

**Descriptive study of the differences in the level of the conus medullaris
in four different age groups**

A. van Schoor¹, M.C. Bosman¹, A.T. Bosenberg²

Original communication

¹ Department of Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa.

² Director Regional Anesthesia, Department Anesthesiology and Pain Management, Seattle Children's Hospital, Seattle, USA.

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***Correspondence to:**

Dr. A. van Schoor,

Department of Anatomy, Section of Clinical Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria 0001, South Africa

Tel: +27 12 3192315

Telefax: +27 12 3192240

E-mail: albert.vanschoor@up.ac.za

ABSTRACT

INTRODUCTION: In performing neuraxial procedures, knowledge of the location of the conus medullaris in patients of all ages is important. The aim of this study was to determine the location of conus medullaris in a sample of

newborn/infant cadavers and sagittal MRIs of children, adolescents and young adults. **MATERIALS AND METHODS:** The subjects of both the samples were subdivided into four developmental stages. No statistical difference was seen between the three older age groups ($p>0.05$). A significant difference was evident when the newborn/infant stage was compared with the other, older stages ($p<0.001$ for all comparisons). **RESULTS:** In the newborn/infant group the spinal cord terminated most frequently at the level of L2/L3 (16%). In the childhood stage, the spinal cord terminated at the levels of T12/L1 and the lower third of L1 (21%). In the adolescent population, it was most often found at the level of the middle third of L1 and L1/L2 (19%). Finally, in the young adult group, the spinal cord terminated at the level of L1/L2 (25%). This study confirmed the different level of spinal cord termination between newborns/infants less than one year old and subjects older than one year. In this sample the conus medullaris was not found caudal to the L3 vertebral body, which is more cranial than the prescribed level of needle insertion recommended for lumbar neuraxial procedures. **CONCLUSION:** It is recommended that the exact level of spinal cord termination should be determined prior to attempting lumbar neuraxial procedures in newborns or infants.

Key words: anatomy; conus medullaris; lumbar puncture; lumbar epidural; spinal anesthesia; neonate

INTRODUCTION

Clinical procedures such as neuraxial and peripheral nerve blocks that either fail to achieve their objective or result in complications can often be linked to a lack of understanding or misunderstanding of the anatomy relevant to that specific procedure (Ger, 1996; AACA, EAC, 1999). Direct trauma to the spinal cord may occur if the needle is inserted too deeply, particularly at higher vertebral levels. Although this is a rare complication, as most punctures are carried out inferior to the conus medullaris (Fischer, 2009; Patel, 2009), a lack of knowledge of the surface anatomy (AACA, EAC, 1999) and imprecise needle insertion could result in spinal cord trauma and even paralysis (Absalom *et al.*, 2001).

The practice of regional anesthesia relies heavily on a sound knowledge of clinical anatomy (Winnie *et al.*, 1975). This is especially true for anesthesiologists who perform neuraxial blocks on pediatric patients (Bosenberg *et al.*, 2002). Anesthesiologists performing these procedures must have a clear understanding of the anatomy, the influence of age and size, and the potential complications and hazards of each procedure if good results are to be achieved (Brown, 1985).

Performing neuraxial procedures on pediatric patients has additional risks, especially since the anatomy described in adults is often not applicable to children of different ages. Many anesthesiologists, particularly those not used to working with children, may lack the knowledge of the relative depths or

position of certain key anatomical structures in children. The anatomy of children of various ages may differ to a greater or lesser degree from that of adults (Brown, 1985; Brown and Schulte-Steinberg, 1988; Bosenberg *et al.*, 2002). A thorough knowledge of these anatomical differences is therefore essential for the success of neuraxial procedures in children, even when ultrasound guidance is used (Siddiqui, 2007; Karmakar, 2010). Bony landmarks are poorly developed in infants if compared to those of adults. Muscular and tendinous landmarks, commonly used as a guide when neuraxial procedures in adults are performed, tend to lack definition in young children. Classical anatomical landmarks might also be absent or difficult to define in children with congenital deformities (Bosenberg *et al.*, 2002).

In performing neuraxial procedures, knowledge of the precise location of the conus medullaris in patients of all ages is important. The exact location of the conus medullaris in different age groups remains controversial. In previous studies, this level was determined by means of cadaver dissections (Needles, 1935; Barson, 1970; Govender *et al.*, 1989), analysis of magnetic resonance images (MRIs) (Wilson and Prince, 1989; Demiryürek *et al.*, 2002) and ultrasound imaging on younger patients (Wolf *et al.* 1992; Sahin *et al.*, 1997; Zalel *et al.*, 2006; Willischke *et al.*, 2007). These studies are dependent on the availability of specimens and, to the authors' knowledge, no existing studies have compared the accuracy of cadaver and imaging findings.

The aim of this study was to determine the precise location of conus medullaris – in relation to the vertebrae – in a sample of neonatal cadavers and sagittal MRIs of children, adolescents and young adults.

MATERIALS AND METHODS

Sample:

This study examined the level of the conus medullaris in two separate samples and included cadavers and MRIs of patients.

The subjects of both the samples were subdivided into four developmental stages. The first was (1) the newborn and infant stage (term to less than one year). These were exclusively cadavers. Toddlers (ages 1 to 4) and children (ages 5 to 12) were grouped together to represent the second stage – (2) the childhood stage (combined ages 1 to 12). The third stage was (3) the adolescence stage (ages 13 to 20), while the fourth stage was (4) early adulthood (ages 21 to 29). Stages 2 to 4 were exclusively MRIs of patients.

The newborn / infant cadavers examined in this study were within the ranges of very low birth weight (<1.5 kg), low birth weight (1.5 kg to 2.5 kg) and normal birth weight (>2.5 kg). No information regarding growth restriction or gestational age was available from the cadaver records. However, the cadaver sample were representative of neonates or premature infants who would present for neuraxial procedures, such as lumbar punctures, spinal anesthesia and lumbar epidural blocks in clinical practice.

MRIs were taken with a Philips 3T Ingenia MRI scanner. Only T2 or Proton Density Fat Suppression images of the lumbar region in the sagittal plane were examined. The slice thickness was 3mm. Observations were made on the DICOM files using the manufacture's software (GEARView Basic 2.1 PACSGEAR™ 2013 USA).

Ethical considerations:

All cadavers were legally obtained according to the requirements of the South African National Health Act, number 61 of 2003 and stored in the Department of Anatomy, University of Pretoria, South Africa for research and teaching purposes. Ethical clearance to perform this study (dissection of neonatal cadavers as well as examination of the MRIs of patients) was obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria. Permission to access the MRIs was also obtained from the Departments of Radiology of Unitas and Steve Biko Academic Hospitals, Gauteng, South Africa.

Stage 1. Newborn / infant stage (term to less than one year):

This group was examined by means of cadaver dissections. Only cadavers without macroscopic pathology or malformation of the back and vertebral column were included in the study. The lumbar and sacral regions of 44 neonatal cadavers (mean length: 0.42 m \pm 0.07 m; mean weight: 1.61 kg \pm 0.86 kg) were carefully dissected to expose the laminae and spinous

processes of the lumbar vertebrae and sacrum. The lumbar vertebrae were carefully marked for future reference.

Both the laminae of the sacrum and the lumbar vertebrae were cut and the spinous processes carefully removed with a scalpel, effectively exposing the dural sac within the vertebral canal. A midline incision was made through the dural sac and the two halves of the transected dural sac were reflected laterally to expose the spinal cord and cauda equina within (Figure 1).

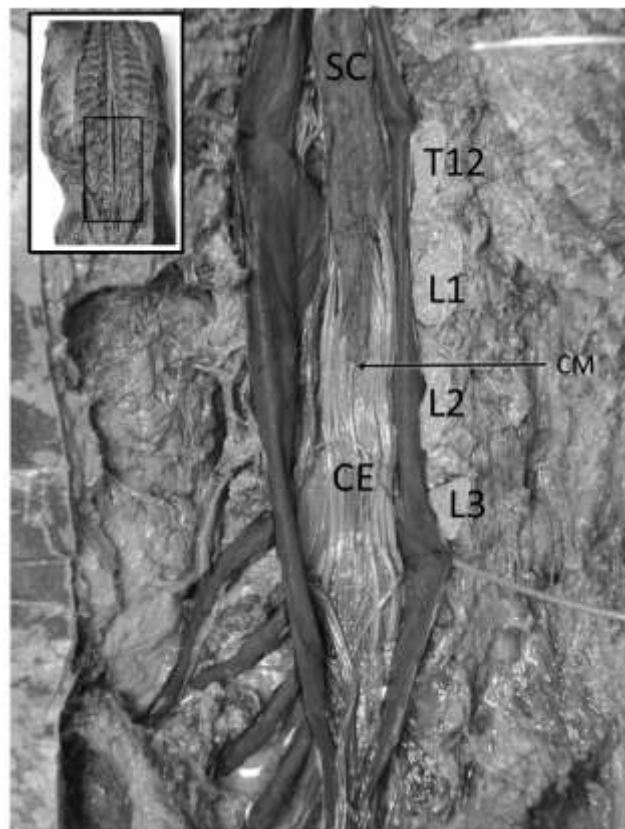


Figure 1: An exposed spinal cord (SC) and cauda equina (CE) of a neonatal cadaver. The T12-L3 vertebrae and conus medullaris (CM) are also indicated.

High-quality digital photographs were taken of the dissected vertebral columns. These photographs were imported into UTHSCSA Image Tool V3.0 that was used to analyze the photographs. Each vertebra on the photograph was divided into thirds and each third and each interlaminar space was given a corresponding number. For example, the upper third of thoracic vertebra (T) 12 was marked “1”, the middle third of T12 was “2”, the lower third of T12 was “3” and the space between T12 and lumbar vertebra (L) 1 was “4”. Numbering then continued from the upper border of L1 (which was “5”) to the lower third of L5 (which was “23”).

Stages 2, 3 and 4. Older subjects (1 to 29 years):

In older subjects, the termination of the conus medullaris was examined on MRIs. In order to compare this level with subjects representing different age groups, a series of 100 midsagittal, T2-weighted MRIs of the lumbar and sacral regions was obtained. Only patients that did not present with pathology, injury or malformation of the vertebral column, as indicated in the patient files and confirmed by a radiologist, were included in the study.

Each vertebra on the MRI was divided into thirds and each third and each intervertebral disc was given a corresponding number in a similar manner as for the cadaver sample (Figure 2).

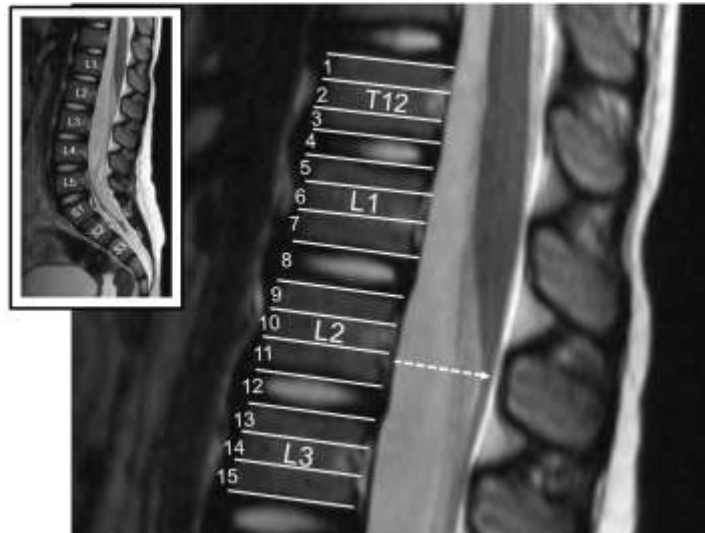


Figure 2: MRI of a 2 year old showing how the vertebrae were divided into thirds and numbered accordingly. The termination of the spinal cord is indicated by an arrow.

Statistical analysis:

The vertebral level where the spinal cord ended (the conus medullaris) was identified in the cadavers and on the MRIs. The number that corresponded to the observed vertebral level was noted and captured on a Microsoft Excel 2010 spreadsheet. The data was exported to SPSS statistical program (IBM SPSS 22 statistics, IBM Corporation and other(s) 2013). The median level at which the spinal cord terminated, as well as the cephalic (minimum) and caudal (maximum) ranges were determined through basic descriptive statistical analysis. All the analyses that were done between the groups were done using non-parametric methods because of the ordinal nature of the data. The Kruskal-Wallis test was used to assess the difference in median termination of the spinal cord between the four development-stage groups. The Mann-Whitney U test was then used to compare the median levels of spinal cord termination between each of the different developmental-stage

groups examined in this study. The three higher developmental-stage groups were then pooled because no clear difference could be demonstrated between them. The median spinal cord termination level was then compared between the infant group and the pooled higher developmental-stage groups using the Mann-Whitney-U test.

RESULTS

The median level as well as the range of termination of the spinal cord is summarized in Table 1.

Table 1: Vertebral level of conus medullaris for the four age groups is shown. The corresponding number is given in parentheses.

Developmental stage	n	Median	Cephalic level (minimum)	Caudal level (maximum)
Newborn / infant	44	Middle third L2 (10)	T12/L1 (4)	Middle third L3 (14)
Childhood	19	Lower third L1 (7)	Lower third T12 (3)	L2/L3 (12)
Adolescence	26	Lower third L1 (7)	T12/L1 (4)	L2/L3 (12)
Early adulthood	55	Lower third L1 (7)	Lower third T12 (3)	Middle third L2 (10)

When all four age groups were compared, a statistically significant difference for the level at which the spinal cord terminated was exhibited ($p < 0.001$). In further exploration of the differences between all combinations of group pairs

no statistical difference was seen when the levels of the conus medularis between the childhood, adolescent and young-adult stages were compared ($p > 0.05$). There was, however, a statistically significant difference in a comparison of this level in the newborn / infant stage with the childhood, adolescent and early adult stages ($p < 0.001$ for all comparisons).

The levels where the spinal cord terminated most frequently are summarized in Table 2.

Table 2: Level of spinal-cord termination in the four age groups, represented as a percentage at each level and as a block and whisker plot.

Vertebral level	Newborn / infant (<1 year)	Childhood (1-12 years)	Adolescence (13-20 years)	Early adulthood (21-29 years)
	%	%	%	%
Lower third T12	0	5	0	2
T12/L1	14	21	12	20
Upper third L1	2	11	15	13
Middle third L1	7	11	19	15
Lower third L1	2	21	15	15
L1/L2	9	11	19	25
Upper third L2	14	5	8	4
Middle third L2	14	5	4	7
Lower third L2	6	5	4	0
L2/L3	16	5	4	0
Upper third L3	11	0	0	0
Middle third L3	5	0	0	0

The shaded blocks show the vertebra as a whole (and not divided into thirds), in this way providing an overview of the prevalence of spinal cord termination per vertebral level.

As was shown in Table 2, the results of the current study showed that in the newborn / infant group the spinal cord terminated most frequently at the level of L2/L3 (16%) and the median level of termination was at the middle third of L2. In the childhood stage, the conus medullaris was found to be at the levels of T12/L1 and the lower third of L1 (both in 21% of the sample). In the adolescent population, the conus medullaris was most often found at the level of the middle third of L1 and the L1/L2 interlaminar space (19%). In the young adult group, the conus medullaris was most frequently found at the level of L1/L2 (25%) followed by the T12/L1 level (20%) and then the middle and lower thirds of L1 (15%). The median point of spinal cord termination for the childhood, adolescent and early adult stages were all at the level of the lower third of L1.

DISCUSSION

Knowledge of the level of spinal cord termination is important when performing neuraxial procedures on patients of all age groups, especially on newborns and infants, where the anatomy is often not well known. The required knowledge does not only include the level of termination of the spinal cord, but also the range of possible levels of termination. Although rare, potential trauma to the spinal cord still remains a very real risk whenever neuraxial procedures are performed without sufficient anatomical knowledge. The current study clearly showed a difference in the level of the conus medullaris between infants and older children. Between older age groups no clear difference could be demonstrated.

Barson (1970) was the first to dissect term and preterm cadaveric specimens in order to track the ascent of the conus medullaris throughout gestational development. He reported a rapid ascent to L4 during the 19th week of development, followed by a slower ascent to L2 at term, reaching the adult level of L1/L2 at two months. Wolf *et al.* (1992) conducted a similar study using ultrasonography. These authors found that the tip of the conus medullaris, in the first group (gestational age: 30-39 weeks) was between L2 and L4 in 84% of cases. In the second group (gestational age: 40-63 weeks) this level was most often between T12/L1 and L1/L2. Zalel *et al.* (2006) and Rozzelle *et al.* (2014) also used ultrasound to assess the level of the normal conus medullaris in fetuses and infants. The former examined 110 fetuses and found that in all cases the conus medullaris was at the level of L4 between gestational weeks 13 to 18 weeks. At term, all fetuses showed the conus medullaris above the level of L2, with a distinct ascent between gestational weeks 13 to 40. Rozzelle *et al.* (2014) conducted a retrospective review of more than a thousand lumbar ultrasounds of infants referred to a pediatric tertiary referral center. They found that the level of the conus medullaris ranged between T12 and L4, with the median corresponding with the L1/L2 interlaminar space. The spinal cord terminating at the level of L2 in the newborn / infant group examined in the current study coincides with the findings of the above-mentioned studies.

MRI studies have been shown to be a reliable method of determining the level of the conus medullaris. Wilson and Prince (1989) reviewed a sample of 184 lumbar MRIs in children of different ages and found that the range of conus

levels was T12 to L3 and that the adult level (L1/L2) was attained during the first few months of life. In an adult sample, Saifuddin *et al.* (1998) assessed 504 lumbar MRIs and concluded that the position of the conus medullaris ranged between the middle third of T12 and the upper third of L3. Similar to these studies, the MRI results of the subjects in the current study also showed that the most common level of termination was at adult levels, approximately at the level of L1/L2.

Malas *et al.*, (2000) examined the level of conus medullaris in fetuses and adults. These researchers dissected 25 fetuses, used ultrasonography in 25 premature babies, and examined MRIs of 25 adults. They found that the conus medullaris terminated between L1 and L3 in both fetuses and premature babies and between T12 and L2 in adults. Sahin *et al.* (1997) also examined the vertebral level of the conus medullaris in preterm- and term babies. They found that the spinal cord ended at L1/L2 in 88% of the preterm and 78% in the term babies examined of the samples. In the total sample, the conus medullaris was found below the level of L4 in two cases. Willschke *et al.* (2007) conducted an extensive ultrasonographic study on 145 term- and preterm neonates undergoing epidural catheter placement. The authors' aim was to describe the sonographic anatomy of the epidural space of patients in this age group and include the skin-to-ligamentum flavum depth at various levels as well as the level of the conus medullaris. In their study, the conus medullaris was found between L1 and L2 in all the neonates (1 kg to 4 kg) except in the low-birth weight premature neonates (< 1 kg), which was at the level of L2. The similarity of this level to the findings in the newborn / infant

group supports the results that were found in the current study, which was found to be most frequently at the level of L2.

Demiryürek *et al.* (2002) studied a large sample of lumbar MRIs (n = 639) to determine the range of conus medullaris levels in adults patients (ages 20 to 69 years). The authors found that the spinal cord terminated between the T11/T12 interlaminar space and the upper third of L3. These findings were similar to those of Needles (1935), Boonpirak and Apinhasmit (1994), Saifuddin *et al.* (1998), and Malas *et al.* (2000). The mean level of the conus medullaris in Demiryürek and co-workers' (2002) study was located at the T12/L1 intervertebral disc space in 22.38% of their entire population. These authors also felt that it would be of greater clinical value to give minimum and maximum levels, as these represent possible variations that should be taken into account in performing lumbar punctures, spinal or epidural blocks. Demiryürek *et al.* (2002) reported that the conus medullaris was located between the lower third of T12 and the middle third of L1 in 35% of their sample. In the current study, the level of the conus medullaris was found at the level of the L2 vertebra in 34% of the newborn / infant sample. This was followed by the L2/L3 intervertebral space and the L3 vertebra (16% each). These levels progressively ascended to higher vertebral levels as the sample's age increased. There was no case in the newborn / infant group where the spinal cord terminated lower than the level of L3. This finding is not surprising since having a conus medullaris below this level is regarded as pathological and suggestive of a tethered cord. Wolf *et al.* (1992) reported a spinal cord terminating at the level of L4 in a healthy three-month-old infant,

while Sahin *et al.* (1997) reported two cases where the conus medullaris was found below L4. Regardless, the most caudal level of the conus medullaris was two cases where the level was at the middle third of L3.

In the childhood and adolescent groups the lowest level was at L2/L3 (one case). This caudal level is similar to the findings of the study conducted by Demiryürek *et al.* (2002). The results of similar studies are summarized in Table 3.

Table 3: Summary of the literature. A range is given for each age group, and, where possible, the mean level (in parentheses). Whenever possible, the range where the conus medullaris can most frequently be found is also given in brackets.

Study	Newborn / infant (<1 year)	Childhood (1-12 years)	Adolescence (13-20 years)	Early adulthood (21-29 years)
Needles, 1935	-	-	-	T12 - L3 [L1 - L2 (49%)]
Barson, 1970	L1 - L3	L1 - L3	L1/L2	-
Govender <i>et al.</i> , 1989	T12 - L3/L4 (Mean: L1)	-	-	-
Wilson & Prince, 1989	T12/L1 - L1/L2	T12/L1 - L2	L1 - L2	-
Wolf <i>et al.</i> , 1992	T12/L1 - L4 [L1/L2 - L2/L3 (76%)]			
Boonpirak & Apinhasmit, 1994	-	-	-	T12 - L3 (Mean: L1/L2)
Sahin <i>et al.</i> , 1997	T12 - L4 [L1/L2 (78%)]			
Saifuddin <i>et al.</i> , 1998	-	-	-	T12 - L3 (Mean: L1)
Demiryürek <i>et al.</i> , 2002	-	-	-	T11 - L3 [T12/L1 - L1/L2 (86%)]
Soleiman <i>et al.</i> , 2005	-	-	-	T11/T12 - L3 (Mean: L1)
Zalel <i>et al.</i> , 2006	[L1 - L1/L2 (79%)]	-	-	-
Willischke <i>et al.</i> , 2007	L1 - L3 (Mean: L2)	-	-	-
Current study	T12/L1 - L3 [L2-L3 (66%)]	T12 - L2/L3 [L1 - L2 (69%)]	T12/L1 - L2/L3 [L1 - L2 (84%)]	T12 - L2 [T12/L1 - L1/L2 (87%)]

Hale et al. (2010) questioned the accuracy of modern clinical and surface anatomy texts in reporting surface anatomy landmarks. They analyzed thirteen popular texts and provided evidence-based recommendations for the termination of the spinal cord. What they found was similar to most of the studies summarized in Table 3, and also corresponds with the current study. In their article, Hale et al. stated that the adult spinal cord terminates between T11 and L3. They did not look at the termination of the spinal cord in children however.

Anatomical studies remain the foundation of clinical procedures. Significant neurological complications and even death have occurred following neuraxial procedures on patients of all age groups where the anatomy was not clear or improperly understood (Flandin-Bety and Barrier, 1995; Allison *et al.*, 2008; Meyer *et al.*, 2012). Direct trauma to the spinal cord that causes paralysis can be the result of procedures done without proper knowledge of the anatomy. Awareness of the range of termination of the conus medullaris is therefore important to avert disasters when neuraxial procedures are performed. Prior ultrasound evaluation is invaluable, but is really only clinically practical in infants and neonates before ossification of the vertebral column has occurred (Willschke *et al.*, 2007).

The available samples proved to be a limitation to this study as it was difficult to obtain newborn / infant MRIs in sufficient numbers. Neonatal cadavers were therefore used to determine the level of conus medullaris. The fact that the

observations were made on two different samples – a cadaver sample, for the neonates, and a sample of MRIs – should be taken into account.

CONCLUSION

This study confirmed the different level of spinal cord termination between newborns / infants less than one year old and subjects older than one year. In this sample the conus medullaris was not found lower than the L3 vertebral body, which is higher than the prescribed level of needle insertion recommended for lumbar neuraxial procedures at L4/L5 or L5/S1 (Willschke *et al.*, 2007; Fischer, 2009; Patel, 2009). It is still recommended that, if at all possible, the exact level of spinal cord termination should be determined prior to attempting lumbar neuraxial procedures in newborns or infants.

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CONFLICT OF INTERESTS

There is no conflict of interest to declare by any of the authors.

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