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review

The role of sonographic evaluation of spinal canal in children

Živa Zupančič

Clinical Radiology Institute, University Medical Center Ljubljana, Slovenia

Background. *Spinal sonography is a valuable diagnostic imaging modality as it has the ability to demonstrate good anatomic detail of the spinal canal, its contents, and the surrounding structures. The examination technique, the anatomy of the cord, the most common anomalies, and the evaluation of the sonography compared to magnetic resonance imaging are presented.*

Conclusions. *Spinal sonography is recommended as the primary imaging modality for congenital anomalies of the lower spine in infants and as the screening modality for closed spinal dysraphism in infants and small children. The examination technique, the anatomy of the cord, the most common anomalies, and the evaluation of the sonography compared to magnetic resonance imaging are presented.*

Key words: spinal dysraphism-ultrasonography; spinal canal- ultrasonography; child

Introduction

High-resolution real-time sonography of the spinal canal in children has been performed for over fifteen years.[1] It has the ability to demonstrate good anatomic detail, is noninvasive, easy to use, can be brought to bedside, does not require sedation, and is of low cost. The application of sonography is possible in the neonate and in children up to school age because of poor ossification of the posterior vertebral elements. It can demonstrate the spinal canal, its contents, that is the cord, the cauda equina, the dural sac and intracanalicular, as well as related extracanalicular masses. It is used to measure the spinal canal, to determine the level of the conus medullaris, to detect cord anomalies, and examine soft tissue abnormalities. The most common indications are to determine the level of the conus medullaris, looking for a tethered spinal cord in infants with midline back abnormalities,[1,2] to study the spinal cord for associated malformations in the newborn period in children with spinal dysraphism, such as myelomeningocele and meningocele, and to look for retethered cord after myelomeningocele repair.[3]

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Correspondence to: Živa Zupančič, M.D., Ph.D., Clinical Radiology Institute, University Medical Centre Ljubljana, Zaloška 7, SI-1525 Ljubljana, Slovenia.

Technique of examination

Examination is usually performed with the child prone or in a lateral decubitus position

with thoracolumbar spine flexed to separate the spinous processes, using a high frequency linear array transducer. Small infants can be scanned over the midline between the spinous processes, but in older infants and larger children it is better to scan with the transducer placed slightly lateral and aimed medially into the spinal canal.[1] Transverse and longitudinal scanning of the entire spine is performed, preferably starting over the sacrum where the spinal canal is easily found.[1] A standoff pad can be used to improve nearfield resolution. Longitudinal and transversal pictures are taken for documentation.

Normal cord anatomy

In the spinal canal the spinal cord is visualised as a slightly more echogenic structure than the surrounding anechoic cerebrospinal fluid, it has an echogenic dorsal and ventral surface and a central echo complex just ventral to the central canal (Figure 1).

The cervical cord, as seen in the transverse plane, is oval in shape, thoracic circular and lumbar circular but larger than thoracic. The conus is tapered caudally and is well seen in the longitudinal plane. The normal cord usually ends above the L-2 level, and so the tip of the conus medullaris is seen cranially to the L-3[1,4] and is central in the spinal canal. Caudally to the conus the roots of the cauda equina are visualised as echogenic strands in longitudinal plane and as echogenic dots in the transverse plane. The tip of the thecal sac often corresponds to S-2.[1] To estimate the vertebral level of the conus on the sonogram, palpable landmarks are used: the tip of the lowest rib corresponds to the level of the L-2, and the same rib as followed back to the spine locates T-12, the iliac crest corresponds to the L-5.[4] For the orientation it is also important to know that the cocyx in neonate is unossified and is a hypoechoic structure just distal to the sacral segments. It should not be mistaken for a cystic lesion.

The anterior spinal artery and epidural veins can be demonstrated using colour flow Doppler imaging. During the examination, the spinal cord and cauda equina oscillations in dorsoventral and cephalocaudal direction are observed with heart beating, breathing,

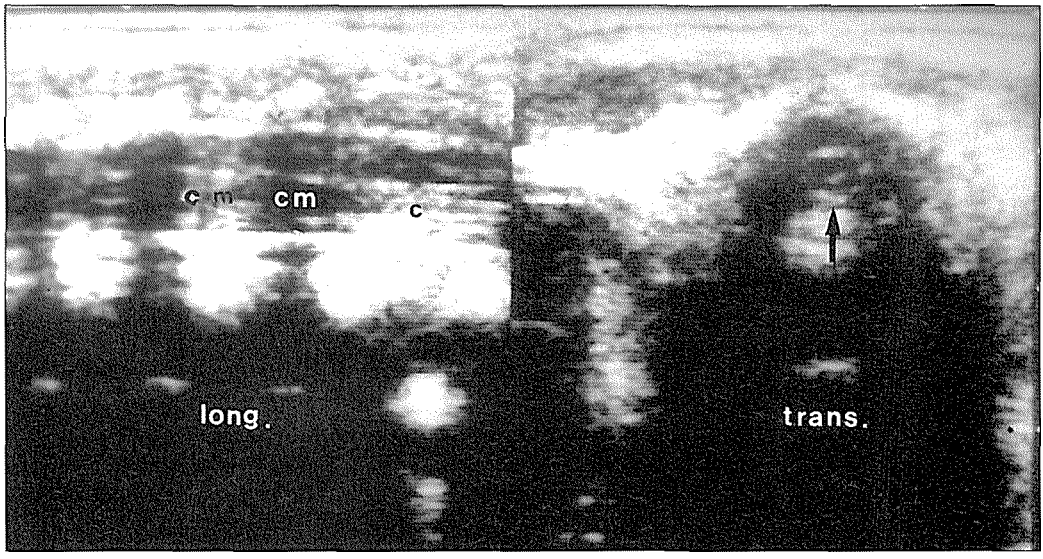

Figure 1. Normal lumbosacral canal. Longitudinal scan: spinal cord (c) with central echo complex, conus medullaris (cm), cauda equina (c). Transverse scan: spinal cord with central echo complex (arrow).

crying, and moving. Oscillation can be documented with M-mode sonography.[1]

The tethered spinal cord

The most common indication for sonography is to determine the vertebral level of the tip of conus medullaris, that is to diagnose or to rule out tethered spinal cord.[1] A conus medullaris that terminates in the spinal canal below the superior aspect of L-3 is probably a tethered cord.[1] A tethered cord is a pathologic fixation of the spinal cord in an abnormal caudal location, so that the cord suffers mechanical stretching, distortion and ischemia with daily activities, growth, and development.[5,6] It results in neurologic deficits as reflex changes, sensory loss, muscle wasting, power loss, and sphincter problems. The child might be normal at birth and develop deficits later. A child with an occult tethered cord can present with a lower-extremity deformity or abnormal gait.[1]

There are several pathologic entities that can cause spinal cord tethering, the most common are leptomeningocele, intraspinal lipoma, thick filum terminale, diastematomyelia, and dermal sinus. Risk factors for tethered cord are also lumbosacral skin abnormalities, anorectal malformations, presacral anomalies and lipomeningomyelocele.[1]

To diagnose a tethered cord on sonography one has to 1) estimate the vertebral level of the tip of the conus using on the longitudinal views the sonographic landmarks, as mentioned above (the L-2 corresponds to the level of the tip of the lowest rib and L-5 to the iliac crest). When one is not certain in determining the vertebral level of the tip of the conus, a radiopaque marker can be placed on the skin at the level of the conus tip to take a radiographic film and then to determine the level on that film. One also 2) looks for the position of the conus within the spinal canal. The tethered cord is usually eccentric, more dorsal than normal. In addition, one has 3) to observe for cord oscillations which are diminished or absent at or above the point of tethering[7] (but may be normal in the newborn until tethered later[1]).

Skin abnormalities and occult tethered spinal cord

Midline, lumbosacral, skin abnormalities as subcutaneous lipoma, hair tuft, sinus tract, skin defect, dimple, hemangioma, skin tag or appendage, or pigmented nevi can be associated with an occult spinal dysraphism (that is spina bifida occulta) and a tethered cord. Children with these abnormalities can develop, as they grow, foot and lower extremity deformity, decreased sensation, scoliosis, weakness, abnormal gait and bladder disfunction.[1]

So sonographic screening for these children was recommended in infancy[8] in order to detect a tethered cord and any other associated abnormalities and to treat the children (early surgical treatment or close neuropediatric follow-ups). Among the above mentioned skin abnormalities, the lumbosacral dimple has been studied for its significance most commonly.[1] Lumbosacral dimples and pits are common skin abnormalities and when they are only shallow and superficial and not deep crater like or connected to a dermal sinus (which appears as a hypoechoic band which might extend to the dural sac) they do not indicate a high risk of occult spinal dysraphism and there is no need to screen for a tethered cord.[9]

Lipomas

Lipomas are subcutaneous masses of fat and fibrous tissue which may be associated with dermal sinuses, hamangioma, nevi, myelomeningocele (Figure 2), and meningocele. They can be only superficial or are deep and extend into the spinal canal and attach to the meninges, cord, conus, or filum terminale, can tether the cord, and even grow into the

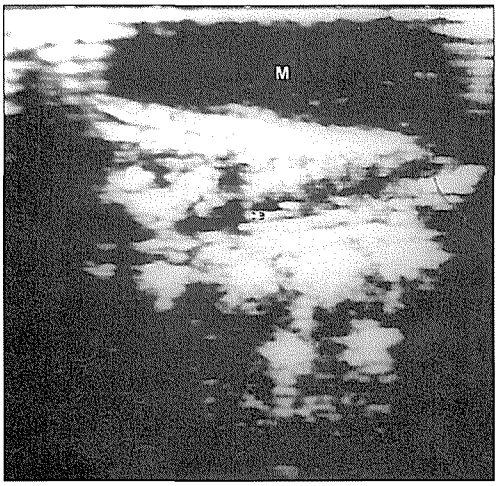

Figure 2. Lumbosacral meningocele. Longitudinal view: cauda equina (ce), meningocele (M).

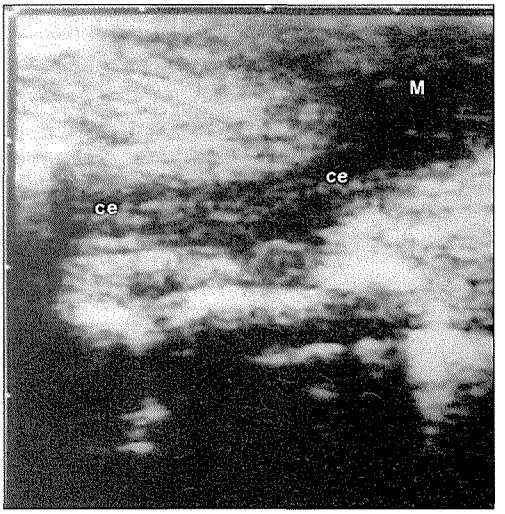

Figure 3. Lumbosacral myelomeningocele. Longitudinal view: cauda equina (ce) with the nerve roots extending into the myelomeningocele (M). Myelomeningocele enlarged with crying.

cord (complete surgical removal is then not possible).[1,10] On sonography they are echogenic masses, the tethered cord is dorsal and does not oscillate freely.

Hydromyelia, diastematomyelia

Hydromyelia is a dilatation of the cord's central canal that can be focal or involves the entire cord and can be found with myelomeningocele and diastematomyelia. On sonography, the central echogenic lines are separated and the central canal is distended by hypoechogenic fluid. In diastematomyelia the cord is split and two hemicords with central canal in each are demonstrated on sonography. The vertebral column is nearly always abnormal, spina bifida is common.

Myelomeningocele

The abnormal fusion or the closure of embryonic dorsal structures results in myelocele or myelomeningocele.[11] The abnormality is visible and imaging is not needed, only occasionally sonography is performed to distinguish a meningocele (Figure 3) from a myelomeningocele (in the former the sac is empty, in the latter nerve roots can be seen) (Figure 4) and to diagnose associated anomalies. For sonographic scanning, the sac is covered by a plastic wrap and scanned gently. The spinal cord is usually thinner than normal.

After myelomeningocele repair, neurologic functions should not deteriorate. If they do, it may be caused by retethered spinal cord (incidence 15 %)[12] due to adhesions and scarring. The cord in myelomeningocele is low and remains low after surgery, but oscillates normally. When retethered, it does not oscillate normally, it is fixed to the posterior wall of the spinal canal and dense adhesions may be present.[12] The oscillation of the cord is more easily assessed with sonography than with MR. In myelomeningocele scanning over the cervical canal and toward the foramen magnum can demonstrate echogenic tissue of the cerebellar vermis of the Chiari II malformation.

Sonography and magnetic resonance imaging (MR)

With the availability of MR, the imaging modality which is the best for the demonstra-

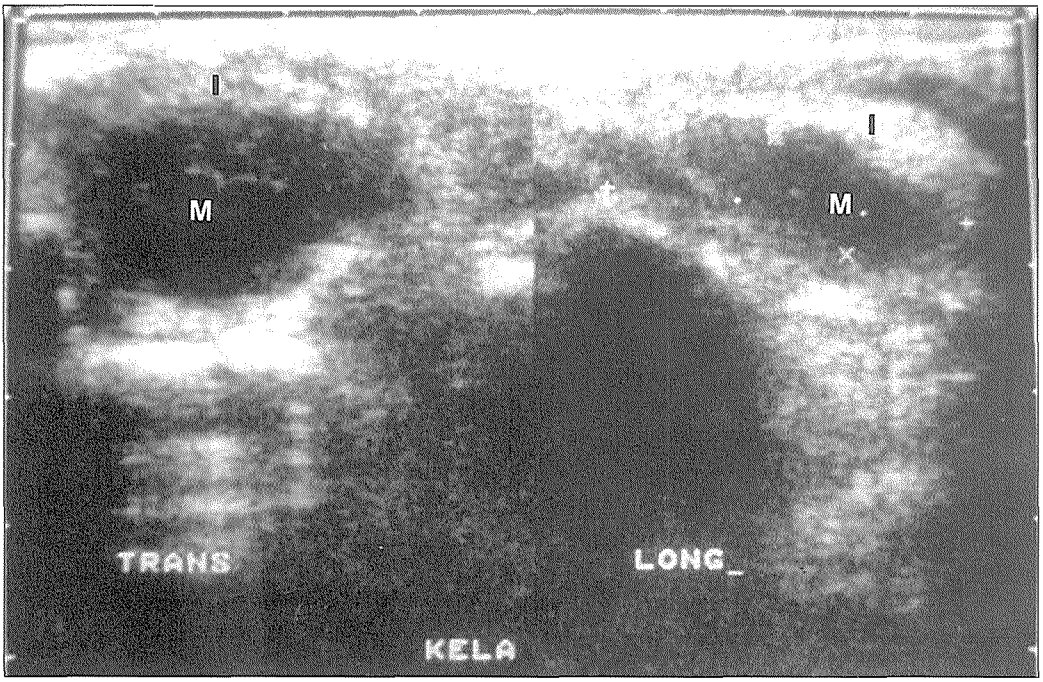

Figure 4. Lumbosacral lipoma associated with meningocele. Transverse and longitudinal views: poorly defined hiperechoic lipoma (l) and hypoechoic meningocele (M).

tion of the anatomic details of the spinal canal, spine, and surrounding soft tissues, the role of sonographic imaging had to be reevaluated. Several studies comparing sonography and MR were conducted. Evaluating 755 children with myelomeningocele in a study conducted to propose a diagnostic radiological model to accurately evaluate the neurological problems in the myelomeningocele child[3] the authors found MR to be the best modality to evaluate the posterior fossa and the total spine. At times MR may not adequately diagnose subtle cases of tethering of the spinal cord, cord infarction, arachnoid cysts, or diastermatomyelia. In these cases, further evaluation is necessary with sonography to look at cord pulsations in cases of tethering, and computed tomography (CT) for other cases. In severe scoliosis MR is not adequate and CT is indicated.

As spinal sonography has become an accepted study to screen for occult dysraphism in neonates and infants, it was important to correlate sonography and MR. The authors of a study correlating sonography and MR confirmed the role of sonography in screening and stressed that MR is most useful when sonographic findings are abnormal or equivocal or when the normal skeletal maturation limits the sonographic visualisation of the intracanalicular contents.[11] In another study of imaging of terminal myelomeningocele (in a low number of patients) the authors compared sonography, CT, and MR and concluded that MR is the imaging modality to diagnose and evaluate children with a myelomeningocele.[3] Important are the results of the study on diagnostic value of spinal sonography, a comparative study with MR imaging in paediatric patients.[13] In 32 of 38 examinations sonography allowed exactly the same diagnosis as MR. In five examinations, sonography depicted the main abnormality but MR revealed additional findings. Whenever sono-

graphy scans were normal, MR images also did not depict any spinal disorder. In all 24 examinations with abnormal MR findings, sonography enabled detection of the abnormality.

Concluding, spinal sonography represents a valuable diagnostic tool for congenital anomalies of the lower spine in infants and small children and is recommended as the primary imaging modality in those patients.

References

1. DiPietro MA The pediatric spinal canal. In: Rumack CM, Wilson SR, Charboneau J W, editors. *Diagnostic ultrasound*. St. Louis: Mosby Year Book; 1998. p. 1589-615.

2. Vocke AK, Ruhmann O, Lazovic D. Standardised sonographic investigation of the lumbar spine in 247 newborn. *Klin Pediatr* 1999; **211:** 22-6.

3. Byrd SE, Radkowski MA. The radiological evaluation of the child with a myelomeningocele. *J Natl Med Assoc* 1991; **83:** 608-14.

4. DiPietro MA. The conus medullaris: normal US findings throughout childhood. *Radiology* 1993; **188:** 149-63.

5. Reigel DH. Tethered spinal cord. *Concepts Pediatr Neurosurg* 1983; **4:** 142-64.

6. Yamada S, Zinke DE, Sanders D. Pathophysiology of the "tethered cord syndrome". *J Neurosurg* 1981; **54:** 494-503.

7. Raghavendra BN, Eipstein FJ, Pinto RS, Subramanyam BR, Greenberg J, Mitnick JS. The tethered spinal cord: diagnosis by high -resolution real-time ultrasound. *Radiology* 1983; **149:** 123-8.

8. Hall DE, Udvarhelyi GB, Altman J. Lumbosacral skin lesions as markers of occult spinal dysraphism. *JAMA* 1981; **246:** 2606-8.

9. Gimson PJ, Britton J, Hall DM, Hill CR. Lumbosacral skin markers and identification of occult spinal dysraphism in neonates. *Acta Paediatr* 1995; **84:** 208-209.

10. Chapman PH. Congenital intraspinal lipoma: anatomic considerations and surgical treatment. *Child's Brain* 1982; **9:** 37-47.

11. Korsvik HE, Keller MS. Sonography of occult dysraphism in neonates and infants with MR imaging correlation. *Radiographics* 1992; **12:** 297-306.

12. Tamaki N, Shirataki K, Kojima N, Shouse Y, Matsumoto S. Tethered cord syndrome of delayed onset following repair of myelomeningocele. *J Neurosurg* 1988; **69:** 393-8.

13. Rohrschneider WK, Forsting M, Darge K, Troger J. Diagnostic value of spinal US: comparative study with MR imaging in pediatric patients. *Radiology* 1996; **200:** 383-8.