EVALUATION OF PAEDIATRIC REGIONAL ANAESTHETIC PROCEDURES IN THE HEAD AND NECK REGION

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Declaration

I declare that the dissertation that I am hereby submitting to the University of Pretoria for the MSc degree in Anatomy, is my own work and that I have never before submitted it to any other tertiary institution for any degree.

Lané Prigge

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Summary

Evaluation of paediatric regional anaesthetic procedures in the head and neck region.

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Advancements in the medical field with regard to the development of new techniques, reassessment and analyses of the old and unsatisfactory techniques and the expansion and improvement of acceptable techniques have led to an increase in the use of regional anaesthetic nerve blocks in paediatric patients. However, several regional anaesthetic procedures are currently not being performed by anaesthetists due to the high number of complications and difficulties experienced. Some medical practitioners are under the impression that they lack the knowledge and confidence to perform these regional nerve blocks, especially on neonatal and infant patients. In order to assist these doctors in refining their anatomical knowledge and increasing their confidence in performing these nerve blocks, the procedures which are experienced as problematic need to be identified and evaluated.

The aim of this study was therefore: (1) to establish the most efficient method of blocking the maxillary nerve within the pterygopalatine fossa; (2) to investigate which head and neck regional nerve blocks are performed most frequently on paediatric patients and identify problem procedures that are performed by practicing anaesthesiologist in South Africa; (3) to develop a clinical anatomy information base for the selected procedures.

Three methods / techniques for maxillary nerve blocks were simulated and compared on 24 dry paediatric skulls and 30 dissected paediatric cadavers. The depth and angles at which the needle travels to block the maxillary nerve in the pterygopalatine fossa, after existing the skull through the foramen rotundum, was measured and compared. The method using the supra-zygomatic approach (method B), from the frontozygomatic angle towards the pterygopalatine fossa, exhibited no statistical significance ($p > 0.05$) when comparing the measurements in the skulls and cadavers. Method A, a supra-zygomatic approach from the midpoint on the lateral border of the orbit, as well as method C, an infra-zygomatic approach with an entry at the site of a vertical line extending along the lateral orbit wall, showed statistical significance when comparing measurements in the skulls and cadavers. It can therefore be concluded that method B produces the most consistent data and should be tested in a clinical setting.

Seventeen commonly performed paediatric regional nerve blocks were identified. A detailed questionnaire was completed by 111 respondents, either electronically or from others attending either the Pain Interventions and Regional Anaesthesia Conference or the South African Society of Anaesthesiologists Conference. Difficulties in performing the regional anaesthetic nerve blocks, and complications encountered, were the main areas of focus, when selecting the four problem procedures. The problem procedures selected are the following: supra-orbital and supra-trochlear nerve blocks, infra-orbital nerve block (Extra-oral approach), superior laryngeal and recurrent laryngeal nerve blocks. A detailed anatomical information base was developed through an extensive literature review. This will aid in educating and facilitating doctors in performing paediatric regional nerve blocks, thereby enabling them to successfully practice medicine.

OPSOMMING

Evaluasie van pediatriese narkoseprosedures in die kop- en nek-area.

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Vooruitgang in die mediese veld met betrekking tot die ontwikkeling van nuwe tegnieke, herevaluering en ontleding van verouderde en onbevredigende tegnieke, asook die uitbreiding en verbetering van aanvaarbare tegnieke, het daartoe gelei dat lokale senuweeblokke meer dikwels of pediatriese pasiënte uitgevoer word. Verskeie lokale narkoseprosedures word tans egter nie deur narkotiseurs toegepas nie, as gevolg van die hoë aantal komplikasies en ander uitdagings wat ondervind word. Sommige mediese praktisyns glo dat hulle die nodige kennis en selfvertroue tekort kom om die lokale senuweeblokke uit te voer, veral op neonatale- en baba- pasiënte. Ten einde die dokters by te staan om hul anatomiese kennis te verfyn en hul vertroue te verhoog sodat hul die senuweeblokke kan toepas, moet die prosedures wat as problematies beskou word, geïdentifiseer en ge-evaluëer word.

Hierdie studie stel daarom die volgende doelwitte: (1) om die mees doeltreffende metode daar te stel om die maksillêre senuweeblok binne die fossa pterygopalatina, uit te voer; (2) om ondersoek in te stel na welke lokale senuweeblokke in die kop-en-nek mees algemeen op pediatriese patiënte uitgevoer word, en die probleemprosedures wat praktiserende narkotiseurs in Suid-Afrika ondervind, te identifiseer; (3) om ‘n kliniese anatomie inligtingsbasis vir die verkose prosedures te ontwikkel.

Drie tegnieke vir die maksillêre senuweeblok is nageboots en vergelyk op 24 droë pediatriese skedels en 30 gedissekteerde pediatriese kadawers. Die diepte, asook die hoeke waardeur die naald beweeg om die maksillêre senuwee in die fossa pterygopalatina te blok, nadat dit die skedel deur die foramen rotundum verlaat het, is gemeet en vergelyk. Die supra-zygomatiese benadering (metode B), vanaf die fronto-zygomatiese hoek na die fossa pterygopalatina, het geen statisties betekenisvolle waarde getoon nie ($p > 0.05$), wanneer die meetings tussen die skedels en kadawers vergelyk is nie. Metode A, ‘n supra-zygomatiese benadering vanaf die middelpunt van die laterale grens van die orbita, sowel as metode C, ‘n infra-zygomatiese benadering met ‘n ingangspunt op ‘n vertikale lyn wat strek langs die laterale benige orbita, het ‘n statisties betekenisvolle waarde getoon wanneer die meetings in die skedels en kadawers vergelyk is. Die gevolgtrekking kan daarom gemaak word dat metode B die mees konstante data lewer, en dat dié metode in ‘n kliniese omgewing getoets behoort te word.

‘n Lys van 17 algemeen gebruikte pediatriese lokale senuweeblokke is saamgestel. ‘n Breedvoerige vraelys is voltooi deur 111 respondente, óf elektronies, óf deur ander wat een van twee konferensies bygewoon het, naamlik die “Pain Interventions and Regional Anaesthesia Conference” of die “South African Society of Anaesthesiologist Conference”. Probleme en komplikasies wat teëgekom is tydens die uitvoer van lokale senuweeblokke, is die belangrikste areas waarop gefokus is, om vier vier probleemprosedures te identifiseer. Die probleemprosedures wat gekies is, is die volgende: supra-orbitale en supra-trochleêre senuweeblokke, infra-orbitale senuweeblokke (Ekstra-orale benadering), blokke van N. laryngeus superioris en N. laryngeus recurrens. ‘n Gedetailleerde anatomiese inligtingsbasis is ontwikkel deur ‘n uitgebreide literatuurstudie. Hierdie inligtingsbasis sal daartoe bydrae dat dokters se kennis uitgebrei word ten opsigte van pediatriese senuweeblokke en hulle dan ook fassiliteer met die suksesvolle uitvoer van hierdie prosedures.

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1.1. Introduction

1.1.1 History of anaesthesia

The term anaesthesia has been defined as an agent capable of supressing the senses and thus relieving pain, permitting otherwise distressing surgical operations to be performed without discomfort to the patient (Dumas, 1932).

The first known methods of producing a state of painless procedures, where used by the ancient Assyrians. The carotid artery was digitally compressed, by pressing profoundly onto the carotid artery, and therefore disrupting blood supply to the brain, in order to produce a state of anaesthesia during circumcisions (Dumas, 1932).

The Babylonians, Egyptians and Greeks used several medicinal plants such as mandragora for their anaesthetic properties. Dioscorides stated in 100 A.D: “Three wine-glassfuls of a liquid preparation of the root are given to those who are about to be cut or burnt, for they will not feel the pain” (Dumas, 1932).

In 1842 Robert Collier used alcohol as an anaesthetic, after seeing a plantation worker pass out while stirring a vat of rum, became unconscious, fell and broke his hip. The worker declared that he felt no pain during the accident. However, the glory for the discovery of modern anaesthesia is shared by three men: Horace Wells for nitrous oxide gas, WTG Morton for ether and Sir James Young Simpson for chloroform (Dumas, 1932).

The first surgical procedure to be completed by means of general anaesthesia was on 31 December 1846 in Bristol with the use of ether. A letter entitled ‘Surgical operation without pain’ was published in the London Medical Gazette on 4 January 1847 (Weller, 1999).

The first local anaesthetic agent introduced to the medical practice was cocaine. This was done by Koller in 1884 (Kumar, 1998). However, the pioneer in the field of regional anaesthesia is considered to be Louis Gaston Labat, who brought the knowledge he required from his mentor, Victor Pauchet, to the United States in the early 20th century (Coté *et al.*, 2003; Eisenach, 2008). He was influential in outlining anaesthesiology in the practice of medicine and his textbook, 'Regional Anaesthesia: Its technique and clinical application', published in 1922, was considered to be innovative and well-liked. He played a remarkable role in the development of the organization in 1920, that is today known as the American Society of Regional Anaesthesia and Pain Medicine (ASRA) (Bacon, 2002; Coté *et al.*, 2003; Neal, 2006; Eisenach, 2008; Vachon *et al.,* 2008).

Although the original ASRA was dissolved in 1940 because of decreasing interest and membership, Dr Alon Winnie, along with four others refounded the ASRA in 1975. Dr Winnie proclaimed the need for the present society to finish the work of the old society: "We must see to it again that we do not forget the heritage of the past and be forced to rediscover it repeatedly. Nor can we forget the lethal impact of allowing the society to cease in its efforts to make certain that regional anaesthesia is always available to the patients for whom we care" (Ptaszynski *et al.*, 2006).

1.1.2 Importance of clinical anatomy

Clinical anatomy is frequently referred to as anatomy related to patient care. This consists of the accomplishment of a proper clinical examination, which solely relies on the comprehensive and thorough knowledge of human anatomy (Boon *et al.,* 2002). Since patients can be considered as 3-dimensional objects, spatial knowledge and wisdom is required to understand their care and health. Therefore, clinical anatomy is the basis of successful health care (Marks, 2002). The basic science of anatomy has reinforced the teaching of medicine for many years and forms the essential foundation for all medical procedures (Miles, 2005).

Various authors (Abrahams and Webb, 1975; McMinn *et al*., 1984; Beahrs *et al*., 1986; Crisp, 1989; Ger and Evans, 1993; American Association of Clinical

Anatomists, 1999; Boon *et al*, 2004a) have emphasized the important role of sound anatomical knowledge, to ensure a safe and successful clinical procedure.

In a recent study done by the Medical Schools Liaison Committee of the Royal College of Surgeons of England, to evaluate the significant changes to the medical curriculum, the Heads of Department of both Anatomy and Surgery consider the teaching of anatomy of the utmost importance in the advanced levels of education (Gogalniceanu *et al.,* 2009). A study by Waterston and co-workers, showed that 64% of clinicians believed that students had an inadequate knowledge of anatomy and 61% felt that newly qualified doctors had insufficient anatomical knowledge to practice medicine safely (Waterston and Stewart, 2005).

The above mentioned facts/results and studies are of the utmost importance in times where new techniques for imaging anatomy and invasive procedures are escalating. As a result of the advanced imaging techniques and the invasive procedures, which focus on specific organs and/or sites within them, knowledge of gross anatomy has become progressively significant (American Association of Clinical Anatomists, 1999; McCuskey, Carmichael, Kirch, 2005).

In the 1879 Hunterian oration, GM Humphry states that: “The knowledge of the facts of anatomy is essential to the practice of surgery and to an appreciation of physiology; and the correct learning of them promotes the habit of attention, and the accuracy which is the associate of attention” (Miles, 2005).

Anatomy provides the primary basis for the successful, safe and competent performance of invasive procedures. Procedures that fail to achieve their objective, or that result in complications, can often be linked to a lack of understanding or misunderstanding of the relevant anatomy (American Association of Clinical Anatomists, 1999). Between 1995 and 2000 claims related to anatomical errors, submitted to the Medical Defence Union in the United Kingdom, increased sevenfold (Ellis, 2002). Cahill *et al.,* (2000) have voiced concern that of the 80,000 avoidable deaths per year in the United States, at least some can be attributed to anatomical incompetence.

In a time where anaesthesia, especially regional anaesthesia, is becoming increasingly popular, the question about the importance of clinical anatomy is continuously raised. Since the development of regional anaesthesia in 1884, until the second half of the 20th century, regional anaesthesia was practiced as an art, with the utmost important requirement, the knowledge of anatomy (Franco, 2008).

However, since the increased development of new technologies such as nerve stimulators and ultrasound, in the field of regional anaesthesia, the need for anatomy has diminished, or so it is believed. According to Dr C Franco, the need for anatomy knowledge in the field of anaesthesiology is even greater, due to the refocusing on cross-sectional anatomy instead of traditional anatomy in the 'long axis'. He states: "Now, as it was in the beginning of our speciality, the need for a good understanding of the nerves and related structures, is crucial for a successful practice" (Franco, 2008).

Gaston Labat published the first textbook on regional anaesthesia in 1922, entitled 'Regional Anaesthesia: Its technique and clinical application'. In this book he emphasized the importance of anatomical knowledge and the education of the operator during regional anaesthetic procedures (Coté *et al.,* 2003). This is still as relevant and important today, as it was when it was first mentioned.

With the advancements in medicine in terms of the development of new techniques, the scrutinizing and analyses of old and unsatisfactory techniques and the improvement of adequate techniques with regard to equipment use and safety, a thorough knowledge of anatomy is essential to ensure safe practice (Dale and Checketts, 2010).

1.1.3. Anatomical variances between adults and children

Gregory states that "It has been recognized that infants and small children are not really small adults, and that we cannot apply adult standards to the care of paediatric patients" (Ferrari, 1999). This is of the utmost importance in a time where regional anaesthesia on paediatric patients is gaining preference (Ivani and Negri, 2001).

When examining the differences between adults and children, it is important to note that certain physical proportions differ. If a comparison is made between a child's body and head, a child has a larger head in proportion to its trunk, and therefore brain. The skin surface area is also larger. Infants have a surface area that is twice that of their body weight, which results in greater heat loss (Brown, 2000). They have a different metabolic rate which makes the correct calculations related to medicine and drugs more vital (Dalens, 1990).

Children, especially infants have twice the oxygen consumption of adults. This is important to note during the use of general anaesthesia, due to children being induced more rapidly and emerging from anaesthesia more rapidly. This is mostly due to the smaller lung capacity to body weight ratio. Immature blood brain barriers and decreased ability to metabolise certain drugs can increase the neonate's sensitivity to opioids. This results in smaller dosages used, which will ultimately expose children and neonates to a reduced amount of pharmacological products than adults. However, infants below the age of six months are more susceptible to the respiratory depressant effect of opioids (Rusy and Usaleva, 1998). This population is therefore more suitable for regional anaesthetic blocks.

The use of regional anaesthesia on paediatric patients comes with its own set of complications. Firstly, the anaesthesiologist must already have acquired experience and dexterity with regional anaesthesia in adults before he makes use of the technique in children. This is to ensure that his hands have acquired a feeling for the needle as it passes through different tissues, such as ligaments and aponeuroses, and encounters obstructions such as cartilage and bone. This is especially important, because the size of the space to be located can be very small in young children. Skill and experience are therefore prerequisites (Saint-Maurice and Steinberg, 1990).

Secondly, the lack of knowledge of the anatomical differences between small children and adults is a leading cause of surgical complications. Knowledge of the relevant anatomy will aid in the prevention of such complications. When close attention is paid to the changes in the body-size of individuals (newborns to adults), the following will be noticed:

- The depth of important structures varies significantly in patients, depending on size and age;
- Ligaments and fascia are thinner in children and therefore more easily penetrable;
- The nerves of children are thinner;
- Myelination is incomplete, which will lead to satisfactory blocks achieved with lower concentrations of the anaesthetic (Saint-Maurice and Steinberg, 1990; Stanton-Hicks, 2007; Narouze, 2007).

Infants cannot be considered as anatomical miniatures of adults (Morris, 1998; Avidan *et al.,* 2003). A thorough understanding of the anatomical differences between children, especially neonates, and adults is essential and needs to be acknowledged.

1.1.4. Head and Neck surgery in children

Children and neonates undergo surgery for a variety of conditions, often requiring urgent intervention. Surgery may range from relatively minor procedures, such as inguinal hernias or circumcisions, to major procedures such as open heart surgery (to repair an atrial or ventricular septal defect, or repair a leaking valve) (Berde *et al.*, 2005).

Ear, nose and throat (ENT) surgery represents a large proportion of pediatric surgeries and remains one of the most challenging medical fields, due to the frequency of airway obstruction in infants and small children. Common head and neck surgeries include tympanoplasty, tonsillectomy or adenoidectomy, frenulectomy, laryngoscopy, tracheostomy, thyroglossal duct cyst or branchial cleft cyst, to name but a few (Litman, 2004).

Although major head and neck surgery is not performed readily on children, the tendency to administer regional anaesthesia in these procedures is escalating. Some of the most common surgeries carried out with regional anesthesia include cleft lip repair with an infraorbital nerve block and otoplasties (surgical correction of “bat ears”) performed with a cervical plexus nerve blockade. Conditions of allergic rhinitis and atopic dermatitis have also been improved by a stellate ganglion block (Bosenberg, 1999). Trigeminal nerve blockades are performed on a variety of surgeries related to the structures of the face. The greater palatine nerve can also be blocked to assist with analgesia during clept lip repairs (Belvis *et al.,* 2007). Meticulous attention is required in performing blocks of the head and neck, because the anatomy is compact and a close relationship exists between the cranial and cervical nerves to vital structures (Bosenberg, 1999).

With the increased survival of premature infants in recent years, the number of premature neonates presenting for surgery has also increased. These premature neonates present with either chronic or acute defects that urgently need to be repaired. The risk of general anaesthesia is significant in these patients as they are at a greater risk of developing respiratory failure and post-operative apnoea, compared to full term infants of the same age (Welborn *et al.*, 1986). Recent concerns regarding the harmful effects of general anaesthesia on the developing brain, further justifies the use of regional anaesthesia in this vulnerable age group. The use of regional anaesthesia, therefore, may have considerable advantages, not only in neonates but also in infants and children (Sun *et al.*, 2008), especially during head and neck surgeries.

Although head and neck surgeries are not commonly performed, knowledge and experience related to paediatric surgeries are extremely important. This will ensure that any procedure performed is less traumatic to the patient and family members. By applying this knowledge, complications can be kept to a minimum and the goal achieved with more ease and effectiveness.

1.1.5. Regional anaesthesia in children

1.1.5.1 Pain perception and pain management

According to the International Association for the Study of Pain, pain can be defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (Doyle, 2007).

Juneja and Jaggar (2009) stated that pain is an elaborate interaction between sensory, behavioural and emotional aspects, and that past experiences of pain can dictate an individual's future response. In evolutionary terms, pain as a sensation, serves to prevent on-going trauma and to protect the injured area from harm whilst it is healing. However, there are situations where the painful experience far outlasts any tissue damage and does not convey any survival value although it does prolong the suffering of the individual.

Albert Camus, a philosopher, author and Nobel Prize winner for literature, once stated: "Perhaps we can never create a world where there are no suffering children, but we can create a world where there are fewer suffering children." The treatment of pain in neonates, infants and children of all ages has seen dramatic improvements over the past 25 years (Tobias and Deshpande, 1996).

The relief of pain and anxiety in children has been overlooked by healthcare professionals for many years, possibly because of the perceived high risk of cardiorespiratory compromise (Deshpande and Tobias, 1996). Until recently, little was understood about the way infants and small children experience pain. As a result there was an unfortunate tendency to ignore the need for analgesia during painful procedures and even during and after surgical procedures. The effect was increased sensitivity to pain as they grow older. This is postulated to be caused by persisting alterations in the infant's central processing of painful stimuli (Stewart and Lerman, 2001).

Ranger *et al.* (2007) cited that the shorter the gestational age of infants, the more painful procedures they will undergo. Although the ascending pathways conducting nociception may develop by the 20th week of gestation, descending pathways do not mature until the last trimester. These pathways play a role in the inhibition of incoming pain impulses, which will increase the preterm infant's sensitivity to pain (Ranger, 2007). The incomplete development of inhibitory pathways is now widely acknowledged to cause a higher susceptibility towards pain (Parry, 2008).

In recent times, it is considered as unconstitutional not to provide the necessary analgesia for painful procedures and surgeries to paediatric patients. The realization of pain perception by neonates and children, coupled with humanitarian concerns, mandates that we search for safe and effective means to provide sedation and pain control (Deshpande and Tobias, 1996).

The perceived effects of pain on neonates have been debated for several years. Ranger *et al.* (2007) states that the more fragile a neonate, the greater the cost of crying can be to their health. Prolonged crying can lead to increased intracranial pressure and high energy consumption, which could result in serious adverse consequences (Ranger, 2007). Infants and children who have received inadequate treatment or prevention for procedural pain or stress may have significant behavioural or school related problems long after the actual procedure. Untreated pain can also lead to amplified physiological energy expenditure, increased secretion of adrenal stress hormone, altered cerebral blood flow, and disrupted sleep patterns (Tobias and Deshpande, 1996).

The pain resulting from repetitive paediatric procedures can be successfully treated by regional analgesic nerve blocks, and these should be used whenever possible. Frequently, no other or only mild analgesic is required by the patient. The side effects of narcotics are thus avoided and the child rapidly returns to full activity after minor surgery. After surgery, nerve blocks using local analgesic drugs may permit a reduction of the narcotic dosage and earlier mobilization of the patient (Stewart and Lerman, 2001).

The important side effects of untreated pain on the wellbeing, comfort and recovery of surgical patients are now widely recognized (Breivik, 1995). For this reason, the development of regional anaesthesia for post-operative relief has thrived.

Post-operative pain relief can be achieved through peripheral nerve blocks that can also alleviate chronic or acute pain. Peripheral nerve blocks are also seen as alternative for general anaesthesia for specific surgical procedures (Tobias and Deshpande, 1996).

Although the implementation of an improved post-operative pain management programme is not simple or a straightforward undertaking, the cost / benefit relation can be excellent (Breivik, 1995). Many benefits attributed to the use of peripheral nerve blocks, are in fact due to the lack of side effects when compared to alternative techniques, such as opioid usage. Children will also awaken more rapidly following their procedure either without, or with only minimal pain. Fluids and food will also be more rapidly accepted and discharge will not be delayed (Morton and Raine, 1994).

The success of administering peripheral nerve blocks accurately requires knowledge of the human anatomy, proper equipment, and an understanding of the risks involved with regional blockade in paediatric patients. However, pain management is a key measure of quality in children's healthcare and addressing this problem requires specialized knowledge, skill and most importantly a commitment to provide care as pain-free as possible for each child (Tobias and Deshpande, 1996).

1.1.5.2 Mechanism of action

Anaesthesia is considered to be the absence of awareness of sensation, either locally or systemically, resulting from drug administration. General anaesthesia influences the whole body and results in unconsciousness, while local anaesthesia affects regions of the body while the patient remains cognisant. In many circumstances, both types of anaesthesia can be combined (Wicker and O'Neill, 2010). Nevertheless, criticism exists about the use of 'double' anaesthesia, due to the perception that a 'double' risk is eminent. Yet, reports from various paediatric anaesthesiologists have demonstrated the safety of regional anaesthesia being utilized in children (Ivani and De Negri, 2001).

When a painful stimulus is received, an action potential across the nociceptor membrane is produced by naturally occurring sensitising agents causing the opening of sodium channels and the movement of Na^+ ions, in turn resulting in depolarisation and rapid pain impulse. Local anaesthetic agents act on the sodium channels, inhibiting them along the nerve fibres. Since depolarization cannot occur, the nerve impulse and the pain impulse are blocked (Scott, 2009).

To effectively understand the mechanism of anaesthesia, different terms need to be defined for clarification. General anaesthesia produces a loss of consciousness. This can be done by means of inhalations or intravenous administrations. Regional anaesthesia anesthetizes a nerve or nerve plexus usually at the trunk, which will affect all the relevant branches, such as a maxillary nerve block, that will anaesthetize the entire palate and maxilla. Local anaesthetic agent is injected into the area to be operated on, such as dental work (Peters, 2012).

General anaesthetic agents target both the spinal cord and the brain to induce loss of consciousness, loss of unequivocal memory and absence of response to pain (Peck *et al*., 2008). All regional anaesthesia is based on the exposure of nerves to local anaesthesia or local anaesthetic agents that have been introduced in close proximity of the relevant nerves (Parizkova and George, 2009). Local anaesthetics are drugs that reversibly block nerve conduction (Wicker and O'Neill, 2010).

The most common use of local or regional anaesthesia is the foundation of effective post-operative analgesia. Regional nerve blocks performed immediately after surgery, provided optimal pain relief (Jöhr, 2000). Peripheral nerve blocks have an important, though specialised role in procedures related to neonates, or in the treatment of post-operative pain experienced by neonates (Parry, 2008). Various techniques can be used as part of a balanced anaesthetic. Depending on the type of block used, post-operative analgesia of varying degrees and duration can be produced (Morton and Raine, 1994).

Peripheral nerve blocks are often referred to as central neuroaxial blocks, due to the analgesia provided being limited to the site of surgery. They are commonly believed to be safe and with minimal complications. A wide spectrum of blocks is feasible, mostly depending on the knowledge and skill of the anaesthesiologists (Jöhr, 2000).

When used appropriately, these techniques are safe and effective in many situations (Tobias and Deshpande, 1996). However, although local anaesthetics are widely used in the paediatric population, there are enormous gaps in our knowledge about their use in this population (Berde *et al.*, 2005).

1.1.5.3 Advantages of regional anaesthesia

The main advantage of regional anaesthesia is the ability to effectively anaesthetize a selected region of the body, with little or no effect to other areas, such as the brain, lungs and heart. All the patient’s protective reflexes remain intact, with the patient being fully conscious but without the discomfort of pain (Mayo clinic, 2006).

Regional anaesthesia has always been popular, especially in the paediatric population, due to its efficacy and avoidance of the use of opioids with their adverse effects (Aziza *et al.*, 2009). The response to opioid analgesics can be quite variable in neonates and infants, if compared to adults. This is considered problematic in terms of treatment of severe post-operative pain. In the first week of life, the elimination half-life of morphine is more than twice as long in neonates when compared to older children or adults, and even longer in preterm infants (Tobias and Deshpande, 1996).

Bosenberg (1999) highlighted the advantages of regional anaesthesia over local infiltration. Local infiltration provides a restricted area of anaesthesia in the immediate region of the injection. Large volumes of local anaesthetic agents are required if larges areas are to be blocked. A peripheral nerve block however can provide a greater area of anaesthesia with a smaller volume of local anaesthetic agent, thus limiting the risk of toxicity, particularly in paediatric patients.

Other advantages of regional anaesthesia include the fact that less general anaesthesia is necessary, due to the analgesic effect of the regional block. Muscle relaxation can be achieved by the use of a local anaesthetic and will therefore reduce the use of other drugs. The stay in the hospital can also be shortened due to reduced post-operative effects of the regional anaesthesia (Saint-Maurice and Steinberg, 1990; Belvis *et al.,* 2007). Due to the patient requiring less pain medication after the surgery, less nausea and grogginess might be experienced (Mayo clinic, 2006).

Regional anaesthesia provides a low risk alternative for general anaesthesia in certain cases. Gwinnutt (2009) states the following advantages for regional anaesthesia:

- Analgesia or regional anaesthesia is administered predominantly in the area required, thereby avoiding the systemic effects of drugs;
- In patients with chronic respiratory disease, spontaneous ventilation can be preserved and respiratory depressant drugs can be avoided;
- There is generally less interference in the control of coexisting systemic disease requiring medical therapy, for example diabetes mellitus;
- The airway reflexes are predominantly preserved, and in a patient with a full stomach, the risk of aspiration is reduced;
- Blood loss can be reduced with controlled hypertension, due to the hypertensive action of regional anaesthetics;
- When used in conjunction with general anaesthesia, less anaesthetic agent is required. This is achievable given that the regional anaesthetic assists with analgesia and muscle relaxation;
- Post-operative pain relief can be continued;
- Complications after major surgery are significantly reduced (Gwinnutt, 2009).

In a survey undertaken, 63% of 3 498 anaesthetists prefer regional anaesthesia for themselves, should the situation permit it (Katz, 1973). The reasons cited by them include: (Glassford, 1985)

- Ease of administration;

- Lower incidence of major intra-operative or post-operative complications;
- Avoidance of toxic effects of some general anaesthetic agents;
- Pleasant recovery, with little or no difficulty experienced in the recovery room;

The above mentioned study was done in 1973. It would be interesting to obtain the opinions of these respondents today, after all the advances in the field of medical technology.

In the light of the detrimental side effects of general anaesthesia on the neurodevelopment of children, regional anaesthesia is often considered as the better option. The ability of general anaesthesia to produce immobility, amnesia and unconsciousness quickly and effectively, as well as the beneficial effects such as neuroprotection and cardioprotection, are often masked by the increased concern about the long-term detrimental effects. Such effects include neurotoxicity and neurodegeneration which can be linked to usage of anaesthesia (Lugli *et al.,* 2009).

Eisenach (2008) cited several animal studies which suggested that anaesthetics may be toxic to the immature developing brain. Recent work also indicates that neurotoxicity could indeed occur with regard to the range of dosage (Eisenach, 2008). There is also published data of the presence of these effects in multiple animal species including mice, rats and more recently, non-human primates (Maxwell, 48th Clinical conference in paediatric anesthesiology). Investigators at the Mayo Clinic have reported a correlation between repeated exposure to anaesthetics (≥ 3 times) prior to four years of age, and the subsequent identification of learning disabilities diagnosed by school testing (Wilder *et al.*, 2009). Due to the side effects linked to general anaesthesia in infants, the usage of regional anaesthesia could be seen as an advantage based on the absence of these side effects.

Peripheral nerve blocks are valuable tools in the diagnosis and management of pain. However, clinicians should be familiar with the anatomy related to the nerve block and procedure, to avoid potential serious complications (Narouze, 2007).

1.1.5.4 Indications of regional anaesthesia

Apart from the advantages of regional anaesthesia, especially in neonates, several other factors play a role in considering patients for this procedure. Some of the factors include:

- Fear of general anaesthesia. Patients are often afraid of "going to sleep" and may be less anxious if the surgical procedure is performed with the use of regional anaesthesia;
- The patient is considered a high anaesthetic risk (according to the American society of anaesthesiologists grading):
    - Patient has poor pulmonary function;
    - Patient had myocardial infarction six months prior to scheduled surgery;
- Patients requiring emergency laryngectomy for laryngeal perichondritis with abscess;
- Patients who prefer regional anaesthesia (Prasad and Shanmugam, 1998);
- Patients scheduled for surface and peripheral surgical procedures;
- Patients scheduled for day surgery (Parry, 2008);
- Patients with other medical conditions such as diabetes mellitus, hypertension, congestive heart failure, cerebrovascular accidents, respiratory disease and urinary disease (Glassford, 1985).

Neonates differ remarkably from adults in the way they respond to anaesthesia, especially general anaesthesia, and other related drugs. Their responses are determined by a large number of physiological factors which change rapidly during the early months of life. In general, increased rates of absorption and distribution, as well as reduced ability for elimination and immaturity of the organ systems increase the risk of over dosage and toxicity (Hughes *et al.,* 1996). Neonates are therefore better suitable for regional anaesthesia, rather than general anaesthesia, if the procedure and situation allow it.

Another important indication for regional anaesthesia relates to the skills of the anaesthesiologist, the presence of accessory personnel as well as the available facilities. The sites of operation as well as the duration of the operation also play an important role in the choice of anaesthesia (Glassford, 1985).

As with most surgical procedures, the induction of regional anaesthesia can be a stressful experience, and all measures to establish and maintain patient comfort should be employed and maintained (Hu *et al.,* 2007).

1.1.5.5 Contra-indications for regional anaesthesia

Despite the many advantages of regional anaesthesia, its use is subject to the same risk-benefit analyses that apply to any surgical technique. There are absolute and relative contra-indications (Glassford, 1985; Mulroy, 2006).

Absolute contra-indications include:

- Patient refusal;
- Infection, especially at the site of needle insertion. The possibility of spreading the infection is seen as dangerous risk. However, HIV infection is not specifically contra-indicative for the use of regional anaesthesia;
- Coagulopathy or anaemias, due to the possibility of unwanted bleeding associated with needle insertion (Glassford, 1985; Mulroy, 2006);
- History of allergic reactions to local anaesthetics agents (Prasad and Shanmugam, 1998).

Relative contra-indications include:

- Pre-existing neurologic deficit, since paraesthesia can be difficult to achieve due to neuropathy (as in diabetics), however a nerve stimulator or ultrasound guidance can be used accordingly;
- Lack of cooperation, hysterical or uncomprehensive patients. The inability to communicate, or the inability to remain cooperative and calm, makes for a poor candidate for regional nerve block;

- Lack of responsiveness, due to the possibility of nerve contact or injury not being noted.

There are several acknowledged indications and contra-indications for regional anaesthesia. The advantages must be weighed against the contra-indications, and a risk-benefit ratio needs to be established for each case or individual (Mulroy, 2006).

1.1.5.6 Complications of regional anaesthesia

Although general anaesthesia is considered safe, no technique is totally free from the risk of serious systemic adverse events (Association for perioperative practice, 2007). General complications experienced due to regional anaesthesia can be divided into three different categories: local, regional/remote and drug related (Parizkova and George, 2009).

Local complications include the following:

- Nerve trauma / intraneural injection. The patient will present with severe pain upon injection. This complication can however be minimalized by using short bevel / blunt needles;
- Vascular complications. Due to the presence of nerves in neurovascular bundles, accidental puncture of the artery and vein can occur. Damage to vascular structures can result in lacerations of arteries and veins resulting in ischemia, false aneurysms, shunt formation and haematomas;
- Neurotoxic injectate due to inappropriate solution used;
- Infection or abscesses. This complication often occurs due to the injection site being infected prior to the procedure (Skin infection is considered a contra-indication).

Regional / remote complications are often linked to the incorrect technique or approach used. These complications include pneumothorax during supraclavicular approach, subdural migration of epidural catheter, pressure or temperature changes of the anaesthetised area (Parizkova and George, 2009).

Drug related complications include toxicity or anaphylaxis. Toxicity can occur during intravascular injection or overdose (Parizkova and George, 2009). Intravascular injections can be largely avoided by injecting gently, and by drawing back slightly on the syringe to check that the needle is not located within a blood vessel (Association for perioperative practice, 2007). Newer and safer agents and medical technologies, such as ultrasound guidance and nerve stimulators, can assist in the decreasing of these complications. Anaphylaxis or hypersensitivity is rarely seen, but can be caused by ester agents, and older, previously used agents (Parizkova and George, 2009).

Dover *et al.* (1996) stated that not only the surface anatomy of the entrance site of the needle, but various other pitfalls and complications are directly dependent on the understanding of anatomy. Stanton-Hicks (2007) also emphasized the importance of anatomy with the statement: “A lack of appreciation for the anatomical relationships poses a significant risk for complications”.

Boon *et al.* (2004b) stated that in the absence of contra-indications, and with a thorough knowledge of the relevant anatomy and technique, as well as adequate prior skills practice, several regional anaesthetic procedures can be performed without complications.

1.1.5.7 Considerations in paediatric anatomy as applied to regional anaesthesia in head and neck surgeries

While regional anaesthesia of the head and neck is not a common practice, several procedures are more frequently performed in the practice of paediatric anaesthesia (Bosenberg, 1999). The ability to provide safe anaesthesia for children requires a clear understanding of the anatomical, physiological, pharmacological and psychological differences between patients in different age groups, from premature neonates to young children (Doyle, 2007).

Several considerations need to be noted with regard to regional anaesthesia for paediatric patients, especially relating to head and neck surgeries. The anatomical landmarks are considered constant in adults but may differ in paediatric patients due to the development of the skull. This has a very great significance with regard to the performing of nerve blocks in this population (Bosenberg, 1999). Even though the skull is still developing, the anatomical landmarks are fairly easily located (Belvis *et al.,* 2007).

The nerves to be blocked in the head and neck are predominantly terminal nerves, which limits nerve damage. Sensory nerves also require a smaller volume of local anaesthetic agents, which ensures that the plasma level is unlikely to become toxic in neonates and infants (Belvis *et al.,* 2007). However, the volumes of concentrations need to be carefully calculated, since the high cardiac output in paediatric patients can cause a rapid increase of the regional anaesthetic in the blood levels (Aziza *et al.,* 2009).

One of the biggest considerations in paediatric regional anaesthesia remains the “double” dose, whether to combine regional anaesthesia with light general anaesthesia, or to provide regional anaesthesia separately (Dalens, 2006). Adults generally receive regional anaesthesia while being in a conscious state. This allows them to describe and elaborate on the effects of paraesthesia, numbness and analgesia (Berde *et al.*, 2005).

Due to the immaturity of the child and the necessity of the patient to be immobile during the procedure neonates, infants and small children are often anaesthetized prior to administering the peripheral nerve block (Dalens, 2006). This unfortunately has a disadvantage, due to the patient being unable to report on sensory changes that occur during the placement of the needle and the injection of the regional anaesthetic (Berde *et al.*, 2005).

A thorough understanding of the anatomical relations of the nerve to be blocked is crucial due to the extremely compact anatomy of the head and neck, and the nerves being in close proximity to several other vital structures. Nerve blocks of the head and neck are nearly unexplored in the paediatric population (Bosenberg, 1999).

With sound knowledge, judgement and appropriate scientific acquaintance, regional anaesthesia represents the best technique in many instances to provide adequate intra-operative and post-operative pain relief in paediatric patients (Dalens, 2006).

Information about peripheral nerve blocks in the head and neck is readily available on the internet. This, as well as an increase in indications for head and neck nerve blocks, may fuel the demand for these nerve blocks to be performed (Belvis *et al.,* 2007).

Although considerable progress has been made in studying the safety, efficacy, dose response, and clinical outcomes associated with the use of anaesthesia in neonates and infants in head and neck procedures, there are major gaps in our knowledge that hinder optimal clinical practice (Berde *et al.*, 2005).

There is now enough evidence to proof that clinical benefits outweigh risks from anaesthesia or analgesia intervention during procedures on neonates and infants (Derbyshire, 2008). The only limitation is the lack of knowledge with regard to the clinical anatomy.

1.2 Aims

1.2.1. To evaluate the anatomy of three different techniques of blocking the maxillary nerve in neonates and infants and to establish the most efficient method of blocking the maxillary nerve within the pterygopalatine fossa.

1.2.2. A: With regard to the regional nerve blocks of the head and neck, the second aspect of the study aims to investigate which head and neck regional nerve blocks are performed most frequently on paediatric patients by South African anaesthesiologists.

1.2.2. B: Results obtained from the second aim will be used to identify problem procedures that are executed by practicing anaesthesiologists in South Africa.

1.2.3. The final aim will be to develop a clinical anatomy information base for the selected procedures including maxillary nerve block.

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2.1 Introduction

Cleft lip and/or palate is considered to be the most frequently presenting craniofacial malformation (Haberg *et al.,* 1998) with an incidence of 1 in 1000 live births (Thaller *et al*., 1995; Strong and Buckmiller, 2001; Moore *et al*., 2011). Congenital cleft palate surgery is deemed an extremely painful surgical procedure in infants, with the most significant pain experienced in the post-operative period, 24 – 48 hours following surgery (Doyle and Hudson, 1992; Obayah *et al*., 2010).

It has been advocated that regional anaesthesia can provide post-operative analgesia in neonates without the risk of respiratory depression (Hatch, 2002). Blocking of the maxillary nerve at its trunk, within the pterygopalatine fossa, should provide adequate analgesia (Rochette *et al.*, 2009). Mesnil *et al.* (2010) state: “The maxillary nerve block can be considered efficient, simple and safe and it will improve patient comfort and relief of post-operative pain”. Several techniques to block the maxillary nerve have been described in the literature (Stechnison and Brogan, 1994; Du Plessis, 2010; Mesnil *et al.*, 2010). Limited numbers of these techniques or procedures have been simulated on paediatric skulls and cadavers. Therefore, the best method for blocking the maxillary nerve in paediatric patients has yet to be established.

The aim of this chapter is two-fold. The first aim is to evaluate the anatomy, with regard to relevant bony landmarks and specific angles and distances used in three different techniques of blocking the maxillary nerve in neonates and infants. The second aim is to establish the most efficient method of blocking the maxillary nerve within the pterygopalatine fossa. This chapter will therefore comprise of the following topics:

- Embryological development of the skull and head
- Clinical anatomy of the trigeminal nerve, especially the maxillary division of this nerve
- Cleft lip and palate, with special reference to the usage of regional nerve blockade of the maxillary nerve during surgical repair.

2.1.1 Embryological development of the skull

Knowledge of the anatomy of the skull and the surrounding tissue is vital in reducing the amount of trauma during any procedure, as well as to limit invasiveness. It is of cardinal importance that the anatomy is understood (Fehrenbach, 1996).

Embryology, the study of human development, is essential for the understanding of relationships in gross anatomy, and for many congenital abnormalities (Mitchell and Sharma, 2009).

The structural development of the head and neck occurs between the third and eight week of gestation (Patel, 2009). The branchial apparatus, consisting of branchial arches, pouches and membranes contributes significantly to the formation of the head and neck. Most congenital malformations of the head and neck originate during the transformation of the branchial apparatus into adult derivatives (Moore *et al*., 2011). However, Sadler (1990) states: “Although the development of the pharyngeal arches, clefts and pouches resemble the formation of gills in fishes and amphibia, in the human embryo, real gills (branchia) are never formed. Therefore, the term pharyngeal arches, clefts and pouches have been adopted for the human embryo”.

The head region of the embryo develops around the cranial end of the neural tube, which will ultimately form the brain. Ventral to the brain, pharyngeal arches, lying on each side of the stomodeum (developing oral cavity) will develop into the face and neck. These arches give rise to the cartilages, bones and muscles involved in chewing and swallowing (Mitchell and Sharma, 2009).

The pharyngeal arches start developing early in the fourth week, and by the end of the fifth week, all the pharyngeal arches emerge as rounded swellings, detectable on the surface. The first pair of pharyngeal arches does not only develop into the upper and lower jaws, but also plays a key role in the development of the face and palate (Mitchell and Sharma, 2009).

The facial prominences or swellings that begin to form the face appear during the fourth week, around the stomodeum or primitive mouth. These five facial prominences will develop into the following structures: (Mitchell and Sharma, 2009; Moore *et al.*, 2011)

- Single frontonasal prominence: Forehead, nose, philtrum and primary palate (Cranial boundary of stomodeum);
- Paired maxillary prominences: Part of cheek, maxilla, zygoma, lateral portion of upper lip, secondary (hard and soft) palate (Lateral boundaries, or sides of stomodeum);
- Paired mandibular prominences: Lower lip, part of cheek and mandible (Caudal boundary of stomodeum).

Development of the face occurs during the fifth to eighth weeks. The mandibular prominences are the first to fuse due to merging of the medial ends (Moore *et al.*, 2011). During the fifth week, the maxillary prominences, located on the lateral aspect of the stomodeum grow in a medial direction, uniting with the two thickenings, the nasal placodes that developed on the frontonasal prominence. The nasal placodes differentiate into two horseshoe-shaped elevations, the medial and lateral nasal processes. The maxillary prominences fuse with the lateral nasal processes, which form continuity between the sides of the nose (formed by the lateral nasal processes) and the cheeks (formed by the maxillary prominences) (Mitchell and Sharma, 2009; Moore *et al.*, 2011). However, posterior to this fusion between the lateral nasal processes and the maxillary prominences, the developing nasal floor communicates with the oral cavity (Patel, 2009).

Facial abnormalities result either from failure of the facial prominences to fuse or from variations in the merging of the maxillary and mandibular prominences. Therefore, failure of fusion of various primordial facial processes will result in anomalies, such as the oblique facial cleft where the nasolacrimal duct is visible on the surface due to failure of fusion between the lateral nasal process and maxillary prominence (Mitchell and Sharma, 2009; Patel, 2009).

By the eighth week, the face has developed a more normal appearance, with closure of the facial fissures. The upper and lower jaws are formed due to union of the maxillary and mandibular prominences respectively. The development of the skull progresses, as membranous ossification continues due to the presence of the ossification centres within the mesenchyme. The flat bones of the skull, paired frontal and parietal bones, develop from these ossification centres adjacent to the developing brain (Patel, 2009).

The palate develops from the fusion of the primary palate with the intermaxillary segment, and the secondary palate formed by the two palatine processes from the maxillary prominences. Although palatogenesis begins toward the end of week five, fusion of the different parts is not complete until the 12th week of gestation (Mitchell and Sharma, 2009; Moore *et al.*, 2011).

The primary palate develops from the deepest section of the intermaxillary segment. This segment develops due to the merging of the median nasal prominences. The small part anterior to the incisive foramen, which constitutes a small part of the adult hard palate with the incisor teeth, derives from the primary palate (Moore *et al.*, 2011).

The secondary palate develops from two horizontal projections extending from the internal aspects of the maxillary prominences, called the lateral palatine processes. Each palatine process grows obliquely downwards, lateral to the sides of the tongue. At the end of the ninth week, these processes elevate rapidly to a horizontal position above the tongue. This movement is caused by the developing head and neck and results in the tongue moving downwards (Mitchell and Sharma, 2009; Moore *et al.*, 2011).

After the elevation, the lateral palatine processes fuse with the primary palate and then unite in the midline with each other at the location of the palatine raphe. The anterior portion unites prior to the posterior portion. At the same time, the nasal septum is formed by the union of the frontonasal process and the median nasal processes, which grow inferiorly to merge with the surface of the newly developed palate. Therefore, the secondary palate matures into the section of the hard and soft palate located posterior to the incisive foramen (Mitchell and Sharma, 2009; Moore *et al.*, 2011).

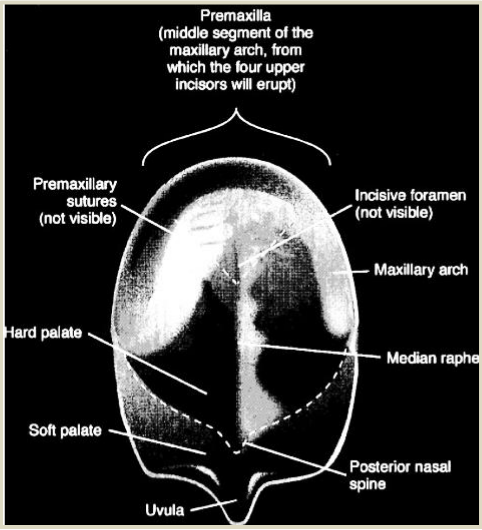


Figure 2.1: Schematic representation of the infant palate (Peterson-Falzone *et al*., 2010).

In Figure 2.1 Peterson-Falzone *et al.* (2010) illustrates the development of the hard and soft palate. It can be seen that the upper lip is located anterior the premaxilla. The embryonic primary palate forms the wedge-shaped section between the left and right premaxillary sutures, extending back to the incisive foramen. The medial portion of the lip and the premaxilla is derived from the primary palate. The rest of the hard palate and all of the soft palate arise from the secondary palate (Peterson-Falzone *et al*., 2010).

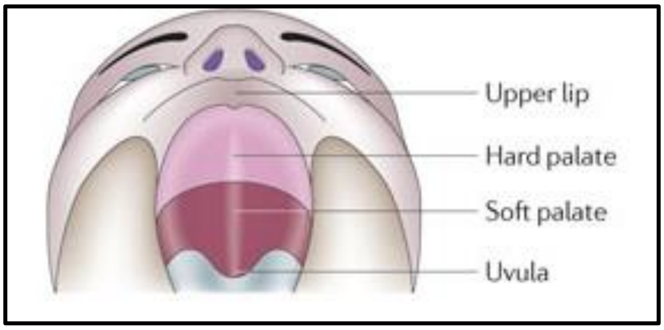


Figure 2.2: Illustration indicating the components of the palate often affected by cleft lip and palate (Dixon *et al.,* 2011).

2.1.1.1 Embryological development of cleft lip and palate

Cleft palate and cleft lip are common defects resulting in abnormal facial appearance. This can influence speech and can result in difficulties associated with feeding. There are two major groups of cleft lip and palate, with the incisive foramen acting as the dividing landmark. Anterior deformities, located anterior to the incisive foramen, include clefts involving the upper lip and the anterior part of the maxilla, with or without involvement of parts of the remaining hard and soft palate. Posterior deformities involve the hard and soft palate (secondary palate) as well as the uvula (Mitchell and Sharma, 2009; Moore *et al.*, 2011). Patel (2009) believes that the presence of clefts occur due to a mechanical disruption of programmed field interactions, and a better understanding of embryonic fields will result in improved surgical strategies.

The following components affecting palatal development could cause cleft lip and palate:

- Insufficient mesenchyme or matrix for shelf elevation, shelf elevation being too late, or incomplete fusion;
- Certain drugs taken during pregnancy will increase the incidence of cleft palate;

However, any of the above mentioned abnormalities can be successfully corrected through surgery after birth (Mitchell and Sharma, 2009). The first described cleft palate was detected in ancient texts, despite the first surgical repair of the cleft palate only being attempted in the 19th century. Since then, the advancement in understanding both the anatomy and function of the palate has motivated the drive towards a functional repair. Despite the abundance of literature regarding cleft palate repair, there are still disputes about the optimal techniques (Liau *et al.*, 2010). There is general consensus though, that competency requires appropriate decision making, based on knowledge of anatomy, pathology and surgical technique, combined with technical proficiency (Schendel *et al.*, 2005).

2.1.2 Clinical anatomy of the trigeminal nerve

Zide and Swift (1998) made the statement: 'Seeing that procedures can be performed with the use of regional anaesthesia and has become more technically demanding, the need for anatomic detail has skyrocketed'. Anatomy provides the foundation for the successful, safe and competent performance of invasive procedures. A direct comparison can be made between procedures that fail to achieve their objective, or that result in complications, and a lack of understanding or misunderstanding of the relevant anatomy (American Association of Clinical Anatomist, 1999).

The cranial nerves are a very important part of the peripheral nervous system (PNS) (Fehrenbach and Herring, 2007). The peripheral nerves are described as those nerves connecting the central nervous system (CNS) to peripheral structures, and are therefore located 'outside' the CNS. Peripheral nerves can either be spinal nerves, which emerge from the spinal cord and travel through the intervertebral foramina, or cranial nerves (Moore and Dalley, 2006).

Cranial nerves are defined as those nerves emerging from, or entering, the cranium or skull (Stedman's Medical Dictionary, 2006). They pass through the foramina or fissures of the skull, and are connected to the base of the brain (Fehrenbach and Herring, 2007). These nerves are either afferent (containing sensory fibres that convey impulses to the CNS from the sensory organs), efferent (containing motor fibres that convey neural impulses to the effector organs from the CNS), or mixed (containing both sensory and motor fibres) (Moore and Dalley, 2006).

The trigeminal nerve is the fifth cranial nerve (CN V) and the largest of the twelfth cranial nerves. It is a mixed nerve, due to the presence of both afferent and efferent fibres connected to the sensory and motor roots. The trigeminal nerve is responsible for general sensation (afferent fibres) from, and motor (efferent fibres) to derivatives of the first pharyngeal arch (head, including the face, teeth, mouth, nasal cavity and dura mater of the cranial cavity).

The large sensory root of the trigeminal nerve contains the trigeminal ganglion. The main trunk divides into three divisions or nerves: ophthalmic nerve (CN V_1) which provides sensation to the upper face and scalp, maxillary nerve (CN V_2) and the mandibular nerve (CN V_3) which supplies the middle and lower regions of the face respectively. Each of the sensory nerves enters the skull through different foramina, and can therefore be easily anaesthetised separately. The motor root of the trigeminal nerve is distributed exclusively along the mandibular nerve (CN V_3) and is responsible for the motor innervation of the muscles of the first pharyngeal arch, namely the muscles of mastication, anterior belly of the digastric muscle, tensor veli palatini and tensor tympani (Moore and Dalley, 2006; Fehrenbach and Herring, 2007).

The maxillary nerve (CN V_2) is the second division of the trigeminal nerve, and is an exclusively sensory nerve, innervating the derivatives of the maxillary prominence of the first pharyngeal arch (Moore and Dalley, 2006). This nerve runs forward in the lateral wall of the cavernous sinus, below the ophthalmic nerve (CN V_1). The meningeal branch originates from the maxillary nerve prior to the nerve passing through the foramen rotundum and entering into the upper part of the pterygopalatine fossa. It has a brief course within the pterygopalatine fossa, after which it turns laterally, passing through the inferior orbital fissure to enter the orbit as the infra-orbital nerve (Sinnatamby, 2011).

The maxillary nerve is connected to the pterygopalatine ganglion through two ganglionic branches. Several branches of the main trunk enter the ganglion and communicate with the postganglionic branches of the greater petrosal and deep petrosal nerves, both originating as fibres of the nerve of the pterygoid canal. The branches of the maxillary nerve that originate within the ganglion are the nasal (nasopalatine and posterior superior nasal), palatine (greater and lesser), pharyngeal and orbital branches. The maxillary nerve also carries parasympathetic fibres within the zygomatic branch, which is responsible for the parasympathetic nerve supply to the lacrimal gland (Sinnatamby, 2011).

The maxillary nerve is responsible for the sensory innervation of the lower eyelid, the upper lip, the skin between the aforementioned areas, as well as the roof of the mouth and the palate (Mesnil *et al.*, 2010). Cutaneous branches of the maxillary nerve include the zygomaticotemporal, zygomaticofacial and infra-orbital branches.

The zygomaticotemporal branch exits the zygomatic bone and supplies a small area of the anterior temple above the zygomatic arch. The zygomaticofacial nerve leaves the zygomatic bone via the zygomaticofacial foramen and supplies a fairly small area of skin over the zygomatic bone. The infra-orbital nerve exits the skull through the infra-orbital foramen located inferiorly to the orbital opening. Before exiting the skull it gives origin to the anterior and middle superior alveolar branches that supply the upper teeth. When it emerges, the infra-orbital nerve immediately divides into several branches that innervate the skin of the lower eyelids, cheeks, side of the nose and the upper lip (Drake *et al.*, 2005).

The pterygopalatine fossa, where the maxillary nerve is located extra-cranially, is a small pyramidal-shaped area, located inferior to the apex of the orbit. The pterygomaxillary fissure that leads into the pterygopalatine fossa separates the lateral pterygoid plate from the maxilla. The fissure is located at the anterior end of the medial wall of the infratemporal fossa.

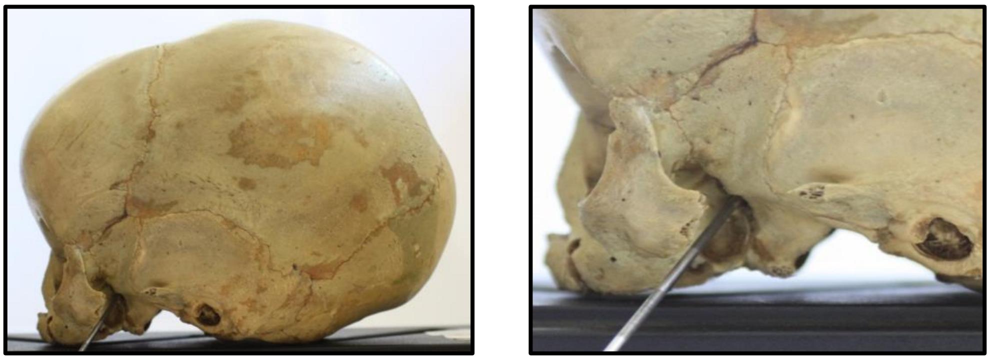


Figure 2.3A and Figure 2.3B: Photo demonstrations of the position and boundaries of the pterygopalatine fossa. The tip of the rod is located within the pterygopalatine fossa.

As seen in Figures 2.3 A and B, the pterygopalatine fossa is bordered medially by the perpendicular plate of the palatine bone, which forms part of the lateral wall of the nose. The roof of the fossa contains the sphenopalatine foramen that communicates with the nasal cavity. The posterior wall of the maxilla forms the anterior wall of the fossa, while the posterior border is formed by the sphenoid bone that contains the foramen rotundum, through which the maxillary nerve exits the skull and enters the fossa (Sinnatamby, 2011). However, anatomical literature does not define the margins of the fossa very clearly, or tends to dispute many aspects. It is therefore a challenging task to locate, as well as describe its precise area and location (Daniels *et al.,* 1998).

The fossa contains the maxillary vessels and nerve, pterygoid venous plexus as well as the pterygopalatine ganglion and fat. The pterygopalatine ganglion is considered a relay station between the superior salivary nucleus in the pons and the lacrimal gland, as well as mucous and serous glands of the palate, nose and paranasal sinuses. It is therefore known as the ganglion of ‘hay fever’. It is closely related to the maxillary nerve due to its location inferior and medial to the foramen rotundum (Sinnatamby, 2011).

The pterygopalatine ganglion receives parasympathetic and sympathetic fibres from the Vidian nerve (nerve of pterygoid canal). From this ganglion sympathetic and parasympathetic innervation is supplied to the mucosa of the nasal cavity, palate, upper pharynx, and lacrimal gland. Sensory fibres from the maxillary nerve pass through the ganglion and are responsible for the sensory innervation of the hard and soft palate, septal and lateral walls of the nasal cavity and nasopharynx. The infra-orbital nerve, which is considered to be the continuation of the maxillary nerve, receives afferent fibres from the upper lip, oral mucosa and gingiva as well as external surface of the nose and lower eyelid. All of these sensory fibres can be anaesthetized by a maxillary nerve block (Baddour *et al.*, 1979).

The maxillary artery, a terminal branch of the external carotid artery, enters the pterygopalatine fossa through the pterygomaxillary fissure. The artery passes anterior to the pterygopalatine ganglion and gives off five branches which accompany the branches of the maxillary nerve. The five branches of the maxillary artery within the pterygopalatine fossa are the sphenopalatine artery, posterior superior alveolar artery, greater palatine artery, pharyngeal artery and artery of the pterygoid canal. The maxillary artery terminates as the infra-orbital artery which continues along the floor of the orbit and infra-orbital canal to emerge with the infra-orbital nerve on the face (Sinnatamby, 2011).

The vascular structures that are found within the pterygopalatine fossa usually lie anterior to the neural structures. The course of the maxillary artery within the pterygopalatine fossa is considered as being tortuous and variable. General consensus exists that the artery lies within the fat located anterior to the neural structures. The neural structures include the nerve of the pterygoid canal, the maxillary division of the trigeminal nerve, the pterygopalatine nerve and the greater palatine nerve (Stattham and Tami, 2006).

The pterygoid venous plexus is a small network of veins that lies around and within the lateral pterygoid muscle. The veins draining the plexus correspond with the branches of the maxillary artery. This plexus is connected to several other veins, including the inferior ophthalmic vein, deep facial vein and maxillary vein. The plexus is also connected to the cavernous sinus through emissary veins. The pterygoid venous plexus acts as a ‘heart’ due to the assistance with the return of venous blood that takes place due to the pumping action of the closely related lateral pterygoid muscle (Sinnatamby, 2011).

2.1.3 Cleft lip and palate

2.1.3.1 Definition

A cleft lip is considered a congenital split in the upper lip, while a cleft palate is a congenital split in the palate, the roof of the mouth (Johnson, 2005). Cleft lip is also known as cheiloschisis, while cleft palate is known as palatoschisis (Nordqvist, 2009). According to Stedman’s Medical Dictionary (2006) *schisis* means fissure, pertaining to the fissure or gap in the upper lip or palate respectively.

2.1.3.2 Factors and conditions influencing cleft lip and palate formation

Embryological development of cleft palate (secondary palate) differs from the development of the cleft lip (primary palate) (Johnson, 2005).

Cleft lip is the result of the lack of fusion of the soft tissue of the upper lip during developing life. These clefts can be unilateral or bilateral as seen in Figure 2.4 A – H. However, they can vary greatly in the degree of deformity, from a small notch on the upper lip, to a cleft that extends into the inferior portion of the nose. Extreme clefts can extend as high as the inferior border of the eye (Fortunato and McCullough, 1998). Cleft lips can occur with or without the existence of a cleft palate.

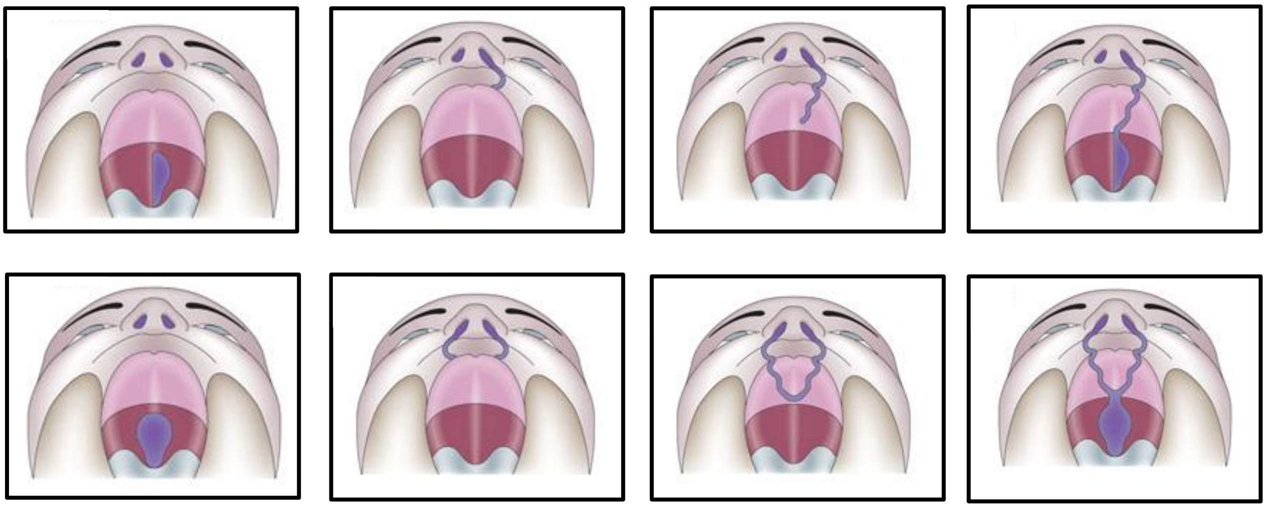


Figure 2.4 A – H: Illustrations of the different types of cleft lip and palate
A – D: Unilateral clefting, *E – H*: Bilateral clefting.
A and E: Clefting of the soft palate only
B and F: Cleft lip only
C and G: Clefting of the upper lip, alveolus and hard palate
D *and H*: Clefting of the upper lip, alveolus, hard and soft palate
(Dixon *et al*., 2011)

A cleft palate is a separation in the midline of the roof of the mouth. Cleft palates originate in the soft palate, and depending on the degree, can involve the hard palate and maxilla, sometimes extending superiorly into the nose. In extreme cases a cleft may extend to the inferior aspect of the orbit, and therefore involve facial clefts. Cleft palate may occur in isolation, or with the presence of cleft lip (Fortunato and McCullough, 1998).

The combination of cleft lip with a cleft palate is considered a common deformity, due to a cleft lip increasing the probability of a cleft palate developing (Johnson, 2005). However, because the lips and palate develop independently, it is possible for a child to be born with a cleft lip or cleft palate only, or a cleft lip with a cleft palate (Napoli and Vallino, 2011). The cleft of the lip occurs earlier in the embryonic development. The lip discontinuity will result in the obstruction of the tongue migration, which will prevent the horizontal alignment and fusion of the palatal shelves (Johnson, 2005).

Numerous factors contribute to the incidence of cleft lip and palate, including environmental exposure, genetic factors, increased parental age and low socio-economic status with the main focus on malnutrition (Fortunato and McCullough, 1998). Slavkin (1996) and Nordqvist (2009) discussed risk factors that could lead to craniofacial-oral-dental birth defects. These factors include excess vitamin A analogue, anticonvulsant medications such as phenytoin, alcohol abuse and smoking. Family history can also be an indicator (Fortunato and McCullough, 1998; Napoli and Vallino, 2011). Nordqvist (2009), states that scientists have identified certain genes that can predispose a child to developing a cleft. The majority of babies with clefts have a parent or close relative with a cleft, therefore indicating that clefts can be inherited.

Several other anomalies and factors, such as club foot, cardiac deformities, CNS malformations, folic acid deficiency and exposure to rubella might also result in the prevalence of cleft lip or palate (Fortunato and McCullough, 1998). However, in the majority of cases of cleft lip and cleft palate, multiple factors can determine the presence. These deformities are considered multifactorial inheritance due to multiple factors each causing only a minor development defect. These factors seem to affect the neural crest cells that can lead to the development of clefts. Some clefts appear as part of syndromes determined by single mutant genes (Fraser, 1980; Thompson and Thompson, 1980). A few cases have also been documented where teratogenic agents are known to have caused clefts (Moore *et al.*, 2011). However, according to Napoli and Vallino (2011), the cause of the cleft is mostly unknown.

Cleft lip and palate is part of more than 400 syndromes. These include Waardenburg syndromes, Pierre Robin sequence and Down syndrome, to name a few. According to a fact sheet of the American academy of otolaryngology – head and neck surgery (2011), approximately 30% of cleft deformities are associated with a syndrome. Peterson-Falzone (2011) states that a large percentage of children born with clefts, suffer from other congenital anomalies as well. The percentage may vary, based on the source of the report, but is much higher than expected several decades ago. Milerad *et al*. (1997) also found a connection between clefts, especially severe clefts and additional malformations.

The Pierre Robin sequence is one of the most well-known syndromes that include cleft palate. The Pierre Robin sequence was first described by Pierre Robin, a French physician, in 1923. He recognized the combination of a small lower jaw (micrognathia), tongue displacement (glossoptosis) and respiratory distress (Cleftline, 1999; Sesenna *et al*., 2012). Robin later revised the characteristics of this syndrome, and included cleft palate as an additional factor that could be present (Sesenna *et al*., 2012).

Pierre Robin sequence refers to a complex birth condition that involves the mandible being either set back in relation to the maxilla (retrognathia) or small in size (micrognathia). As a result, the tongue tends to be displaced posteriorly in the throat (glossoptosis) where it can obstruct the airway. If the mandible does not develop and grow properly, the tongue can prevent the palate from fusing properly, resulting in a cleft palate. However, not all infants suffering from Pierre Robin sequence necessarily present with a cleft palate (Cleftline, 1999). It is important to recognize that a high percentage of children with nonsyndromic clefts also have other structural or functional disorders (Peterson-Falzone, 2011).

2.1.3.3 Types of cleft lip and palate

Several methods of classification exist for the types of facial clefts. There are several variations in the types of cleft lip as well as cleft palate, due to the different mechanisms involved in the clefting progression (Witt, 2008). Clefts are described based on their location and severity.

A cleft lip may appear as a small notch in the edge of the lip only, or extend into the nose or the gums. A cleft can also vary in size, localized within the soft palate alone, or extend through the entire soft and hard palate. Due to the difference in embryonic development, cleft lip and cleft palate do not always occur simultaneously (Napoli and Vallino, 2011). Isolated cleft palate refers to the occurrence of a cleft lip without the presence of a cleft lip (Witt, 2008).

The location of the cleft with regard to the presence on either both sides or only one side of the midline, assists in the determination of the type of cleft. If a cleft is located on one side of either the upper lip or palate, the cleft is referred to as a unilateral cleft (Witt, 2008; Napoli and Vallino, 2011; MU, Pediatric plastic surgery, 2012). However, cleft lip and palate is most frequently located on the left side (MU, Pediatric plastic surgery, 2012). If the cleft lip or palate occurs on both sides, it is known as a bilateral cleft (Witt, 2008; Napoli and Vallino, 2011; MU, Pediatric plastic surgery, 2012). Yet, bilateral cleft is the least common type of cleft lip and palate (MU, Pediatric plastic surgery, 2012).

The terms “incomplete clefts” and “complete clefts”, refer to whether the cleft extends all the way through the palate, alveolus and lip into the nose (Peterson-Falzone, 2011). A small cleft that does not extend from the mouth into the nose is known as an incomplete or partial cleft, while a cleft that extends all the way to the nose is referred to as a complete cleft (Nordqvist, 2009; MU, Pediatric plastic surgery, 2012). A small notch on the upper lip is referred to as a microform cleft (MU, Pediatric plastic surgery, 2012). An incomplete cleft palate only resembles a hole in the palate, while a complete cleft palate can present as a fissure in the entire maxilla, (Nordqvist, 2009) extending from the soft palate through the alveolus and nose (Witt, 2008).

In a personal contact session with Prof KW Bütow, Clinical Head of Steve Biko Academic Hospital, full time Professor and Chief Specialist in Maxillo-Facial and Oral surgery at the University of Pretoria, Head of the Facial Cleft Deformity Clinic (FCDC) and one of the foremost Maxillo-Facial and Oral surgeons in South Africa, he explained that the FCDC, based at the dental hospital at the University of Pretoria, categorises facial clefts into eight categories:

- CL - Cleft lip: Cleft lip without a cleft palate;
- CLA - Cleft lip alveolus: Cleft lip extending into the alveolus and gums;
- CLAP – Cleft lip alveolus palate: Cleft extending from the upper lip into the hard and soft palate;
- hP – Hard palate: Cleft is restricted to the hard palate only;
- hPsP – Hard palate and soft palate: Cleft is found in both components of the palate;
- sP – Soft palate: Cleft is localized to the posterior aspect of the palate, the soft palate only;
- COMBI: combination of the above mentioned clefts;
- Oblique: Facial cleft extending from the modiolus.

The FCDC has performed 3591 surgical repairs of facial clefts from 1983 until December 2011. The most common type of cleft is the CLAP, including both the upper lip and palate (1426 out of 3591, 39.71%), with the isolated hard palate cleft being the least encountered clefts (28 out of 3591, 0.77%).

Lateral or transverse facial clefts are quite rare since only 0.3 – 1.0% incidences have been recorded (Bütow and Botha, 2010). This type of cleft is usually very obvious, unless it is combined with another facial deformity. Lateral cleft lip involves a transverse cleft traversing soft tissue, often including bony components such as the pterygomaxillary junction, maxilla, zygomatic body, mandibular condyle, or even the pterygoid plates (David *et al*., 1989).

Submucous cleft palate is another type of cleft palate that is often diagnosed. It is only confined to the hard palate and soft palate, and can often go undiagnosed due to the intact oral mucosa covering the cleft, making it less visible. Variable amounts of bone or muscle is present between the incisive foramen and the uvula. Certain submucous clefts do not require surgical intervention, due to no direct problems with regard to speech production. Submucous clefts are often described as the best examples to illustrate the possible depth of palatal clefts (Peterson-Falzone, 2011).

The wide variety of types and severity into which facial clefts can be differentiated can easily be explained and understood by the underlying embryological development of the maxilla, lip and palate. However, each type of cleft needs to be individually considered with regard to all the relevant aspects prior to the determination of the route of treatment. Buccheri (2007) states: “Plastic surgery and architecture are disciplines that yield artistic beauty, yet are bound by functional and practical constraints; indeed, they achieve a goal that is deeply rooted in reality by fulfilling the wishes of those who need help”.

2.1.3.4 Problems associated with cleft lip and palate

Cleft palate and lip can be associated with several other problems. These include feeding difficulties, middle ear fluid accumulation and associated hearing loss, dental abnormalities, as well as speech difficulties (American academy of otolaryngology, 2011; Napoli and Vallino, 2011). Other less common problems include cardiac abnormalities, CNS problems as well as clubfoot (MU, Pediatric plastic surgery, 2012).

- Feeding problems – This is experienced more greatly in patients with a cleft palate, than a cleft lip. The palate prevents food and liquids from entering the nasal cavity. A baby with an unpaired cleft palate has difficulty sucking on a regular nipple. Special nipples and bottles are required, as well as proper positioning of the bottle.
- Ear infections and associated hearing loss – Malformation of the upper airway can result in malfunctioning of the Eustachian tube. The hypothesis with regard to the Eustachian tube relates to the abnormal insertion of the tensor and levator veli palatini muscles. These muscles insert on the Eustachian tube and therefore assist in the function of the tube to equalize

pressure in the middle ear and to prevent reflux from the nasopharynx into the Eustachian tube. Fluid accumulation in the middle ear can result in ear infections that can ultimately lead to hearing loss due to the increase infections, and presence of fluid behind the tympanic membrane.

- Dental abnormalities – These occur when a cleft involves the gums, alveolar arch and jaw of a child and interferes with the proper alignment of the jaw and normal development of teeth. This can include the absences of teeth, teeth being smaller than normal, extra teeth or incorrect placement of the teeth. Defects in the alveolar ridge can displace, rotate or prevent eruption of permanent teeth.
- Speech abnormalities – Normal development of the palate and lips is vital for the proper formation of sound, which leads to clear and efficient speech skills. Excess nasality or hyper-nasality often occurs, due to the absence of the palate. Due to the open oral cavity difficulty arises during the formation of words and sounds. Nasal air emission also results due to the failure of building up the intra-oral air pressure during the production of consonants (Witt, 2008; American academy of otolaryngology, 2011; Napoli and Vallino, 2011).

The complex needs of a child with a cleft lip and palate, as well as other difficulties are best addressed by an interdisciplinary team of professionals from various specialities. These include paediatricians, plastic surgeons, otolaryngologists, orthodontists, dentists, speech-language pathologists, audiologists and psychologists (Napoli and Vallino, 2011). Once the cleft lip and palate are fixed, the other abnormalities and difficulties can be attended to more effectively.

2.1.3.5 Treatment of cleft lip and palate

MacGregor (1953) stated that patients with facial anomalies encounter social discrimination and may suffer psychological consequences. Although the nature of a facial defect is of critical importance to repair and has implications with regard to treatment, the significance extends beyond the individual. Emerging psychological processes and experiences are often affected by functional and structural limitations associated with a defect (Clifford, 1984). The presence of cleft palate has aesthetic as well as functional implications for patients with regard to their social interactions, particularly their ability to communicate effectively (Patel, 2012).

Since the defect deviates from the normal level of acceptability, the patient's perception with regard to acceptance by others, as well as self-concepts can be negatively affected (Clifford, 1984). It is well recognized that a patient with an unrepaired cleft palate suffers from detrimental disordered speech (Sell, 1992). Psychological motivations, rather than physical or functional factors, often cause families and patients to seek surgical treatment for craniofacial malformations (Clifford, 1984). Despite the motives for treatment, the good news is that both cleft lip and cleft palate are treatable, often through accurate and remarkable surgery (Napoli and Vallino, 2011). Agrawal (2009) states that a child born with a cleft palate, regardless of the presence of a cleft lip, should not be considered unfortunate, because surgical repair of cleft palate has reached a highly satisfactory level.

The goal of surgical repair is to re-establish an anatomical and physiological environment that will be conductive to the development of normal speech patterns and swallowing for the patient (Fortunato and McCullough, 1998). Cleft palate is associated with functional problems, such as regurgitation, speech, recurrent ear- and upper airway infections as well as possible hearing problems. Social acceptance can also be affected by the aesthetic appearance of the affected individual. From a functional perspective, cleft palate repair is deemed important (Onah *et al*., 2007).

Cleft repair is an integral part of the current craniomaxillo-facial surgical field (Bütow and Botha, 2010), despite the fact that the first surgical repair was only performed in the 19th century, decades after these clefts were explained in ancient texts (Losee and Kirshner, 2009). From that time, the advancement in the understanding of the palate's anatomy and function has excelled the existing concepts of a functional cleft repair (Liau *et al.,* 2010).

Despite the abundance of literature available on the repair of cleft palates, disputes still exist with regard to the optimal techniques and timing for a surgical repair (Liau, *et al.,* 2010).

2.1.3.5.1 Preferred time for repair of cleft lip and palate

Jousimies-somer *et al.* (1986) states: “It is important that the surgical technique, resulting in the fewest complications is used at the correct time.” The question now arises as to when will it be the correct time for surgical intervention.

The correct timing for palatoplasty (surgical repair of a cleft palate) is profoundly debated in the available literature (Marrinan *et al.,* 1998; Witt, 2008; Liau *et al.*, 2010). Witt (2008) states that neuromuscular control synchronisation, and integration into the neurological system should occur at the optimal time otherwise, ineffective coordination and abnormal compensatory habits may result. Speech dependant functions are known to be affected by age. A child, who was deprived of hearing during the initial years of life, does not develop normal speech, even if hearing is later corrected. Therefore, the possibility exists that if a palate is not corrected at the optimal time, abnormal linguistic patterns could be formed which might ultimately be uncorrectable even if the palate is surgically repaired (Witt, 2008).

Mcheik *et al*. (2006) state that the optimal time for cleft lip and nose repair is widely accepted to be between two and six months of age. However, they have always given the opportunity for early neonatal repair of the cleft lip and nose to patient’s parents who requested it. They conducted a retrospective study that included 123 neonatal patients, average age of 13.5 days that had been operated on by one specific surgeon between the years 1985 and 1995. They recently re-examined the patients’ medical records, at which time the respective patients were aged between 9 and 19 years old, to accesses the effectiveness of early repair of cleft lip and nose. They conclude: “In the full-term baby with cleft lip and nose without associated malformations, we are currently encouraging early repair”.

Mcheik and Levard (2010) evaluated the growth of 34 infants born with a nonsyndromic unilateral cleft lip and palate (NSUCLP) over a two year period. The cleft lip was repaired during the neonatal period, while the cleft palate was repaired at six months of age. They conclude stating that they prefer to re-establish the normal anatomy of the lip. This will ensure stability of the orbicularis oris muscle, to rehabilitate effective latching. Growth and readjustment of the arcade maxilla with normal anatomical conditions will follow (Mcheik *et al.,* 2006).

Goodacre *et al*. (2004) states that several centres in the United Kingdom have adopted the protocol of neonatal lip repair. They studied the attractiveness of cleft lip repair, as to whether early neonatal repair will have an effect on the aesthetic appearance of the scar. This study also focused on the psychological effect of the time of surgical repair on the parents. Infants with cleft lip repaired in the neonatal period, compared to patients whose clefts were repaired at a later and more conventional time (usually around three months of age). This is due to a belief that neonatal repair of a cleft lip might be beneficial to the parent-child relationship (Weatherley-White *et al*., 1987; Freedlander *et al*., 1990).

Goodacre *et al.* (2004) conclude their study by stating that there was no distinctive advantage for facial appeal (scar healing) with regard to neonatal repair, compared to the surgical repair at three months. Due to the fact that there was no difference in both appeal and success between the timing of the repair, the psychological aspects for each case will influence the determination of the time of surgical repair considerably.

The reasons for delaying cleft lip repair were based on three main facts:

- The anaesthetic risk is lower in older infants than in the neonates;
- The aesthetic appearance will be better if the structures are larger therefore making the surgery slightly easier;
- The psychological acceptance of the patient and its appearance will be enhanced if a time period has elapsed for “living with the defect” (Mcheik *et al.,* 2006).

However, in 1968 Stark already realised the advantage of early surgical repair, by pointing out that the safest time for surgical repair is during the first fourteen days. He also observed that the lip grows less than 2mm in vertical height in the first three months, casting doubt on the hypothesis that the structures will be bigger, and therefore making the surgery easier (Stark. 1968).

Cannon (1967), in an editorial written for the New England Journal of Medicine, stated that surgical repair of a cleft lip can be performed in the first 24 hours if the baby is healthy in every aspect. He also noted that if the proper anaesthesia is administered and adequate supportive treatment is provided, the surgery has no bigger risk than surgery performed at a later age. This is also supported by Freedlander *et al.* (1990), testifying that neonatal repair of a cleft lip carries minimal morbidity, can provide good results and has distinctive advantages for the child as well as the parents.

After decades of debating presumed factors that modify the success of cleft palate repair, the debaters are older, but only a little wiser (Bardach and Kelly, 1991; Shprintzen, 1991). However, with regard to the optimal time for palatoplasty, no consensus has been reach. One of the points of debate for earlier repair of a cleft palate is the presence of *Staphylococcus aureus* bacteria found in high numbers in the anterior portion of the nasal cavity. In a patient with a cleft facial deformity, an increased presence of this bacterium can be found intra-orally due to the easy passage through the cleft. This bacterium is most likely linked to increased post-operative complications. Therefore, higher presence of this bacterium increases the possibility for post-operative complications (Mÿburgh and Bütow, 2009).

Articles adressing the timing of surgical palate repair show variable results (Liau *et al.,* 2010). The dilemma with regard to timing of palatoplasty is based on the following questions:

- Can proper speech production and satisfactory maxillofacial growth be achieved effectively after palatal repair?
- What is the optimal age for surgical intervention, so that neither speech dysfunction nor growth disruption occurs? (Witt, 2008)

Witt (2008) states that several studies have concluded that delaying surgery to complete hard palate repair in children older than 18 months results in unsatisfactory speech development, while earlier repair produces no significant difference in facial growth compared to delayed repair. A study by Dorf and Curtin (1982) supports surgical intervention in patients younger than six months. Their research compared the speech performance of patients who underwent palate repair before and after one year. They concluded that the best results for speech performance were obtained when children underwent early palatoplasty. However, this report has been heavily criticized due to the research design (Witt, 2008).

One of the deciding factors with regard to early surgical intervention is based on velopharyngeal competence after cleft palate repair. According to Stedman's medical dictionary (2006), "velopharyngeal" pertains to the soft palate (velum palatinum) and the pharyngeal walls.

Desai (1983) reported that all 100 patients, on whom he repaired cleft palates before the patients were four months old, had velopharyngeal competence. This was also reported by Grobbelaar *et al.,* (1995) who documented that soft cleft palate repair prior to six months of age produced statistically better velopharyngeal function than patients operated on up to 18 months. Neonatal intervention with regard to palatoplasty has also been reported to be a safe procedure, although no results regarding velopharyngeal function and phonological development have been assessed (Denk and Magee, 1996). Consequently, the importance of early cleft palate closure with regard to velopharyngeal sufficiency has been authenticated (Randall *et al.,* 1983; Haapanen and Rantala, 1992; Grobbelaar *et al.,* 1995).

In the personal contact session with Prof KW Bütow, Head of the FCDC he explained that they only repair cleft palates in patients aged five months and older, due to the following reasons:

- Size and strength of the infant, which reduce the risk of anaesthesia and surgery;
- Development of the muscles. Better developed, larger muscles increase the success rate;

The treatment of cleft lip and palate is considered a long-term period, extending well into the growth phase of a child and the outcome of the treatment is influenced by multiple factors (Gopalakrishna and Agrawal, 2010). Cleft treatment protocols must take all the required considerations into account and balance this with the necessary concerns of developing normal speech while allowing normal facial growth (MU, Pediatric plastic surgery, 2012). Liau *et al*. (2010) state that there is no sufficient data to support the hypothesis of surgical repair of the palate prior to seven months, neither data that show improved outcomes if the palate is repaired earlier than five months. Given this information, we propose that surgical intervention with regard to cleft palate can only be performed from five months of age. However cleft lip can be surgically repaired during the neonatal period.

2.1.3.5.2 Use of regional nerve blocks during surgical repair

The increased incidence of cleft lip and palate was explained by Fogh-Andersen (1961) who claims that the increased incidence can be directly related to the decreasing postnatal mortality and more successful surgeries. Increased fertility of individuals and the higher incidence of cleft lip and palate due to an increase of anomaly within the gene pool can be directly related to the increased surgical results.

Even though certain surgical procedures are necessary for the life and continuing health of a patient, the surgical procedure and related undertakings can produce severe anxiety. Adults recover fairly quickly from the particular emotional stress and might not exhibit any anxiety afterwards, but this is not the case with a child undergoing surgery (Pearson, 1941). Due to the increased perception and realisation that even neonates are capable of experiencing pain, several well established techniques need to be re-modified and adapted to ensure that any psychological or physical trauma inflicted on the patient is minimized, no matter the age of the patient (Booker, 1990).

Surgical repair of a cleft palate is deemed an extremely painful procedure (Doyle and Hudson, 1992; Obayah *et al.,* 2010). Extensive measures need to ensure a fairly pain free experience for all patients. Regional anaesthesia combined with sedation or general anaesthesia is gaining more preference due to the increased success rate. However, a lack of information regarding this practice in paediatric patients needs to be addressed (Rochette, *et al.,* 2007).

In 1922 William J Mayo, proclaimed: “Regional anaesthesia is here to stay.” This statement is as true today as it was approximately a century ago (Hebl and Lennon, 2010). General anaesthesia is extensively and safely administered in major oral and maxillofacial surgical procedures, while techniques with regard to peripheral nerve blocks need to be investigated to correct and modify these techniques (Stajčić *et al.,* 2010). In a study performed by Gopalakrishna and Agrawal (2010), one of the respondents stated: “We learn techniques from our teachers, who incorporate their own slight modifications, and then over the years modify it further ourselves.” However, Liau *et al.* (2010) claim that no evidence exists to indicate that randomized studies were conducted to compare local anaesthetics for cleft palate repair.

One of the advantages of regional anaesthesia is the prevention of post-operative pain, especially when the techniques are performed skilfully (Andre, 1988). Regional anaesthesia is used rather than morphine or other opioids, and is considered safer and more effective (Sola, *et al.,* 2012). Regional anaesthesia of the maxillary nerve is most commonly indicated for the surgical repair of cleft lip and palate (Captier, *et al.,* 2009; Sola, *et al.,* 2012) due to the innervation of the hard and soft palate by various branches of maxillary nerve (Mahoney, 1977; Malamed and Trieger, 1983; Molliex, *et al*., 1996; Tremlett, 2004; Notgarnie, 2005). The maxillary nerve is a pure sensory nerve, and if anaesthetised at its trunk, prior to it branching off, the sides of the nose, lower eyelid, upper lip and roof of the mouth, soft palate, as well as tonsil and mucous lining of the nasal cavity will be anaesthetised (Notgarnie, 2005; Captier *et al.,* 2009).

To anaesthetise the maxillary nerve at the trunk, the pterygopalatine fossa needs to be reached. Important structures such as the maxillary artery and pterygoid venous plexus need to be avoided (Notgarnie, 2005; Captier *et al.,* 2009). Regional anaesthesia is the practice of applied anatomy that requires a detailed knowledge of body structures and their relationship to one another (Hebl and Lennon, 2010).

Even though facial clefts are more commonly repaired than other malformations, no prospective studies with regard to different anaesthetic techniques exist (Tremlett, 2004). The trajectory of the maxillary nerve in infants needs to be thoroughly investigated due to the significant difference from the corresponding adult landmarks (Captier *et al.,* 2009). Stechison and Brogan (1994) also state that the foramen rotundum and nearby region is not easily accessed percutaneously, and this results in the absence of a standardised technique. According to Mahoney, (1977) the very multiplicity of the proposed techniques of the maxillary block, suggest that this block is often unsuccessful or more often than not, associated with complications. A standardised technique needs to be acquired to anaesthetise the maxillary nerve at the foramen rotundum in infants, which will lead to the best possible outcome with a minimal presence of complications.

2.2. Aims

The following aims will be addressed in this research chapter:

2.2.1 To evaluate the anatomy of three different techniques of blocking the maxillary nerve in paediatric patients;

2.2.2 To establish the most efficient method of blocking the maxillary nerve within the pterygopalatine fossa.

2.3. Materials and Methods

2.3.1 Selection of the three techniques

During an extensive literature study, three techniques to block the maxillary nerve within the pterygopalatine fossa were identified and tested to establish the most efficient method.

Several methods were employed to determine three effective techniques for blocking the maxillary nerve within the pterygopalatine fossa:

- The Medline (Ovid) database and the Pubmed database were studied via the online services of the Academic Information Service of the University of Pretoria using keywords including “maxillary nerve block”, “pterygopalatine fossa”, and “paediatric regional nerve blocks” to ensure that only relevant articles were obtained.
- Several books and journals were obtained from the library and academic support facilities of the University of Northumbria, Newcastle upon Tyne, North-East England during a visit made possible by the Post-Graduate Study Abroad Program of the University of Pretoria.
- Several search engines were employed to locate information on several digital libraries using the keywords “maxillary nerve blocks”, “pterygopalatine fossa”, and “regional paediatric nerve blocks”.

Once sufficient information on the different methods of blocking the maxillary nerve within the pterygopalatine fossa was successfully retrieved, the three most often described techniques found in the literature were chosen to be simulated on paediatric skulls and cadavers at the Department of Anatomy of the University of Pretoria.

Two of the techniques can be described as supra-zygomatic approaches (Technique A and B) while the third is considered an infra-zygomatic approach (Technique C). All three techniques are extra-oral approaches to the pterygopalatine fossa.

- In Technique A, the needle is placed adjacent to the lateral orbital wall, at the midpoint of the orbital opening. The needle is then advanced in an inferior direction to reach the pterygopalatine fossa (Du Plessis, 2010).
- Technique B is the most described method. The needle is placed at the frontozygomatic angle, between the superior edge of the zygomatic arch, and the posterior orbital rim. It is then advanced almost perpendicular to the skin to reach the pterygopalatine fossa (Captier, *et al.,* 2009; Mesnil *et al.*, 2010; Stajčić *et al.,* 2010; Sola *et al*., 2012).
- Technique C, the only infra-zygomatic approach selected, was developed using a point of entry through the face at the intersection of a vertical line extending along the lateral orbital wall and a horizontal line perpendicular to the lateral aspect of the inferior surface of the zygomatic process of the maxilla (Stechison and Brogan, 1994; Mesnil *et al.*, 2010).

2.3.2 Comparison of different techniques

The study consists of both an osteological and cadaveric part.

2.3.2.1 Simulation on paediatric skulls

All three techniques were simulated on ten paediatric dried skulls which are part of the Pretoria Bone Collection of the Department of Anatomy, University of Pretoria.

A B C

Figure 2.5 A – C: Technique A, B and C simulated on paediatric skulls

The three techniques were simulated on both the left and right sides of the paediatric skulls. Exclusion criteria for the skulls depended on the morphology of the lateral side of each skull:

- In the case of a broken or absent zygomatic arch the skull was excluded from the study;
- Should the area be damaged in such a way that the visibility of the pterygopalatine fossa was obstructed, or the lateral orbital wall could not be effectively utilised, the skull was removed from the sample size.

Each skull was placed on a horizontal flat surface. Each of the procedures was simulated by systematically advancing a lumbar puncture (LP) needle from the specific bony landmarks, until the tip of the needle was located within the pterygopalatine fossa. The distance that the needle travelled was marked. High quality digital photographs were taken during the simulation of each procedure, from an anterior, superior and lateral view, to assist with the craniometrical measurements. The horizontal distance from the zygomatic arch to the deepest aspect of the pterygopalatine fossa was also photographed. These photographs were imported into an image software program to assist with the determination of the relevant craniometrical measurements.

2.3.2.2 Simulation on paediatric cadavers

The cadaveric part of the study included a total of 30 paediatric cadavers from the cadaveric collection of the Department of Anatomy, University of Pretoria. This study is permissible under the South African National Health Act, number 61 of 2003. None of these cadavers were dissected in the facial region prior to this research study. The cadavers were dissected in the temporal and infra-temporal areas to expose the zygomatic arch, lateral orbital wall as well as the pterygopalatine fossa. The cadavers were placed in a supine position, with the head turned laterally to allow for comparison of the techniques. The layers of soft tissue through which the needle would pass to ultimately reach the fossa in each procedure, were also noted and photographed.

The three chosen extra-oral techniques which can be used to block the maxillary nerve within the pterygopalatine fossa were simulated on the dissected cadavers. A LP needle was used to effectively illustrate the intended procedure. The distance that the needle travelled was marked and photographed. The angles at which the needle will be placed and then directed were also photographed from a superior, anterior and lateral view. These photographs were imported into an image software program to determine the craniometrical measurements.

A B C

Figure 2.6 A – C: Techniques A, B and C simulated on paediatric cadavers

2.3.2.3 Craniometrical analysis

The first aim of this chapter is to compare and evaluate the anatomy of three different techniques of blocking the maxillary nerve in the pterygopalatine fossa. In order to effectively compare the different techniques, similar craniometrical measurements needed to be established for each of the different techniques, on both the paediatric skulls and cadavers.

The following craniometrical measurements were calculated:

- Depth to the pterygopalatine fossa. The distance that the needle travelled to ultimately reach the pterygopalatine fossa, was measured from the zygomatic arch. The tip of the needle was advanced until it reached the perpendicular plate of the palatine bone, which forms the medial wall of the fossa. Once the needle reached the pterygopalatine fossa, the exact distance was marked on the LP needle. The needle was then photographed next to a scale (Figure 2.7A) to precisely determine the distance the needle travelled, with the use of an image software program (Image Tool V3.0).

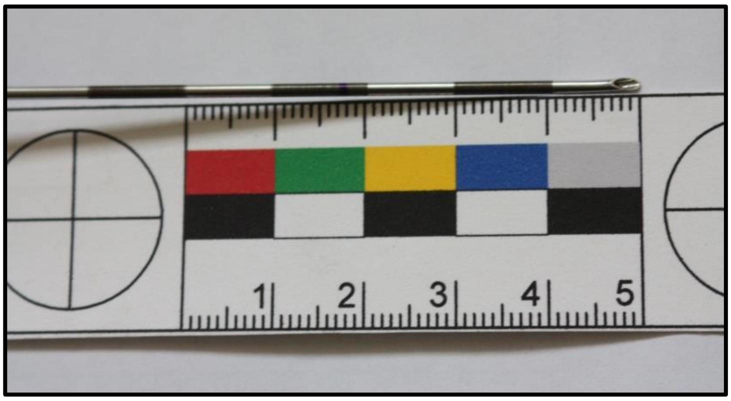


Figure 2.7A: Photograph illustrating the measurement of the depth to the pterygopalatine fossa*.*

- The angles at which the needle needs to be inserted to effectively reach the pterygopalatine fossa. In order to determine these angles, photographs were taken from superior and anterior. A protractor was used to determine the exact degrees.
  - On the anterior view, the plane perpendicular to the median plane was considered to be 0°. When the needle was angled superiorly towards the pterygopalatine fossa, it was considered as an increase (+) in the angle, therefore a "positive" angle. If the angling of the needs is in an inferior direction, it was deemed to be a decrease (-), a "negative" angle. (Figure 2.7B)

  - On the superior view, the perpendicular plane was again considered to be 0° with any anterior deviation seen as an increase (+) in the gradient, and a posterior deviation as a decrease (-) in the angle (Figure 2.7C)

B C

Figure 2.7 B and C: Anterior and superior view of paediatric skull, respectively

2.3.2.4 Statistical analysis

In order to accurately compare the skulls and the cadavers, the sample was divided into two age groups:

- Group 1 consisted of skulls and cadavers of neonates (0 – 28 days after birth);
- Group 2 included the skulls and cadavers of infants between 28 days and one year of age.

Group 1 included seven neonatal skulls and 25 neonatal cadavers, while three paediatric skulls and five cadavers were measured for age Group 2.

All three methods used to locate the pterygopalatine fossa generated data with regard to the superior-inferior and anterior-posterior angles, as well as the distance that the needle needs to travel to ultimately reach the pterygopalatine fossa. All the measurements taken from the skulls and cadavers were captured in separate MS Excel data sheets. The following standard statistical comparisons were made using Statistix ® analytical software:

- The mean or average of each measurement;
- The standard deviation was calculated to establish the range of the sample;
- 95% confidence interval was used to establish the true population value for the statistic value, including upper and lower ranges;

All three techniques were simulated on the left and right sides of both the skulls and cadavers. A paired t-test was done to determine whether any significant difference existed between the left and right sides (a p-value of <0.05 was regarded a statistically significance).

The second aim of the study was to establish the most efficient method of blocking the maxillary nerve within the pterygopalatine fossa. This was done by statistically comparing the measurements between the skulls and cadavers for each specific technique. The following measurements were compared during this evaluation:

- The left and right sides of both the skulls and cadavers, to ensure these measurements and angles are not side specific;
- 95% confidence intervals, to establish that all the relevant data are closely related to the mean;
- Where these measurements expressed no statistical significant difference ($p < 0.05$) the technique was directly compared between the skull and cadaver samples;
- Once the skulls and cadavers were directly compared, the technique with the smallest degree of variation was identified as the most efficient method.

The importance of the direct comparison between the skulls and cadavers is to ensure that this technique is the ideal method, based on the skull measurements being the ideal values, while the cadaver measurements need to be statistically realistic to ensure that this nerve block can be effectively performed in a clinical setting.

2.4. Results

2.4.1 Identification of the three techniques

The following three techniques for blocking the maxillary nerve within the pterygopalatine fossa were identified by means of an extensive literature study as seen on page 75.

- Technique A, a supra-zygomatic approach, with needle insertion alongside the midpoint of the lateral orbital wall (Du Plessis, 2010).
- Technique B, a supra-zygomatic approach, where the needle is inserted at the frontozygomatic angle (Mesnil *et al.*, 2010; Stajčić *et al.,* 2010; Sola *et al*., 2012).
- Technique C, an infra-zygomatic approach, where the needle pierces the skin inferior to the zygomatic process of the maxilla (Stechison and Brogan, 1994).

2.4.2 Comparison of different techniques

No statistically significant differences ($p > 0.05$) were found between the left and the right sides of either the skulls or cadavers. The results obtained were therefore combined into a total sample.

2.4.2.1 Simulation on paediatric skulls

The dimensions and measurements for Group 1, (seven neonates 0 -28 days after birth) are summarised in Table 2.1

Table 2.1: Neonatal skulls part of Group 1

	Technique A			Technique B			Technique C		
	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)
n	14	14	14	14	14	14	14	14	14
Mean	13.80	16.20	24.40	0.73	13.21	22.34	-26.80	24.25	21.42
SD	6.33	8.50	6.11	4.83	7.74	7.04	9.05	7.99	6.70
CI95%	3.31	4.45	3.20	2.53	4.06	3.69	4.74	4.18	3.51
Lower	10.48	11.74	21.20	-1.80	9.16	18.65	-31.54	20.06	17.91
Upper	17.11	20.65	27.60	3.26	17.27	26.02	-22.06	28.43	24.93

CI95%: Confidence Interval of 95%
Lower: Lower range of values with a 95% confidence level
Upper: Upper range of values with a 95% confidence level
Negative (-) value with relation to superior – inferior angle indicates that the needle is entered from an inferior angle and proceded superiorly.

For technique A, the needle was advanced for 24.40mm at a superior angle of 13.80° and an anterior angle of 16.20°, while the needle was advanced 22.34mm for technique B, at an almost horizontal level of 0.73°, and from an anterior direction with an angle of 13.21°. In technique C, the needle had to be entered at a negative angle of 26.80°, which emphasised that the needle was advanced in an upwards direction for 24.14mm, at an anterior angle of 24.25°.

The measurements for Group 2 are represented in Table 2.2.

Table 2.2: Infant skulls part of Group 2

	Technique A			Technique B			Technique C		
	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)
n	6	6	6	6	6	6	6	6	6
Mean	13.93	12.43	32.73	-3.25	9.06	31.48	-28.72	23.37	34.77
SD	2.28	5.48	6.14	2.38	6.15	6.48	4.62	5.20	3.66
CI95%	1.82	4.38	4.91	1.90	4.92	5.18	3.70	4.16	2.93
Lower	12.11	8.05	27.82	-5.15	4.14	26.29	-32.42	19.21	31.84
Upper	15.76	16.82	37.64	-1.35	13.98	36.66	-25.02	27.53	37.70

The average distance that the needle was advanced to reach the pterygopalatine fossa for technique A, was 32.73mm. The needle was directed at a superior angle of 13.93° and from an anterior direction, at an angle of 12.43°. Technique B and C both had a negative angle with regard to the superior-inferior angle, therefore in both techniques the needle had to be advanced in an upward direction of 3.25° and 28.72° respectively, while the anterior angles were 9.06° and 23.37°, respectively.

2.4.2.2 Simulation on paediatric cadavers

A total of 30 paediatric cadavers were dissected and the relevant measurements are summarised in the following two tables:

- Table 2.3, 25 neonatal cadavers in Group 1;
- Table 2.4, five infant cadavers in Group 2.

Table 2.3: Neonatal cadavers part of Group 1

	Technique A			Technique B			Technique C		
	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)
n	50	50	50	50	50	50	50	50	50
Mean	20.03	12.13	21.60	0.07	12.91	21.10	-32.53	27.04	21.33
SD	5.47	5.73	3.36	6.90	4.67	3.07	9.70	9.00	3.24
CI95%	1.52	1.59	0.93	1.91	1.29	0.85	2.69	2.49	0.90
Lower	18.51	10.54	20.66	-1.84	11.62	20.25	-35.22	24.54	20.44
Upper	21.55	13.72	22.53	1.98	14.21	21.95	-29.85	29.53	22.23

The distances that the needle had to be advanced to reach the pterygopalatine were very similar for the three techniques. These distances were on average, 21.6mm for technique A, 21.1mm for technique B and 21.33mm for technique C. The anterior-posterior angles for procedure A and B were also similar. Both had to be inserted from an anterior direction with angles of 12.13° and 12.91° respectively. Yet, technique C had a much greater anterior angle of 27.04°. However the superior-inferior angles differed greatly. The angles were on average 20.03°, 0.07° and –32.53° for procedures A, B and C, respectively.

Table 2.4: Infant cadavers part of Group 2

	Technique A			Technique B			Technique C		
	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)	Sup – Inf (°)	Ant – Post (°)	Depth (mm)
n	10	10	10	10	10	10	10	10	10
Mean	24.97	12.13	27.74	2.50	12.06	26.74	-31.17	26.53	28.55
SD	8.53	4.10	3.01	6.34	6.27	4.53	6.12	5.78	2.74
CI95%	5.29	2.54	1.87	3.93	3.89	2.81	3.79	3.58	1.70
Lower	19.68	9.59	25.87	-1.42	8.18	23.94	-34.96	22.95	26.86
Upper	30.26	14.67	29.61	6.43	15.95	29.55	-27.37	30.11	30.25

The measurements for the cadavers in Group 2 followed a similar pattern as those in Group 1, with the distance differing only slightly between technique A, (27.74mm), technique B, (26.74mm) and technique C, (28.55mm) ($p < 0.05$). The anterior-posterior angles for technique A and B differ greatly from those of technique C, while there was a large variation between the superior-inferior angles for all three. This resembled the differences in needle direction when the needle is advanced to the pterygopalatine fossa. In technique A, the needle was advanced at an inferior angle of 24.97°, while in technique B the needle was inserted almost horizontally at an angle of 2.5°. Finally, in technique C the needle was advanced in a superior direction at an angle of 31.17°.

2.4.2.3 Comparison of the skulls and cadavers for each technique

In order to effectively establish the most accurate method to block the maxillary nerve within the pterygopalatine fossa, the results of all three techniques needed to be compared between the skulls and cadavers for each age group.

Figures 2.8 A and B are illustrations directly comparing the measurements for each technique between the specific age groups.

Figure 2.8A: Overall sample for Group 1 (neonates) showing the results of the measurements for both cadavers and skulls

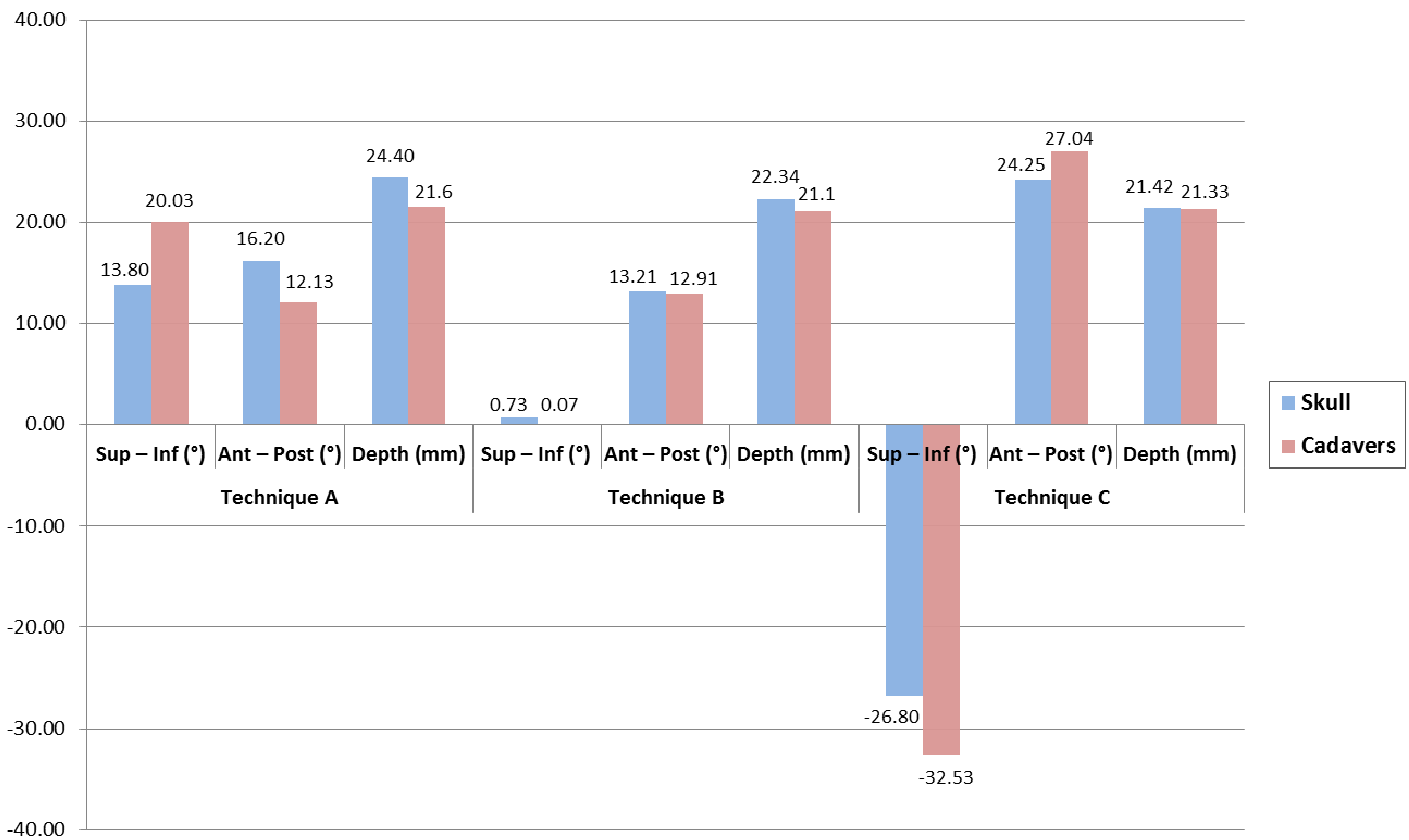
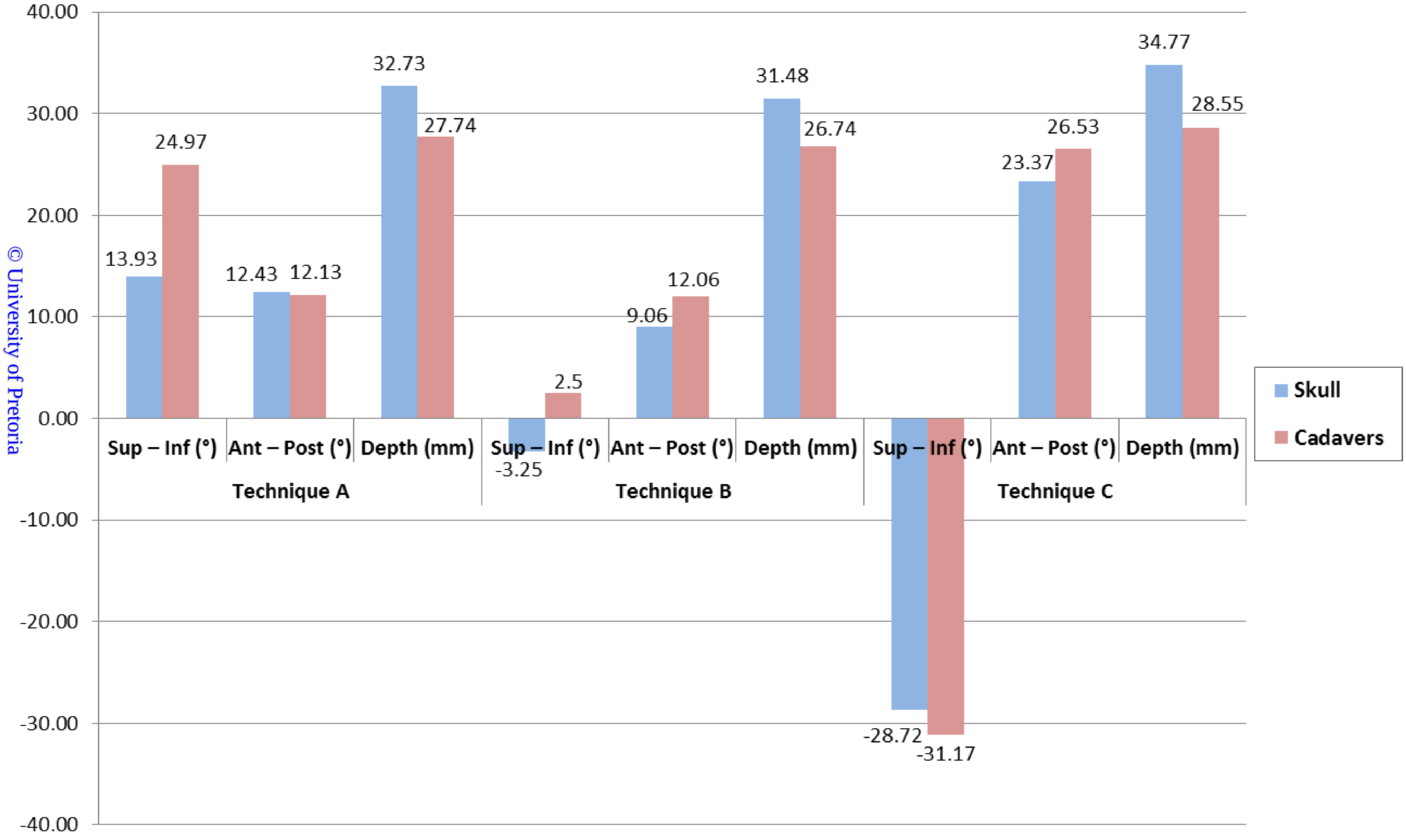


Figure 2.8B: Overall sample for Group 2 (infants) showing the results of the measurements for both cadavers and skulls



When evaluating Figures 2.8 A and B, it is clear that the values for technique B, especially in age group 1, are not significantly different ($p > 0.05$) when comparing the values obtained from the cadavers and the skulls.

When comparing the different techniques with regard to the measurements obtained from the skulls and cadavers, the following can be perceived:

- Technique A, the supra-zygomatic approach at the midpoint of the lateral orbital wall, exhibited a statistical difference ($p < 0.05$) in both Groups 1 and 2, when comparing the superior-inferior angle of the needle between the values of the skulls and the cadavers;
- Technique B, the supra-zygomatic approach at the frontozygomatic angle, expressed no statistical significance when comparing the measurements for both age groups;
- Technique C, the infra-zygomatic approach, displayed a statistical difference ($p < 0.05$) with regard to the depth the needle in Group 2;

Because technique B is the only technique that did not exhibit a statistical difference when comparing the values of the skulls and cadavers for both age groups, the angles and depth that the needle travel to block the maxillary nerve in the pterygopalatine fossa were combined to give a total sample of 64 as seen in Table 2.5.

Table 2.5: Results of technique B for the combined sample for both Groups 1 and 2

	Age group 1			**Age group 2**		
	Sup – Inf (°)	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**
n	64	64	64	16	16	16
Mean	0.21	12.98	21.37	0.35	10.94	28.52
SD	6.48	5.42	4.22	5.85	6.20	5.65
CI95%	1.59	1.33	1.03	2.87	3.04	2.77
Lower	-1.37	11.65	20.34	-2.52	7.90	25.75
Upper	1.80	14.30	22.41	3.21	13.98	31.28

Looking at the results of Table 2.5, it can be seen that for Group 1 the needle can be angled almost perpendicular to the median plane (0.21° ± 1.59°) (in a superior-inferior plane), while the needle is angled anteriorly (12.98° ± 1.33°), i.e., the needle will traverse in a posterior direction. The needle can be advanced to a depth of approximately 21.37mm ± 1.03mm in order for the tip of the needle to be in the pterygopalatine fossa. For Group 2, the needle can be inserted at an angle of 0.35° ± 2.87° in the superior-inferior plane, 10.94° ± 3.04° in the anterior-posterior plane and advanced approximately 28.52mm ± 2.77mm to successfully enter the pterygopalatine fossa.

2.5. Discussion

Cleft lip and palate are considered the most common anomaly of the craniofacial region, with more than 300 syndromes being associated with orofacial clefting. However, most of those anomalies occur in isolation, being void from other abnormalities (Goodacre and Swan, 2011).

The maxillary nerve block performed in cleft palate repair surgeries of paediatric patients is gaining preference over the use of opioids in the post-operative period. Regional anaesthetic nerve blocks dramatically reduce the consumption of opioids for post-operative pain relief (Jonnavithula *et al.,* 2010; Mesnil *et al.,* 2010). Milić *et al.* (2010) also state that cleft palate surgery has specific surgical complications associated with the surgical procedure itself, therefore the use of an anaesthetic agent that may cause further complications should rather be avoided.

Since younger patients, especially children, lack the ability to communicate their pain experiences and analgesic needs, post-operative pain management is of high importance (Tobias and Deshpande, 1996; Litman, 2004). Untreated post-operative pain is a leading cause of anxiety regarding morbidity, particularly in children that underwent palatoplasty, based on poor oral intake (Jonnavithula *et al.,* 2010). Not only can maltreatment of pain result in serious physiological disorders, but complications such as pulmonary dysfunction, delayed wound healing and ultimately delayed recovery can be the end result (Tobias and Deshpande, 1996; Jonnavithula *et al.,* 2010; Wells, 2010).

Tobias and Deshpande state in their book entitled ‘Pediatric pain management for primary care, 2nd edition’, published in 1996, that “The last decade has provided paediatric anaesthesia practitioners with significant experience, and that nearly 300 articles have been published on the use of regional anaesthesia in children during this time.” With the increasing popularity of regional nerve blocks, especially during cleft palate repair surgery, an earlier surgical repair is also being advocated (Agrawal, 2009; Kwari *et al.,* 2010).

Since the onset of cleft surgery, there has been a debate with regard to the optimal timing of surgical repair, and in particular, the timing of cleft palate closure. In a recently published article by Hodges, (2010), they performed a combined early cleft lip and palate repair on 106 children under 10 months of age, with 71% of the children being under six months of age. They had tremendous success with the one stage repair, with no evidence of either any mortality or significant complications. Furthermore, 92% of their patients did not require any further surgical interventions.

In a study by Desai (1983), he performed neonatal cleft lip surgery on 100 patients followed by cleft palate repair at 16 weeks of age, while De Mey *et al.,* (2002) performed a complete lip and palate repair on 18 infants at 3 months of age. A surgeon performing reconstructions of cleft facial deformities on an infant is under pressure to effectively correct the appearance of the patient as soon as possible (Mÿburgh and Bütow, 2009). Marrinan *et al.* (1998) also stated that the earlier the surgical repair of a cleft palate, the less likely a pharyngeal flap will be needed. However, when performing procedures on infants, it is of extreme importance that factors which may alter the outcome, are noted (Lyon, 2005).

Several anatomical and physiological differences exist between adults and children, and need to be kept in mind (Kumar, 1997). There are great differences between neonates, infants, young children and adults. In general, the observation can be made that the younger the patient, the greater the differences (Avidan *et al.,* 2003). Kwari *et al.* (2010) affirm that the anaesthetic complications are more commonly encountered in neonates and infants than adults, due to the peculiar anatomy and physiology. The differences in anatomy are vital factors that need to be remembered when performing regional anaesthetic procedures on infants. Infants and children cannot be considered as small adults (Ferrari 1999; Avidan *et al.,* 2003). Therefore, thorough knowledge of the relevant anatomy is required.

The success of a block, the time of onset and the duration of analgesia depend on the volume of anaesthetic agent injected, the agent used, and the accuracy of the injection. Wells (2010) states that incorrect local anaesthetic positioning, due to incorrect needle placement, has resulted in a 20% failure rate for regional anaesthetic techniques. Dalens (1990) states that "To the inexperienced, regional anaesthesia appears somewhat mysterious and unreliable, an impression which is, all too often, grounded in an insufficient knowledge of the basic anatomy."

2.5.1 Selection of the three techniques

The maxillary nerve block is useful for surgical operations with regard to the nose, mouth and medial parts of the face. Therefore, if the maxillary nerve is anaesthetised at its trunk, it will provide adequate anaesthesia of the maxilla and all its associated structures (Mahoney, 1977; Methathrathip *et al.,* 2005).

Several methods are found in the literature to block the maxillary nerve. These blocks can be divided into intra-oral and extra-oral approaches. Intra-oral include techniques such as the "high tuberosity approach", where the needle is inserted at the region of the muco-buccal fold at the second maxillary molar. It is then directed superiorly, medially and posteriorly along the zygomatic and infratemporal surfaces of the maxilla, in order to reach the pterygopalatine fossa. Another technique is via the greater palatine canal where the needle is placed within the greater palatine foramen, and then advanced through the canal until the pterygopalatine fossa is reached (Malamed and Trieger, 1983; Hawkins and Isen, 1998).

Neither of these techniques can be used when performing the maxillary nerve block in infants. The "high tuberosity approach" requires the identification of the second maxillary molar, which is absent in infants (Captier *et al.,* 2009; Mesnil *et al.,* 2010). The "greater palatine canal approach" is considered too dangerous, based on the size of the canal and the closely related greater palatine artery. The position of the greater palatine canal also differs greatly, since the palate is still maturing (Hawkins and Isen, 1998; Captier *et al.,* 2009). Intra-oral approaches were not considered in this study due to anatomical limitations.

However, several extra-oral techniques to block the maxillary nerve within the pterygopalatine fossa can be found in the literature:

- Needle insertion is at a point below the midpoint of the zygomatic arch and overlying the coronoid notch of the mandible. The needle is entered at the level of the external acoustic meatus, and advanced perpendicular to the base of the skull, until the lateral pterygoid plate is reached. The needle is then advanced anteriorly until it enters the pterygopalatine fossa (Sist, 1997).
- Approaching the pterygopalatine fossa from a lateral aspect, where the needle is inserted inferior to the zygomatic arch, approximately at its midpoint, and then advanced 40 to 50mm until the tip of the needle contacts the lateral pterygoid plate (Singh *et al.,* 2001; Kumar and Banerjee, 2005).
- Robiony *et al.* (1998) used a needle inserted posterior to the coronoid process of the mandible under the zygomatic arch. The needle is advanced on a plane perpendicular to the skin, until the lateral pterygoid plate is reached, after 40 to 50mm advancement. The needle is then withdrawn to the subcutaneous level and reinserted in an anterior-superior direction to a point 10mm deeper that the initial point.
- The needle can be inserted at the intersection between a vertical line extending along the lateral orbital wall and a horizontal line tangential to the lateral aspect of the inferior surface of the zygomatic process. From the point of entry, the needle is directed in a 30° angle medial to the vertical line and 45° above the tangential line (Stechison and Brogan, 1994; Mesnil *et al.,* 2010).
- The needle is placed at the frontozygomatic angle, formed by the superior edge of the zygomatic arch below, and posterior orbital rim anteriorly. The needle is inserted perpendicular to the skin. It is then advanced to reach the greater wing of the sphenoid in the axial plane, ± 2.7mm. The needle is then withdrawn to orient the tip 20° in an anterior direction and 9° in an inferior direction. The needle is then advanced toward the pterygopalatine fossa (Captier *et al.,* 2009; Stajčic *et al.,* 2009; Mesnil *et al.,* 2010; Sola *et al.,* 2012).

- The needle is placed adjacent to the lateral orbital wall, at the midpoint of the orbital opening. The needle is then advanced in an inferior direction to reach the pterygopalatine fossa (Du Plessis, 2010).
- The landmark for skin penetration is the most concave point on the inferior border of the zygomatic arch. The needle is inserted at 90° to both the skin and sagittal plane, while contact is continuously maintained between the needle and the arch of the zygoma. The needle is advanced until the lateral pterygoid plate is reached (Meechan, 2010).

Three techniques were chosen to be simulated on the paediatric skulls and cadavers. Techniques A and B, were both supra-zygomatic approaches to the pterygopalatine fossa while technique C was an infra-zygomatic approach.

2.5.2 Comparison of different techniques

In order to ultimately establish the most effective method of blocking the maxillary nerve at its trunk within the pterygopalatine fossa, the technique needed to be simulated on paediatric skulls and then compared to simulations on paediatric cadavers. The skull measurements can be seen as the “ideal” values, while the cadaver measurements are considered to be the “real” values since it will be applied in a clinical setting. To ensure that the values are accurate they should be directly compared, with no significant difference present.

2.5.2.1 Simulation on paediatric skulls

To achieve the best possible results with the maxillary nerve block, the anaesthetic solution needs to be deposited as close to the nerve trunk within the pterygopalatine fossa, as possible (Methathrathip *et al.,* 2005). This procedure can easily and effectively be simulated on a skull due to no soft tissue being present and the pathway to the pterygopalatine fossa being easily visible. This will ultimately ensure that the obtained results are truthful and accurate.

However, in a study by du Plessis (2010), where a formula to determine the location of the pterygopalatine fossa in adult skulls was developed, the author makes a very important statement: "It seems that the main factor of variability is in fact the angle at which the needle is inserted and not the depth. The most important aspect is that the tip of the needle is placed either at the entrance to the fossa or close to the pterygopalatine fissure. It is possible that the anaesthetising agent will enter the fossa even if the needle is not placed in the fossa itself."

After comparing Group 1 and Group 2, it was found that the angles are fairly similar, with slight differences to the degrees, which can be contributed in the growth of the infant skull during the initial months of life. The superior-inferior angles were determined at 13.93° ± 1.82°; - 3.25° ± 1.9° and -28.72° ± 3.7° for techniques A, B and C respectively. For technique A, the anterior angle was determined at 12.43° ± 4.38°, while 9.06° ± 4.92° was measured for technique B. In the technique C, the needle is directed superiorly at 23.37° ± 4.16°.

No direct comparison can be made to other studies with regard to the simulations on the infant skulls, as other studies examined either living patients, with soft tissue present, or on adult skulls.

2.5.2.2 Simulation on paediatric cadavers

Although several methods have been developed to block the maxillary nerve within the pterygopalatine fossa, none of these included dissections on neonatal and infant cadavers. A few studies with regard to the supra-zygomatic maxillary nerve block have been performed by means of imaging techniques, for instance:

- Captier *et al.,* (2009) used computed tomographic (CT) scans to establish the distance and angles to block the maxillary nerve from the frontozygomatic angle;
- In a recently published study by Sola *et al.,* (2012) ultrasound was used in the blocking of the maxillary nerve from the frontozygomatic angle, in 25 children. This study can be considered as ground-breaking research due to the increased importance of ultrasound guidance in the field of regional anaesthetic nerve blocks.

In the author's opinion, there are several advantages in performing these procedures on cadavers by means of dissections. These include, "real-life" performance of procedures which will ensure that the results obtained will closely resemble what is experienced in theatre. Another advantage is observing the specific layers through which the needle will travel during the performance of the nerve blocks. This will assist the doctor performing the procedure to have knowledge of the anatomical structures that the needle needs to traverse in order to reach the target location.

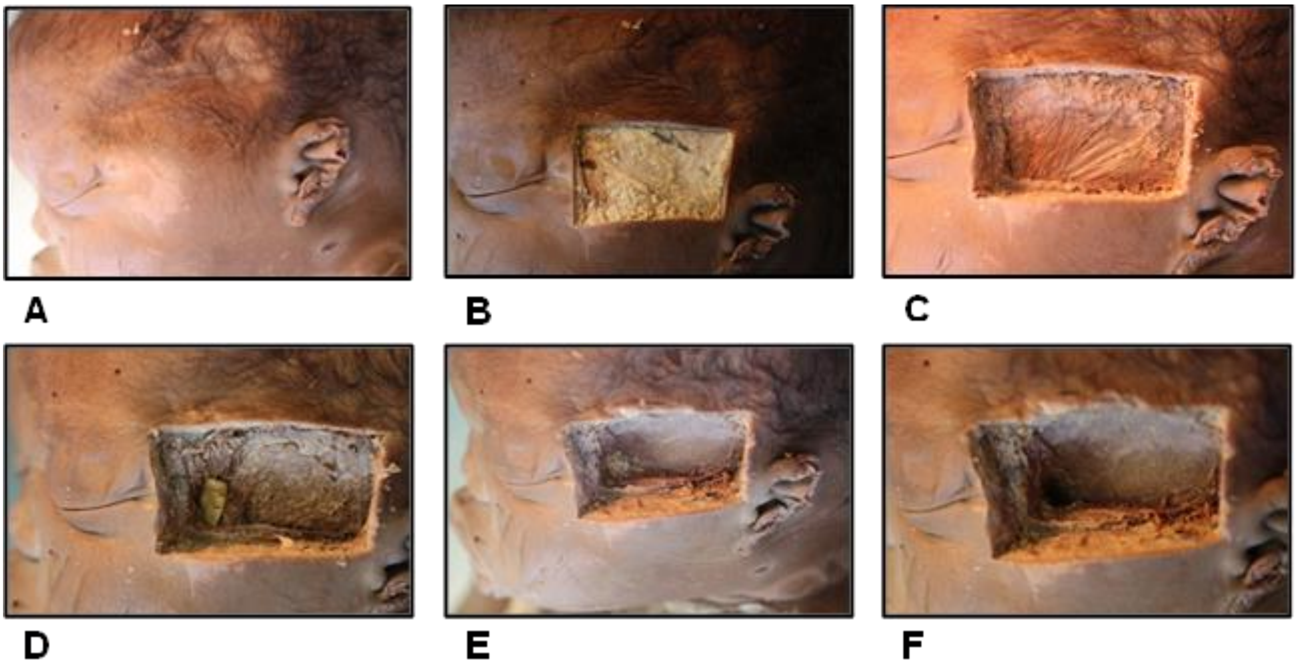


Figure 2.9 A – F: Cadaver dissections illustrating the layers through which the needle will travel to reach the pterygopalatine fossa, for techniques A and B.

In Figure 2.9 the following layers which will be traversed when techniques A or B is performed, including other structures, can be seen:

- A: Skin
- B: Subcutaneous fat and fascia
- C: Superficial layer of temporalis muscle
- D: Deep layer of the temporalis muscle including the temporal fat pad located between the layers of the temporalis muscle
- E: Portion of fat pad continuous with the buccal fat pad
- F: Pterygopalatine fossa

Techniques A and B are both supra-zygomatic approaches to the pterygopalatine fossa. Due to the close proximity of the structures, all the above-mentioned layers are consistent for both techniques.

The superficial temporal fat pad is important to note, to ensure that no anaesthetic is injected into the fat pad. According to Zuckerman *et al.,* (1990) fat necrosis could occur should the anaesthetic be accidently injected into the fat.

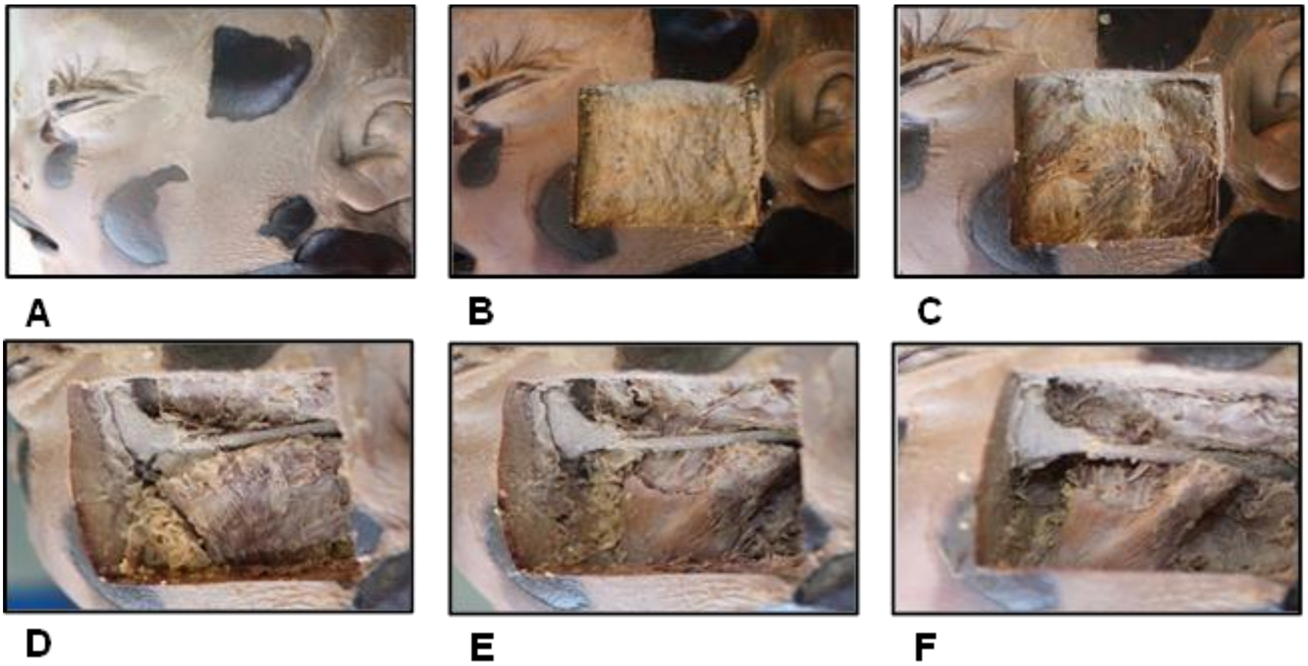


Figure 2.10 A – F: Photographs of cadaver dissections illustrating the layers traversed during the performance of technique C.

From Figure 2.10 A – F the following layers and structures can be seen that will be traversed when technique C is performed:

- A: Skin
- B: Subcutaneous fat and fascia
- C: Muscles of facial expression
- D: Buccal fat pad and masseter muscle
- E: Buccal fat pad, adjacent to the ramus of the mandible
- F: Pterygopalatine fossa

From Figure 2.10 the observation can be made that the buccal fat pad is also pierced by the needle, during the advancement to the pterygopalatine fossa. The needle will be inserted inferior to the zygomatic arch, and anterior to the ramus of the mandible.

The angles at which, and the distances that the needle travels during the performance of techniques A, B and C for Groups 1 and 2 are plotted in Table 2.3 and Table 2.4 respectively. Compared to other studies, the data falls within the normal range of obtained values. Sola *et al.* (2012) tracked the needle for the maxillary nerve block by means of ultrasound. The needle was advanced for 35 – 45mm from the frontozygomatic angle to the pterygopalatine fossa. However, this study was conducted on children (no age mentioned). In our study the needle is advanced 21.1mm ± 0.85mm for Group 1 and 26.74mm ± 2.81mm for Group 2 respectively. The “shorter” distances in Group 1 can be attributed to the age of the “patients/specimens” used.

Captier *et al.* (2009) performed technique B with the use of CT scans. From the skin to the foramen rotundum, the needle was advanced 47.4mm ± 4.1mm for children up to age 16 months. They state “These distances and angles must be slightly adapted for infants younger than six months.” However, a limitation to this study can be considered the lack of specific age of the skulls and cadavers. However the age was determined within the neonatal and infant categories by a paleo-anthropologist.

2.5.2.3 Comparison of the skulls and cadavers for each technique.

To effectively achieve anaesthesia or analgesia by means of regional anaesthesia, the needle needs to be placed in close proximity to the nerve or plexus, to block transmission of nerve impulses. The success of regional nerve blocks is predominantly dependant on the correct identification of the nerve and accurate needle placement (Nicholls *et al.,* 2009).

In order to ultimately establish the best method of blocking the maxillary nerve within the pterygopalatine fossa, the different techniques where compared with regard to the skull and cadaver simulations.

These comparisons were done after the values of the left and right sides were assessed. No statistically significant difference ($p > 0.05$) was noted when comparing the two sides, which indicate that the distance and angle measurements are not side specific.

In Figures 2.8 A and B, the values from the cadavers and skulls were compared for each specific technique related to the age group. Technique A exhibited a statistical difference ($p < 0.05$) with regard to the superior-inferior angle for both Groups 1 and 2. This technique was more difficult to perform due to the difficulty in palpating the bony landmarks in the cadavers. This might explain the difference in angles between the skull and cadaver measurements.

Technique C exhibited a statistical difference ($p < 0.05$) in Group 2, with relation to the depth the needle needs to travel to reach the pterygopalatine fossa. The cadaver measurements presented greater difficulty due to the increased soft tissue present.

In technique B, the bony landmarks could more easily be palpated. No statistical difference ($p > 0.05$) was observed when comparing the skull and cadaver measurements for both age groups. Consequently, the measurements with regard to the angles and depth that the needle travels to reach the maxillary nerve at the foramen rotundum within the pterygopalatine fossa, were combined to give a total sample of 64, as seen in Table 2.5.

When the measurements were compared, the only technique that showed the smallest differences between the results obtained from the skulls and cadavers was technique B. Therefore, according to this study, technique B is the most efficient method of blocking the maxillary nerve. This corresponds to several other documented studies. Stajcic and Todorovic (1997) state that this technique can be considered the safest approach and recommended method to reach the foramen rotundum through which the maxillary nerve passes, due to the trajectory of the needle, which limits its insertion to only the anterior part of the pterygopalatine fossa. Thus avoiding puncture of the infra-orbital contents that can occur should the needle pass through the infra-orbital fissure.

A limitation that exists in this study is the absence of tissue depth from the skin to the level of the zygomatic arch. However, the bony landmark can easily palpated, therefore the needle can be inserted, and “guided” along the zygomatic arch from where the obtained depth can be used to advance the needle.

Nevertheless, this technique still needs to be tested in a clinical setting to ensure that the measurements in terms of the angles and depths that the needle travel to reach the pterygopalatine fossa is truthful and can be used in blocking the maxillary nerve in paediatric patients.

2.6 Conclusion

In conclusion, the supra-zygomatic approach from the frontozygomatic angle (technique B**)** produces the most consistent results in a young paediatric sample.

When this frontozygomatic approach is used, for the neonatal group, the needle can be angled almost perpendicular to the median plane (0.21° ± 1.59°), while it is also angled anteriorly (12.98° ± 1.33°), travelling in a posterior direction. The needle should be progressed approximately 21.37mm ± 1.03mm from the zygomatic process in order for the tip of the needle to be within the pterygopalatine fossa.

For the infant group of cadavers, the needle is also inserted almost perpendicular to the median plane, at an angle of 0.35° ± 2.87° in the superior-inferior plane, while in the anterior-posterior plane it should be angled 10.94° ± 3.04° and advanced 28.52mm ± 2.77mm from the zygomatic process to successfully enter the pterygopalatine fossa.

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3.1. Introduction

Walonick (2000) states that we are currently residing in the information age. More information has been published in the last decade than in all previous history. Information is useful in making decisions that will determine the future, and should the information be accurate, the probability of making a good decision increases.

The opposite is also true. Inaccurate information diminishes our ability to generate correct. Therefore, better information usually leads to better decision making. Information can be obtained through a literature review, communication with people either in direct conversations, telephone surveys or interviews, as well as the use of mailing surveys or questionnaires (Walonick, 2000).

Questionnaires are one of the most common methods of gathering information, and are therefore used widely in surveys to retrieve the views and opinions of large numbers of people (Robinson, 2006; Livesey, 2010). It is a simple method for collecting and recording information related to a particular interest. Questionnaires consist of a list of questions directly related to the objective of the research and are usually associated with quantitative research, asking questions related to performance, frequency, satisfaction and complications (Kirklees, 2008). The higher the quality of the questions, the more accurate the feedback the researcher obtains.

However, the quality of the questions is not nearly as important as the actual information that the researcher is trying to obtain. In this study the aim of the questionnaire is related to paediatric regional anaesthesia. Dr Paul Miles, member of the American board of paediatrics Inc., states that pain management is a key measure of quality in children's healthcare and addressing this problem requires specialized knowledge, skill and, most important, a commitment to provide care as pain-free as possible for each child (Tobias and Deshpande, 1996).

In the last two decades the use of regional anaesthesia in paediatric patients has increased tremendously (Giaufré *et al*., 1996). Several paediatric studies have indicated the advantages of using regional anaesthesia in a variety of surgeries.

Less nausea, sedation of respiratory depression is observed when using regional anaesthesia rather than systemic opioids (Shandling and Steward, 1980; Tree-Trakarn and Pirayavaraporn, 1985; Dalens *et al*., 1986; Berde, 1989; Tverskoy *et al*., 1990).

The driving force in the field of paediatric regional anaesthesia is the knowledge that children do not only experience pain, but it is experienced at a much higher and more intense level than adults. Maltreatment of this experienced pain will not only result in serious physiological consequences, but complications such as pulmonary dysfunction, delayed wound healing, and ultimately delayed recovery will be the result of the day (Brenda and Krane, 2003; Jonnavithula *et al*., 2007).

A very effective method of pain management is the use of peripheral nerve blocks (Narouze, 2007). A pain-free patient, especially during the post-operative period, is easier to manage, which will also ensure that the surgical site is better cared for, and therefore resulting in better healing (Jonnavithula *et al*., 2007). However, clinicians should only practise nerve blocks if they are familiar with the anatomy and procedure, to avoid potential critical complications (Narouze, 2007).

Paediatric regional anaesthesia, especially in head and neck surgeries, is considered a strange and undiscovered practice by some, even though it is a growing field. However, the following important factors need to be flawlessly understood: Adult landmarks, measurements, and methods which differ significantly from paediatric patients, due to the still developing skull, organs and bony structure (Bosenberg, 1999).

An impeccable anatomical knowledge, including the significant differences between different age groups, needs to be established prior to the performance of regional anaesthetic nerve blocks in the head and neck region of paediatric patients. Therefore, the success of correctly placing peripheral nerve blocks requires detailed knowledge of the applicable human anatomy and the use of proper equipment (Tobias and Deshpande, 1996).

Yet, some doctors performing nerve blocks are often unfamiliar or unpractised in the art of correctly placing nerve blocks. The failure of accessing and understanding the correct relevant information will ultimately lead to a higher incidence of complications and difficulties experienced. In order to assist these doctors in refining their anatomical knowledge and increasing their confidence in performing these nerve blocks, the procedures which are experienced as problematic first need to be identified and evaluated.

3. 2. Aims

The aims of the following research chapter are:

3.2.1 To develop a quantitative research method by means of a detailed questionnaire to determine the following:

3.2.1.1 Which paediatric regional anaesthetic procedures are regularly performed in the head and neck region, by a reliable sample?

3.2.1.2 The frequency of occurrence of the procedures.

3.2.1.3 The importance of each regional anaesthetic procedure in the practice of anaesthesiology.

3.2.1.4 How comfortable the practising anaesthesiologist feels whilst performing each procedure on paediatric patients.

3.2.1.5 Difficulties and anatomically related complications experienced during the performance of each procedure on paediatric patients.

3.2.1.6 The role that a sound anatomical knowledge plays in the prevention of these difficulties and complications.

3.2.1.7 The importance of clinical anatomy knowledge in improving the comfort levels of the anaesthesiologist whilst performing these blocks.

3.2.2 To select four procedures from the list of paediatric regional anaesthetic procedures (listed in Table 3.1) using the selection criteria in 3.2.1

Difficulties in performing the regional anaesthetic nerve blocks, and complications encountered, will be the main areas of focus when selecting the four problem procedures.

3.3. Materials and Methods

3.3.1 Development of survey

A quantitative research method was employed by means of a detailed questionnaire (Appendix B) to determine which paediatric regional nerve blocks of the head and neck are performed most frequently on paediatric patients by South African anaesthesiologists.

The questionnaire was developed through a widespread and thorough literature review, after which a total of 17 regional nerve blocks most commonly performed on the head and neck region of paediatric patients were selected. Nine nerve block procedures were selected for the head region and eight for the neck region. The chosen procedures for each section are listed in Table 3.1.

Table 3.1: Complete list of selected procedures

Paediatric regional anaesthetic procedures
Blocks performed in the head region
Facial nerve block (Block 1)
Trigeminal nerve block
Ophthalmic division
Supra-orbital and supra-trochlear nerve block (Block 2)
Maxillary division
Infra-orbital nerve block: INTRA-ORAL approach (Block 3)
Infra-orbital nerve block: EXTRA-ORAL approach (Block 4)
Zygomaticotemporal nerve block (Block 5)
Zygomaticofacial nerve block (Block 6)
Palatine nerve block (Block 7)
Mandibular division
Mental nerve block (Block 8)
Auriculotemporal nerve block (Block 9)

Table 3.1: Complete list of selected procedures (continued)

Blocks performed in the neck region
Cervical plexus nerve block (Block 1)
Greater auricular nerve block (Block 2)
Lesser occipital nerve block (Block 3)
Anterior cutaneous / Transverse cervical nerve block (Block 4)
Supraclavicular nerve block (Block 5)
Glossopharyngeal nerve block (Block 6)
Superior laryngeal nerve block (Block 7)
Recurrent laryngeal nerve block (Block 8)
Stellate ganglion block (Block 9)

The questionnaire commenced with a detailed cover page explaining the aim and importance of the relevant research. (Appendix A)

Demographic data was obtained from the participating respondents with regard to the years of practice and experience of the practising anaesthesiologists. This data was used to determine the validity of the response.

The questionnaire was developed to identify the following within a reliable sample:

- Which paediatric regional anaesthetic procedures are regularly performed;
- The frequency of occurrence of the procedures;
- The importance of each regional anaesthetic procedure in the practice of anaesthesiology;
- How comfortable the practising anaesthesiologist feels whilst performing each procedure on paediatric patients;
- Difficulties and anatomically related complications experienced during the performance of each procedure on paediatric patients;
- The role that a sound anatomical knowledge plays in the prevention of these difficulties and complications;
- The importance of clinical anatomy knowledge in improving the comfort levels of the anaesthesiologist whilst performing these blocks.

The above mentioned criteria were determined through an extensive literature review. Each question sited within the questionnaire reflected a specific aim and objective (Table 3.2A). It also included the most common complications for each procedure, which the practising anaesthesiologist might experience. These are summarised in Table 3.2B. The respondent could identify more than one related complication, by indicating them in the questionnaire. If no options were identified, it was assumed that no complications were experienced by the anaesthesiologist when performing the specific procedure. The response of the participating anaesthesiologist aided in the comparison of the collected data and were analysed as categorical data.

Demographic data were also obtained from each of the contributing practitioners. This included the years of experience that the contributing respondent has completed:

- Anaesthesiology registrar
- 1 – 3 years
- 4 – 6 years
- 7 – 9 years
- 10 years or more

Table 3.2A: Summary of questionnaire containing the objective, related question or statement as well as the possible responses

<table>
<tr><th>Objective</th><th>Question/ Statement</th><th colspan="60">Response</th></tr>
<tr><td rowspan="2">Which paediatric regional anaesthetic procedures are regularly performed by a reliable sample</td><td>I perform this procedure:</td><td colspan="30">Yes</td><td colspan="30">No</td></tr>
<tr><td>I perform this procedure on</td><td colspan="20">Adults</td><td colspan="20">Children</td><td colspan="20">Adults and Children</td></tr>
<tr><td>The frequency of occurrence of the procedures</td><td>How many times did you perform this procedure in the past year?</td><td colspan="15">More than 20</td><td colspan="15">10 – 20</td><td colspan="15">5 – 10</td><td colspan="15">Less than 5</td></tr>
<tr><td>The importance of each regional anaesthetic procedure in the practice of anaesthesiology</td><td>The performance of this procedure is important for my practice</td><td colspan="15">Essential</td><td colspan="15">Desirable but not essential</td><td colspan="15">Useful</td><td colspan="15">Not necessary</td></tr>
<tr><td>How comfortable the practising anaesthesiologist feels whilst performing each procedure on paediatric patients</td><td>I feel comfortable to perform this procedure</td><td colspan="15">Very comfortable</td><td colspan="15">Fairly comfortable</td><td colspan="15">Uncomfortable</td><td colspan="15">Very uncomfortable</td></tr>
<tr><td>Difficulties and anatomically related complications experienced during the performance of each procedure on paediatric patients</td><td>I find difficulty to perform this procedure due to the following reasons:</td><td colspan="15">Knowledge of the procedure itself</td><td colspan="15">Equipment necessary for the procedure</td><td colspan="15">Practical skills to perform the procedure</td><td colspan="15">Regional anatomy knowledge</td></tr>
<tr><td rowspan="2">To determine the specific complications encountered while performing regional anaesthetic procedures</td><td rowspan="2">I met the following complications and difficulties when performing this procedure</td><td colspan="60">Facial nerve block is provided as an example:</td></tr>
<tr><td colspan="12">Intra-vascular injection</td><td colspan="12">Difficulty in palpation of bony landmarks</td><td colspan="12">Respiratory obstruction/ difficulty in swallowing</td><td colspan="12">Permanent unilateral palsy of facial musculature</td><td colspan="12">Ipsi-lateral facial weakness</td></tr>
<tr><td>The role that a sound anatomical knowledge plays in the prevention of these difficulties and complications</td><td>The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure</td><td colspan="15">Strongly agree</td><td colspan="15">Agree</td><td colspan="15">Disagree</td><td colspan="15">Strongly disagree</td></tr>
<tr><td>The importance of clinical anatomy knowledge in improving the comfort levels of the anaesthesiologist whilst performing these blocks</td><td>Improvement of my anatomical knowledge will increase my confidence in performing this procedure</td><td colspan="15">Strongly agree</td><td colspan="15">Agree</td><td colspan="15">Disagree</td><td colspan="15">Strongly disagree</td></tr>
</table>

Table 3.2 B: Anatomical complications relevant for each selected procedure.

Blocks performed in the head region							
Nerve block	Complications						
Facial nerve block	Intravascular injection	Difficulty in palpation of bony landmarks	Respiratory obstruction / difficulty in swallowing	Permanent unilateral palsy of facial musculature	Ipsi-lateral facial weakness	❖
Trigeminal nerve: Ophthalmic division (Supra-orbital and Supra-trochlear nerve block)	Deficient needle placing, resulting in spread of anaesthetic	Intravascular injection	Difficulty in palpation of bony landmarks	Incorrect anaesthetic due to variable location of nerves	Damage to eye globe	Black eye due to injury of loose vascular connective tissue
Trigeminal nerve: Ophthalmic division (Infra-orbital nerve block) INTRA-ORAL APPROACH	Needle placed in wrong direction	Difficulty of palpation of infra-orbital foramen or bony landmarks	Damage of nerve by compression within foramen	Damage of orbital contents through penetration of orbital floor	❖	❖
Trigeminal nerve: Ophthalmic division (Infra-orbital nerve block) EXTRA-ORAL APPROACH	Difficulty of palpation of infra-orbital foramen or bony landmarks	Injury to nerve	Intravascular injection	❖	❖	❖
Trigeminal nerve: Maxillary division (Zygomaticotemporal nerve block)	Inadequate anaesthesia due to subcutaneous infiltration	Difficulty in palpation of bony landmarks	❖	❖	❖	❖
Trigeminal nerve: Maxillary division (Zygomaticofacial nerve block)	Inadequate anaesthesia due to subcutaneous infiltration	Difficulty in palpation of bony landmarks	❖	❖	❖	❖
Trigeminal nerve: Maxillary division (Palatine nerve block)	Intravascular injection	Intraneural injection	Difficulty in palpation of bony landmarks	❖	❖	❖
Trigeminal nerve: Mandibular division (Mental nerve block)	Intravascular injection	Damaging of neural structures	Difficulty in palpation of mental foramen or bony landmarks	❖	❖	❖
Trigeminal nerve: Mandibular division (Auriculotemporal nerve block)	Intravascular injection	Penetration of superficial temporal artery	Damaging of neural structures	Difficulty in palpation of bony landmarks	❖	❖

Blocks performed in the neck region						
Nerve block	Complications					
Cervical plexus (Great auricular nerve block)	Intravascular injection [puncturing of external jugular vein (EJV)]	Difficulty in palpation of bony landmarks	Inability to identify muscular landmarks	Blocked deep cervical plexus	Blocked phrenic nerve	❖
Cervical plexus (Lesser occipital nerve block)	Intravascular injection [puncturing of EJV)	Difficulty in palpation of bony landmarks	Inability to identify muscular landmarks	❖	❖	❖
Cervical plexus (Greater occipital nerve block)	Intravascular injection [puncturing of occipital artery]	Difficulty in palpation of bony landmarks	Difficulty in identifying of muscular landmarks	❖	❖	❖
Cervical plexus (Transverse cervical nerve block)	Intravascular injection [puncturing of EJV]	Difficulty in palpation of bony landmarks	Difficulty in identifying of muscular landmarks	❖	❖	❖
Cervical plexus (Supraclavicular nerve block)	Intravascular injection [puncturing of EJV]	Difficulty in palpation of bony landmarks	Difficulty in identifying of muscular landmarks	Injury to nerve	Pneumo-thorax due to penetration of apical pleura	❖
Glossopharyngeal nerve block	Intravascular injection [puncturing of the vertebral artery, common carotid artery or IJV]	Blocked facial nerve	Facial weakness	Facial sensory deficit	CSF leak	Blocked vagus and accessory nerves resulting in weakness of SCM and trapezius muscles and hoarseness
Superior laryngeal nerve block	Intravascular injection	Damage to other closely related structures	Difficulty in palpation of bony landmarks	❖	❖	❖
Recurrent laryngeal nerve block	Horner's syndrome	Hoarseness	Sensation of having a lump in the throat	Shortness of breath due to paralysis of phrenic nerve	❖	❖
Stellate ganglion block	Intravascular injection [puncturing of vertebral or common carotid artery	Diffusion of local anaesthetic to adjacent neural structures	Horner's syndrome [ptosis, myosis, enopthalmos, anhidrosis of neck and face	Dural puncture resulting in intraspinal injection	Pneumo-thorax	Needle trauma to closely related structures

3.3.1.1 Conveyance of survey

A qualitative research method was employed by means of a detailed questionnaire (Appendix B). An electronic mail message (e-mail) containing a detailed cover letter explaining the intent/aim of the survey, as well as the conditions of participation, was sent to 698 anaesthesiologists registered on the Medpages website (www.medpages.co.za).

The questionnaire was completed anonymously, to prevent all favouritism or any bias on any and all areas, relating to years of experience, preferred procedures and prevalence of regional anaesthetic nerve blocks.

The anaesthesiologists completed the questionnaire unaccompanied and on their own time schedule. Depending on the amount of regional anaesthetic procedures the respondent performed, completion took approximately 20 minutes.

Each questionnaire contained several questions, preceded by a box. The respondent answered the question by ticking in the box. This assisted the respondent in choice, as well as provided a system able of comparing the data categorically due to various calculations being performed.

After completing the questionnaire electronically, they were returned as an attachment to the e-mail address. All returned questionnaires were saved on a secure drive and no information regarding the respondent was or will be made available.

The aim was to reach a sample size of 100 completed electronic questionnaires. Initially the e-mail response to the questionnaires was poor, with only 54 complete questionnaires retrieved from participating anaesthesiologists. In an attempt to receive a better outcome, questionnaires were handed out and completed in personal meetings and contact sessions. Anaesthesiologists were also approached at two South African anaesthesiology conferences (Pain Interventions and Regional Anaesthesia and South African Society of Anaesthesiologists) held in

2011. The purpose and aim of the questionnaire were briefly explained to each willing participant, after which they completed a hard copy of the questionnaire.

Although some of the questionnaires were completed on printed copies, anonymity remained the same. The completed questionnaires were placed in a box, without any information pertaining to the respondent being noted. The researcher protected anonymity at all times and abstained from violating proper ethical conduct.

The only exclusion criteria related to experience. Only already qualified anaesthesiologists or registrars were included in the study. The survey was conducted country wide and contained doctors from various demographic backgrounds. Demographic data was noted and included in the study.

3.3.1.2 Analysis of data produced by the questionnaire

In order to accurately analyse the retrieved data, every possible option in the questionnaire was given a corresponding numerical value in order to effectively compare the received responses. These numerical data were entered into an Excel workbook for statistical analysis.

The incidence of performance was firstly calculated with regard to two questions. The first question in the survey pertains to whether the specific procedure is performed. “Yes” is represented by **(1)**, and “No” by **(2)**. The second question identified the type of patients on which this nerve block is performed. “Adults only” is indicated with **(1)**, “Children only” with **(2)** and Adults and children with **(3).**

The remainder of the questions was only analysed if the practising anaesthesiologist indicated “Yes” in question 1, with the exception of question 8 and question 9, which establish the necessity of anatomical knowledge in the accurate performance of the indicated nerve block. The frequency of the specific nerve block is established by the following values: Performed more than 20 times **(1)**; 10 – 20 times **(2)**; 5 – 10 times **(3)**; and less than 5 **(4)**.

The importance of the indicated nerve block was assessed based on the following four categories: Essential **(1)**; Desirable but not essential **(2)**; Useful **(3);** Not necessary **(4)**.

The level of comfort by which the nerve block is performed was quantified as follows: Very comfortable **(1)**; fairly comfortable **(2)**; Uncomfortable **(3)** and Very uncomfortable **(4)**.

The reason for difficulty experienced by the respondent can be linked to any of the following four statements, each which is quantified as follows: Lack of knowledge of the procedure itself **(1)**; Unavailability of necessary equipment to perform procedure **(2)**; Absence of practical skills to perform necessary nerve block **(3)**; Insufficient regional anatomical knowledge **(4)**.

The complications that can be experienced during the performance of each nerve block differ greatly. Each of the various complications receives a numerical value that allows quantification of the question.

With regard to the two final categories, all the complete questionnaires were evaluated regardless of whether the specific nerve block is performed by the respondent. These categories assess the perceptions of the respondent, regardless of years of experience, to establish the necessity of clinical anatomical knowledge in the understanding and accurate performance of the specific nerve block.

To assess the importance of improving clinical anatomical knowledge in the reduction of difficulties and complications, Strongly agree **(1)**, Agree **(2)**, Disagree **(3)** and Strongly disagree **(4)** were the categories that the respondent completed, based on their own knowledge, training and perceptions.

To evaluated whether the respondents feel that improved anatomical knowledge will increase their personal confidence level while performing this procedure, the following four categories were quantified as follows: Strongly agree **(1)**, Agree **(2)**, Disagree **(3)** and Strongly disagree **(4)**

A simple count function (COUNTIF) was conducted on all the above mentioned quantified data to establish the exact quantity of hits that occurred in each specific category.

3.3.1.3 Ethical concerns

Ethical clearance for the conduction of the survey was obtained from the Ethics and Research Committee of the Faculty of Health Sciences at the University of Pretoria.

The survey was accompanied by a Letter of Inform Consent, which explained that:

- the respondent is not obliged to complete the questionnaire, which is therefore voluntarily completed;
- any acquired information will be handled confidentially;
- the respondent gives permission for the data from the survey to be used in the conduction of this study, once completed.

3.3.2 Selection of procedures and criteria for selection

Due to the nature of this study, no available criteria for selection existed that could be used. Therefore several possible scoring options were developed to ensure that the best possible representation of the selection criteria is portrayed.

Scoring options I, II and III were developed (see Appendix C).

Option III was selected due to the best representation of the selection criteria with regard to the:

- the specific block performed;
- complications and difficulties based on anatomical knowledge which could be identified;

- improvement of anatomical knowledge which will result in fewer complications and difficulty experienced and will result in an increased incidence during the performance of the block.

Scoring option III is as follows:

1. Patient demographics:		
	> Adults than children	1 point
	Adults = children	2 points
	> Children than adults	3 points
2. Incidence of performance:		
	0 - 4%	1 point
	4.1 - 8 %	2 points
	8.1 – 12 %	3 points
	12.1 – 15 %	4 points
	> 15 %	5 points
3. Essentiality:		
	< 40 %	1 point
	40 – 59 %	2 points
	60 – 79 %	3 points
	80 – 100%	4 points
4. Comfortability:		
	Uncomfortable 10 - 19 %	1 point
	Uncomfortable 20 – 29 %	2 points
	Uncomfortable > 30 %	3 points
	Uncomfortable > comfortable	4 points
5. Difficulty or complications, related to anatomy, experienced by:		
	10 – 19 %	1 point
	20 – 29 %	2 points
	> 30 %	3 points
6. Critical anatomical knowledge will reduce difficulties and complications:		
	80 – 90%	1 point
	91 – 100 %	2 points
7. Improvement of anatomical knowledge will increase confidence during performance of the procedure:		
	80 – 90 %	1 point
	91 – 100 %	2 points
	Maximum score	**23 points**

Due to the main focus of this study being the difficulties in performance of the regional anaesthetic nerve blocks and complications encountered, greater emphasis will be placed on these specific criteria, as well as the influence of enhancing anatomical knowledge in the reduction of these complications and difficulties.

Scoring option III best portrays these specific criteria, and was therefore used to select the procedures that the participating anaesthesiologist:

- felt essential in their practice;
- experienced the most complications and difficulties with;
- where they emphasised the importance of increase anatomical knowledge in the successful performance of paediatric regional nerve block of paediatric patients.

3.4. Results

3.4.1 Conduction of the survey

A total of 111 completed questionnaires were obtained either electronically form some respondents, from others attending either the Pain Interventions and Regional Anaesthesia Conference or the South African Society of Anaesthesiologists Conference.

The demographic data obtained from the respondents include the number of years of experience. Respondents had to choose one of the following options:

- Anaesthesiology registrar
- 1 – 3 years
- 4 – 6 years
- 7 – 9 years
- 10 years or more

A 98% completion rate, for the demographic data, resulted in an accurate representation of the years of experience of the general population. This can effectively assist in the understanding of the nerve blocks performed by the participating doctors. Figure 3.1 exhibits the demographic data by means of a pie-chart.

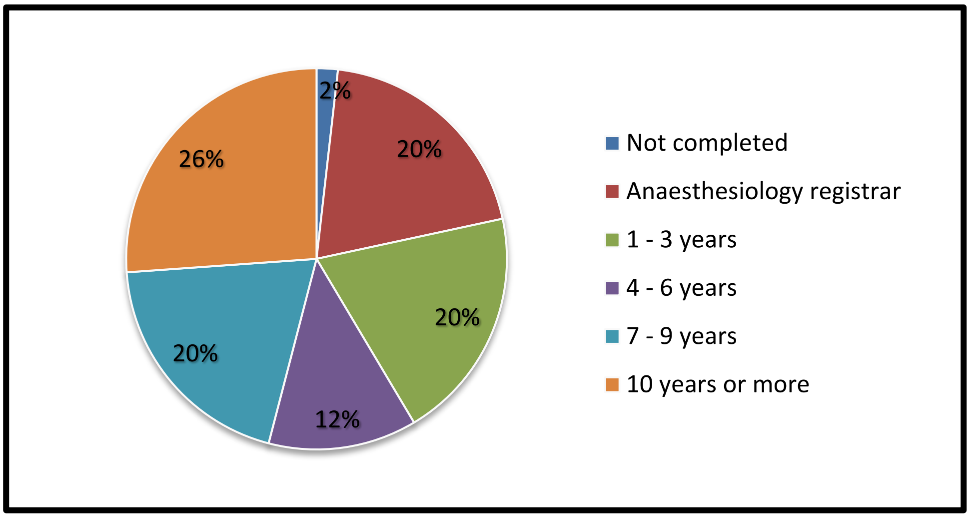


Figure 3.1: Distribution of demographic data

The results obtained from the questionnaires can be seen in Table 3.3. Due to the importance of questions 3, 7, 8 and 9 with regard to the evaluation of the frequency of performance, complications experienced and perceptions related to the importance of anatomy, separate tables and figures are used to emphasise these vital questions.

The responses for the following questions are represented in terms of percentage of completion in Table 3.3A

- Question 1: Percentage that performs the specific procedure
- Question 2: Percentage of blocks performed on children
- Question 4: Percentage that regards block as important
- Question 5: Percentage that feels comfortable with performing the specific nerve block
- Question 6: Percentage that experiences difficulty with one of the following:
    - Knowledge of the procedure itself
    - Equipment necessary for the procedure
    - Practical skills to perform this procedure
    - Regional anatomical knowledge

In Table 3.3A, each nerve block is associated with two sets of numbers. The first set contains the information relevant to only the doctors that perform each nerve block. The second line/set relates to opinions and perceptions of doctors who do not perform the specific nerve block. This might be explained by unfamiliarity of the specific block, or the specific specialisation of the participating doctor. Often a doctor chooses not to perform a nerve block, due to a lack of knowledge, or unfamiliarity in performing the nerve blocks. The second set of statistics will assist in the explanation of these cases and the ultimate goal of identifying the problem procedures.

Table 3.3A: Results obtained from questionnaires

Nerve block	Question 1	Question 2	Question 4	Question 5	Question 6			
	% that performs the block	% that performs block on children	% that feels the block is important for their practice	% that feels comfortable performing the block	% that experiences difficulty with:			
					Knowledge of procedure	Required equipment	Practical skills	Regional anatomical knowledge
Facial	1.8% (2/111)	50% (1/2)	50% (1/2)	50% (1/2)	50% (1/2)	0	0	0
			12.5% (1/8)	*28.6% (2/7)*	*62.5% (5/8)*	*0*	*25% (2/8)*	*12.5% (1/8)*
Supra-orbital & supra-trochlear	14% (15/111)	33.3% (5/15)	80% (12/15)	93.3% (14/15)	6.7% (1/15)	6.7% (1/15)	20% (3/15)	13.3% (2/15)
			83.3% (15/18)	*93.8% (15/16)*	*25% (2/8)*	*12.5% (1/8)*	*37.5% (3/8)*	*25% (2/8)*
Infra-orbital (INTRA-ORAL)	3.6% (4/11)	75% (3/4)	100% (4/4)	50% (2/4)	25% (1/4)	0	25% (1/4)	0
			62.5% (5/8)	*40% (2/5)*	*75% (3/4)*	*0*	*25% (1/4)*	*0*
Infra-orbital (EXTRA-ORAL)	8.1% (9/111)	77.8% (7/9)	88.9% (8/9)	88.9% (8/9)	0	0	11.1% (1/9)	11.1% (1/9)
			76.9% (10/13)	*83.3% (10/12)*	*33.3% (2/6)*	*0*	*33.3% (2/6)*	*33.3% (2/6)*
Zygomatico-temporal	0.9% (1/111)	0	100% (1/1)	100% (1/1)	0	0	0	0
			50% (3/6)	*25% (1/4)*	*66.7 (4/6)*	*0*	*16.7% (1/6)*	*16.7% (1/6)*
Zygomatico-facial	0.9% (1/111)	0	100% (1/1)	0	0	0	0	0
			50% (3/6)	*0*	*50% (2/4)*	*0*	*25% (1/4)*	*25% (1/4)*
Palatine	0	0	0	0	0	0	0	0
			40% (2/5)	*33.3% (1/3)*	*57.1% (4/7)*	*0*	*14.3% (1/7)*	*28.6% (2/7)*
Mental	4.5% (5/111)	60% (3/5)	100% (5/5)	80% (4/5)	0	0	0	0
			66.7% (6/9)	*66.7% (4/6)*	*50% (1/2)*	*0*	*50% (1/2)*	*0*
Auriculo-temporal	1.8% (2/111)	100% (2/2)	100% (2/2)	100% (2/2)	0	0	0	0
			50% (3/6)	*50% (2/4)*	*100% (3/3)*	*0*	*0*	*0*
Great auricular	1.8% (2/111)	50% (1/2)	100% (2/2)	100% (2/2)	0	0	0	0
			50% (3/6)	*50% (2/4)*	*100% (3/3)*	*0*	*0*	*0*
Lesser occipital	3.6% (4/111)	25% (1/4)	100% (4/4)	75% (3/4)	0	25% (1/4)	50% (2/4)	0
			62.5% (5/8)	*83.3% (5/6)*	*50% (3/6)*	*16.7% (1/6)*	*33.3% (2/6)*	*0*
Transverse cervical	2.7% (3/111)	33.3% (1/3)	100% (3/3)	100% (3/3)	0	0	33.3% (1/3)	0
			57.1% (4/7)	*75% (3/4)*	*75% (3/4)*	*0*	*25% (1/4)*	*0*
Supraclavicular	6.3% (7/111)	14.3% (1/7)	100% (7/7)	85.7% (6/7)	14.3% (1/7)	28.6% (2/7)	14.3% (1/7)	14.3% (1/7)
			80% (8/10)	*75% (6/8)*	*28.6% (2/7)*	*42.9% (3/8)*	*14.3% (1/7)*	*14.3% (1/7)*
Glosso-pharyngeal	2.7% (3/111)	33.3% (1/3)	100% (3/3)	66.7% (2/3)	33.3% (1/3)	0	33.3% (1/3)	33.3% (1/3)
			57.1% (4/7)	*60% (3/5)*	*50% (3/6)*	*16.7% (1/6)*	*16.7% (1/6)*	*16.7% (1/6)*
Superior laryngeal	13% (14/111)	21.4% (3/14)	92.9% (13/14)	78.6% (11/14)	14.3% (2/14)	0	7.1% (1/14)	35.7% (5/14)
			88.2% (15/17)	*80% (12/15)*	*33.3% (3/9)*	*0*	*11.1% (1/9)*	*55.6% (5/9)*
Recurrent laryngeal	5.4% (6/111)	16.7% (1/6)	100% (6/6)	66.7% (4/6)	66.7% (4/6)	0	16.7% (1/6)	33.3% (2/6)
			80% (8/10)	*62.5% (5/8)*	*62.5% (5/8)*	*0*	*12.5% (1/8)*	*25% (2/8)*
Stellate ganglion	4.5% (5/111)	0	80% (4/5)	80% (4/5)	40% (2/5)	0	20% (1/5)	20% (1/5)
			62.5% (5/8)	*85.7% (6/7)*	*50% (3/6)*	*16.7% (1/6)*	*16.7% (1/6)*	*16.7% (1/6)*

From Table 3.3A, it can clearly be establish that the following head and neck nerve blocks are performed most commonly:

- Supra-orbital and supra-trochlear nerve blocks which are performed by 14% of the participating doctors;
- Superior laryngeal nerve block is performed by 13% of the doctors;
- Infra-orbital nerve block, extra-oral approach is performed by 8.1% of the anaesthesiologists who participated in this survey.

Although the information of whether the nerve blocks are performed has been attained, the specific number or frequency of performance of these nerve blocks by the participating doctors will further assist in the clarification and understanding of these nerve blocks. Table 3.3B represents the frequency of performance of each nerve block.

Table 3.3B: Frequency of performance of each nerve block

Nerve block	**Question 2: % of how often the nerve block is performed per year**			
	More than 20 (> 20)	10 - 20	5 - 10	Less than 5 (< 5)
Facial	0	0	25%	75%
Supra-orbital & supra-trochlear	20%	27%	20%	33%
Infra-orbital (INTRA-ORAL)	0	0	0	100%
Infra-orbital (EXTRA-ORAL)	11%	22%	44%	11%
Zygomatico-temporal	0	0	0	100%
Zygomaticofacial	0	0	100%	0
Palatine	0	0	0	0
Mental	0	0	60%	40%
Auriculotemporal	0	0	50%	50%
Great auricular	50%	50%	0	0
Lesser occipital	25%	25%	25%	25%
Transverse cervical	33.3%	0	0	66.7%
Supraclavicular	14.2%	28.6%	0	57.1%
Glossopharyngeal	0	0	0	100%
Superior laryngeal	0	7.7%	30.8%	61.5%
Recurrent laryngeal	30%	30%	20%	20%
Stellate ganglion	20%	20%	40%	20%

From Table 3.3B it is evident that the nerve blocks most commonly performed are the supra-orbital and supra-trochlear with 20% of the procedures occurring more than 20 times a year and 27% of the procedures done between 10 and 20 times a year. The extra-oral approach of the infra-orbital nerve block, as well as the recurrent laryngeal nerve block, is performed 11% and 30% more than 20 times a year respectively.

The cervical plexus nerve blocks: Great auricular nerve block, lesser occipital nerve block, transverse cervical nerve block, lesser occipital and supraclavicular nerve blocks are performed by a small percentage of the anaesthesiologists; however, they perform these nerve blocks frequently with 50%, 25%, 33.3% and 14.2% of occurrence being more than 20 times a year.

Procedures such as zygomaticotemporal and zygomaticofacial nerve blocks are performed less than 10 times per annum, by one participating doctor. Auriculotemporal nerve blocks are infrequently performed, less than 10 times per annum; while the palatine nerve block is rarely performed by anaesthesiologists in Southern Africa. A direct correlation can therefore be seen between the percentage of doctors that perform certain nerve blocks as well as the frequency that they perform these nerve blocks.

Not only is the frequency of performance of each block of clinical importance, but the complications and difficulties doctors experience while performing these nerve blocks, have an imperative effect on their confidence and comfort levels. Yet each nerve block has its own set of complications. Table 3.3C summarises the complications experienced by the participating doctors, expressed as a percentage for each specific complication.

Table 3.3 C: Regional nerve block complications and difficulties

Blocks performed in the head region												
Nerve block	**Complications**											
Facial nerve block	Intravascular injection	0	Difficulty in palpation of bony landmarks	0	Respiratory obstruction / difficulty in swallowing	0	Permanent unilateral palsy of facial musculature	0	Ipsi-lateral facial weakness	50% (1/2)	❖	❖
Trigeminal nerve: Ophthalmic division (Supra-orbital & Supra-trochlear nerve block)	Deficient needle placing, resulting in spread of anaesthetic	27.7% (5/18)	Intravascular injection	11.1% (2/18)	Difficulty in palpation of bony landmarks	22.2% (4/18)	Incorrect anaesthetic due to variable location of nerves	11.1% (2/18)	Damage to eye globe	5.6% (1/18)	Black eye due to injury of loose vascular connective tissue	22.2% (4/18)
Trigeminal nerve: Ophthalmic division (Infra-orbital nerve block) INTRA-ORAL APPROACH	Needle placed in wrong direction	25% (1/4)	Difficulty of palpation of infra-orbital foramen or bony landmarks	50% (2/4)	Damage of nerve by compression within foramen	0	Damage of orbital contents through penetration of orbital floor	0	❖	❖	❖	❖
Trigeminal nerve: Ophthalmic division (Infra-orbital nerve block) EXTRA-ORAL APPROACH	Difficulty of palpation of infra-orbital foramen or bony landmarks	55.6% (5/9)	Injury to nerve	0	Intravascular injection	0	❖	❖	❖	❖	❖	❖
Trigeminal nerve: Maxillary division (Zygomaticotemporal nerve block)	Inadequate anaesthesia due to subcutaneous infiltration	0	Difficulty in palpation of bony landmarks	0	❖	❖	❖	❖	❖	❖	❖	❖
Trigeminal nerve: Maxillary division (Zygomaticofacial nerve block)	Inadequate anaesthesia due to subcutaneous infiltration	0	Difficulty in palpation of bony landmarks	0	❖	❖	❖	❖	❖	❖	❖	❖
Trigeminal nerve: Maxillary division (Palatine nerve block)	Intravascular injection	0	Intraneural injection	0	Difficulty in palpation of bony landmarks	0	❖	❖	❖	❖	❖	❖
Trigeminal nerve: Mandibular division (Mental nerve block)	Intravascular injection	0	Damaging of neural structures	0	Difficulty in palpation of mental foramen or bony landmarks	20% (1/5)	❖	❖	❖	❖	❖	❖
Trigeminal nerve: Mandibular division (Auriculotemporal nerve block)	Intravascular injection	0	Penetration of superficial temporal artery	0	Damaging of neural structures	0	Difficulty in palpation of bony landmarks	0	❖	❖	❖	❖

Blocks performed in the neck region												
Nerve block	**Complications**											
Cervical plexus (Great auricular nerve block)	Intravascular injection (puncturing of external jugular vein)	0	Difficulty in palpation of bony landmarks	0	Inability to identify muscular landmarks	0	Blocked deep cervical plexus	0	Blocked phrenic nerve	0	❖	❖
Cervical plexus (Lesser occipital nerve block)	Intravascular injection (puncturing of external jugular vein)	0	Difficulty in palpation of bony landmarks	66.7% (2/3)	Inability to identify muscular landmarks	33.3% (1/3)	❖	❖	❖	❖	❖	❖
Cervical plexus (Transverse cervical nerve block)	Intravascular injection (puncturing of external jugular vein)	0	Difficulty in palpation of bony landmarks	33.3% (1/3)	Difficulty in identifying of muscular landmarks	0	❖	❖	❖	❖	❖	❖
Cervical plexus (Supraclavicular nerve block)	Intravascular injection (puncturing of external jugular vein)	14.2% (1/7)	Difficulty in palpation of bony landmarks	28.6% (2/7)	Difficulty in identifying of muscular landmarks	42.9% (3/7)	Injury to nerve	0	Pneumo-thorax due to penetration of apical pleura	0	❖	❖
Glossopharyngeal nerve block	Intravascular injection (puncturing of the vertebral artery, common carotid artery or internal jugular vein)	0	Blocked facial nerve	0	Facial weakness	0	Facial sensory deficit	0	CSF leak	0	Blocked vagus & accessory nerves resulting in weakness of sternocleidomastoid & trapezius muscles and hoarseness	33.3% (1/3)
Superior laryngeal nerve block	Intravascular injection	0	Damage to other closely related structures	0	Difficulty in palpation of bony landmarks	50% (7/14)	❖	❖	❖	❖	❖	❖
Recurrent laryngeal nerve block	Horner's syndrome	0	Hoarseness	33.3% (2/6)	Sensation of having a lump in the throat	16.7% (1/6)	Shortness of breath due to paralysis of phrenic nerve	0	❖	❖	❖	❖
Stellate ganglion block	Intravascular injection (puncturing of vertebral or common carotid artery)	16.7% (1/6)	Diffusion of local anaesthetic to adjacent neural structures	0	Horner's syndrome (ptosis, myosis, enopthalmos, anhidrosis of neck & face)	83.3% (5/6)	Dural puncture resulting in intraspinal injection	0	Pneumo-thorax	0	Needle trauma to closely related structures	0

From Table 3.3C, the following observations can be made:

- The supra-orbital and supra-trochlear nerve blocks appear problematic to the doctors who perform these nerve blocks, due to the variety in complications and difficulties experienced. Several doctors also selected multiple options with regard to complications, therefore the total is 18, even though only 15 doctors indicated that they perform this nerve block
    - 27.7% of doctors experience difficulties based on needle placing;
    - 11.1% experience intravascular injection complications;
    - 22.2% find it difficult to palpate the bony landmarks;
    - 11.1% struggle with the variable location of the nerves;
    - 5.6% have experienced damage to the eye globe;
    - 22.2% have caused a black eye due to loose vascular connective tissue.
- The extra-oral approach of the infra-orbital nerve block, resulted in a 55.6% complication rate due to difficulty in palpating the bony landmark;
- The supraclavicular nerve block leads to problems with intravascular injection (14.2%), palpation of bony landmarks, (28.6%) and identification of muscular landmarks (42.9%);
- Superior laryngeal nerve block has a 50% complication rate based on difficulty of palpation of bony landmarks;
- Zygomaticotemporal, zygomaticofacial, palatine and auriculotemporal nerve blocks had no complications, due to the infrequent performance of these nerve blocks.

Most of these complications and difficulties can directly be related to an insufficient anatomical knowledge, or a misunderstanding of the relevant anatomy. Questions 8 and 9 attempted to evaluate the perceptions about anatomical knowledge and complications encountered. Figure 3.2 illustrates the results on Question 8: “Improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure,” while Figure 3.3 illustrates Question 9: “Improvement of my anatomical knowledge will increase my confidence in performing this procedure”.

Figure 3.2: Results of Question 8: “The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure”

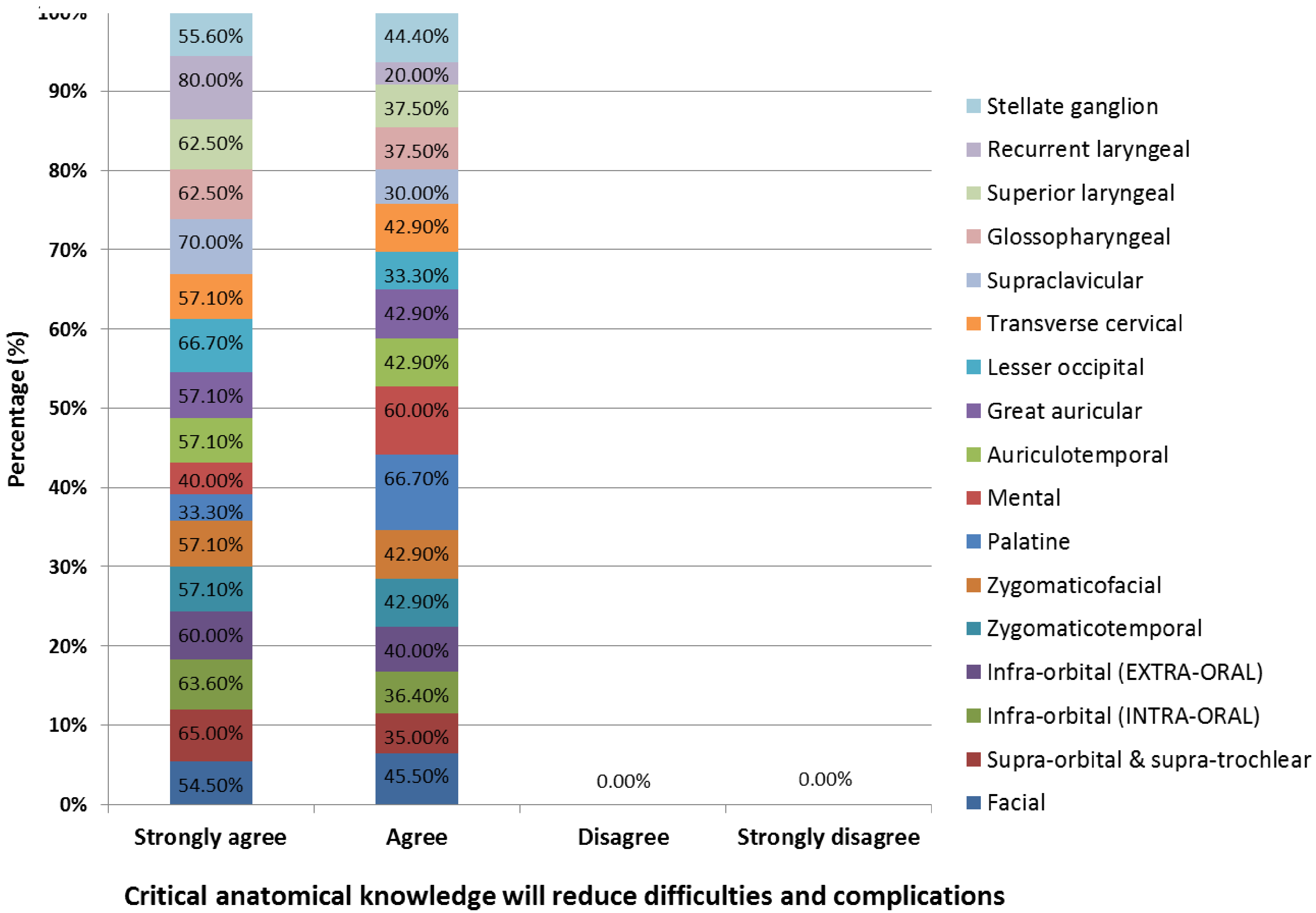
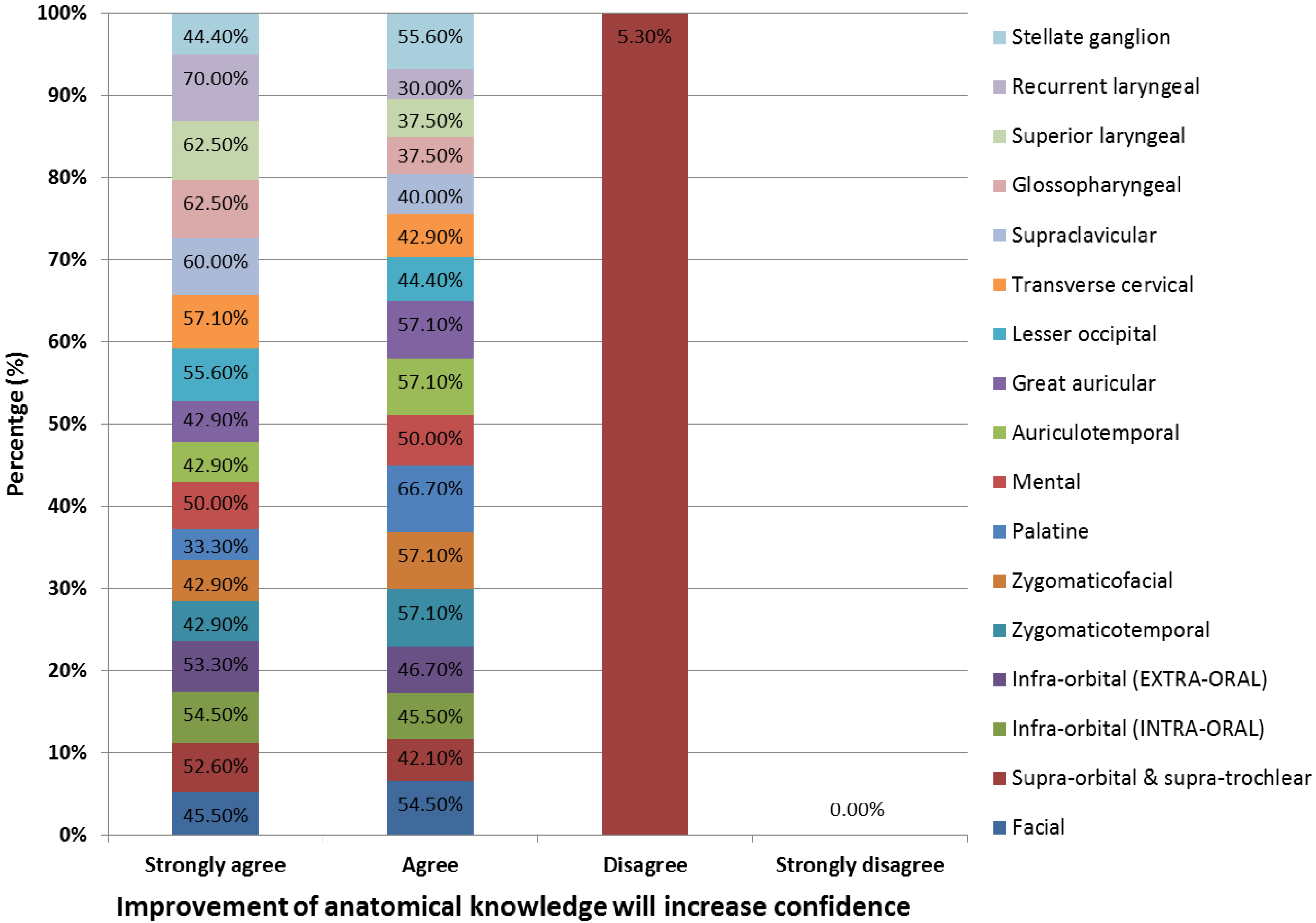


Figure 3.3: Results of Question 9 “The improvement of my anatomical knowledge will increase my confidence in performing this procedure.”



Figures 3.2 and 3.3 illustrate the results of questions 8 and 9. In these two questions, all the obtained responses have been used, even if an anaesthesiologist did not perform the specific nerve block. This can be explained based on the perception that a doctor does not need to perform a nerve block, to appreciate and realise the importance of clinical anatomy in the performance of these nerve blocks. Anatomical knowledge will assist in the reduction of complications and difficulties, and the successful completion of the performed nerve block.

It is clear that, with the exception of one, all the doctors expressed the importance of thorough clinical anatomy knowledge in the reduction of complications, and the improvement of confidence during the performance of these nerve blocks. This is of the utmost importance not only in the field of regional anaesthesia, especially paediatric patients, but also in the medical field in general.

The aforementioned statement clearly indicates the need for doctors to ensure that they have sufficient anatomical knowledge regarding paediatric regional anaesthetic nerve blocks. Therefore, it is of the utmost importance to identify the gaps present in the knowledge and correct it. This is done by identifying the problem procedures and developing an anatomical information base, which will not only perfect certain paediatric nerve blocks, but will also; shed new light on the dynamic field of paediatric regional anaesthesia, as well as the vast differences between adults and children with regard to the anatomy.

3.4.2 Selection of problem procedures

The following nerve blocks were excluded from further statistical analysis based on less than 5% of the participating doctors performing these blocks:

- Facial nerve block
- Infra-orbital nerve block (INTRA-ORAL approach)
- Zygomaticotemporal nerve block
- Zygomaticofacial nerve block
- Palatine nerve block
- Mental nerve block
- Auriculotemporal nerve block
- Great auricular nerve block
- Lesser occipital nerve block
- Transverse cervical nerve block
- Glossopharyngeal nerve block
- Stellate ganglion nerve block

The five remaining nerve blocks were compared with one another based on the values they scored using Scoring option III. A numeric value, based on the scoring option, was allocated to each question and the totals are therefore captures in Table 3.4.

Table 3.4: Results after Scoring option III was applied

Question	Nerve block				
	Supra-orbital & supra-trochlear	Infra-orbital (EXTRA-ORAL)	Supra-clavicular	Superior laryngeal	Recurrent laryngeal
1	1	3	1	1	1
2	4	3	2	3	2
3	3	1	3	2	3
4	1	1	2	1	3
5	2	3	1	3	2
6	2	2	2	2	2
7	2	2	2	2	2
TOTAL	**15**	**16**	**13**	**14**	**15**

The five procedures were revisited to establish the four procedures that best portrayed the problem procedures. Based on question 5, the complications experienced, the supraclavicular nerve block was excluded as a problem procedure, due to the small percentage of complications experienced based on the related anatomy.

The following four problem procedures have been identified and will be thoroughly investigated, after which a detailed anatomical information base will be compiled:

- Supra-orbital and supra-trochlear nerve block
- Infra-orbital nerve block (EXTRA-ORAL approach)
- Superior laryngeal nerve block
- Recurrent laryngeal nerve block

3.5 Discussion

Several studies have been published in the last decade on neonates and infants and how they experience and deal with pain. Sellam *et al.,* (2011) links several articles to the statement that neonates and young children who experience repeated exposure to pain in early life, may develop changes in how they process pain, not only as an infant but also later in life. Effective treatment of pain and anxiety will result in a decrease of patient suffering, increased patient care and, ultimately, improve the patient's end result (Goldstein, 2010).

A pain-free patient does not only have less physiological problems, but a pain-free child is also easier to attend to. Less movement at the surgical site results in better preservation of the site and easier drinking and feeding of the patient (Jonnavithula *et al.,* 2010). However, due to the variable results of opioid usage in neonates and infants, the treatment of post-operative pain can be seen as problematic. Due to the elimination half-life of morphine being twice as long in neonates as in adults and older children, other effective methods of post-operative pain management is required (Tobias and Deshpande, 1996).

Breivik (1995) states: "The current increased interest in improving post-operative pain management is due to the wider availability of effective methods for pain relief and a growing awareness of beneficial effects of optimal post-operative pain relief." Several drugs, as well as regional analgesia techniques, have been developed and are available to treat post-operative pain in infants and children (Landsman and Cook, 1995).

Landsman and Cook, (1995) list several studies that include paediatric patients, where regional anaesthesia, used in a variety of surgeries, caused fewer side effects. The side effects include nausea, sedation and respiratory depression. Regional nerve blocks may result in analgesia lasting up to six hours or longer after the block has been performed.

According to Bosenberg, (1999) regional anaesthesia of the head and neck region is a rare practice in paediatric anaesthesia. This is based on the fact that there are few publications available on this subject. The unfamiliarity of the anaesthesiologists with performing these nerve blocks in this region and the little opportunity to perform regional nerve blocks during head and neck procedures, greatly affect the development of these nerve blocks in paediatric patients.

Due to the cranial and cervical anatomy being extremely compact, a thorough understanding of the anatomical relationships is vital (Bosenberg, 1999). Not only is a thorough information base required, but nerve blocks, commonly related to specific complications, need to be identified and improved.

3.5.1 Conduction of the survey

In this study, the questionnaire used, consisted of a list of regional anaesthetic nerve blocks that are performed by anaesthesiologists. This list was assembled by means of an extensive literature study. A list of 17 regional nerve blocks was documented, and a questionnaire was developed to evaluate various aspects of each of these procedures. Several questions relating to the importance of anatomy and anatomy related to each block was also included.

A total of 111 questionnaires were completed by doctors ranging from one anaesthesiology registrar to specialists with more than 10 years of experience, as seen in Figure 3.1. The demographic data portrays a good sample of doctors with different years of experience. The smallest group, 12%, represented the doctors with 4 – 6 years of experience, while the doctors with 10 years and more experience represented 26% of the respondents. The remaining groups were each represented by 20%, while 2% did not complete the demographic data. This is statistically considered a good representation of the doctors in the field, and therefore the results from the survey will ultimately portray the distribution of knowledge and experience.

A limitation for this study can be considered as the following: Only 111 questionnaires were completed and returned, which does not necessarily represent sufficient respondents. Also, in personal communication with Prof K Bütow, he indicated that, as a maxillo-facial surgeon (Oral and Dental Hospital, University of Pretoria, South Africa), he performs most of the regional nerve block without the assistance of an anaesthesiologist. This occurs due to the perception that he is very familiar in this region. This survey should perhaps have been sent to anaesthesiologists and maxillo-facial surgeons. Nonetheless, this study presents findings of a representative number of anaesthesiologists who perform these regional anaesthetic nerve blocks. Resulting in a type of study that have not been done before.

From Table 3.3A, the three most commonly performed nerve blocks, by the participating doctors, can be identified. These include both the INTRA-ORAL and EXTRA-ORAL approaches to the infra-orbital nerve blocks, as well as the auriculotemporal nerve block. From these three nerve blocks, only the infra-orbital nerve block (extra-oral approach) is performed predominantly on infants. Only two doctors indicated that they perform this nerve block, however both on children.

It can also be seen from Table 3.3A that the most commonly experienced difficulties when performing these nerve blocks are a lack of knowledge of the specific procedures and regional anatomical knowledge required to successfully perform the blocks.

Table 3.3B represents the total number of nerve blocks performed per annum by the participating doctors. Only eight nerve blocks are performed more than 20 times a year. Certain nerve blocks like the great auricular nerve block, lesser occipital nerve block and transverse cervical nerve block, are performed by less than five respondents. Therefore the frequency of performance of each nerve block should be evaluated with the number of doctors that perform the specific nerve block.

Wells (2010) argues that techniques based on bony landmarks are considered better than techniques based on soft tissue, since a higher success rate is achieved in comparison to the techniques that use tissue landmarks. However, from Table 3.3C it is evident that several doctors experience problems with the palpation of bony landmarks. This can be a result of the lack of publications or literature, especially with regard to infants. Bosenberg (1999) makes the statement that anatomical landmarks in adults are fairly constant, but differ greatly in the developing skulls of infants. This problem is aggravated by the lack of publications that considers this aspect when describing nerve blocks, particularly in neonates and infants.

From Table 3.3C several other complications can be identified:

- Deficient or inaccurate needle placement, resulting in incorrect spread of anaesthetic
- Intravascular injection
- Incorrect anaesthetic due to variable location of nerves
- Needle placed in wrong direction
- Inability to identify muscular landmarks

All these complications are directly related to the regional anatomy. Careful attention should be given to the close relationships of the cranial and cervical nerves to other vital structures. Correct needle placement can only be achieved by thorough knowledge and understanding of the regional anatomy related to the area in which the nerve block is performed (Bosenberg, 1999). Marks (2002) states: “Clinical anatomy is the basis of successful health care”.

The development of a sufficient anatomical information base will result in fewer complications experienced and an increase in the confidence of the practising anaesthesiologists when performing these nerve blocks on paediatric patients.

All the participating practitioners who expressed the importance of anatomical knowledge in the reduction of complications and difficulties are seen in Figure 3.2. An increased anatomical knowledge will also assist in increasing the confidence levels of these doctors when performing the regional nerve blocks. This statement is supported by all but one of the participating doctors, as seen in Figure 3.3.

The important role that a sound anatomical knowledge plays in the safe and successful performance of clinical procedures cannot be emphasised enough (Abrahams and Webb, 1975; McMinn *et al*., 1984; Beahrs *et al*., 1986; Crisp, 1989; Ger and Evans, 1993; Captier, *et al*., 2009). The identification of problem procedures and the development of an effective information base are therefore of the utmost importance.

3.5.2 Selection of problem procedures

Only five regional nerve blocks were evaluated by means of Scoring option III, due to the low frequency of performance by the participating doctors. Procedures that are not performed regularly, and minimally optimised, were therefore excluded from further statistical analysis, based on the necessity of these procedures in the current field of regional anaesthetic procedures in the paediatric population.

Due to the unavailability of scoring options applicable to the survey used in this study, three scoring options were developed. Scoring option III was chosen due to this option not only evaluating the nerve blocks that are performed more frequently, but also the significance of the anatomical knowledge and complications experienced. All the questions from the questionnaire were included when this scoring option was applied.

From the five regional nerve blocks evaluated through Scoring option III, four problem procedures were identified, namely the supra-orbital and supra-trochlear, infra-orbital (EXTRA-ORAL approach), superior laryngeal and recurrent laryngeal nerve blocks.

When comparing and evaluating the nerve blocks in Table 3.4, the following observations can be made according to the questions included in Scoring option III:

- Question 1: The infra-orbital nerve block (extra-oral approach) is the only nerve block performed predominantly on children.
- Question 2: The supra-orbital and supra-trochlear nerve blocks are performed most frequently (12.1% - 15%) by the respondents.
- Question 3: The supra-orbital and supra-trochlear, supraclavicular and recurrent laryngeal nerve blocks are considered a necessity to their practice by 60 – 79% of the respondents.
- Question 4: More than 30% of the doctors performing the recurrent laryngeal nerve block feel uncomfortable during the performance of the procedure.
- Question 5: 20 – 29% of the participants experience complications (although minor) when performing the supra-orbital and supra-trochlear, and recurrent laryngeal nerve blocks, while more than 30% of the participants experience complications (again minor) when performing the infra-orbital and superior laryngeal nerve blocks.
- Question 6: All the respondents agreed that an increase in anatomical knowledge will result in a decrease in complications.
- Question 7: All the respondents, except one, feel that an increased anatomical knowledge will increase the doctor's confidence while performing these nerve blocks.

Due to the increased practice and requirements related to regional anaesthesiology, especially in the paediatric population, questions need to be asked based on the complications encountered, difficulties experienced and the related regional anatomical knowledge. From this study a notable lack of anatomical knowledge is evident. This exists either due to the lack of research and publications available, the inexperience of South African doctors with regard to the technological development in the health care system, or the inadequate training of these doctors. Waterston and Stewart, (2005) support this statement. In their study, they concluded that 64% of clinicians considered students to have an inadequate knowledge of anatomy, while 61% felt that recently qualified doctors do not retain sufficient anatomical knowledge to effectively and safely practice medicine.

In order to correct the vast inexperience and lack of knowledge, a sufficient information base should be developed and implemented.

3.6 Conclusion

In conclusion, the following four problem procedures have been identified based on criteria from a detailed questionnaire including most frequently performed, most anatomical complications experienced and a shortage of confidence to perform this specific nerve block due to the absence of relevant anatomical knowledge:

- Supra-orbital and supra-trochlear nerve block
- Infra-orbital nerve block (EXTRA-ORAL approach)
- Superior laryngeal nerve block
- Recurrent laryngeal nerve block

Due to the lack of anatomical knowledge and practical experience, regional nerve blocks performed on paediatric patients are often considered as a dangerous alternative to opioids for post-operative pain relief. Therefore, a detailed anatomical information base has been developed (Chapter 4) to educate and facilitate doctors during the performance of these nerve blocks in paediatric patients.

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4.1. Development of a clinical anatomical knowledge base for each of the selected procedures

The use of regional anaesthesia is becoming increasingly common and accepted in the field of paediatric anaesthesia. This is in greater part due to the extended pain-free period that can be obtained. Also, fewer complications are encountered when regional anaesthesia is used instead of opioids and non-steroidal anti-inflammatories (Jonnavithula, *et al.,* 2010).

However, safe nerve blockade requires a sound knowledge of anatomy, to ensure that the needle tip is placed close to the nerve, but without damaging it (Doyle, 2007; Captier *et al*., 2009). Therefore, the key to a successful regional anaesthetic nerve block is the familiarity of the doctor with the position of the nerve and its relationship to associated bony landmarks (Salam, 2004). Consequently, to effectively perform and evaluate these nerve blocks, the relevant anatomical knowledge needs to be assessed and corrected, especially in the paediatric population.

Paediatric patients endure a variety of surgical procedures in the head and neck region. Several peripheral nerve blocks have been introduced to provide adequate intra-operative and post-operative pain control (Suresh and Voronov, 2006; Voronov and Suresh, 2008).

Four problem paediatric head and neck nerve blocks have been identified through a qualitative survey, based on frequency of incidence, complications and difficulties experienced and comfortability of the performing doctors. These are the:

- Supra-orbital and supra-trochlear nerve block
- Infra-orbital nerve block (EXTRA-ORAL approach)
- Superior laryngeal nerve block
- Recurrent laryngeal nerve block

In an attempt to increase the familiarity as well confidence when performing these four nerve blocks, a detailed knowledge base was developed for each of the problem procedures identified. Each nerve block was discussed and evaluated based on the following headings and criteria:

- Indications
- Contra-indications / Precautions
- Step-by-step procedure
- Anatomical pitfalls
- Complications (anatomically relevant)
- References

The most recent and relevant literature was studied extensively in order to compile each anatomical knowledge base.

4.2 Problem procedures

4.2.1 Supra-orbital and supra-trochlear nerve block

The trigeminal nerve (the largest cranial nerve) is a sensory nerve of the head and face, as well as the motor nerve to the muscles of mastication. The ophthalmic nerve, the first and smallest division of the trigeminal nerve, is a purely sensory nerve. Three branches arise from the ophthalmic nerve: the frontal nerve, lacrimal nerve and nasociliary nerve. The largest branch of the ophthalmic nerve, the frontal nerve, enters the orbit through the superior orbital fissure before dividing into the two terminal cutaneous branches, the supra-orbital and supra-trochlear nerves (Suresh and Wagner, 2001; Suresh and Voronov, 2006; Voronov and Suresh, 2008; Osborn and Sebeo, 2010).

The supra-orbital and supra-trochlear nerves are responsible for cutaneous innervation of the forehead and scalp, anterior to the coronal suture. The supra-orbital nerve exits the supra-orbital foramen or notch, with the supra-orbital vessels, and continues superiorly (Zide and Swift, 1998; Suresh and Voronov, 2006; Osborn and Sebeo, 2010). It divides into deep lateral and superficial medial sensory branches. The lateral branches run within the areolar tissue supplying the scalp sensation, while the medial branches pierce the frontalis muscle, supplying the anterior scalp (Suresh and Voronov, 2006; Osborn and Sebeo, 2010; Byrne and Izzo, 2012).

Certain discrepancies with regard to the emerging of the supra-trochlear nerve from the skull exist in the literature. Some authors say that the supra-trochlear nerve leaves the supra-orbital foramen prior to supplying the medial forehead (Pulcini and Guerin, 2006; Osborn and Sebeo, 2010). However, Salam (2004) and Young *et al.,* (2008) mention that the, supra-trochlear nerve exits along the upper border of the orbit 10mm medial to the supra-orbital foramen. Suresh and Wagner (2001) also states: “The supra-trochlear nerve leaves the orbit between the trochlea and the supra-orbital foramen.”

Suresh and Voronov (2006) indicate that the supra-trochlear nerve exits the orbit at the superior orbital rim through a notch, other than the supra-orbital foramen. This notch is located above the trochlea and medial to the supra-orbital notch. They conclude from their study, that most skulls (97%) exhibited bilateral supra-trochlear notches, one percent had a unilateral foramen while the other two percent had a notch on one side and a foramen on the other. Although the exact bony landmark through which the supra-trochlear nerve leaves the skull is still debated, there is general consensus that the supra-trochlear nerves penetrate the corrugator and frontalis muscles and supply the central vertical area of the forehead, as well as the medial part of the upper eyelid (Bosenberg, 1999; Suresh and Voronov, 2006; Voronov and Suresh, 2008).

4.2.1.1 Indications

Several indications permit the use of supra-orbital and supra-trochlear nerve blocks. These blocks are predominantly performed in adults, even though in minor cases they are performed in the paediatric population.

Suresh and Bellig (2004) reported a case where a low birthweight neonate underwent a series of regional nerve blocks namely the supra-orbital, great auricular and greater occipital nerve blocks prior to a neurosurgical procedure. They conclude that they were able to successfully use peripheral nerve blocks resulting in minimised physiologic responses to surgical stress, without compromising haemodynamic stability using opioids.

Supra-orbital and supra-trochlear nerve blocks can be used in paediatric patients undergoing craniosynostosis repair, as well as awake procedures for deep brain stimulations during treatment of dystonia (Adam and Jankovic, 2007).

Bosenberg (1999) and Kim (2009) describe several regional anaesthetic nerve blocks specifically for children. Bosenberg (1999) states that the supra-orbital and supra-trochlear nerve blocks are used for minor surgical procedures in the head. These include removal of cysts, suture of lacerations and, in conjunction with other nerve blocks of the scalp, it can be used for craniofacial surgery. These blocks can also be utilised for frontal craniotomies as well as epidermal nevus excisions on the scalp (Kim, 2009).

According to Suresh and Voronov (2006) these nerve blocks can also be utilised for surgery performed on the scalp, specifically the region anterior to the coronal suture. These include frontal craniotomies, anterior midline dermoid excisions, frontal ventriculoperitoneal shunts, Omayya reservoir placement in neonates and nevus excisions. Plastic surgical procedures include excision of lesions like aplasia cutis, nevus sebaceous, haemangiomas and congenital nevi (Suresh and Wagner, 2001). Cohen *et al.* (2011) cite that pheochromocytoma and paraganglioma are neuroendocrine tumours rarely diagnosed in paediatric patients. However, they performed a supra-orbital nerve block on a 14-year old patient prior to performing an excision of a skull lesion.

The following procedures are also indicative of supra-orbital and supra-trochlear nerve blocks:

- Supra-tentorial craniotomy (Hartley *et al.,* 1991);
- Abcess incision and drainage;
- Closed reduction of fractures (Salam, 2004);
- Trabeculectomy surgery (Tay *et al.,* 2006);
- Post-operative analgesia;

- Treatment of certain supra-orbital neuralgias (Pulcini and Guerin, 2007; Evans and Pareja, 2009);
- Wound closure;
- Anaesthesia for debridement (Byrne and Izzo, 2012).

4.2.1.2 Contra-indications / Precautions

Several contra-indications exist for the use of all or any regional anaesthetic nerve blocks. These include any allergic reaction or sensitivity to the anaesthetic agent, evidence of infection at the injection site or distortion of anatomical landmarks (Byrne and Izzo, 2012). If a patient is uncooperative or suffers from excessive anxiety or dementia, regional nerve blocks are not recommended (Tay *et al.,* 2006).

Tay *et al.,* (2006) also mentioned that patients suffering from strabismus or nystagmus were excluded from their study in which they used a supra-orbital nerve block during trabeculectomy surgery.

Physicians' lack of knowledge or familiarity of these nerve blocks, are also considered a contra-indication, according to Salam, 2004. If coagulopathy or bleeding disorders have been diagnosed in the patient, regional anaesthetic nerve blocks should be avoided, as a safety precaution (Osborn and Sebeo, 2010).

4.2.1.3 Step-by-step procedure

Several different techniques to block the supra-orbital and supra-trochlear nerves are described in the literature. These different methods can be divided into two major groups:

- A single injection to anaesthetise both the supra-orbital and supra-trochlear nerves;
- Different sites for the injection of the anaesthetic solution to block each nerve separately.

The different methods will be discussed based on the aforementioned classifications, with divisions between different points of entry and the population group used in the specific study.

4.2.1.3.1 Single-site injection

The most commonly described single-site injection in the literature is at a position that correlates to the midpoint of the pupil. This is the technique described by Bosenberg (1999); Suresh and Voronov (2006) and Kim (2009) for supra-orbital and supra-trochlear nerve blocks in children, while Serra-Guillen *et al.* (2009) and Byrne and Izzo (2012) refer to this technique for use in adults. The technique can be performed by following these steps:

- Locate the foramen by visualising a medial vertical line through the pupil, as a reference point for the location of the supra-orbital neurovascular bundle;
- Palpate the supra-orbital ridge until a subtle notch is felt;
- Once the notch is located, the local anaesthetic solution is injected subcutaneously;
- Gentle pressure is maintained to decrease the formation of a haematoma (Suresh and Voronov, 2006; Kim, 2009; Byrne and Izzo, 2012);
- Byrne and Izzo (2012) state that the needle should be introduced at a perpendicular angle in adults. However, Bosenberg (1999) explains that the needle should be inserted above the root of the nose, and directed laterally in infants due to the supra-orbital foramen being slightly more medial.

The above mentioned authors only mention a single-injection in one direction. Serra-Guillen *et al.* (2009) state that both nerve blocks can be performed using a single needle entry. The supra-orbital nerve is anaesthetised with the mid-pupil point of entry. Then, using the same puncture point, the needle is slightly withdrawn and aimed towards the nasal root to successfully block the supra-trochlear nerve.

Suresh and Voronov (2006) also block the supra-trochlear nerve separately, using a single injection. After the anaesthetic fluid is injected into the space around the supra-orbital notch, the needle is withdrawn to the level of the skin. It is then directed medially for several millimetres towards the root of the nose, where another dose of anaesthetic solution is injected to block the supra-trochlear nerve. No reference to the specific amount of millimetres was made in the article.

Other published articles also describe a single injection to block both the supra-orbital and supra-trochlear nerves. Due to the supra-orbital rim being easily palpated in younger patients, the supra-orbital foramen can be found if the orbital rim is followed from the midline (Voronov and Suresh, 2008). After anaesthetic solution is injected around the supra-orbital neurovascular bundle, the needle is withdrawn and directed medially towards the tip of the nose, to effectively anaesthetise the supra-trochlear nerve (Suresh and Wagner, 2001; Voronov and Suresh, 2008).

Zide and Swift (1998) describe a completely different method of blocking the supra-orbital nerve.

- The block is performed with an easy injection along the supra-orbital ridge;
- The needle is inserted from a lateral angle and advanced medially;
- The needle should be aimed at the supra-orbital notch, which can be easily palpated;
- After the anaesthetic solution is injected in the vicinity of the notch, deep to the orbicularis oculi muscle, the needle is moved medially a few millimetres, after which more solution is deposited;
- The needle is then advanced in a medial direction again, until it meets the nasal bone where more anaesthetic solution is injected.

Thomsen and Setnik (2005) also describes a lateral approach to blocking the supra-orbital and supra-trochlear nerves.

- These nerves can be blocked with a single injection along the supra-orbital rim;

- The landmark for the puncture site is above the medial limbus on the superior medial orbital rim;
- The needle is inserted into the lateral edge of the middle third of the eyebrow, after which the needle is advanced medially toward the medial canthus (angle where the upper and lower eyelids join).

The aforementioned authors describe techniques with similar methods of blocking both the supra-orbital and supra-trochlear nerves. However, Salam (2004) describes a single injection for blocking both nerves, without the necessity of advancing the needle in any direction or a second injection site. The proposed technique includes an injection beneath the medial two thirds of the eyebrow, just superior to the bone. This will result in the blocking of both these cutaneous nerves.

4.2.1.3.2 Multiple-site injections

In the event of only one nerve having to be anaesthetised, it is more desirable to only block that specific nerve. For that reason different injecting sites are used. Should only the supra-orbital nerve be blocked, the following authors suggest the following methods:

- Small volumes of anaesthetic solution should be injected in the eyebrow, superior to the supra-orbital canal. This canal can be palpated under the orbital ridge, in line with the middle of the pupil (Young *et al.,* 2008);
- The supra-orbital nerve is blocked by inserting the needle towards the supra-orbital foramen, palpated along the upper orbital border, approximately 25mm lateral to the midline of the face (Salam, 2004);
- Peltier (2006) states that palpitation is performed to find the supra-orbital notch. The needle is then advanced, while anaesthetic solution is injected, until paraesthesia is experienced by the patient, in the distribution of the nerve;
- According to Osborn and Sebeo (2010), the supra-orbital nerve can be blocked once it emerges from the orbit. The supra-orbital notch is palpated, and the needle is inserted perpendicular to the skin, along the orbital border, approximately 10mm medial to the supra-orbital foramen.

No distinct method for the location of the supra-orbital notch can be obtained from the current literature, specifically for the use of regional nerve blocks within the infant population. Further research needs to be conducted to determine the exact location of the supra-orbital notch, and subsequently, the best method of anaesthetising the supra-orbital nerve.

Different locations of the supra-trochlear nerve results in different explanations and methods for the blocking of the supra-trochlear nerve, as can be seen below:

- The supra-trochlear nerve exits a foramen, near the medial edge of the eyebrow. This foramen is approximately 10mm medial to the supra-orbital foramen. The needle should be inserted into the eyebrow, superior to the location of the canal (Young *et al.,* 2008);
- Salam (2004) claims that the supra-trochlear nerve should be successfully blocked when the anaesthetic is injected 10mm medial to the supra-orbital foramen along the upper orbital margin;
- Osborn and Sebeo (2010) state that the supra-trochlear nerve can either be blocked by a medial extension of the supra-orbital nerve block, or as it emerges above the eyebrow, a finger's breadth medial to the supra-orbital nerve;
- The supra-trochlear nerve can be anaesthetised by injecting anaesthetic solution at the point where the nose meets the supra-orbital ridge, which coincides with the superior medial corner of the orbit (Peltier, 2004).

The exact location of the supra-trochlear nerve, especially in children, is still widely debated. Therefore, the exact location, as well as the best method for discontinuing sensory input from this nerve, needs to be determined and evaluated.

4.2.1.4 Anatomical pitfalls

The biggest anatomical pitfalls acquired from the literature are related to the anatomical landmarks, or the lack of a specific known location and the lack of relevant anatomical knowledge.

Due to the close proximity of the supra-orbital artery and ~nerve, and supra-trochlear artery and ~nerve, vascular compression of the nerve might occur due to the adjacent artery (Evans and Pareja, 2009).

Osborn and Sebeo (2010) state that careful identification of the specific anatomic landmarks will contribute to better identification of the nerve and, therefore, prevent intra-neural injections.

4.2.1.5 Complications (anatomically relevant)

Osborn and Sebeo (2010) mention that even though complications for these nerve blocks are relatively uncommon, certain complications could occur. Intra-vascular injection resulting in haematoma formation or intra-neural injection can occur due to the incorrect needle placement (Suresh and Voronov, 2006; Osborn and Sebeo, 2010). The possible risk of peri-orbital haematoma formation could be reduced by injecting the anaesthetic solution between the skin and skull, above the eyebrow (Bosenberg, 1999).

Voronov and Suresh (2008) also mention that apart from haematoma formation and intravascular injection, eye globe damage could also be a possible complication, although very rare, experienced during the performance of these nerve blocks.

Suresh and Wagner (2001) stated that the loose areolar tissues of the eyelid predispose the supra-orbital area to oedema and ecchymosis. However, this complication could be minimised, if gentle pressure is applied to the area for approximately five minutes after the block was performed. Kim (2009) also mentions that light pressure can reduce the possibility of a haematoma forming.

Pulcini and Guerin (2007) warns that nerve damage should be prevented at all costs. This can be achieved by avoiding penetration of the nerve within the foramen or notch. The needle must therefore make contact with bone approximately 10mm from the targeted area for the emerging of these nerves. They also mention that transitory palpebral ptosis might be observed during the supra-orbital nerve block, due to the diffusion of the anaesthetic solution towards the elevator muscle of the eyelid, levator palpebra superioris muscle.

Systemic toxicity, resulting in light-headedness, tinnitus, visual disturbance, seizures or coma, is a rare complication that might be experienced due to intravascular injection or an overdose of the anaesthetic (Salam, 2004).

The following complications have also been identified from the obtained literature:

- Bleeding
- Haematoma formation
- Allergic or systemic reaction to anaesthetic agent
- Infection
- Unintentional injection into the artery or vein
- Failure to anaesthetise
- Nerve damage
- Swelling of the eyelid (Byrne and Izzo, 2012)
- Peri-orbital ecchymosis (Zide and Swift, 1998)

Suresh and Wagner (2001) state “The use of local anaesthetics in peripheral nerve blocks can reduce the need for potent postoperative analgesics during scalp lesion excisions. However, careful attention to the anatomy and innervation is necessary to identify the appropriate nerves to each area of the scalp.”

4.2.1.6 References

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4.2.2 Infra-orbital nerve block (EXTRA-ORAL approach)

The maxillary nerve, the second division of the trigeminal nerve, is a pure sensory nerve. It is mainly responsible for cutaneous innervation of the skin derived from the embryonic maxillary prominence. Once it leaves the cranium through the foramen rotundum, it gives rise to branches travelling to the pterygopalatine ganglion, as it passes through the pterygopalatine fossa. The maxillary nerve enters the orbital cavity through the inferior orbital fissure. After giving off the zygomatic nerve, it passes anteriorly into the infra-orbital groove as the infra-orbital nerve (Dubash *et al.,* 2006; Moore and Dalley, 2006).

As the infra-orbital nerve travels through the infra-orbital canal, the middle and anterior superior alveolar nerves branch off. These nerves form part of the alveolar plexus which is responsible for sensory innervation of the anterior gingiva and maxillary teeth (Zide and Swift, 1998; Dubash *et al.,* 2006; Moore and Dalley, 2006; Bhargava *et al.,* 2011). Once the nerve enters the face through the infra-orbital foramen, it branches into the inferior palpebral, internal nasal, external nasal and superior labial nerves (Moore and Dalley, 1998; McAdam *et al.,* 2005; Dubash *et al.,* 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008).

The infra-orbital nerve and its branches are responsible for innervating the following structures:

- Lower eyelid (skin and conjunctiva);
- Upper lip (skin and oral mucosa);
- Lateral part of the nose, including the antero-inferior part of the nasal septum;
- Skin of the cheek;
- Mucosa of the maxillary sinus and palate;
- Labial glands;
- Premolar, canine and incisor maxillary teeth (Zide and Swift, 1998; Moore and Dalley, 1998; McAdam *et al.,* 2005; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008; Kim, 2009; Wells, 2010; Bhargava *et al.,* 2011).

According to Suresh *et al.* (2006); Voronov and Suresh (2008) and Bhargava *et al.* (2011), careful attention must be given to the infra-orbital neurovascular bundle during the performance of this nerve block. Due to the close proximity of the infra-orbital artery and ~vein to the nerve, as they emerge onto the maxilla, the exact relationship needs to be noted. Suresh *et al.* (2006) states that the infra-orbital nerve is located more superficial than the blood vessels, therefore it is more easily accessed.

General consensus in the literature with regard to the location of the infra-orbital foramen, establishes that the foramen is usually aligned with the centre point of the pupil (Bosenberg, 1999; McAdam *et al.,* 2005; Peltier, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008; Kim, 2009; Wells, 2010).

Even though the general observations for the location of the infra-orbital foramen are similar with regard to the mid-point of the pupil, the supplementary descriptions differ:

- Eipe *et al.* (2006) used the following landmark: the point of intersection of a vertical line through the pupil and a horizontal line through the alae of the nose.
- The infra-orbital foramen is in the mid-pupillary line, 10mm inferior to the orbital rim and approximately 25mm lateral to the facial midline (Wells, 2010).
- Kim (2009) states that the infra-orbital foramen can be located about 20mm from the midline. This is normally aligned with the midpoint of the pupil.
- McAdam *et al.* (2005) mention that the infra-orbital foramen is often located in line with the pupil, at the floor of the orbital rim.

Several other methods for locating the infra-orbital foramen are also described:

- The infra-orbital foramen is located in line with the angle of the mouth and the pupil. Where this line transects the infra-orbital rim. The foramen can be palpated (Peltier, 2006).

- Suresh and Voronov (2006) mention that it can be found approximately 25mm from the midline, inferior to the pupil, at the floor of the orbital rim. This was established by means of CT scan images.
- The surface landmark can be identified as a point situated approximately halfway along a line drawn from the angle of the mouth to the midpoint of the palpebral fissure (Rajamani *et al.,* 2007).
- Salam (2004) refers to the location of the infra-orbital foramen as "just inferior to the orbit, slightly nasal to an imaginary line drawn through the middle of the infra-orbital rim".
- The infra-orbital foramen is located on a line drawn inferiorly from the medial limbus of the iris, approximately 4 to 7mm from the orbital rim (Zide and Swift, 1998).

In order to facilitate the detection of the infra-orbital foramen, Suresh *et al.* (2006) developed a mathematical formula to determine the position of the foramen. This formula was developed based on the evaluation of CT scans. They conclude that the age of the patient plays a very important role in the variation of their formula. They state that the following formula can predict the distance (in mm) of the infra-orbital foramen from the midline: 21.3 + 0.5 x age (in years).

According to Bosenberg (1999) the age of the patient is vital for the exact location of the infra-orbital foramen. He states that the foramen lies just below the orbital rim, inferior to the mid-point of the pupil. This can easily be palpated 5mm below the junction of the medial and middle thirds of the lower orbital rim. However, due to the foramen not being easily palpable in neonates and small infants, a measurement from the angle of the mouth to the palpebral fissure is used. The foramen will be located at half the distance from the palpebral fissure (15mm) and a quarter of the distance from the alae nasi (7.5mm) (Bosenberg and Kimble, 1995).

Based on the different possible locations of the infra-orbital foramen, a standardised method for location of the foramen needs to be determined. This will ensure that blocking the infra-orbital nerve can occur effortlessly.

4.2.1.1 Indications

According to the literature studied, the most common indication for the use of the infra-orbital nerve block, especially in paediatric patients, is described for cleft-lip repair. This can be used in conjunction with general anaesthesia, lighter sedation or in the treatment of post-operative pain (Bosenberg and Kimble, 1995; Bosenberg, 1999; Suresh and Voronov, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Jonnavithula *et al.,* 2007; Rajamani, 2007; Kim, 2009; Prabhu *et al.,* 2009).

Voronov and Suresh (2008) state that this nerve block is performed routinely in their practice for endoscopic sinus surgery as well as for cleft lip repair. This is based on the easy localisation and the sufficient intra-operative and post-operative pain relief obtained through this nerve block.

Several other nasal procedures are performed using this nerve block. These include rhinoplasty (McAdam *et al.,* 2005), nasal tip reconstruction (Belvis *et al.,* 2007) and nasal septal repair (Kim, 2009). Mole removal (Belvis *et al.,* 2007), pulse dye laser for removal of the portwine stains, and excision of a congenital nevus (Voronov and Suresh, 2008) are also indicated.

McAdam *et al.* (2005) reported that they used a bilateral infra-orbital nerve block for analgesia in an 11-year-old girl who underwent a trans-sphenoidal resection of a pituitary tumour. Even though this is the first report of the use of the infra-orbital nerve block for a trans-sphenoidal hypophysectomy, the surgeon, patient and family were very satisfied with the procedure and the post-operative pain relief achieved.

4.2.1.2 Contra-indications / Precautions

Several contra-indications exist for the use of infra-orbital nerve blocks. The following contra-indications were obtained from the literature:

- Any allergy or sensitivity to the anaesthetic agent;

- Evidence of infection at the injection site (Jonnavithula, 2007; Byrne, 2012);
- Coagulopathy;
- Any major systemic illnesses (Jonnavithula, 2007);
- Uncooperative patient;
- Distortion of the anatomical landmarks (Byrne, 2012).

The only contra-indication specifically indicated for this nerve block is the distortion of the anatomical landmarks. Based on the necessity of the palpation of these landmarks, the nerve block is considered dangerous if the landmarks cannot be located.

4.2.1.3 Step-by-step procedure

There are two well described methods of blocking the infra-orbital nerve in the paediatric population: the extra-oral approach and the intra-oral approach. Voronov and Suresh (2008) state: “In our experience, we note that the risk of hematoma is much lower with the intra-oral approach.” However, Bosenberg (1998) states: “The author believes that the intra-oral approach is contra-indicated in neonates and small infants because of the proximity of the orbit”.

Several advantages, such as the absence of needle marks, less pain experienced, and higher success rates are often experienced with the intra-oral approach (Jonnavithula *et al.,* 2007). However, based on the results from the questionnaire study in Chapter 3, only the extra-oral approach will be discussed.

Apart from the different methods for locating the infra-orbital foramen, various techniques of blocking the infra-orbital nerve transcutaneously are describe in the literature. The most commonly described technique is the approach advocated by Bosenberg and Kimble, (1995) especially for neonates and infants:

- A needle is introduced perpendicular to the skin at a point situated approximately halfway along a line drawn from the angle of the mouth to the midpoint of the palpebral fissure;

- It is advance until bony resistance is experienced;
- The needle is then withdrawn slightly and the local anaesthetic is injected (after obtaining negative aspiration);
- If resistance is experienced during injection of the anaesthetic solution, the position of the needle tip is adjusted slightly;
- Pressure is applied to the area, after the injection, for approximately five minutes.

Voronov and Suresh (2008) also describe a technique used on neonates and infants. This is the same technique described by Eipe *et al.* (2006):

- The infra-orbital foramen can be gently palpated at the floor of the orbital rim;
- A finger is always placed at the level of the infra-orbital foramen to prevent the needle from advancing superiorly;
- A needle is advanced perpendicular to the skin towards the foramen, till bony resistance is felt;
- To prevent intraneural injection, the needle should not be placed within the infra-orbital canal;
- The anaesthetic agent is injected after confirmation of the extravascular placement;
- Gentle pressure is recommended.

The following technique is recommended by Belvis *et al.* (2007):

- The patient must be placed in the supine position;
- The foramen is identified by means of palpation at the floor of the orbital rim;
- The needle is entered and advanced towards the foramen until bone is contacted;
- Withdraw the needle, aspirate and inject the anaesthetic agent;
- Apply pressure to the affected area.

Salam (2004) describes a similar technique as the aforementioned, however, the needle is inserted approximately 10mm inferior to the infra-orbital foramen and advanced superolaterally, to prevent the needle from passing through the foramen and into the orbit.

The following technique is described by Wells (2010), however, predominantly for the use in adult patients:

- Identify the target area for the needle insertion (roughly 5mm inferior to the infra-orbital foramen;
- Hold the syringe vertically, with the needle aimed superiorly, and puncture the skin;
- Advance the needle posteriorly and superiorly until contact with the bone is sensed in the vicinity of the foramen. Withdraw the needle and aspirate;
- If no blood is withdrawn, inject the anaesthetic solution near and around the foramen, but care should be taken not to inject into the foramen.

Zide and Swift (1998) describes a completely different method:

- The needle should enter a point in the centre of an imaginary inverted “V” at the level of the alar base. The imaginary “V” is defined by the nasal labial fold and the alar base inset;
- Holding the needle like a pen, with the other hand is placed on the infra-orbital rim;
- The patient is asked to look straight forward;
- The needle is passed through the imaginary “V”;
- The needle is then directed upward and laterally to a point 5 - 7mm below the infra-orbital rim, where the anaesthetic solution is injected.

The majority of the techniques described are similar based on the approach being from an inferior angle. The best method to reach the infra-orbital foramen and anaesthetise the infra-orbital nerve needs to be determined and evaluated with regard to neonates and infants.

4.2.1.4 Anatomical pitfalls

The most problematic anatomical pitfall is determining the location of the infra-orbital foramen. This is due to a lack of knowledge, as well as to the great variability observed. In a study performed by Suresh and co-workers (2006), CT scans of 48 patients were evaluated to determine the exact location of the infra-orbital foramen. Intra-patient variability occurred in all but three patients, based on the position of the right and the left foramen. The age of the patient also accounted for variation. The exact location of the foramen for specific age groups needs to be effectively determined.

According to Byrne (2012), careful consideration must be placed on the close proximity of the facial artery and ~vein to the infra-orbital foramen. Therefore, aspiration should be performed to ensure that the needle is not placed within a blood vessel.

It has been well documented that the direction of the infra-orbital canal extends laterally and in an upward direction, from where the foramen is observed on the anterior maxilla (Bhargava *et al.,* 2011). Due to the damage that could occur if the needle is placed within the canal, the practitioner should be careful when directing and advancing the needle towards the infra-orbital foramen.

4.2.1.5 Complications (anatomically relevant)

Brennan (2009) states that complications are seldom encountered with local anaesthetics. Yet, local complications may involve nerve damage, with trismus, haematoma formation or needle breakage. Systemic complications may occur due to toxicity or an allergic response (Brennan, 2009; Byrne, 2012).

Certain complications can easily occur in any nerve block executed. These include haematoma formation and intravascular injection, should the nerve be closely related to blood vessels. Intraneural injection could also occur if the needle makes contact with the nerve (Belvis *et al.,* 2007; Voronov and Suresh, 2008; Byrne, 2012).

Care should be taken on the distance that the needle travels to prevent transgression of the needle, further than necessary. Should the needle exceed the required distance, it could result in eye globe damage. The required distance can be regulated by placing a finger at the level of the infra-orbital foramen (McAdam *et al.,* 2005; Voronov and Suresh, 2008).

Several other complications could also arise from the infra-orbital nerve block. Rajamani *et al.* (2007) discuss the following complications:

- Swelling and ecchymosis of the inferior eyelid can occur. However, this can be prevented if pressure is applied to the area;
- Should orbital injection of the anaesthetic solution occur, it will result in excessive pain, diplopia, exophthalmos and blindness.

Due to the sensory distribution of the infra-orbital nerve, a nerve block will result in the numbness of the upper lip. It is important to stress this fact to the patients or parents, due to the possibility that it may interfere with oral feeding, or the child can bite on the lip without experiencing any pain (Suresh and Voronov, 2006; Belvis *et al.,* 2007; Rajamani *et al.,* 2007; Kim, 2009).

Wells (2010) mentions that injection pressures should be kept low, because of the possibility of retrograde passage of the local anaesthetic into the orbit. This can result in temporary blindness which can be very disconcerting for the patient. Infections, nerve damage and failure to anaesthetise the nerve can also be experienced (Byrne, 2012). In a study conducted by Jonnavithula and co-workers, (2007), one of their patients experienced an erythema on the cheek near the infra-orbital foramen after the performance of the nerve block. The erythema diminished after three hours.

4.2.1.6 References

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4.2.3 Superior laryngeal nerve block and recurrent laryngeal nerve block

A combination of techniques is required to sufficiently anaesthetise the upper airway structures when awake intubation is performed. Specific nerve blocks accomplish adequate anaesthesia for awake intubation (Pani and Rath, 2009). Due to the innervation of the larynx, both the superior laryngeal nerve and recurrent laryngeal nerve are simultaneously blocked.

Iida *et al.* (2012) state: "The translaryngeal (recurrent laryngeal nerve) block alone is not sufficient to reduce the adverse reflex of the lingual radix, epiglottis and cricothyroid muscle. The superior laryngeal nerve block facilitates awake fiberoptic bronchoscope intubation by reducing the gag and cough reflex." Therefore the superior laryngeal and recurrent laryngeal nerve blocks will be discussed simultaneously.

Both the superior laryngeal and recurrent laryngeal nerves arise from the vagus nerve. The vagus nerve, CN X, is a mixed nerve with sensory, motor and parasympathetic components. The sensations originating from the inferior pharynx, larynx, and thoracic and abdominal organs are transmitted through the vagus nerves. Special sense of taste from the root of the tongue and taste buds on the epiglottis travels with the vagus nerves to be interpreted by the brain. The motor component supplies the muscles of the soft palate, pharynx, intrinsic laryngeal muscles and the palatoglossus muscles (Moore and Dalley, 2006).

The vagus nerve has the longest course and the most widespread distribution of all the cranial nerves. It leaves the cranium through the jugular foramen and travels within the carotid sheath, 20 -30mm lateral to the esophagus, through the cervical region towards the mediastinum (Liebermann-Meffert *et al.,* 1999; Moore and Dalley, 2006).

The superior laryngeal nerve is a branch of the vagus nerve (Liebermann-Meffert *et al.,* 1999; Peltier, 2006; Alalami *et al.,* 2008; Chelly, 2009; Lang *et al.,* 2012). Once the superior laryngeal nerve branches off, it runs deep to the carotid artery, along the vagus nerve. After a short distance, it emerges anterior to the carotid artery where it divides into its two terminal branches, the internal and external laryngeal nerves, at the level of the greater cornu of the hyoid bone (Chelly, 2009).

The external laryngeal nerve, the motor component of the superior laryngeal nerve, is the smaller terminal branch. It travels posterior to the sternothyroid muscle, accompanied by the superior thyroid artery, on the inferior constrictor muscle (Moore and Dalley, 2006). It pierces this muscle before supplying the cricothyroid muscle (Liebermann-Meffert *et al.,* 1999; Moore and Dalley, 2006; Peltier, 2006; Chelly, 2009).

The larger, internal laryngeal nerve is responsible for the sensory innervation of the laryngeal mucous membrane of the laryngeal vestibule and the middle laryngeal cavity. This includes the superior epiglottis, aryepiglottic folds, arytenoids and the superior surface of the vocal folds (Moore and Dalley, 2006: Chelly, 2009; Lang *et al.,* 2012). The internal laryngeal nerve travels along the inferior border of the greater cornu of the hyoid bone, after branching from the superior laryngeal nerve. Here it pierces the thyrohyoid membrane and travels deep to the mucosa of the piriform recess (Chelly, 2009; Pani and Rath, 2009). Its ascending branch supplies the epiglottis and vestibules, while the descending branch innervates the mucosa at the level of the vocal cords (Chelly, 2009).

The recurrent laryngeal nerves branch from the vagus nerves, as they enter the mediastinum. The left recurrent laryngeal nerve arises at the level of the ligamentum arteriosum, where it hooks around the aortic arch. The right recurrent laryngeal nerve loops around the proximal part of the subclavian artery (Liebermann-Meffert *et al.,* 1999; Chelly, 2009).

Moore and Dalley (2006) state that the recurrent laryngeal nerves enter the larynx by passing medial to the lamina of the thyroid cartilage and deep to the inferior border of the inferior constrictor of the pharynx. However, Liebermann-Meffert *et al.* (1999) report that the recurrent laryngeal nerves enter the pharynx just posterior to the inferior cornua of the thyroid cartilage. Despite the exact entry point of the recurrent laryngeal nerve, it is accompanied by the inferior laryngeal artery, a branch of the inferior thyroid artery (Moore and Dalley, 2006).

The recurrent laryngeal nerves give rise to branches that innervate the posterior cricoarytenoid muscles, cricopharyngeal, lateral cricoarytenoid muscles, the transverse and oblique arytenoid muscles, as well as the thyroarytenoid and aryepiglottic muscles. Therefore, the recurrent laryngeal nerve innervates all the laryngeal muscles, except the cricothyroid muscle which is supplied by the external branch of the superior laryngeal nerve (Liebermann-Meffert *et al.,* 1999).

Liebermann-Meffert *et al.* (1999), as well as Lang *et al.* (2012) report that connections exist between the superior laryngeal nerves and the recurrent laryngeal nerves. Due to the presence of these connections, both nerves are commonly blocked as a preventative measure. Liebermann-Meffert *et al.* (1999) state that knowledge of the nerve and its anatomy is very important. Therefore, the distribution, location and pathway of the superior laryngeal and recurrent laryngeal nerves need to be evaluated with regard to paediatric regional nerve blocks.

4.2.1.1 Indications

The most common indication for the use of the superior and recurrent laryngeal nerve blocks obtained from the literature, is for managing the airway. Pani and Rath (2009) state that undesirable sympathetic and parasympathetic effects such as excessive salivation and gag- and cough reflexes can occur, should a laryngobronchoscopy be executed on an awake, unsuspecting patient. This will result in difficulty with intubation of the patient.

Intubation, under deep anaesthesia, can be easily and effortlessly performed on a healthy patient. However, in emergency situations, elderly patients, patients with increased intracranial pressure, or patients with hypertension, general or deep anaesthesia should preferably be avoided. Therefore, intubation with the assistance of local or regional nerve blocks is indicated (Ovassapian *et al.,* 1983).

Anaesthesia of the airway can be used to facilitate diagnostic laryngoscopy and bronchoscopy (Wedel, 2000; Chelly, 2009; Pani and Rath, 2009; Waldman, 2009). Should an awake endotracheal intubation be performed, anaesthesia of the airway can result in a comfortable placement of the tracheal tube (Wedel, 2000). Superior laryngeal nerve block can assist in the diagnosis and treatment of painful conditions of to the larynx and pharynx, superior to the glottis (Waldman, 2009).

According to Chelly (2009), the following are general indications for airway blocks:

- To provide airway blocks before anaesthetic induction in patients with a compromised airway, cervical instability, or trauma to the upper respiratory tract;
- To abolish or blunt reflexes such as laryngospasm, coughing and other undesirable cardiovascular reflexes that often occur during procedures involving manipulation of the airway (awake laryngoscopy, nasal intubation and fiberoptic intubation);
- To provide patient comfort and airway anaesthesia during the performance of the abovementioned procedures.

Chelly (2009) also states that the superior and recurrent laryngeal nerve blocks will be specifically implemented to prevent haemodynamic responses or the gag reflex during laryngoscopy or bronchoscopy.

Trivedi and Sharma (2012) conducted a study entitled: “Evaluation of airway blocks versus general anaesthesia for diagnostic direct laryngoscopy and biopsy for carcinoma larynx.” They report that patients who received general anaesthesia showed a significant haemodynamic change with regard to mean arterial pressure and pulse rate during the peri-operative period. This is in contrast to the group that received regional anaesthetic airway blocks. This group expressed a more stable arterial pressure and pulse rate and also appeared to be less agitated, which can be attributed to the longer postoperative analgesia experienced.

The superior laryngeal nerve block has also been employed to relieve severe laryngospasm that can prevent intubation (Das and Pearce, 2002). According to Hampson - Evans *et al.* (2008) laryngospasms are more commonly encountered in the paediatric anaesthetic practice than in adults, due to the inhibition of the glottis reflexes after induction of anaesthesia or the increased stimuli. Superior laryngeal nerve block has been reported to treat laryngospasm, even though this practice has not been widely adopted.

Alalami *et al.* (2008) also investigated the prevention and treatment of laryngospasm. They mention that laryngospasm occurs due to a reflex closure of the upper airway. Should this reflex be aggravated, it may result in complete glottic closure, ending in threatening respiratory dysfunction. Monso *et al.* (1999), as well as Mevorach (1996), reported the successful treatment of post-extubation laryngospasm with a superior laryngeal nerve block.

Superior laryngeal nerve blocks can be employed in thyroid surgeries. In laryngectomies superior laryngeal and translaryngeal (recurrent laryngeal) nerve blocks are performed, with a supplementary glossopharyngeal, deep and superficial cervical plexus block (Prasad and Shanmugam, 1998). Sato *et al.* (2007) reported that they experienced two cases of superior laryngeal neuralgia that were successfully treated by performing a superior laryngeal nerve block. In the treatment of neuralgia, the administration of a nerve block can immediately relieve the pain experienced.

4.2.1.2 Contra-indications / Precautions

According to Prasad and Shanmugam (1998), patients who exhibit or experience the following criteria should be excluded from the usage of regional anaesthesia:

- Patients experiencing lower backaches and arthritis;
- Patients with a poor tolerance to local anaesthetic procedures;
- Patients who are apprehensive of regional anaesthesia, or who are considered mentally immature;

- Patients who are obese or have a short neck;
- Patients with upper spinal cord injuries;
- Patients suffering from recurrent laryngeal nerve palsy;
- Any patient allergic to the anaesthetic solution used in the nerve block.

Pani and Rath (2009) mention who patients that exhibit hepatic dysfunction should be carefully scrutinised to prevent toxic plasma levels. In the case of a patient being unwilling or exhibiting distorted anatomy, regional anaesthetic nerve blocks on the neck region should not be performed. A patient with poor pulmonary function or a previous myocardial infarction should be carefully observed (Prasad and Shanmugam, 1998).

The ultimate contra-indication for the performance of a superior or recurrent laryngeal nerve block relates to the ability of the patient to cough. Wedel (2000) and Miller (2010) state that a translaryngeal nerve block should not be performed in patients where coughing is undesirable, due to the increased stimulating effect of the anaesthetic solution on the cough reflex.

4.2.1.3 Step-by-step procedure

According to Chelly (2009) and Pani and Rath (2009), the superior laryngeal nerve can be blocked by an internal non-invasive approach, or an external invasive approach. The internal non-invasive approach consists of the direct placement of a gauze or cotton ball covered with anaesthetic solution, in the piriform recess. This pear-shaped fossa is located in the wall of the laryngopharynx, medial to the lamina of the thyroid cartilage and lateral to the arytenoid cartilages. The cotton swab must be held in place for approximately five minutes, to successfully block the superior laryngeal nerve that runs deep to the mucous membrane. This method, however, is the least commonly performed procedure.

General consensus exists with regard to the exact location for the performance of the external invasive approach to the superior laryngeal nerve block. The needle is placed inferior to the greater horn of the hyoid bone, and superior to the thyroid cartilage (Prasad and Shanmugam, 1998; Wedel, 2000; Vas and Sawant, 2001; Cunnington, 2002; Peltier, 2006; Chelly, 2009; Pani and Rath, 2009; Waldman, 2009). The needle pierces the thyrohyoid membrane, a popping sound can be heard, as a slight loss of resistance is experienced (Cunnington, 2002; Peltier, 2006).

Additional information should be taken into consideration before applying this procedure:

- Prasad and Shanmugam (1998), Wedel (2000), Chelly (2009) and Miller (2010), state that the hyoid bone should be displaced toward the side that is being blocked. This will facilitate the accurate identification of the landmarks.
- The carotid artery needs to be displaced laterally and posteriorly (Chelly, 2009; Miller, 2010; Iida *et al.,* 2012). Cunnington (2002) mentions that the needle should be placed medial to the carotid pulse.
- To insure the exact location for the needle entry point, the needle tip is “walked off” the greater cornu of the hyoid, in an anterior-inferior direction (Prasad and Shanmugam, 1998; Wedel, 2000; Chelly, 2009; Miller, 2010).
- Wedel (2000), Peltier (2006), Chelly (2009) and Miller (2010) report that this nerve block should be performed bilaterally. However, Waldman (2009) comments that the bilateral block should be avoided, to minimise the adverse effects of this block.

Chelly (2009) provided the following useful information when performing the superior laryngeal nerve block:

- Firmly displace the hyoid bone towards the side to be blocked, even if it causes the patient minor discomfort;
- “Not to insert the needle into the thyroid cartilage, since injection of local anaesthetic at the level of vocal cords may cause oedema and airway obstruction”;
- If air is aspirated, the laryngeal mucosa is pierced and the needle should be retracted;

- If blood is aspirated, a blood vessel has been punctured. The needle should be redirected anteriorly, while pressure is applied to the specific area to prevent the formation of a haematoma.

Pani and Rath (2009) state that the recurrent laryngeal nerve block is easily accomplished by means of a translaryngeal nerve block which is considered a topicalisation technique. This is performed by means of an injection into the larynx, involving a needle being passed through the cricothyroid membrane. Direct infiltration is contra-indicated by these authors, due to the possibility of airway obstruction as a result of all the muscles of the larynx, except the cricothyroid muscle, being affected.

The recurrent laryngeal nerve block is referred to as a transtracheal block (Peltier, 2006; Chelly, 2009) or a translaryngeal block (Prasad and Shanmugam, 1998; Wedel, 2000; Chelly, 2009; Miller, 2010; Iida *et al.,* 2012). Regardless of the exact name for this nerve block, the location remains constant, according to the obtained literature.

The translaryngeal nerve block is sufficient for providing topical anaesthesia to the laryngotracheal mucosa. In order to accurately enter the laryngeal cavity, the patient's neck should be hyperextended, or the pillow removed (Chelly, 2009). The cricothyroid membrane is identified by placing the index and third finger on the thyroid and cricoid cartilage respectively (Chelly, 2009; De Oliveira *et al.,* 2011). The needle pierces the cricothyroid membrane perpendicular to the skin (Prasad and Shanmugam, 1998; Wedel, 2000; Peltier, 2006; Chelly, 2009; Miller, 2010; Iida *et al.,* 2012).

Special attention needs to be placed on the speed of the performance of this nerve block. The patient is required to forcefully exhale, prior to the anaesthetic solution being injected. The anaesthetic solution is injected as soon as the patient inhales which results in the patient coughing profusely, spreading the anaesthetic solution (Peltier, 2006; Chelly, 2009; Miller, 2010; De Oliveira, 2011). Therefore, the needle must be withdrawn immediately after the anaesthetic has been injected (Prasad and Shanmugam, 1998; Peltier, 2006).

Chelly (2009) provides the following helpful hints with regard to the recurrent laryngeal nerve block:

- If a regular needle is used instead of a catheter, the needle must be removed immediately after injection. Surrounding structures such as the posterior tracheal wall can be damaged if stabilisation of the needle has not occurred.
- Should a catheter be used, it must be kept in place until the intubation is complete. This will assist with the administration of more anaesthetic solution, and decrease the possibility of subcutaneous emphysema.

4.2.1.4 Anatomical pitfalls

De Oliveira *et al.* (2011) and Iida *et al.* (2012) mention that the most profound challenge when performing these nerve blocks, relate to the difficulty in recognising or identifying the landmarks. This is especially difficult in obese patients, or where anatomical abnormalities exist due to pathology. Excessive swelling can also result in difficulty palpating the landmarks (Iida *et al.,* 2012). Even though ultrasound guidance can facilitate the performance of these nerve blocks doctors are often reluctant to perform these nerve blocks.

The possibility of increased bleeding or haematoma formation, that can result in airway obstruction, also discourages doctors in using these nerve blocks, regardless of the helpful assistance during awake intubations (Iida *et al.,* 2012).

4.2.1.5 Complications (anatomically relevant)

The following complications can result due to the superior laryngeal nerve block:

- Haematoma formation: Due to puncturing of a vascular structure or intravascular injection. Can be minimised by maintaining pressure on the affected area (Das and Pearce, 2002; Chelly, 2009; Waldman, 2009).
- Systemic toxicity: Due to the proximity of the external carotid artery, external jugular vein and other blood vessels, as well as the perfused

mucosa of the airway, absorption of the anaesthetic solution can occur rapidly. Therefore, careful attention must be placed on total drug dosages (Wedel, 2000; Chelly, 2009; Waldman, 2009).

- Waldman (2009) states that the close relationship between the trachea and the superior laryngeal nerve makes intratracheal injection a possibility. Therefore, occult aspiration can put the patient at risk, especially if a bilaterally nerve block is performed.
- A patient with a possible full stomach must be carefully observed, due to the abolished airway reflexes, even though this complication is rare (Wedel, 2000).
- Alalami *et al.* (2008) state: "Laryngospasm may occur secondary to loss of inhibition of the laryngeal closure reflex as a result of abnormal excitation."
- Iida *et al.* (2012) report that one of their patients complained of slight hoarseness after surgery. This, however, disappeared within a day after surgery.

Chelly (2009) lists the following complications related to the translaryngeal nerve block:

- Risk of coughing: This nerve block rapidly induced the coughing reflex. During this procedure, the patient should not talk, swallow and cough. Therefore, this block is contra-indicated in patients with an unstable neck, or in whom coughing is undesirable.
- Structural injuries: The close proximity of the posterior tracheal wall and the vocal cords puts these structures at risk, especially if the needle is not stabilised during injection, or removed immediately.
- Intravascular injection, vascular injury: Arterial or venous structure can easily be damaged. Therefore, aspiration should be performed prior to the injection of the anaesthetic fluid, and pressure must be applied over the injection area to minimise the possibility of haematoma formation.
- Systemic toxicity: The risk increases during airway nerve blocks, because multiple techniques are frequently performed. The risk of systemic toxicity can be minimised by carefully calculating the combined dosages administered to the patient during the different regional nerve blocks.

4.2.1.6 References

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5. Conclusion

Neonates and infants often require surgery performed under general anaesthesia. Such surgery is often associated with severe post-operative pain. Peripheral nerve blocks not only reduce the amount of anaesthetic solution required, thus minimising the possible side effects, but can also provide sufficient pain relieve in the post-operative period. This study was primarily conducted to gain insight into the field of regional anaesthetic nerve blocks, and the importance and relevance of the related clinical anatomy. The knowledge obtained from the different aspects of this study, not only empowers doctors with the much essential knowledge required for the performance of these nerve blocks, but has also raised several questions with regard to the beneficial effect of anatomical knowledge, or the detrimental effect in the absence of that knowledge.

Considering the progressive and swift rate at which the medical field changes with regard to technology and possible techniques, it is of the utmost importance to ensure that the foundation, anatomical knowledge, is in place. From this study, the different approaches, techniques and landmarks for various peripheral nerve blocks were investigated. However, due to the vast differences obtained from the results with regard to locations, methods, bony landmarks and procedures, several future studies, mostly dissection based, are needed to successfully answer the identified questions. This will lead to the substantial improvement in the field of regional anaesthetic nerve blocks. An improvement in the relevant anatomical knowledge for each procedure will decrease the failure rate, ensure fewer complications and difficulties encountered and will result in an increase in the comfort levels of the performing doctors when executing these procedures.

Appendix A

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

6 July 2011

Dear Doctor

For my M.Sc. Anatomy (University of Pretoria) thesis I aim to investigate the prevalence of a range of paediatric regional anaesthetic procedures performed in South-Africa and the knowledge required to ensure that these procedures are safely and successfully performed. Your time and contribution to this study will not only be gladly appreciated, but the information obtained from this survey will give valuable insights to nerve blocks performed in the head and neck on children in South Africa, and subsequently aid in the development and improvement of these regional anaesthetic procedures

Your participation in this study is entirely voluntary. If you however decide to participate in this nation-wide study, the completion of a simple questionnaire, is all that will be required of you. If this is the case we assume that you have consented to participate in the study, knowing full well that your questionnaire will be kept strictly confidential and no information identifying you will be released or published.

You need only to tick your answer (where applicable) in the provided tick-box. Each of the 17 procedures has 9 questions.

A much appreciated word of thanks for your time and cooperation in the completion of this questionnaire.

Thanking you in future

Miss L van der Merwe (Primary investigator)
Department of Anatomy

Prof MC Bosman (Supervisor)
Department of Anatomy

Dr AN van Schoor (Co-supervisor)
Department of Anatomy

Appendix B

Years of anaesthesiology experience

- ☐ Anaesthesiology registrar
- ☐ 1 – 3 years
- ☐ 4 – 6 years
- ☐ 7 – 9 years
- ☐ 10 years or more

I perform this procedure in my practice:

- ☐ Facial nerve block
- ☐ Trigeminal nerve: Ophthalmic division (Supra-orbital and supra-trochlear nerve blocks)
- ☐ Trigeminal nerve: Maxillary division (infra-orbital nerve block) Intra-oral approach
- ☐ Trigeminal nerve: Maxillary division (infra-orbital nerve block) Extra-oral approach
- ☐ Trigeminal nerve: Maxillary division (Zygomaticotemporal nerve block)
- ☐ Trigeminal nerve: Maxillary division (Zygomaticofacial nerve block)
- ☐ Trigeminal nerve: Maxillary division (Palatine nerve block)
- ☐ Trigeminal nerve: Mandibular division (Mental nerve block)
- ☐ Trigeminal nerve: Mandibular division (Auriculotemporal nerve block)
- ☐ Cervical plexus (Greater auricular nerve block)
- ☐ Cervical plexus (Lesser occipital nerve block)
- ☐ Cervical plexus (Greater occipital nerve block)
- ☐ Cervical plexus (Transverse cervical nerve block)
- ☐ Cervical plexus (Supra-clavicular nerve block)
- ☐ Glossopharyngeal nerve block
- ☐ Superior laryngeal nerve block
- ☐ Recurrent laryngeal nerve block
- ☐ Stellate ganglion block
- ☐ I do not perform any of the above mentioned nerve blocks
- ☐ By ticking this box you give consent for your completed questionnaire to be used in the M.S.c study described in the above cover letter.

Comments: ______________________________________

____

____

Facial nerve block

1. I perform this procedure in my practice
    - ☐ Yes
    - ☐ No
2. I perform this procedure on
    - ☐ Adults
    - ☐ Children
    - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
    - ☐ More than 20
    - ☐ 10 – 20
    - ☐ 5 – 10
    - ☐ Less than 5
4. The performance of this procedure is important for my practice
    - ☐ Essential
    - ☐ Desirable but not essential
    - ☐ Useful
    - ☐ Not necessary
5. I feel comfortable to perform this procedure
    - ☐ Very comfortable
    - ☐ Fairly comfortable
    - ☐ Uncomfortable
    - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
    - ☐ Knowledge of the procedure itself
    - ☐ Equipment necessary for the procedure
    - ☐ Practical skills to perform the procedure
    - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure (you can make multiple selections)
    - ☐ Intravascular injection
    - ☐ Difficulty in palpation of bony landmarks
    - ☐ Respiratory obstruction / difficulty in swallowing
    - ☐ Permanent unilateral palsy of facial musculature
    - ☐ Ipsi-lateral facial weakness
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree

Trigeminal nerve: Ophthalmic division (Supra-orbital and supra-trochlear nerve blocks)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Deficient needle placing, resulting in spread of anaesthetic
   - ☐ Intravascular injection
   - ☐ Difficulty in palpation of bony landmarks
   - ☐ Incorrect anaesthetic due to variable location of nerves
   - ☐ Damage to eye globe
   - ☐ Black eye due to injury of loose vascular connective tissue
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Trigeminal nerve: Maxillary division (infra-orbital nerve block) Intra-oral approach

1. I perform this procedure in my practice
    - ☐ Yes
    - ☐ No
2. I perform this procedure on
    - ☐ Adults
    - ☐ Children
    - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
    - ☐ More than 20
    - ☐ 10 – 20
    - ☐ 5 – 10
    - ☐ Less than 5
4. The performance of this procedure is important for my practice
    - ☐ Essential
    - ☐ Desirable but not essential
    - ☐ Useful
    - ☐ Not necessary
5. I feel comfortable to perform this procedure
    - ☐ Very comfortable
    - ☐ Fairly comfortable
    - ☐ Uncomfortable
    - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
    - ☐ Knowledge of the procedure itself
    - ☐ Equipment necessary for the procedure
    - ☐ Practical skills to perform the procedure
    - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
    - ☐ Needle placed in wrong direction
    - ☐ Difficulty of palpation of infra-orbital foramen or bony landmarks
    - ☐ Damage of nerve by compression within foramen
    - ☐ Damage of orbital contents through penetration of orbital floor
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree

Trigeminal nerve: Maxillary division (infra-orbital nerve block) Extra-oral approach

1. I perform this procedure in my practice
   - Yes
   - No
2. I perform this procedure on
   - Adults
   - Children
   - Adults and Children
3. How many times did you perform this procedure in the past year?
   - More than 20
   - 10 – 20
   - 5 – 10
   - Less than 5
4. The performance of this procedure is important for my practice
   - Essential
   - Desirable but not essential
   - Useful
   - Not necessary
5. I feel comfortable to perform this procedure
   - Very comfortable
   - Fairly comfortable
   - Uncomfortable
   - Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - Knowledge of the procedure itself
   - Equipment necessary for the procedure
   - Practical skills to perform the procedure
   - Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - Difficulty in palpation of infra-orbital foramen or bony landmarks
   - Injury to the nerve
   - Intravascular injection
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree

Trigeminal nerve: Maxillary division (Zygomaticotemporal nerve block)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Inadequate anaesthesia due to subcutaneous infiltration
   - ☐ Difficulty in palpation of bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Trigeminal nerve: Maxillary division (Zygomaticofacial nerve block)

1. I perform this procedure in my practice
    - ☐ Yes
    - ☐ No
2. I perform this procedure on
    - ☐ Adults
    - ☐ Children
    - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
    - ☐ More than 20
    - ☐ 10 – 20
    - ☐ 5 – 10
    - ☐ Less than 5
4. The performance of this procedure is important for my practice
    - ☐ Essential
    - ☐ Desirable but not essential
    - ☐ Useful
    - ☐ Not necessary
5. I feel comfortable to perform this procedure
    - ☐ Very comfortable
    - ☐ Fairly comfortable
    - ☐ Uncomfortable
    - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
    - ☐ Knowledge of the procedure itself
    - ☐ Equipment necessary for the procedure
    - ☐ Practical skills to perform the procedure
    - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
    - ☐ Inadequate anaesthesia due to subcutaneous infiltration
    - ☐ Difficulty in palpation of bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree

Trigeminal nerve: Maxillary division (Palatine nerve block)

1. I perform this procedure in my practice
   - Yes
   - No
2. I perform this procedure on
   - Adults
   - Children
   - Adults and Children
3. How many times did you perform this procedure in the past year?
   - More than 20
   - 10 – 20
   - 5 – 10
   - Less than 5
4. The performance of this procedure is important for my practice
   - Essential
   - Desirable but not essential
   - Useful
   - Not necessary
5. I feel comfortable to perform this procedure
   - Very comfortable
   - Fairly comfortable
   - Uncomfortable
   - Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - Knowledge of the procedure itself
   - Equipment necessary for the procedure
   - Practical skills to perform the procedure
   - Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - Intravascular injection
   - Intraneural injection
   - Difficulty in palpation of bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree

Trigeminal nerve: Mandibular division (Mental nerve block)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection
   - ☐ Damaging of neural structures
   - ☐ Difficulty in palpation of mental foramen or bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Trigeminal nerve: Mandibular division (Auriculotemporal nerve block)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection
   - ☐ Penetration of superficial temporal artery
   - ☐ Damaging of neural structures
   - ☐ Difficulty in palpation of bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Blocks performed in the neck region

Cervical plexus (Greater auricular nerve block)

1. I perform this procedure in my practice
   - Yes
   - No
2. I perform this procedure on
   - Adults
   - Children
   - Adults and Children
3. How many times did you perform this procedure in the past year?
   - More than 20
   - 10 – 20
   - 5 – 10
   - Less than 5
4. The performance of this procedure is important for my practice
   - Essential
   - Desirable but not essential
   - Useful
   - Not necessary
5. I feel comfortable to perform this procedure
   - Very comfortable
   - Fairly comfortable
   - Uncomfortable
   - Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - Knowledge of the procedure itself
   - Equipment necessary for the procedure
   - Practical skills to perform the procedure
   - Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - Intravascular injection [puncturing of external jugular vein]
   - Difficulty in palpation of bony landmarks
   - Inability to identify muscular landmarks
   - Blocked deep cervical plexus
   - Blocked phrenic nerve
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree

Cervical plexus (Lesser Occipital nerve block)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection [puncturing of external jugular vein]
   - ☐ Difficulty in palpation of bony landmarks
   - ☐ Inability to identify muscular landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Cervical plexus (Greater occipital nerve block)

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection [puncturing of occipital artery]
   - ☐ Difficulty in palpation of bony landmarks
   - ☐ Difficulty in identifying of muscular landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Cervical plexus (Transverse cervical nerve block)

1. I perform this procedure in my practice
    - ☐ Yes
    - ☐ No
2. I perform this procedure on
    - ☐ Adults
    - ☐ Children
    - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
    - ☐ More than 20
    - ☐ 10 – 20
    - ☐ 5 – 10
    - ☐ Less than 5
4. The performance of this procedure is important for my practice
    - ☐ Essential
    - ☐ Desirable but not essential
    - ☐ Useful
    - ☐ Not necessary
5. I feel comfortable to perform this procedure
    - ☐ Very comfortable
    - ☐ Fairly comfortable
    - ☐ Uncomfortable
    - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
    - ☐ Knowledge of the procedure itself
    - ☐ Equipment necessary for the procedure
    - ☐ Practical skills to perform the procedure
    - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
    - ☐ Intravascular injection [puncturing of external jugular vein]
    - ☐ Difficulty in palpation of bony landmarks
    - ☐ Difficulty in identification of muscular landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
    - ☐ Strongly agree
    - ☐ Agree
    - ☐ Disagree
    - ☐ Strongly disagree

Cervical plexus (Supra-clavicular nerve block)

1. I perform this procedure in my practice
   - Yes
   - No
2. I perform this procedure on
   - Adults
   - Children
   - Adults and Children
3. How many times did you perform this procedure in the past year?
   - More than 20
   - 10 – 20
   - 5 – 10
   - Less than 5
4. The performance of this procedure is important for my practice
   - Essential
   - Desirable but not essential
   - Useful
   - Not necessary
5. I feel comfortable to perform this procedure
   - Very comfortable
   - Fairly comfortable
   - Uncomfortable
   - Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - Knowledge of the procedure itself
   - Equipment necessary for the procedure
   - Practical skills to perform the procedure
   - Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - Intravascular injection [puncturing of external jugular vein]
   - Difficulty in palpation of bony landmarks
   - Difficulty in identifying of muscular landmarks
   - Injury to nerve
   - Pneumo-thorax due to penetration of apical pleura
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree

Glossopharyngeal nerve block

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection [puncturing of the vertebral artery, Common carotid artery or Internal jugular vein]
   - ☐ Blocked facial nerve
   - ☐ Facial weakness
   - ☐ Facial sensory deficit
   - ☐ CSF leak
   - ☐ Blocked Vagus and Accessory nerves resulting in weakness of Sternocleidomastoid and trapezius muscles and hoarseness
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Superior laryngeal nerve block

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Intravascular injection
   - ☐ Damage to other closely related structures
   - ☐ Difficulty in palpation of bony landmarks
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Recurrent laryngeal nerve block

1. I perform this procedure in my practice
   - ☐ Yes
   - ☐ No
2. I perform this procedure on
   - ☐ Adults
   - ☐ Children
   - ☐ Adults and Children
3. How many times did you perform this procedure in the past year?
   - ☐ More than 20
   - ☐ 10 – 20
   - ☐ 5 – 10
   - ☐ Less than 5
4. The performance of this procedure is important for my practice
   - ☐ Essential
   - ☐ Desirable but not essential
   - ☐ Useful
   - ☐ Not necessary
5. I feel comfortable to perform this procedure
   - ☐ Very comfortable
   - ☐ Fairly comfortable
   - ☐ Uncomfortable
   - ☐ Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - ☐ Knowledge of the procedure itself
   - ☐ Equipment necessary for the procedure
   - ☐ Practical skills to perform the procedure
   - ☐ Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - ☐ Horner's syndrome
   - ☐ Hoarseness
   - ☐ Sensation of having a lump in the throat
   - ☐ Shortness of breath due to paralysis of phrenic nerve
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - ☐ Strongly agree
   - ☐ Agree
   - ☐ Disagree
   - ☐ Strongly disagree

Stellate ganglion block

1. I perform this procedure in my practice
   - Yes
   - No
2. I perform this procedure on
   - Adults
   - Children
   - Adults and Children
3. How many times did you perform this procedure in the past year?
   - More than 20
   - 10 – 20
   - 5 – 10
   - Less than 5
4. The performance of this procedure is important for my practice
   - Essential
   - Desirable but not essential
   - Useful
   - Not necessary
5. I feel comfortable to perform this procedure
   - Very comfortable
   - Fairly comfortable
   - Uncomfortable
   - Very uncomfortable
6. I find difficulty to perform this procedure due to the following reasons
   - Knowledge of the procedure itself
   - Equipment necessary for the procedure
   - Practical skills to perform the procedure
   - Regional anatomy knowledge
7. I met the following complications and difficulties when performing this procedure
   - Intravascular injection [puncturing of vertebral of common carotid artery]
   - Diffusion of local anaesthetic to adjacent neural structures
   - Horner's syndrome [ptosis, myosis, enopthalmos, anhidrosis of neck and face]
   - Dural puncture resulting in intraspinal injection
   - Pneumo-thorax
   - Needle trauma to closely related structures
8. The improvement of critical anatomical knowledge will reduce difficulties and complications experienced in this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree
9. Improvement of my anatomical knowledge will increase my confidence in performing this procedure
   - Strongly agree
   - Agree
   - Disagree
   - Strongly disagree

Appendix C

Scoring option I:

1. Patient demographics	> Adults than children	1 point
	Adults = children	2 points
	> Children than adults	3 points
2. Incidence of performance	< 7.5%	1 point
	> 7.6 %	2 points
3. Essentiality	< 80 %	1 point
	> 81 %	2 points
4. Comfortability	Uncomfortable > 10 %	1 point
	Uncomfortable > comfortable	2 points
5. Difficulty or complications, related to anatomy, experienced by:		
	20 – 30%	1 point
	> 30 %	2 points
6. Critical anatomical knowledge will reduce difficulties and complications.		
	< 90%	1 point
	> 91 %	2 points
7. Improvement of anatomical knowledge will increase confidence during performance of the procedure		
	< 90 %	1 point
	> 91 %	2 points
	Maximum score	**15 points**

Scoring option II:

1. Patient demographics	> Adults than children	1 point
	Adults = children	2 points
	> Children than adults	3 points
2. Incidence of performance	< 5%	1 point
	5 - 10 %	2 points
	> 10 %	3 points
3. Essentiality	< 60 %	1 point
	60 – 79 %	2 points
	80 – 100 %	3 points
4. Comfortability	Uncomfortable > 10 %	1 point
	Uncomfortable > comfortable	2 points
5. Difficulty or complications, related to anatomy, experienced by:		
	20 – 30%	1 point
	> 30 %	2 points
6. Critical anatomical knowledge will reduce difficulties and complications.		
	80 – 90%	1 point
	91 – 100 %	2 points
7. Improvement of anatomical knowledge will increase confidence during performance of the procedure		
	80 – 90%	1 point
	91 – 100 %	2 points
	Maximum score	**17 points**

Scoring option III:

1. Patient demographics	> Adults than children	1 point
	Adults = children	2 points
	> Children than adults	3 points
2. Incidence of performance	0 - 4%	1 point
	4.1 - 8 %	2 points
	8.1 – 12 %	3 points
	12.1 – 15 %	4 points
	> 15 %	5 points
3. Essentiality	< 40 %	1 point
	40 – 59 %	2 points
	60 – 79 %	3 points
	80 – 100%	4 points
4. Comfortability	Uncomfortable 10 - 19 %	1 point
	Uncomfortable 20 – 29 %	2 points
	Uncomfortable > 30 %	3 points
	Uncomfortable > comfortable	4 points
5. Difficulty or complications, related to anatomy, experienced by:		
	10 – 19 %	1 point
	20 – 29 %	2 points
	> 30 %	3 points
6. Critical anatomical knowledge will reduce difficulties and complications:		
	80 – 90%	1 point
	91 – 100 %	2 points
7. Improvement of anatomical knowledge will increase confidence during performance of the procedure:		
	80 – 90 %	1 point
	91 – 100 %	2 points
	Maximum score	**23 points**