Ref: Ro Med J. 2022;69(3)
DOI: 10.37897/RMJ.2022.3.3

Spinal ultrasound – Identification of the normal structures

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ABSTRACT

The incomplete ossification of the spinal processes allows the ultrasonographic evaluation of the spinal cord and the adjacent structures in neonates and small infants. The paper describes the ultrasonographic examination of the spinal structures and the normal appearance of the spinal cord, the structures within the spinal canal, and the bony and muscular adjacent structures. Sagittal and axial sections at cervical, thoracic, lumbar, and sacral levels are described. There are also mentioned findings in the M mode and Doppler examinations.

Keywords: ultrasonographic, spinal cord, sagittal, axial section

INTRODUCTION

The spinal cord could be visualized by ultrasonography during the neonatal period and the first months of infancy by the means of the ultrasound window due to the incomplete ossification of the vertebral arches [1,2]. The technique offers complete visualization of the spinal cord from the foramen magnum to the conus medularis [1,2,3]. There could be also viewed the thecal sac [1,2], filum terminale [1,2,3], the roots of the spinal nerves [1,3], the oseus parts of the vertebral bodies and arches [4], the paraspinal muscles [4].

Spinal ultrasound provides exact images of the structures within the vertebral canal during the first months of life, the quality of the images decreases after the first 3-4 months, as the vertebral arches ossify and in most of infants, an accurate exam would not be possible after 6 months of age [6].

The ultrasound examination of the spine identifies the normal and pathologic elements with an accuracy comparable with the MRI examination if performed during the above-mentioned time interval [6.7]. The main advantage of the ultrasound examination compared with the MRI is that the ultrasound could demonstrate the motion of the structures, being invaluable in the diagnosis of the tethered cord [1,2,3,5].

The paper is reviewing the examination technique and the normal appearance of the spinal cord and the adjacent structures in the neonate.

The examination technique

For the spinal ultrasound, a linear probe is used for the examination of the vertebral canal from the cervical until the sacrococcygeal zone, with a frequency of 10-15 HHz [1,2,8], and a sectorial or micro convex probe with a frequency of 7.5-10 MHz is

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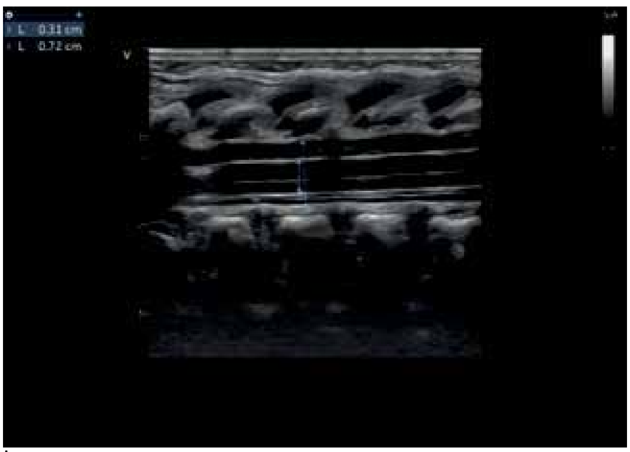
Article History:
Received: 2 September 2022
Accepted: 8 September 2022

used for the examination of the craniocervical junction [1,8,9].

The patient is placed in the prone position, with a cushion or roll under the abdomen in order to expand the intervertebral foramina and help the examination of the older infants1 (Figure 1). There will be realized sagittal sections (Figure 1) and axial sections (Figure 2). Sagittal and coronal sections will be performed also through the foramen magnum (Figures 3 and 4).

a



b

FIGURE 1. a. Sagittal section the position of the transducers b. the image obtained by the sagittal section

There will be performed first the examination in B mode – sagittal and transverse (axial) sections at all the levels of the spinal cord); then the cord and cauda equina are examined in the M mode in order to identify the movements of the spinal cord an exclude a diagnosis of tethered cord [1,10]. In the end, a Doppler examination could be performed in order to visualize the vascular structures [1].

Sections through the craniocervical junction (foramen magnum)

The sections through the craniocervical junction should be part of each spinal ultrasound examination [1,8]. Their aim is to view the structures of the

a

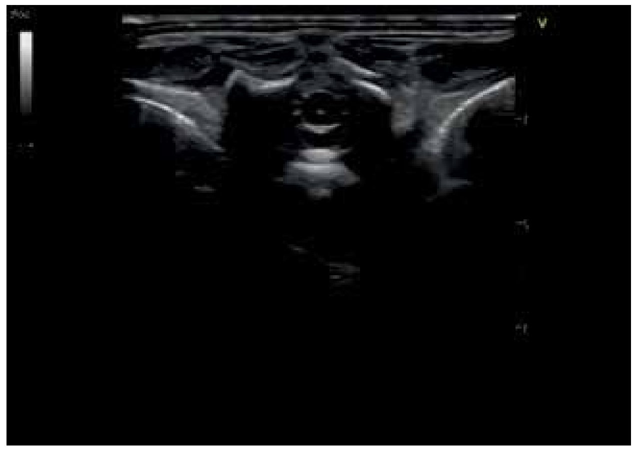


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FIGURE 2. Axial section a. the position of the transducer, b.image obtained by axial section

FIGURE 3. A sagittal section at the level of the craniocervical junction

posterior fossa and cisterna magna, the junction between the medulla and the spinal cord in order to exclude a Chiari malformation [1,9,11].

The examination could be performed with the patient in a prone position [1] or lateral decubitus [9], the head should be flexed [1,9].

In the sagittal section at the level of the craniocervical junction, there could be visualized from posterior to anterior: the occipital bone and the

FIGURE 4. An axial section at the level of the craniocervical junction

a

b

FIGURE 5. a. Sagittal section at the craniocervical junction, b. A parasagittal section at the craniocervical junction – the amygdala is visualized

craniocervical junction, continued inferiorly by the incompletely ossified vertebral arches, cisterna magna – a transonic structure that communicates both with the 4-th ventricle (visible between the cerebellum and the pons) and the vertebral canal. The spine is a hypoechoic structure – more echogenic though than the subdural space and cisterna magna and is continued superiorly with the medulla and the pons – both hypoechoic. Posteriorly to the pons one can see the hypoechogenic cerebellum with the characteristic folia- in the sagittal section – the vermis is visualized (Figure 5 a); in a para-sagittal section – the amygdala is seen (Figure 5b).

In the axial/transverse sections, there are visualized the cisterna magna, the cerebellar hemispheres, and the vermis (Figure 6a); in the superiorly oriented sections we could also see the 4-th ventricle and the pons (Figure 6b)

a.

b.

FIGURE 6. a. Axial section at the level of the craniocervical junction, b. Axial section at the level of the craniocervical junction with the visualization of the 4-th ventricle and the pons

Sagittal sections. Determination of the position of the conus medularis and the diameter of filum terminale

The sagittal section (Figure 1) explores the vertebral canal from the foramen magnum to the sacrococcygeal area (Figures 7-12) [1-3]. In a standard section could be visualized from posterior to anterior: the skin, the muscles and fascia, the spinous processes-ossified or partially ossified, and the vertebral arches, the dura-arachnoid complex [1-4]. If we angulate the probe laterally the epidural space could be identified between the dura mater and the bone [1-3]. Then, the subarachnoid space follows –

the spinal cord could be identified in it – a tubular structure, hypoechoic – but more echogenic than the subarachnoid space, bordered by the pia mater – in its center the central echo complex could be seen [1-3]. The anatomic substrate of the central echo complex is represented by the interface between the white ventral commissure and the central end of the anterior median fissure [15]. Posterior to the spinal cord the subdural space could be seen, the dura-arachnoid complex and the vertebral bodies with different shapes depending on the examined area (see further) [1]. The spinal cord is situated normally in the anterior third of the canal [1-3] – the posterior displacement is suggesting a tethered cord [10]. Within the subarachnoid space, the nerve roots could be seen.

In the inferior part of the cord the terminal elements could be seen (conus medularis and filum terminale) formed by the secondary neurulation process [1,2], the cauda equina – formed by the roots of the spinal nerves and the ending of the thecal sac (Figure 9-10 a). The sacrococcygeal area – with the vertebra and ossification centers could also be identified (Figure 10b)

The determination of the position of the conus medularis is an essential part of the spinal ultrasonographic exam [1-3]. It could be performed by different methods [1-3,8]:

- Counting upwards from the sacral vertebrae
- Counting upwards from the first coccygeal vertebra
- Counting downwards from the first vertebra with rib (usually T12)
- Counting upwards from the end of the thecal sac (usually S2)
- Identifying ultrasonographically the end and marking it with a radiopaque marker, then performing an Xray in order to identify the vertebra

The level of the conus medularis is modified according to the gestational and postnatal ages of the patient [1,3]. Due to the unequal growth of the spine and the bones, a relative ascension of the conus is produced in the last part of the pregnancy and immediately postnatal. Thus, in premature neonates the conus is situated between L2 and L43, it is ascending in the last part of the pregnancy, and in the term neonates, it is situated between L1 and L3, around one month of age the normal position is L1-L2, the position that persists for the rest of the life [1,3].

Filum terminale represents the central continuation of the conus medularis, that is anchored to the interior wall of the vertebral canal [1]. It is measured at the level of S2 and the width should not be more than 2 mm (Figure 10a).

The ultrasound exam allows the identification of the ossification centers at the level of the vertebral arches and bodies [1,4]. At the level of the vertebral body, two centers could be identified – one anterior and one posterior – they fuse in time [4]. Synchondroses between the different centers could also be seen [4].

As the patient grows, the spinous processes ossify and the examination becomes more and more difficult [1]. So, the structures that can be very well-identified during the neonatal period (Figure 12 a,b,c) are hardly seen at 2-3 months (Figure 12 d,e,f).

FIGURE 7. Sagittal section – cervical area. Legend: cda – dural-arachnoid complex; SA – subarachnoid space, CEC – central echo complex; pia – pia mater

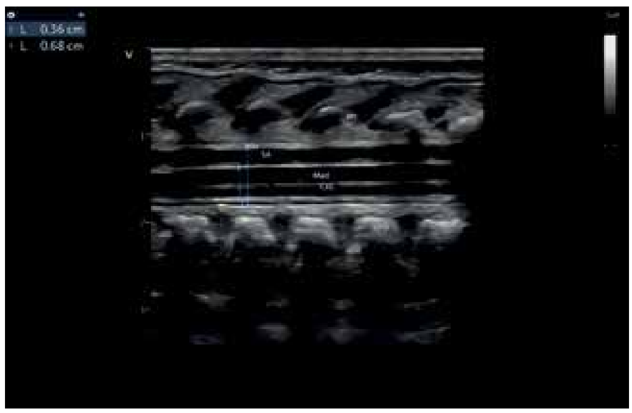

FIGURE 8. Sagittal section – thoracic zone. da – dural-arachnoid complex; SA – subarachnoid space, CEC – central echo complex; mad – spinal cord

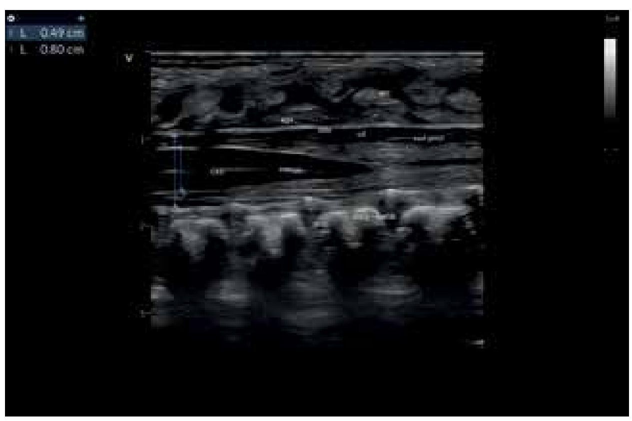

FIGURE 9. Sagittal section. Lumbar zone + conus medularis. Legend: epi – epidural space, cda – dura mater-arachnoid complex; SA – subarachnoid space; rad post – posterior root; CEC – central echo complex

FIGURE 10. a. Sagittal section – sacral zone – thecal sac,
b. Sagittal section – sacro –coccigeal zone. Legend: S5 – the body of 5-th sacral vertebra. Coc – first coccygeal vertebra – note the round appearance of the coccygeal vertebra

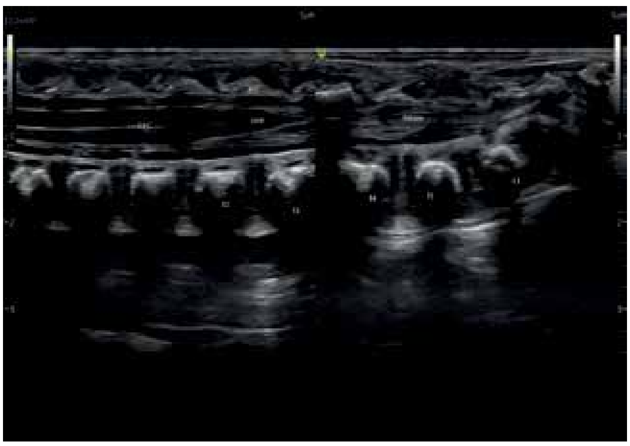

FIGURE 11. Sagittal section – determination of the position of the conus medularis – starting from the sacral S1 vertebra – boomerang shaped

Axial sections

Axial sections (Figure 2) are a mandatory part of any ultrasound examination of the spinal cord [1,2,8]. They are important in order to exclude the presence of a split column because they could identify the central echo complex and its duplication [11] or to exactly measure a syrinx [12]. Also, some authors use the axial section for the M mode examination [1].

In an axial section – from posterior to anterior there could be identified [1-3] (Figures 13-15) – muscles and fascia, vertebral arches [4], with the un-osified spinous processes (that allow the visualization of the structures in the vertebral canal) the dura-arachnoid complex – a hyperechogenic line, the subarachnoid space – transonic – in it there could be visualized hyperechogenic lines – the nerve roots, the spinal cord – hypoechoic – but more echogenic than the subarachoid space, covered by the hyperechogenic piamater, having in the center the central echo complex. The cord is situated in the anterior third of the spinal canal. Laterally to the cord, especially in the thoracic zone – dentate ligaments could be viewed. Anterior to the spinal cord the subarachnoid space could be identified, then the dura-arachnoid complex and the vertebral body – hyperechogenic – the two ossification centers could be identified in it [4]. In the lumbar zone the anterior and posterior roots of the spinal nerves and the filum terminals could be identified (Figure 15). In certain cases, between the dura mater and the bones, the epidural space could be identified [1,4].

Examination in the M mode

As previously mentioned, one of the advantages of the spinal ultrasound over the MRI exam is that the ultrasound could identify the movement of the spinal cord and thus exclude a tethered cord.

The demonstration of the movements of the cord could be realized by the real-time examination in the B mode – three types of movements could be identified – vertical – associated with the movements of the head; horizontal – rapid – due to the vascular pulse and slow – related to respiration [1,10]. The movements of the cord could be demonstrated in the M mode on both sagittal (Figure 16 a) and axial (Figure 16.b) sections. They could be noted both in the neonate and older infants with partially ossified arches (Figure 16c) [10].

Examination – Doppler mode

Doppler examination could identify the anterior and posterior venous plexus (Figure 17a) – best visualized in the lumbar area [1]. The anterior venous plexus is identified anterior to the anterior root of the spinal nerves and the posterior plexus is visualized posteriorly to the posterior root [1]. The vertebral arteries could not be visualized so well, because their course is parallel to the ultrasound beam [1].

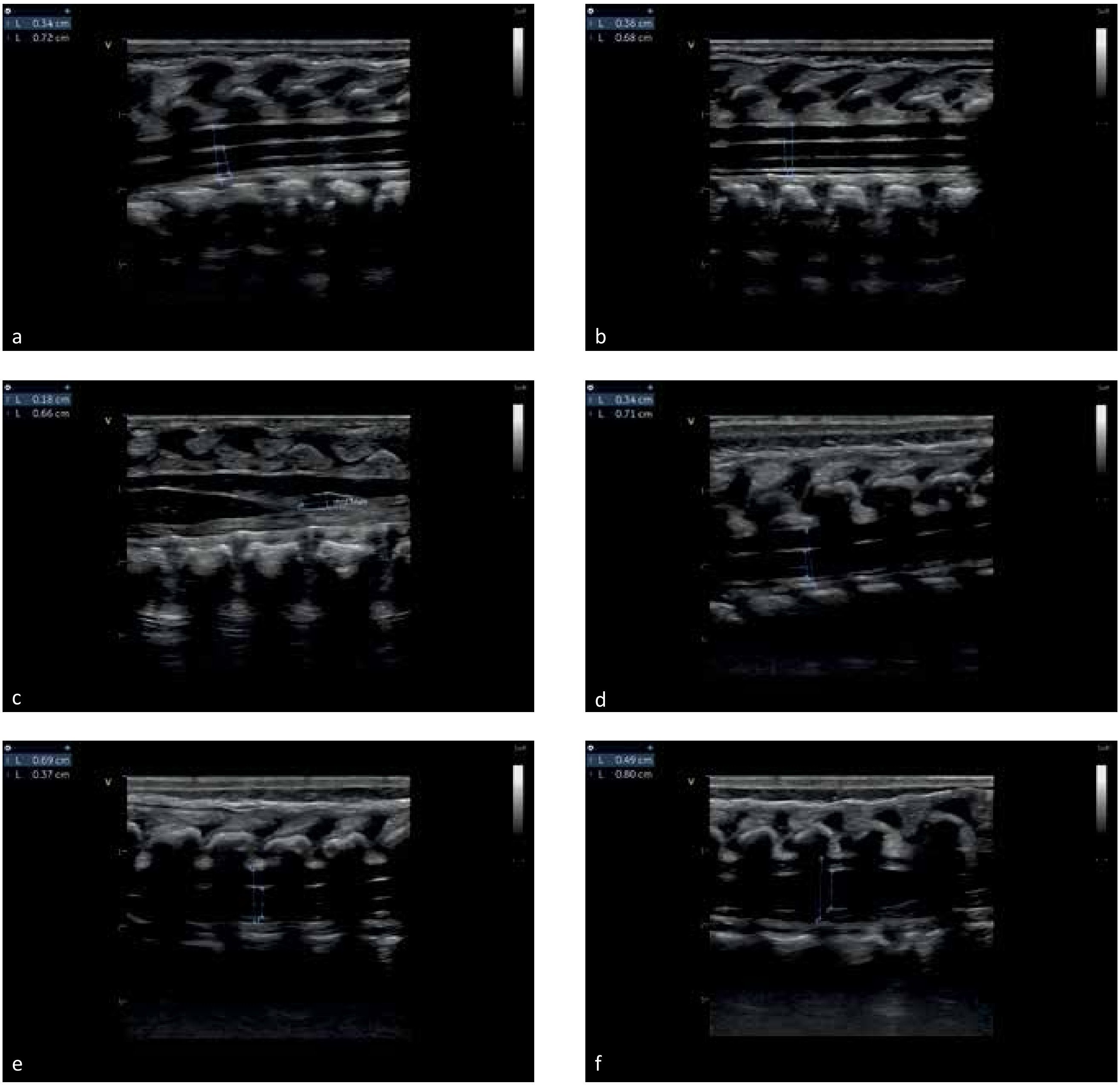

FIGURE 12. Sagittal sections at different ages with diminishing visibility of the spine. A,b,c – sections at the cervical, thoracic and lumbar zones on day of life 3; d,e,f – sections at cervical, thoracic and lumbar zones at 2 months of age. In the sections performed at 2 months, the structures are partially visualized through partially ossified spinal processes

FIGURE 13. Axial section through superior thoracic zone.
Legend – CDA – dural-arachnoid complex; MS – spinal cord ;
CEC – central echo complex; lig - ligament

FIGURE 14. Axial section – Lumbar area.
Legend: MS – spinal cord; ra – anterior root; rp – posterior root

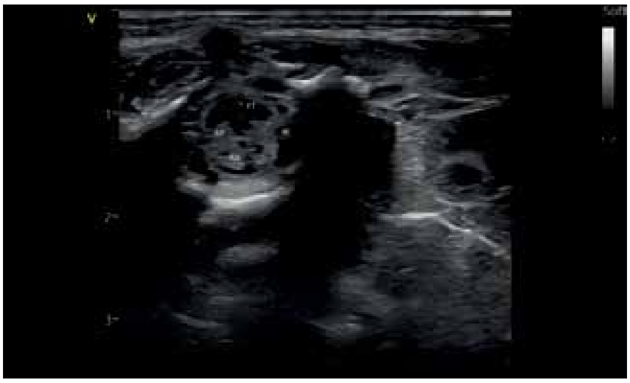

FIGURE 15. Axial section – roots and filum terminale.
Legend> FT – filum terminale; RA – anterior root; RP – posterior root

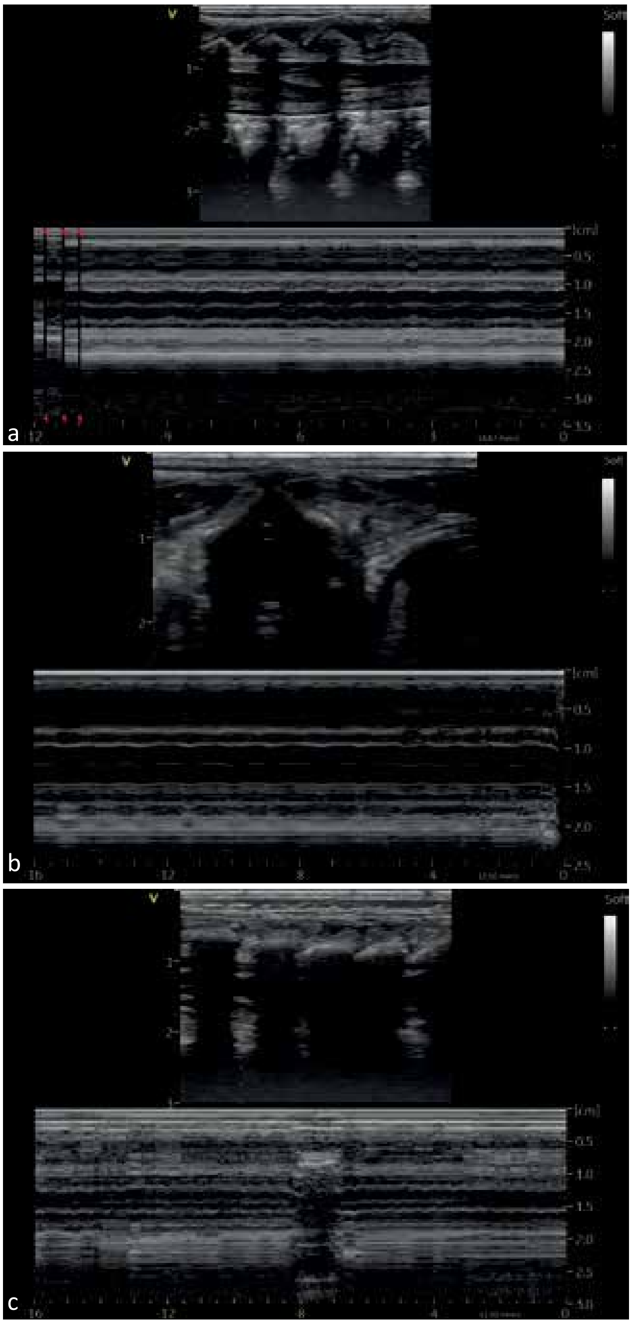

FIGURE 16. a. Demonstration of the movement of the cord – M mode – sagittal section, b. Demonstration of the movement in M mode – axial section, c. Examination in M mode of a patient with a partially ossified spine. The ventrodorsal movements are more evident in the neonate

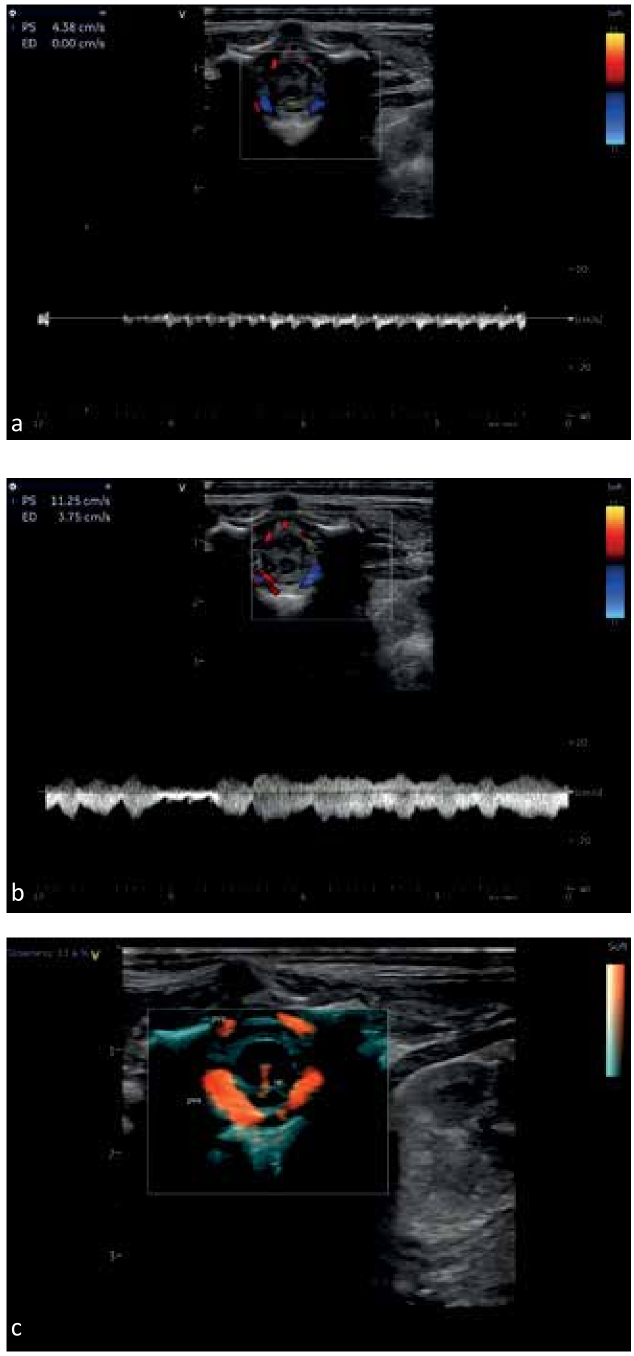

FIGURE 17. a. Color Doppler Exam. Anterior and posterior venous plexuses are viewed, b. Pulsed Doppler Examination, c. Power Doppler Examination. Anterior venous plexus (pva); posterior venous plexus (pvc) and the central branch of the anterior spinal artery (rac)

The posterior vertebral arteries could be visualized only by power Doppler [1]. The central branch of the anterior vertebral artery is situated in the anterior median fissure ending at the central echo complex (Figure 17c) [1].

The pulsed Doppler examination shows a continuous flow in the veins, with variations due to the respiratory movements and the arterial pulsations (Figure 17b)

CONCLUSIONS

Modern ultrasound devices offer very good images of the spinal cord and neighbouring structures, during the first months of life. There could be identified the majority of the spinal structures – the cord, the conus medularis, filum terminale, nerve roots, and membranes. It could also visualize the osseous structures and their evolution/maturation. Due to the easiness of performance and the accuracy of the images, the technique should be a part of the screening in the case of infants with spinal dysraphism.

Conflict of interest: none declared
Financial support: none declared

REFERENCES

1. Deeg KH, Lode HM, Gassner I. Spinal sonography in newborns and infants--Part I: method, normal anatomy and indications. Ultraschall Med. 2007 Oct;28(5):507-17. doi: 10.1055/s-2007-963052. Epub 2007 May 9. Erratum in: Ultraschall Med. 2007 Oct;28(5):517. PMID: 17492573.
2. Coley BD, Murakami JW, Koch BL, Shiels WE 2nd, Bates G, Hogan M. Diagnostic and interventional ultrasound of the pediatric spine. Pediatr Radiol. 2001 Nov;31(11):775-85. doi: 10.1007/s002470100535. PMID: 11692234.
3. Dick EA, Patel K, Owens CM, De Bruyn R. Spinal ultrasound in infants. Br J Radiol. 2002 Apr;75(892):384-92. doi: 10.1259/bjr.75.892.750384. PMID: 12000700.
4. 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(5-6):493-511. doi: 10.1007/BF00344103. PMID: 3540713.
5. Dick EA, de Bruyn R. Ultrasound of the spinal cord in children: its role. Eur Radiol. 2003 Mar;13(3):552-62. doi: 10.1007/s00330-002-1655-0. Epub 2002 Sep 18. PMID: 12594559.
6. Rossi A, Cama A, Piatelli G, Ravegnani M, Biancheri R, Tortori-Donati P. Spinal dysraphism: MR imaging rationale. J Neuroradiol. 2004 Jan;31(1):3-24. doi: 10.1016/s0150-9861(04)96875-7. PMID: 15026728.
7. Santiago Medina L, al-Orfali M, Zurakowski D, Poussaint TY, DiCanzio J, Barnes PD. Occult lumbosacral dysraphism in children and young adults: diagnostic performance of fast screening and conventional MR imaging. Radiology. 1999 Jun;211(3):767-71. doi: 10.1148/radiology.211.3.r99jn09767. PMID: 10352604.
8. The American Institute of Ultrasound in Medicine. Ultrasound Examination of Neonatal and Infant Spine. *AIUM*. 2016.
9. Cramer BC, Jequier S, OGorman AM. Ultrasound of Neonatal Craniocervical Junction. AJNR. 1986;7:449-55
10. Schumacher R, Kroll B, Schwarz M, Ermert JA. M-mode sonography of the caudal spinal cord in patients with meningomyelocele. Work in progress. Radiology. 1992 Jul;184(1):263-5. doi: 10.1148/radiology.184.1.1609089. PMID: 1609089.
11. Deeg KH, Lode HM, Gassner I. Spinal sonography in newborns and infants - part II: spinal dysraphism and tethered cord. Ultraschall Med. 2008 Feb;29(1):77-88. doi: 10.1055/s-2007-963212. Epub 2007 Jul 3. PMID: 17610176.
12. Jones BV. Cord Cystic Cavities: Syringomyelia and Prominent Central Canal. Semin Ultrasound CT MR. 2017 Apr;38(2):98-104. doi: 10.1053/j.sult.2016.07.008. Epub 2016 Jul 12. PMID: 28347422.
13. Gerscovich EO, Maslen L, Cronan MS, Poirier V, Anderson MW, McDonald C, Boggan JE, Ivanovic M. Spinal sonography and magnetic resonance imaging in patients with repaired myelomeningocele: comparison of modalities. J Ultrasound Med. 1999 Sep;18(9):655-64. doi: 10.7863/jum.1999.18.9.655. PMID: 10478975.
14. 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(1):50-2. doi: 10.1007/BF00341038. PMID: 3547168.
15. Nelson MD Jr, Sedler JA, Gilles FH. Spinal cord central echo complex: histoanatomic correlation. Radiology. 1989 Feb;170(2):479-81. doi: 10.1148/radiology.170.2.2643144. PMID: 2643144.
16. Hill CA, Gibson PJ. Ultrasound determination of the normal location of the conus medullaris in neonates. AJNR Am J Neuroradiol. 1995 Mar;16(3):469-72. PMID: 7793365; PMCID: PMC8337675.
17. Beek FJ, de Vries LS, Gerards LJ, Mali WP. Sonographic determination of the position of the conus medullaris in premature and term infants. Neuroradiology. 1996 May;38 Suppl 1:S174-7. doi: 10.1007/BF02278151. PMID: 8811708.
18. Zieger M, Dörr U. Pediatric spinal sonography. Part I: Anatomy and examination technique. Pediatr Radiol. 1988;18(1):9-13. doi: 10.1007/BF02395752. PMID: 3277148.