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RESEARCH

Evaluation of conus medullaris level in newborn infants

Yenidoğan bebeklerde konus medullaris düzeyinin değerlendirilmesi

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Abstract

Purpose: Previous studies have reported that the conus medullaris (CM) is located between T12 and L2 in most adults, but no significant ascent has been observed during childhood. There is evidence that the normal position of the CM in an adult is acquired at birth in the majority of cases. Studies have shown that there are differences in CM levels in neonates. This situation causes problems for interventional procedures in the neonatal period. The aim of this study is to determine CM levels in preterm/term neonates using ultrasound (US).

Materials and Methods: Newborn infants (gestational age: 24–43 weeks) admitted to the neonatal intensive care unit between March 2020 and June 2021 were evaluated for CM levels by the postnatal US. Infants with central nervous system abnormalities, dysmorphic features, somatic or various genetic diseases, or their parent's refusal to participate were excluded from the study.

Results: Of the 189 neonates infants included in our study, 85 (44.6%) were female, 104 (55.4%) were male, 139 (73.54%) were preterm (24–36 weeks), and 50 (26.46%) were term (37–42 weeks) neonates. As a result of the US performed on the first day of 189 neonates, CM levels, 31 (16.4%) were L1, 31 (16.4%) were L1-2, and 71 (37.6%) were L2. There is a strong correlation between birth weight and birth week (r 0.84). There is a negative relationship between birth weight and CM level (r -0,20), gestational age, and CM level (r -0,23).

Conclusion: Conus medullaris level was negatively correlated with gestational age and increased with advancing gestational age. In addition, the CM level shows a slower rise at 28-40 weeks of postmenstrual age and reaches the normal level (L1-L2) in the neonatal period, as in adults. Knowing the level of the CM in the newborn period will ensure that spinal procedures such as lumbar puncture to be applied to the spinal region can be performed safely.

Öz

Amaç: Yapılan araştırmalar, çoğu yetişkinde konus medullaris (KM) seviyesinin T12 ve L2 arasında olduğunu, ancak çocuklukta önemli bir KM yükselişinin olmadığını göstermektedir. Normal yetişkin pozisyonunun aslında vakaların çoğunda doğumla elde edildiğine dair kanıtlar mevcuttur. Yapılan çalışmalarda yenidoğanlarda KM seviyesinde farklılıklar olduğunu göstermiştir. Bu durum yenidoğan döneminde yapılacak girişimsel işlemlerde soruna neden olmaktadır. Bu çalışmada amacımız preterm/term yenidoğanlarda ultrason (US) kulanılarak KM seviyesini tespit etmektir.

Gereç ve Yöntem: Yenidoğan Yoğun Bakım Ünitesi'nde (YYBU) Mart 2020- Haziran 2021 tarihleri arasında kabul edilen preterm/term yenidoğanlarda (gestasyonel haftası 24-43) postnatal US ile KM seviyeleri değerlendirildi. Çalışmada santral sinir sistemi anomalileri, dismorfik vücut bulguları olan, somatik veya çeşitli genetik hastalığı olan olgular ve çalışmayı kabul etmeyen ailelerin bebekleri çalışma dışı bırakıldı.

Bulgular: Çalışmamıza dahil edilen 189 yenidoğanın 85'i (%44,6) kız, 104'ü (%55,4) erkek, 139'u (%73,54) preterme (24-36 hafta) ve 50'si (%26,46) term (37-42 hafta) bebekti. İlk gün yapılan US sonucunda KM seviyesinin 31'i (%16,4) L1, 31'i (%16,4) L1-2 ve 71'i (%37,6) L2 olduğu gözlemlendi. Doğum ağırlığı ile doğum haftası arasında güçlü bir ilişki bulundu (r 0.84). KM seviyesi ile doğum haftası (r -0,23) ve doğum ağırlığı (r -0,20) ile arasında negatif yönlü bir ilişki saptandı.

Sonuç: Konus medullaris seviyesi gebelik haftası ile negatif ilişkiliydi ve ilerleyen gebelik yaşı ile yükseliyordu. Ayrıca konus medullaris postmenstural 28-40 haftalarda daha yavaş bir yükselme göstermektedir ve yenidoğan döneminde erişkindeki gibi normal düzeye (L1-L2) ulaşmıştır. Yenidoğan döneminde konus medullarisin seviyesinin bilinmesi spinal bölgeye uygulanacak lomber ponksiyon gibi işlemlerin güvenle yapılabilmesini sağlayacaktır.

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Anahtar kelimeler: Gestasyonel yaş, konus medullaris, yenidoğan, postnatal ultrason

INTRODUCTION

The conus medullaris (CM) in the fetus ascends during pregnancy and reaches the adult level (L1–L2) level. Although this ascending trend of the CM is well known, there is ambiguity as to when the CM reaches adult levels. Based on postmortem examinations, Barson et al. reported that the CM should reach the adult level two months after birth, whilst James and Lassman argued that it occurred five months after birth[1-2]. Several authors have reported that the CM reaches the average adult level of L1–L2 at birth[3-5]. The conus medullaris ascends gradually throughout fetal development. The fastest ascent was found to occur in the second and third trimesters[6-7]. Results are controversial over the postnatal migration of CM in term infants and the time to reach adult levels[5].

Radiologically, ultrasound(US) and magnetic resonance imaging (MRI) can provide accurate and detailed information about spinal cord-associated abnormalities both prenatally and postnatally[7].

In a recent study, suggesting reference levels of CM for each week of pregnancy between 17 and 40 weeks of gestation for early diagnosis of fetal tethered cord syndrome, a CM level below the L2 vertebra in term fetuses stated to be associated with tethered cord syndrome[8]. In a study involving 588 fetuses during the third trimester, Sun et al. suggested that a CM level at L3 vertebra in the third trimester can be a physiological condition but should be followed. The authors also reported that a fetus with a CM level above L1/2 intervertebral disc can have caudal regression syndrome[9]. In an anatomical dissection study with postmortem 30 fetuses, spinal cord length and CM level were found to be associated with the gestational age of the fetuses. According to this study, the spinal cord length of male fetuses was reported to be longer than that of female fetuses[10]. Previous studies reported that the CM is located between T12 and L2 in most adults but revealed no significant ascent during childhood. Evidence suggests that the normal adult level is acquired at birth in most cases. However, the number of studies including preterm fetuses is limited in the literature. Therefore, in our study, we investigated the effect of birth week and birth weight on CM level in preterm and mature infants in the postnatal period. Besides various studies have shown that there are differences in the CM levels in neonates. This situation causes problems in interventional procedures during the neonatal period. Thus, the aim of our study was to determine the level of the CM in preterm and term infants using US and to determine the exact localisation of invasive procedures without damaging the medulla spinalis.

MATERIALS AND METHODS

Sampling and study design

Approval was obtained from Sivas Cumhuriyet University Non-Invasive Clinical Research Ethics Committee (Decision no: 2020-02/09). Our study was carried out according to the principles of the Declaration of Helsinki. Informed consent was obtained from the parents of the patients for the study. Neonates were divided into four groups according to the gestational week. Group 1 was taken as 24-28 weeks, group 2 as 29-32 weeks, Group 3 as 33-37 weeks, and Group 4 as 38-40+ weeks. The groups were organized as male and female. Informed consent was obtained from the relatives of the patients for the study.

Participants and procedures

A total of 189 preterm and term patients were included in the study. Neonates without genetic diseases, metabolic diseases, syndromes and abnormalities were included in our study. Infants with central nervous system abnormalities, dysmorphic features, somatic or various genetic diseases, or refusal of their parents to participate were excluded from the study.

Newborn infants (gestational age 24–43 weeks) hospitalized in a level-3 neonatal intensive care unit between March 2020 and June 2021 were examined using postnatal spinal US (LOGIQ e, GE Medical Systems, China) to determine the CM levels. The infants were followed by the same neonatologist at a university hospital, and spinal ultrasounds were performed regularly by the same radiologist. Neonates infants underwent US in both longitudinal and transverse positions, with slight flexion in the prone position. The level was located using the lumbosacral junction, lumbosacral angle, and/or the 12th rib.

Statistical analysis

In the power analysis, when α= 0.05 β=0.10 1-β=0.90, by including 189 neonates in the study and the power of the test was found as p=0.90770. Data from the study were analysed using the SPSS 22.00 (IBM Corp., Armonk, NY, USA) program. Since our data did not conform to the normal distribution (Kolmogorov-Smirnov), the measurements obtained from more than two independent groups were compared with the Mann-Whitney U test, when comparing the measurements obtained from two independent groups, the Kruskal-Wallis test and Spearman's rho coefficient were used for correlation analysis. The data were expressed in percentage of the number of individuals (%), arithmetic mean, and standard deviation. A value of $p < 0.05$ was considered statistically significant.

RESULTS

A total of 191 newborn infants were included in the study. Two of the patients were excluded from the study due to the failure to determine the CM level. Of the 189 newborn infants included in the study, 85 (44.6%) were female, and 104 (55.4%) were male. 139 (73.54%) were preterm (24-36 weeks), and 50 (26.46%) were term (37-42 weeks) neonates. The mean birth weight of the infants was 2125.13 ± 843.58 g (min-max 600-5245 g) (Table 1). The mean maternal age was 30.14 ± 6.04 years (min-max 18-48 years), and the mean gestational age was 33.50 ± 3.99 weeks (min–max 24-43 weeks) (Table 1).

Table 1. Demographic characteristics of the neonates

Gender n (%)	Female	104 (0.55)
	Male	85 (0.45)
Maternal age, year Median (min-max)		30.14 (18.00-48.00)
Gestational Week Median (min-max)		33.50 (24.00-43.00)
Birth weight, g Median (min-max)		2125.13 (600.00-5245.00)

g:grams

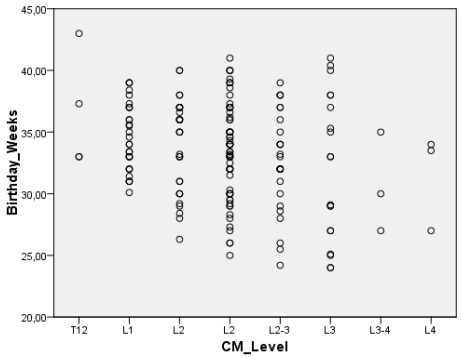
US was performed on the first day of 189 neonates, and CM levels were detected as follows; 31 (16.4%) were L1, 31 (16.4%) were L1-2, and 71 (37.6%) were L2 (Table 2, Graph 1).

There is a negative correlation between the CM level and gestational age ($r = -0.23$ mean 30.60 ± 4.53, 95% confidence interval 29.96–31.26). This relationship was statistically significant ($p < 0.001$). There was also a negative correlation of $r = -0.20$ between the CM level and birth weight. Though not statistically significant, the CM level was found to have a negative correlation with birth weight. There is a strong correlation between birth weight and birth week (r 0.84).

Table 2. Termination level of the conus medullaris

Level	n (%)
T12	4 (2.1)
L1	31 (16.4)
L1-2	31 (16.4)
L2	71 (37.6)
L2-3	27 (14.3)
L3	19 (10.1)
L3-4	3 (1.6)
L4	3 (1.6)
Total	189 (100)

T: Thoracic vertebrae, L: Lumbal vertebrae



Graph 1. Levels of the conus medullaris by gestational age

When the gestational age and CM level were compared, the difference was found to be significant. When the values related to the gestational week were compared in 2, the difference between Group 1 and Group 2, Group 1 and Group 3, Group 1 and Group 4 was found to be significant, while the others were found to be insignificant (Table 3).

When the gestational week and CM levels of girls and boys were compared, the differences were found to be insignificant in Group 1, Group 3, and Group 4, while the difference between genders was significant in Group 2. KM levels were found to be higher in male babies (Table 4).

Gestational weeks of 6 cases, which were reported to be at L3-4 and L4 levels, were between 28-36 weeks. Except for 1 of these babies, 5 of them were followed up. A weekly evaluation was done during follow-up and the CM levels are shown in Table 5 according to their gestational weeks.

Table 3. Relationship between gestational week and level of conus medullaris

	n	Mean	SD	Median	Min.	Max.	p
Group 1 (24-28 w)	26	L3-4	1.31	L2-3	L1-2	L4	KW=15.25 p=0.002*
Group 2 (29-32 w)	48	L2	1.23	L2	L1	L3-4	
Group 3 (33-37 w)	87	L2	1.40	L2	T12	L4	
Group 4 (38-40 w)	28	L2	1.42	L2	T12	L3	

W: weeks; *p<0.05 significant; SD: standard deviation; KW: Kruskal-Wallis test; Min: Minimum, Max.: Maximum, T: Thoracic vertebrae, L: Lumbal vertebrae

Table 4. Comparison of gestational weeks and gender with conus medullaris level

Gestational Weeks	Gender	n	Mean	SD	Median	Min.	Max.	p
Group 1 (24-28 w)	Female	16	L2-3	1.40	L2-3	L1-2	L4	p=0.32
Group 1 (24-28 w)	Male	10	L2	1.19	L2-3	L1-2	L3	
Group 2 (29-32 w)	Female	18	L1-2	1.29	L1-2	L1	L2-3	p=0.01*
Group 2 (29-32 w)	Male	30	L2	1.05	L2	L1	L3-4	
Group 3 (33-37 w)	Female	40	L2	1.25	L2	L1	L3-4	p=0.83
Group 3 (33-37 w)	Male	47	L2	1.54	L2	T12	L4	
Group 4 (38-40 w)	Female	11	L2	1.76	L2	T12	L3	p=0.45
Group 4 (38-40 w)	Male	17	L1-2	1.03	L2	L1	L2-3	

W: weeks, *p<0.05 significant, SD: standard deviation, Min: Minimum, Max.: Maximum

Table 5. Clinical follow-up results of patients with conus medullaris level L3-4 and L4

Gestasyonel Weeks	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
28	L3-4	L4				
29	L3-4	L2-3				
30	L3					
31	L2-3					
32						L3-4
33				L4		L3-4
34			L3-4		L3-4	L3-4
35			L2-3		L3	
36			L2		L2	

L: Lumbal vertebrae

DISCUSSION

The results of this study showed that the CM terminates on average between L1–L2 in newborn infants (gestational weeks 24–43). Furthermore, the CM level has a negative correlation with gestational age and birth weight. The CM level was found to ascend with increasing gestational age and weight. The CM was found to have a slower ascent after the third trimester and reached the adult level (L1–L2) in the neonatal period. When the gestational age and CM level were compared, the difference was found to be significant.

Until the third month of intrauterine life, the medulla spinalis extends to the end of the canalis vertebralis formed between the corpus vertebrae and the arcus vertebrae[11,12]. The conus medullaris gradually moves upward due to the different growth rates of bone and nerve tissues and reaches the third lumbar vertebra in a neonate[1, 11, 13,14]. Previous studies sought to determine the level of vertebral termination of CM in normal and abnormal cases in childhood in autopsied samples, cadavers, and living subjects using dissection, US, computed tomography, MRI, and myelography (Table 6)[1, 14-18]. The conus medullaris ascends relatively steadily throughout fetal life. In a postmortem fetal MRI study, Arthurs et al. showed that at 20 weeks' gestation, approximately 23% fetuses reached a CM level at L3 or higher; by 26 weeks, an estimated 50% reached L3, and 94% reached L3 at 39 weeks[7]. It is known that the spinal cord extends along the entire length of the vertebral canal during the first months of fetal life, with the CM reaching the S1 level by the end of the second trimester and the L3 level at birth. After birth, it gradually ascends and reaches the adult level (L1–L2)[18].

Previous studies on the vertebral termination of the CM in adults reported that the CM level tended to be lower in Blacks than Caucasians and in males than females[19-21]. In our study, we found CM levels to be higher in male infants.

Previous studies have found different levels of termination for the CM in neonates (Table 6)[1, 18, 19,21-24]. Barson examined 252 autopsied infants without intraspinal lesions and speculated that the CM in term infants reaches the adult level, i.e. the lower margin of the L2 vertebra, within two months after birth[1]. In a study of 25 children, James and Lassman concluded that the CM reached the adult level within five months after birth[2]. Based on US results in infants, Raghavendra and Epstein concluded that the ascent of the CM stopped between two months and one year after birth[25]. On the other hand, Wilson and Prince suggested that ascent should stop within the first few months after birth[26]. In a study of 115 autopsied fetuses and neonates using US, Robbin et al. and Zalel et al. confirmed that CM can reach adult levels as soon as the baby is born[3, 27]. Sun et al. found no linear correlation between CM level and postnatal days within the first month or first three months after birth in term infants. In addition, they found no significant difference between the groups in the mean CM level within the first three months postpartum[5]. Malas et al. used US to determine the vertebral termination level of the CM in 101 healthy children aged 0–7 years. They found that the vertebral termination level of the CM ranged between T12–L1 intervertebral space and L2–L3 intervertebral space in all children and reached the adult level of L1–L2 within three months after birth[4]. Ursu et al. reported that spinal canal parameters showed the fastest growth rate between 18–36 weeks and the upper lumbar canal grew faster than the lower lumbar region after 30 weeks of intrauterine life. They reported that the distal end of the dural sac started to ascend from S5 after the 14th gestational week[6]. In a study of stillborn fetuses, Arthurs et al. reported that the CM ascended steadily throughout fetal life and growth may not be linear for each fetus, but most fetuses have a CM level in the normal adult range by 33 weeks of gestation[7]. Studies in term infants have shown that CM reaches normal adult levels at birth and does not ascend further during childhood[15, 26].

While postnatal US studies have suggested a major ascent in the third trimester, especially between 33 and 42 weeks of gestation[28, 29], autopsy studies have reported an earlier ascent, predominantly in the second trimester, between 12 and 25 weeks of gestation[1, 18, 30].

MRI and autopsy methods were also used to determine the CM level, but these techniques require significant time, cost, and manpower. Antenatal US is widely used for monitoring CM in the intrauterine fetus. US examination does not take much time nor does it require the baby to be completely immobilised. US examination is therefore safe, convenient, and accessible for operators and babies. Furthermore, US is non-invasive, thus reproducible and allows dynamic observation during infancy with

very few side effects. In the past, however, due to its low resolution, US was of little benefit in some indeterminate intraspinal lesions such as small lipomas[5]. However, with the development of technology today, US yields clearer images.

Limitations of the study; US was performed only in the postnatal period. Not being able to perform an US evaluation for each patient in the prenatal period was a limitation. Technical difficulties due to COVID-19 limited our study.

As a result of this study, the CM level was found to be negatively correlated with gestational age and increased with advancing gestational age. In addition, the CM showed a slower rise at 28-40 weeks of postmenstrual age and reached the normal level (L1-L2) in the neonatal period, as in adults. Knowing the exact level of the CM in the neonatal period will ensure that spinal procedures such as lumbar puncture to be applied to this region can be performed safely.

To conclude, authors suggest that large-scale, prospective studies should be conducted in which infants are screened with US on a daily or weekly basis, including the antenatal and postnatal periods in the future.

Table 6. Level of the conus medullaris reported in previous studies

Reference	Author	Year	N	Group	Method	CM Level (Mean)
(21)	Içten	1994	40	Term infant	Autopsy	L2-L5
(1)	Barson	1970	252	Fetal	Autopsy	L2/3 by term
(31)	Saifuddin	1998	504	Adult	MRI	L1
(32)	Soleiman	2005	635	Adult	MRI	L1
(33)	Kesler	207	100	Childhood	MRI	L1
(34)	Widjaja	2006	30	Fetal	MRI	L1-L3 above 35 w
(27)	Wilson	1989	184	Childhood	MRI	L1/2 at term
(15)	Dipietro	1993	161	Childhood	US	T10-L2 in childhood
(3)	Zalel	2006	110	Fetal	Antenatal US	Above L2 by term
(30)	Hawass	1987	146	Fetal	Myelogram	Above L3 by 33 w
(18)	Vettivel	1991	78	Fetal	Autopsy	L1/2 by term
(27)	Robbin	1994	33	Fetal	Antenatal US	Below L3/4 abnormal
(28)	Rowland Hill	1995	101	Fetal	Postnatal US	L1/2 at term
(29)	Beek	1996	99	Fetal	Postnatal US	L1/2 at term
(35)	Kim	2003	690	Adult	MRI	T12-L2
(36)	Demiryurek	2002	639	Adult	MRI	T12-L1
(20)	Govender	1989	115	Fetal	Autopsy	L1 at birth
(14)	Wolf	1992	114	Fetal	Postnatal US	T12-L1/2 by term
(7)	Arthurs	2012	80	Fetal	MRI	Above L3 by 33 week
(5)	Sun	2021	26	Term infant	MRI	L1/2,L2 inferior border
(37)	Şahin	1997	106	Neonates, term infant	Antenatal US Postnatal US	L1-L2 Above L2 by term
(4)	Malas	1995	101	Childhood	US	L1-L2
	Yıldız	2023	189	Preterm	US	L1-L2

MRI: Magnetic resonance imaging, US: Ultrasound, W: Weeks

Author Contributions: Concept/Design : BY, GT, BS; Data acquisition: BY, GT; Data analysis and interpretation: BS; Drafting manuscript: GT, BS; Critical revision of manuscript: BY, GT, BS; Final approval and accountability: BY, GT, BS; Technical or material support: BY, GT, BS; Supervision: BY, GT, BS; Securing funding (if available): n/a.
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