the occurrence of pneumothorax, following an intercostal block, appears to be the most prominent complication. Other complications include:

1. *Lack of anatomical knowledge:*

- Difficulty locating the site of needle insertion. Possibly due to lack of anatomical knowledge.

2. *Blocks with associated morbidity:*

- If the needle is inserted too deeply, a pneumothorax can easily occur, especially with the higher posterior approach or parasternal approach. Experience also plays a significant role in avoiding this complication¹³¹.
- If the needle is advanced too deeply when trying to block primarily the last intercostal nerve, damage to the peritoneum and abdominal viscera can occur.
- Haematoma formation often occurs when an intercostal vessel is punctured with the needle, which can, although very seldom, cause respiratory distress. Accidental intravascular injection of anaesthetic solution could lead to CNS toxicity. This can easily be avoided if one aspirates before injecting.

3. *Failed blocks:*

- Failure to block the intercostal nerves is not rare. In two separate studies conducted by Kirno and Lindell¹³⁷ on two samples of 24 cases, the classical intercostal nerve block technique for the first 24 cases and injecting large volumes of anaesthetic solution in the second set of cases was used. They reported 5 and 3 failures respectively.

4. *Blocks with an extensive spread of anaesthetic solution:*

- Even a block with the correct volumes of anaesthetic solution can spread too extensively into adjacent spaces, i.e., paravertebral space, epidural space and even the subarachnoid space, resulting in undesired areas of analgesia.
- Extensive spread could also lead to respiratory distress in patients.

The demographic analysis was somewhat confounded by the small number of anaesthesiologists or anaesthesiologists in training who actually perform this procedure.

6.1.1.18 Digital nerve block

Approximately a third of the anaesthesiologists or anaesthesiologists in training who participated in this survey comfortably perform digital nerve blocks on paediatric patients, even though a small number of anaesthesiologists or anaesthesiologists in training feel that complications, which occur when they perform this procedure, is related to a lack of knowledge of the procedure, necessary equipment, practical skills and a lack of clinical anatomy knowledge.

Complications however remain scarce. Difficulty in locating the correct needle insertion site appears to be the most common difficulty, possibly leading to failed or partially failed blocks. Again anaesthesiologists or anaesthesiologists in training feel that anatomy plays a significant role in possibly decreasing the frequency of these complications and also increasing comfort levels.

When looking at the demographic analysis for digital nerve blocks, anaesthesiologists in training seem more likely to perform this procedure than qualified anaesthesiologists. This might be due to the fact that a qualified anaesthesiologist would rather receive the patients where more extensive analgesia, say of the entire arm, is required. Anaesthesiologists in training

would more likely perform digital nerve blocks on patients where only analgesia of the hand is required as this procedure is fairly easy to perform with adequate knowledge regarding the anatomy of the digital nerves in the hand.

6.1.2 Analysis of demographic data

The odds ratios of the demographic profile for each procedure is summarised in Table 8. The odds ratio allows for the determining of the likelihood of an anaesthesiologist, to perform a specific procedure compared to an anaesthesiologist in training. Therefore the present study can determine whether the procedure is more likely to be performed by practicing anaesthesiologists in either a private practice or government institution, or by anaesthesiologists in training. As can be seen from the results, registered anaesthesiologists have a better chance of performing certain procedures, such as a caudal epidural block (2.78 times more likely), a thoracic epidural block (1.87 times more likely), a lumbar epidural block (2.63 times more likely), an axillary approach to a brachial plexus block (1.34 times more likely), femoral nerve block (1.82 times more likely), “3-in-1” block (1.96 times more likely), ilioinguinal/ iliohypogastric nerve block (3.26 time more likely), and penile block (1.85 times more likely). This could be due to experience, and the fact that certain procedures won't be commonly given to anaesthesiologists in training to perform on paediatric patients.

However certain procedures are more likely to be performed by anaesthesiologists in training than practicing anaesthesiologists. These procedures include a psoas block (0.27), anterior approach of sciatic nerve block (0.44), posterior approach to sciatic nerve block (0.33), intercostal nerve block (0.28), and digital nerve block (0.52). The odds ratio is the odds (likelihood) of a qualified anaesthesiologist to perform a procedure when compared to an anaesthesiologist in training, therefore a figure less than 1 indicates that anaesthesiologists in training are more likely to perform the procedure. Although not completely true in all of the cases these procedures

would likely be technically less difficult than the procedure more likely to be performed by anaesthesiologists.

Another factor that definitely plays a significant role in both choosing the correct procedure, as well as, performing it successfully, is experience. When looking at the role that experience plays in which procedures are performed on paediatric patients (2nd and 3rd columns of Table 8: Odds of anaesthesiologists and anaesthesiologists in training with 5 years or less experience to perform procedure compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience or more than 10 years experience), one can see that a procedure such as a caudal epidural block is 1.98 times more likely to be performed by anaesthesiologists or anaesthesiologists in training with 5 or less experience when compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience and 14 time more likely to be performed when compared to anaesthesiologists or anaesthesiologists in training with more than 10 years experience.

This is the same for procedures such as the axillary approach of the brachial plexus block, where anaesthesiologists or anaesthesiologists in training with 5 years or less experience are 1.71 times more likely to perform this procedure when compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience and 1.76 times more likely when compared to anaesthesiologists or anaesthesiologists in training with more than 10 years experience. Anaesthesiologists or anaesthesiologists in training with 5 years or less years experience are more likely to perform other blocks as well, i.e., 2.56 times and 4.39 time more likely to perform a femoral nerve block when compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience and more than 10 years experience, respectively; 4.44 times and 9.7 times more likely to perform the “3-in-1” block when compared to anaesthesiologists or anaesthesiologists in training with 6-10 years experience and more than 10 years experience, respectively; and a penile block, which less experienced anaesthesiologists or anaesthesiologists in training are 1.74 times and 1.07 times more likely to be perform when compared to anaesthesiologists or anaesthesiologists in training with 6-10

years experience and more than 10 years experience, respectively. This may be due to a renewed emphasis on training registrars (anaesthesiologists in training) regional anaesthetic techniques.

As with qualification, certain procedures are more likely to be performed by the more experienced anaesthesiologists or anaesthesiologists in training (odds ratio < 1), which include anaesthesiologists or anaesthesiologists in training with 6-10 years and more than 10 years experience. These procedures are a thoracic (0.11 and 0.4) and a lumbar epidural block (0.72 and 0.93), as well as, an intercostal nerve block (0.77 and 0.22).

These procedures require a great amount of skill and experience to perform safely and successfully and are therefore more likely to be performed by anaesthesiologists that feel comfortable performing these blocks than less experienced anaesthesiologists who has yet to gain confidence performing regional nerve blocks, either central or peripheral, on paediatric patients.

The rest of the procedures appear to be performed equally by all anaesthesiologists or anaesthesiologists in training regardless of the number of years of experience that they might have.

6.2 Selection of problem procedures and criteria for selection

A total of 5 problem procedures were selected according to Scoring option B. The questionnaire was developed to identify the procedures that are not only performed by anaesthesiologists on a regular basis but also was found to be important in each individual anaesthesiologist's practice or place of work, be it in a private practice or a governmental institution. The main criteria for selection however were anatomical of nature. Emphasis was placed on the significance of anatomical knowledge regarding each specific block. Therefore special attention was given to questions 5 and 6 in the questionnaire and to a lesser degree, questions 7 and 8.

This allowed for the selection of procedures that had high frequency of performance, but also procedures in which anaesthesiologists experienced difficulties performing because of the anatomical knowledge required to perform the procedure successfully.

With the emergence of evidence based medical education, it has become vitally important to focus clinical anatomy training programs on actual data from the clinical setting. There is a need to support anatomical teaching programs with clinical data in order to justify the teaching of these procedures to interns or registrars, as well as, increase the knowledge of certain key procedures that are performed by anaesthesiologists on a daily basis, often without the luxury of proper equipment or sufficient assistance. This is in part due to the fact that South African medical schools are challenged in the training of doctors who need to care for both first and third world patient populations in both rural and urban medical centres. This type of training programs will therefore significantly contribute to proper pain management in paediatric patients and decrease morbidity and mortality associated with paediatric patients.

An evidence base for the regional anaesthetic procedures, performed in the South African context, is unavailable. This study addresses this question and also studies the difficulties and complications experienced

during performance of various paediatric regional anaesthetic procedures. These are usually greatly dependent on a sound anatomical understanding. The procedures performed were systematically determined, and difficulties and complications related to the anatomy were identified. This study therefore forms the foundation on which a clinical anatomy knowledge base for problem procedures, experienced by anaesthesiologists who perform paediatric regional anaesthetic procedures in South Africa, could be developed.

6.3 Development of a clinical anatomy knowledge base for each selected problem procedure

For the 5 selected procedures a clinical anatomy knowledge base was developed. This was done by reviewing the literature, in both the fields of basic and clinical sciences, extensively regarding the clinical anatomy features of the selected procedures. Certain anatomical “gaps” in the literature were also identified, with specific emphasis placed on the anatomical aspects regarding the selected procedures. A list can be found in the **Future studies** found in the **Anatomical pitfalls** section of the clinical anatomy knowledge base for each of the selected problem procedures. This aspect of the study, identifying anatomically based pitfalls in the literature, and proposing possible research topics remains an integral part a of this study.

7. Conclusion

The main objective of this study was to gain knowledge of the practice of paediatric regional anaesthesiology in South Africa. With this knowledge this study hopes to enforce a clear and well-informed view on the content of anaesthesiology training programmes, in order to equip anaesthesiologists with the necessary tools to practice their chosen profession with confidence and enthusiasm.

Furthermore the aim of this study was to promote an increased clinical anatomy knowledge that serves to be one of the most fundamental concepts of performing successful clinical procedures, such as regional anaesthetic techniques, in the medical profession. Even with the rapid rate of technological advances in the fields of clinical examinations, imaging techniques and high-tech equipment, a solid anatomical knowledge remains a necessity. In times when even the most technologically advanced equipment needs to be supplemented with a thorough knowledge of anatomy, especially in situations where access to these tools is scarce or nonexistent.

Several future studies, mostly dissection based, are needed to address identified questions, which may lead to a lower failure rate, decrease incidence of complications and difficulties and lead to an improved confidence of performance.

It is therefore important for anaesthesiologists to gain their own repertoire of paediatric regional anaesthetic procedures to use in the particular setting in which they should find themselves. Only through training and personal experience, as well as, knowledge of your limitations, can this be accomplished effectively, as certain blocks are easier for some and technically more difficult for others.

Almost all the anaesthesiologists who participated in the study agreed that knowledge of the anatomy is essential in decreasing the occurrence of

complications and increasing comfort levels of each regional nerve block. Emphasis is therefore placed on the importance that clinical anatomy plays in the day-to-day practice of anaesthesiologists.

8. References

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Appendix A: Questionnaire

Paediatric regional anaesthetic procedures: clinical anatomy competence, pitfalls and complications

A research study conducted by the Department of Anatomy at the University of Pretoria.

Research study

I (full name)....., willingly agree to participate in the study which is briefly described in the covering letter of the questionnaire.

I understand that:

Purpose of the study

This research focuses on the competency to perform a range of paediatric regional anaesthetic procedures, especially the underlying anatomical knowledge necessary to perform a safe and successful procedure.

Description of the procedures

This study will be conducted by means of a questionnaire.

Risks and discomforts

There are no risks involved in this study.

Benefits

I understand that the information obtained from this study may not be of any direct benefit to my family member(s) or me. This study will be of great value in identifying key anatomical pitfalls and complications relevant to paediatric regional anaesthetic procedures and therefore improving competence of practitioners performing these procedures.

Voluntary participation

Participation in this study is voluntary. No compensation for participation will be given. I understand that I am free to withdraw my consent to participate in this study at any time.

Confidentiality

I understand that a record containing my questionnaire and personal details will be kept on file and also in a computer file at the Department of Anatomy. No information by which I can be identified will be released or published.

.....
(Signature of Participant)

.....
(Date)

.....
(Signature of Witness)

.....
(Date)

Paediatric Regional Anaesthetic Procedures

Dear Dr.

This study is conducted to determine the competency to perform a range of paediatric regional anaesthetic procedures, especially the underlying anatomical knowledge necessary to perform a safe and successful procedure. Your contribution is very appreciated and will help to identify problem regional anaesthetic procedures, which are performed daily around health care facilities around South Africa.

Your questionnaire will be kept confidential. No information by which you can be identified will be released or published. The first part of the questionnaire concerns demographic data, while the second part relates to the use of specific procedures. **You need only to tick your answer in the appropriate box. Every procedure has 8 questions. The questions are repeated on every page. There are three procedures to be evaluated on each page.**

A word of special thanks for your time and cooperation in completing this questionnaire.

Many thanks

Mr AN van Schoor B.Sc. (Hons)
Dept of Anatomy

Prof JM Boon MBChB MMed(Fam Med)
Head: Section of Clinical Anatomy
Dept of Anatomy

PART 1

Demographic data:

Age: _____

Highest qualification: _____

Years in practice: _____

Private practice:

Institution:

Town/City: _____

Province: _____

PART 2:

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year**?
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6		7	8
Paediatric Caudal Epidural Blocks	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty palpating landmarks for needle insertion	Injection of local anaesthesia into sacral bone marrow	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Difficulty piercing the sacrococcygeal ligament	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Dural puncture	Subarachnoid injection	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement into soft tissue or rectum (pelvic viscera)		Strongly disagree	Strongly disagree
	1	2	3	4	5	6		7	8
Paediatric Spinal Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure			Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge			Strongly disagree	Strongly disagree
	1	2	3	4	5	6		7	8
Paediatric Thoracic Epidural Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Dural puncture	Lesions to intervertebral disks and ligaments	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement of epidural catheter		Strongly disagree	Strongly disagree

1. I perform this procedure in my practice.
2. How many times did you perform this procedure in the past year?
3. The performance of this procedure is important in my practice situation.
4. I feel comfortable to perform this procedure.
5. I find difficulty to perform this procedure due to the following reason/s: (order in level of importance)
6. I met the following complication/s and have the following difficulties when performing the procedure (number in order of frequency)
7. The improvement of critical anatomy knowledge necessary to perform this procedure will reduce difficulties and complications.
8. Improvement of anatomy knowledge necessary for the procedure will increase my confidence in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8	
Paediatric Lumbar Epidural Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Dural puncture	Lesions to intervertebral disks and ligaments	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement of epidural catheter		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Brachial Plexus Block: Axillary Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating axillary artery		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Axillary artery puncture		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Pneumothorax		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Brachial Plexus Block: Interscalene Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating interscalene groove	External jugular vein puncture	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Vertebral artery puncture	Blocked phrenic nerve	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Blocked vagus nerve	Epidural anaesthesia	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Sub-arachnoid penetration		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year**?
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8
Paediatric Femoral Nerve Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Femoral artery penetration	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Lateral Cutaneous Nerve of the Thigh Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Difficulty locating position of lateral cutaneous nerve of the thigh	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric 3-in-1 Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8
Paediatric Fascia iliaca compartment Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Psoas Compartment Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Sciatic Nerve Block: Anterior Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty finding landmarks necessary in locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Sciatic nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Femoral artery or vein penetration	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Occurrence of a compression hematoma	Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8
Paediatric Sciatic Nerve Block: Posterior Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty finding landmarks necessary in locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Sciatic nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Sciatic Nerve Block: Lateral Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty finding landmarks necessary in locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Sciatic nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Ilioinguinal and Iliohypogastric Nerve Blocks	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty in visualizing position of ilioinguinal and iliohypogastric nerves	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Blocking of femoral nerve	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Incomplete blocking of ilioinguinal and iliohypogastric nerves	Strongly disagree	Strongly disagree

1. I perform this procedure in my practice.
2. How many times did you perform this procedure in the past year?
3. The performance of this procedure is important in my practice situation.
4. I feel comfortable to perform this procedure.
5. I find difficulty to perform this procedure due to the following reason/s: (order in level of importance)
6. I met the following complication/s and have the following difficulties when performing the procedure (number in order of frequency)
7. The improvement of critical anatomy knowledge necessary to perform this procedure will reduce difficulties and complications.
8. Improvement of anatomy knowledge necessary for the procedure will increase my confidence in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8	
Paediatric Penile Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree	
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree	
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Penetration of corpora cavernosa	Disagree	Disagree	
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree	
	1	2	3	4	5	6	7	8	
Paediatric Intercostal Nerve Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Penetration of peritoneum and viscera	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of intercostal vessels	Failure to block intercostal nerves	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Pneumothorax	Respiratory failure	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge			Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Digital Nerve Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree	
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree	
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree	
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree	

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year**?
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

Regional anaesthetic procedures	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

Appendix B: Pilot Study Questionnaire

Paediatric Regional Anaesthetic Procedures

Dear Dr.

This study is conducted to determine the competency to perform a range of paediatric regional anaesthetic procedures, especially the underlying anatomical knowledge necessary to perform a safe and successful procedure. Your contribution is very appreciated and will help to identify problem regional anaesthetic procedures, which are performed daily around health care facilities around South Africa.

Your questionnaire will be kept confidential. No information by which you can be identified will be released or published. The first part of the questionnaire concerns demographic data, while the second part relates to the use of specific procedures. **You need only to tick your answer in the appropriate box. Every procedure has 8 questions. The questions are repeated on every page. There are three procedures to be evaluated on each page.**

A word of special thanks for your time and cooperation in completing this questionnaire.

Many thanks

Mr AN van Schoor B.Sc. (Hons)
Dept of Anatomy

Prof JM Boon MBChB MMed(Fam Med)
Head: Section of Clinical Anatomy
Dept of Anatomy

Demographic data:

Age: _____

Highest qualification: _____

Years in practice: _____

1. I perform this procedure in my practice.
2. How many times did you perform this procedure in the past year?
3. The performance of this procedure is important in my practice situation.
4. I feel comfortable to perform this procedure.
5. I find difficulty to perform this procedure due to the following reason/s: (order in level of importance)
6. I met the following complication/s and have the following difficulties when performing the procedure (number in order of frequency)
7. The improvement of critical anatomy knowledge necessary to perform this procedure will reduce difficulties and complications.
8. Improvement of anatomy knowledge necessary for the procedure will increase my confidence in performing the procedure.

	1	2	3	4	5	6	7	8	
Paediatric Caudal Epidural Blocks	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty palpating landmarks for needle insertion	Injection of local anaesthesia into sacral bone marrow	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Difficulty piercing the sacrococcygeal ligament	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Dural puncture	Subarachnoid injection	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement into soft tissue or rectum (pelvic viscera)		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Spinal Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle	Strongly agree	Strongly agree	
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree	
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree	
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree	
	1	2	3	4	5	6	7	8	
Paediatric Thoracic Epidural Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle	Strongly agree	Strongly agree	
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Dural puncture	Lesions to intervertebral disks and ligaments	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement of epidural catheter		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8	
Paediatric Lumbar Epidural Anaesthesia	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating the correct placement of the needle		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Dural puncture	Lesions to intervertebral disks and ligaments	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Trauma of the spinal cord and nerve roots	Penetration of vascular structures	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Misplacement of epidural catheter		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Brachial Plexus Block: Axillary Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating axillary artery		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Axillary artery puncture		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Pneumothorax		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8	
Paediatric Brachial Plexus Block: Interscalene Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating interscalene groove	External jugular vein puncture	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Vertebral artery puncture	Blocked phrenic nerve	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Blocked vagus nerve	Epidural anaesthesia	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Sub-arachnoid penetration		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8
Paediatric Femoral Nerve Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Femoral artery penetration	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Lateral Cutaneous Nerve of the Thigh Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Difficulty locating position of lateral cutaneous nerve of the thigh	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric 3-in-1 Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8
Paediatric Psoas Compartment Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Sciatic Nerve Block: Anterior Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty finding landmarks necessary in locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Sciatic nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Femoral artery or vein penetration	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Occurrence of a compression hematoma	Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Sciatic Nerve Block: Posterior Approach	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty finding landmarks necessary in locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Sciatic nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge necessary** for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8
Paediatric Ilioinguinal and Iliohypogastric Nerve Blocks	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty in visualizing position of ilioinguinal and iliohypogastric nerves	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Nerve trauma	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Blocking of femoral nerve	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge	Incomplete blocking of ilioinguinal and iliohypogastric nerves	Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Penile Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Penetration of corpora cavernosa	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Paediatric Digital Nerve Block	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself	Difficulty locating needle insertion site	Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure	Penetration of vascular structures	Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure	Nerve trauma	Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year?**
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
6. I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

1. I **perform this procedure** in my practice.
2. **How many times** did you perform this procedure in the **past year**?
3. The performance of this procedure is **important in my practice situation**.
4. I feel **comfortable to perform** this procedure.
5. I find **difficulty to perform** this procedure due to the following **reason/s**: (order in level of importance)
- 6 I met the following **complication/s** and have the following **difficulties** when performing the procedure (number in order of frequency)
7. The improvement of **critical anatomy knowledge necessary** to perform this procedure will **reduce difficulties and complications**.
8. Improvement of **anatomy knowledge** necessary for the procedure will **increase my confidence** in performing the procedure.

	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree
	1	2	3	4	5	6	7	8
Other	Yes	More than 20	Essential	Very comfortable	Knowledge of the procedure itself		Strongly agree	Strongly agree
		10-20	Desirable but not essential	Fairly comfortable	Equipment necessary for the procedure		Agree	Agree
	No	5-10	Useful	Uncomfortable	Practical skills to perform the procedure		Disagree	Disagree
		Less than 5	Not necessary	Very uncomfortable	Regional anatomy knowledge		Strongly disagree	Strongly disagree

Appendix C: Scoring options

Scoring option A

1.	Incidence of performance	20%-30%	1 point
		31%-40%	2 points
		>40%	3 points
2.	Essentiality	50-75%	1 point
		76-100%	2 points
3.	Comfortability	uncomfortable > 40%	3 points
		uncomfortable 31%- 40%	2 points
		uncomfortable 20%-30%	1 point
4.	Difficulty or complication related to anatomy experienced by	20-34%	1 point
		35-50%	2 points
		>50%	3 points
5.	More than 80% thought that improvement of critical anatomical knowledge necessary to perform the procedure would reduce difficulties and complications.	80-90%	1 point
		91-100%	2 points
6.	More than 80% thought that improvement of anatomical knowledge necessary for the procedure would increase confidence in performing the procedure.	80-90%	1 point
		91-100%	2 points

		Total:	13 points

Scoring option B

1.	Incidence of performance	20%-25%	1 point
		26%-30%	2 points
		>30%	3 points
2.	Essentiality	60-79%	1 point
		80-100%	2 points
3.	Comfortability	uncomfortable > comfortable	2 points
		uncomfortable > 10%	1 point
4.	Difficulty or complications related to anatomy, experienced by	25-35%	1 point
		>35%	2 points
5.	More than 80% thought that improvement of critical anatomical knowledge necessary to perform the procedure would reduce difficulties and complications.	80-90%	1 point
		91-100%	2 points
6.	More than 80% thought that improvement of anatomical knowledge necessary for the procedure would increase confidence in performing the procedure.	80-90%	1 point
		91-100%	2 points

		Total:	12 points

Scoring option C

1. Incidence of performance (>20%) **1 point**
2. Essentiality (>60%) **1 point**
3. Comfortability
(more are uncomfortable than comfortable) **1 point**
4. Difficulty or complications related to anatomy experienced by more than 25% of doctors **1 point**
5. More than 80% thought that improvement of critical anatomical knowledge necessary to perform the procedure would reduce difficulties and complications. **1 point**
6. More than 80% thought that improvement of anatomical knowledge necessary for the procedure would increase confidence in performing the procedure. **1 point**

Total: 6 points

Scoring option D

1. Incidence of performance (>20%) **1 point**
2. Essentiality (>60%) **1 point**
3. Comfortability
(more are uncomfortable than comfortable) **2 points**
4. Difficulty or complications related to anatomy experienced by more than 25% of doctors **2 points**
5. More than 80% thought that improvement of critical anatomical knowledge necessary to perform the procedure would reduce difficulties and complications. **1 point**
6. More than 80% thought that improvement of anatomical knowledge necessary for the procedure would increase confidence in performing the procedure. **1 point**

Total: 8 points