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Ultrasound Determination of the Normal Location of the Conus Medullaris in Neonates

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PURPOSE: To establish the normal range of the position of the conus medullaris in neonates and determine whether it differs from that in adults. **METHODS:** One hundred five healthy neonates born over an 18-day period in a single obstetric unit had ultrasound examinations of their lower spines to relate the conus medullaris to the nearest intervertebral disk or midvertebral level. **RESULTS:** The mean position of the conus was midway between the L1-2 disk and mid-L-2 body, ranging from T-12/L-1 to L-3, with the modal position being L1-2 (47.6%). A small but significant rise in position from 33 to 42 weeks postconceptual age was identified. Comparison with data previously reported from adults showed a small but highly significant difference in conus position of approximately 0.25 vertebral levels. **DISCUSSION:** Our data confirm studies suggesting that ascent of the cord after birth is minor.

Index terms: Spinal cord, conus medullaris; Spinal cord, anatomy; Spinal cord, ultrasound; Infants, newborn

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The position of the conus medullaris in the healthy adult population has been well established (1). Although it is also known that the conus "ascends" from its early fetal location in the sacral canal to the eventual adult position (2–4), the precise timing of the ascent has been a matter of debate for many years. Traditionally it has been thought that the normal conus is located at L-3 vertebral body level at birth, rising to the adult level of L1-2 during childhood, although a report in 1892 (5) suggested that the level of the conus did not alter after the normal gestation period. More recent studies (3, 6–8), have suggested only minor ascent of the cord, if any, after birth, but these studies have either dealt with very small numbers of fetuses and children or have necessarily involved highly selected populations resulting in questionable extrapolation of data to the general population (9).

Knowledge of the range of the normal position of the neonatal conus is essential if the presence of an abnormally low conus is to be a factor in the diagnosis of tethered cord and other anomalies. This is particularly important because surgery performed after the onset of symptoms is unlikely to improve neurologic dysfunction, although further deterioration may be halted. Early surgery therefore may be desirable, and some neurosurgeons advocate prophylactic surgery on asymptomatic individuals (10, 11).

The aim of this study was to establish the range of position of the conus medullaris in healthy neonates using spinal ultrasound. Ultrasound is well established as a safe and noninvasive modality for study of the anatomy and pathology of the infant spine up to the age of at least 3 months (12–16), and excellent delineation of the terminal cord and conus is provided by the echogenicity of the cauda equina in contrast to the anechoic cord.

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Methods

Ultrasound examination of the lower spine was carried out on 105 apparently healthy neonates born over an 18-day period in a single teaching hospital obstetric unit. These were consecutive deliveries except where informed consent was not obtained from the mother. The study was approved by the local research ethics committee. Gestational age was determined from maternal dates or early antenatal ultrasound scan measurements if significantly different and postconceptual age (gestational plus postnatal age) by completed week was recorded. Sex, birth weight, and parental ethnic origin were also documented.

Ultrasound examination was performed using an ATL Ultramark IV machine (Advanced Technology Laboratories, Seattle, Wash) equipped with a 7.5-MHz linear array transducer. All examinations were performed by a single operator (C.A.R.H.). Infants were examined prone, either in a cot or, in a few cases, held by the mother. In most cases the spine was in a neutral or gently flexed position. In eight cases early in the study the effect of flexion and extension was noted. A series of longitudinal and sagittal scans were performed through the lower spine. The lumbosacral junction was identified as the first clear angulation in the caudal spine, and the vertebral body immediately craniad to this was designated L-5. The conus was identified as the apex of the taper of the distal spinal cord and was related to the adjacent intervertebral disk space or midvertebral body, whichever was closer. The conus position was assigned to a numerical scale for later analysis, 0 representing mid-D-12, 0.5 representing D-12/L-1 disk, and so on.

Results

Two infants were excluded on the basis of abnormal findings. Of the 103 remaining subjects, 52 (50.5%) were female and 51 (49.5%) were male. Six subjects were twins. Postconceptual age ranged from 33 to 42 completed weeks (mean, 39.3 weeks). Birth weights ranged from 1960 g to 4750 g (mean, 3286 g). The ethnic origins of the infants were as follows: European, 48 (46.6%); Afro-Caribbean or African, 25 (24.3%); Asian, 9 (8.7%); Arab, 4 (3.9%); Oriental, 2 (1.9%); and mixed, 15 (14.6%). Typical appearances of the conus are shown in Figure 1.

The mean position of the conus was L1.76, that is, midway between the L1-2 disk and midpoint of the L-2 body. The range was from T-12/L-1 disk (3 cases) to mid-L-3 vertebral body (3 cases) with L1-2 the modal position (49 cases). The position of the conus related to postconceptual age is shown in Table 1. There is a small but significant rise in conus level from 33 to 42 weeks (slope of linear regression, 0.055 levels per week; $P<.05$; 95% confidence interval, .004 to .105). A small rise was also found with birth weight (slope of linear regression, 0.21 levels per kilogram; $P<.02$; 95% confidence interval, .033 to .377). There was no significant difference between male and female neonates ($P=.2$) or between the European and Afro-Carribean/African groups ($.1<P<.2$). Other ethnic groups were not compared because of small numbers. In the few cases in which an attempt was made to examine the spine in different degrees of flexion, relative movement of the conus was minimal or nil with the degree of change in flexion achieved and did not alter the assigned level in any case.

Fig 1. Sagittal sonogram shows characteristic angulation of the lumbosacral junction (*curved arrow*) and excellent definition of the anechoic distal cord from the cauda equina. The conus medullaris (*straight arrow*) is readily assigned.

Comparison with the data from 800 adults (1) showed a difference in mean conus level of 0.25 vertebral levels. This small difference was highly significant ($P<.001$; 95% confidence limits, .13 to .36).

The two infants with abnormal findings were as follows: In one there was separation of the

TABLE 1: Vertebral level of the conus medullaris relative to postconceptual age

Postconceptual age, wk	No. of Observations	Mean Level	Standard Deviation	Range
33	1	L2.0	. . .	. . .
34	1	L2.5	. . .	. . .
35	1	L2.5	. . .	. . .
36	5	L1.9	0.42	L1-2–L2-3
37	6	L1.6	0.86	T-12/L-1–L-3
38	20	L1.8	0.44	L-1–L2-3
39	14	L1.9	0.48	L-1–L-3
40	28	L1.7	0.44	T-12/L-1–L2-3
41	15	L1.6	0.28	L-1–L-2
42	12	L1.6	0.48	T-12/L-1–L2-3
Total	**103**	**L1.76**	**0.48**	**T-12/L-1–L-3**

normal midline echoes from the lumbar cord suggesting a syrinx. The cord terminated at L1-2, but the filum terminale was thickened and echogenic. In the other infant the cord terminated at the L-5/S-1 level, lying posteriorly with diminished motion. The sacral segments below S-2 appeared abnormal. This infant has an elder sibling with an anterior sacral meningocele.

Discussion

The position of the conus medullaris in the adult population has been well established from large studies. Reimann and Anson (1) studied 128 cadavers and combined their data with that of other workers (17–19). In the resulting series of 800 healthy subjects, 51% of cords terminated within the confines of the lower third of L-1 and the upper third of L-2. Conus position ranged from the middle third of T-12 to the lower third of L-3. Their method of assigning the level of the conus differed from our series in that they divided vertebral bodies into thirds, but only 4 cords (0.5%) were possibly outside the range found in our series. We used Reimann and Anson's data for statistical comparison with our study data, because it is the largest published series. A similar distribution was found in 80 Punjabee adults (4). A more recent magnetic resonance study of 100 healthy adults investigated for lumbar disk disease reports the average conus level as L-1 (range, T11-12 to L2-3), but these results were not presented in detail to allow statistical comparison (7).

Studies have shown that the most rapid ascent of the conus medullaris relative to the vertebral column takes place during the first half of gestation. Barry (2) analyzed data from 21 fetuses studied by himself or previously reported (20, 21) and showed that maximum ascent occurred between 9 and 16 weeks, although only one fetus was older than 19 weeks, a full-term fetus with conus at L-3. Barson (3) examined 236 fetuses or neonates with grossly normal vertebral axes after death. He described a rapid ascent to the level of the fourth lumbar vertebral body by 19 weeks' gestation followed by a more gradual rise to adult level by 2 months of age. However his suggestion that the level continues to rise between normal term and 2 months of age is based on a small number of observations. Jit and Charnalia (5) in an autopsy study of 50 fetuses and neonates found rapid ascent up to the 120-mm crown-rump-length stage (approximately 16 weeks) followed by more gradual ascent to birth. Of the 10 neonates studied, 50% had a conus at mid-L-2, and none were below L2-3. In a myelographic study of 146 spontaneously aborted fetuses (6) up to 33 weeks of age, there was relatively rapid rise in conus level from 12 to 25 weeks. In 12 fetuses from 25 to 33 weeks of age the conus was between L1-2 and L-3. James and Lassman (22) reported autopsies on 25 children between 1 hour and 8 years of age and found the conus had reached L-2 by 5 months at the latest. Wilson and Prince (7) reviewed magnetic resonance images of 184 lumbar spines of children from newborn to 20 years of age and found no significant difference in the position of the conus over this age span. Their cases included only six infants under 8 weeks of age. An ultrasound study of 161 children from 4 days to 13 years of age (8) included 14 infants less than 2 months of age and also found no significant difference in conus position over the age range. Neither of these studies definitively confirm or refute Barson's suggestion of conus ascent from term to 8 weeks.

The conus is at L-3 in 2.9% in our series and is the position in 1.8% of healthy adults (1). Our data are in keeping with the generally accepted view that a conus below L-3 at birth is abnormal (23–25). A conus at L-3 is known to be associated with abnormality in some cases, although the proportion at this level associated with abnormality is unknown. Authorities recommend that any conus at L-3 warrants further investigation to exclude tethering (24, 25). However if this criterion is used alone it is likely that many healthy infants will be unnecessarily investigated. Ultrasound by an experienced operator would seem to be an ideal investigation for selecting cases for further evaluation.

A possible criticism of the current study is the accuracy with which the lumbosacral junction can be identified. The lumbar spine is straight in the neonate and the lumbosacral junction is readily identifiable as the only prominent angulation in the caudal spine (13, 16). In a few cases in which this was less prominent in the neutral position, examination during gentle extension of the spine clarified the level. The operator had the intention of excluding any case in which this landmark was not identified with confidence, but none arose. Other methods of assigning vertebral level have been described, including tracing back the lowest rib, identifying the termination of the thecal sac, and counting from the coccyx, but these techniques appear to be less successful (8).

A second possible source of error in assigning the correct vertebral level is the occurrence of either four or six lumbar vertebra. Ford and Goodman (26) studied 1614 sets of radiographs of the lumbosacral spine and found the incidence of four and six lumbar vertebrae to be 4.2% and 3.0%, respectively. Therefore the mean conus level in our study is unlikely to be altered significantly by the occurrence of these variations, although theoretically our range could be falsely wide.

The occurrence of abnormality in our study group was 2 (1.9%) cases of 105. The incidence of spinal dysraphism in the general population is not known, but it is interesting that the incidence in our healthy study population is similar to that in a "high-risk" population of infants with cutaneous sacral dimples (27).

Conclusion

Our study has shown that the range of the position of the conus on ultrasound in the healthy neonate (over a range of 33 to 42 weeks' gestational age) does not differ from that established for the adult population but that the mean position of the conus is one quarter of a vertebral level lower than that established for adults. We found a significant but slight rise in mean conus position with postconceptual age. Our findings are in keeping with evidence that most of the cord ascent is completed in early fetal life and dispel the myth that there is more than minimal, if any, cord ascent during childhood.

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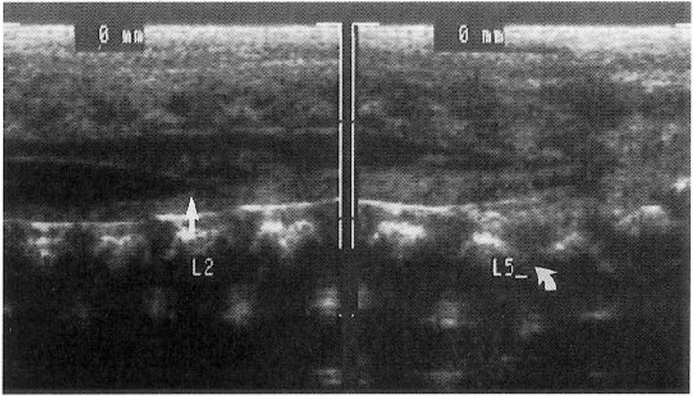
References

1. Reimann AF, Anson BJ. Vertebral level of termination of the spinal cord with report of a case of sacral cord. *Anat Rec* 1944;88:127–138
2. Barry A. A quantitative study of the prenatal changes in angulation of the spinal nerves. *Anat Rec* 1956;126:97–110
3. Barson AJ. The vertebral level of the termination of the spinal cord during normal and abnormal development. *J Anat* 1970;106:489–497
4. Jit I, Charnalia VM. The vertebral level of the termination of the spinal cord. *J Anat Soc India* 1959;8:93–101
5. Ballantyne JW. The spinal column in the infant. *Edinburgh Med J* 1892;37:913–922
6. Hawass ND, El-Badawi MG, Fatani JA, et al. Myelographic study of the spinal cord ascent during fetal development. *AJNR Am J Neuroradiol* 1987;8:691–695
7. Wilson DA, Prince JR. MR imaging determination of the location of the normal conus medullaris throughout childhood. *AJNR Am J Neuroradiol* 1989;10:259–262
8. DiPietro MA. The conus medullaris: normal US findings throughout childhood. *Radiology* 1993;188:149–153
9. Balsam D, Lodespoto M. Normal location of conus medullaris in childhood. *AJR Am J Roentgenol* 1989;153:888–889
10. Stolke D, Zumkeller M, Seifert V. Intraspinal lipomas in infancy and childhood causing a tethered cord syndrome. *Neurosurg Rev* 1988;11:59–65
11. McCullough DC, Levy LM, DiChiro G, Johnson DL. Toward the prediction of neurological injury from tethered spinal cord: investigation of cord motion with magnetic resonance. *Pediatr Neurosurg* 1990–91;16:3–7
12. Kangarloo H, Gold RH, Diament MJ, Boechat MI, Barrett C. High-resolution spinal sonography in infants. *AJNR Am J Neuroradiol* 1984;5:191–195
13. Gusnard DA, Naidich TP, Yousefzadeh DK, Haughton VM. Ultrasonic anatomy of the normal neonatal and infant spine: correlation with cryomicrotome sections and CT. *Neuroradiology* 1986;28:493–511
14. Naidich TP, Radkowski MA, Britton J. Real-time sonographic display of caudal spinal anomalies. *Neuroradiology* 1986;28:512–527
15. Kawahara H, Andou Y, Takashima S, Takeshita K, Maeda K. Normal development of the spinal cord in neonates and infants seen on ultrasonography. *Neuroradiology* 1987;29:50–52
16. Beek FJA, van Leeuwen MS, Bax NMA, Dillon EH, Witkamp TD, van Gils APG. A method for sonographic counting of the lower vertebral bodies in newborns and infants. *AJNR Am J Neuroradiol* 1994;15:445–449
17. Thompson A. Fifth Annual Report of the Committee of the Anatomical Society of Great Britain and Ireland for the year 1893–1894. *J Anat Physiol* 1894;29:46
18. McCotter RE. Regarding the length and extent of the human medulla spinalis. *Anat Rec* 1916;26:559–564
19. Needles JH. The caudal level of termination of the spinal cord in American whites and American negroes. *Anat Rec* 1935;63:417–425
20. Kunitomo K. The development and reduction of the tail and the caudal end of the spinal cord. *Contrib Embryol* 1918;8:161–198
21. Streeter GL. Factors involved in the formation of the filum terminale. *Am J Anat* 1919;25:1–11
22. James CCM, Lassmann LP. *Spinal Dysraphism: Spina Bifida Occulta.* New York: Appleton-Century-Crofts 1972;18–24
23. Harwood-Nash DC, Fitz CR. *Neuroradiology in Infants and Children.* St Louis: Mosby, 1976;1054–1257
24. Barkovich AJ, Naidich TP. Congenital anomalies of the spine. In: Barkovich AJ, ed. *Contemporary Neuroimaging, Volume I: Paediatric Neuroimaging.* New York: Raven Press, 1990;245–246
25. Naidich TP, Zimmerman RA, McLone DG, Raybaud CA, Altman NR. Congenital Anomalies of the Spine and Spinal Cord. In: Atlas SW, ed. *Magnetic Resonance Imaging of the Brain and Spine.* New York: Raven Press, 1991;865–919
26. Ford LT, Goodman FG. X-ray studies of the lumbosacral spine. *South Med J* 1966;59:1123–1128
27. Gibson PJ, Britton JA, Hall DMB, Rowland Hill CA. Lumbosacral skin markers and identification of occult spinal dysraphism in neonates. *Acta Paediatra* (in press)



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