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SPINAL ANESTHESIA UNDER ULTRASONIC CONTROL

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Abstract. *Spinal anesthesia in children has many potential benefits. However, performing spinal anesthesia in children, especially infants, has certain technical difficulties. For more than a century, the technique of performing spinal anesthesia has been based on landmarks and has not changed for many years. Advances in ultrasound technology may provide an opportunity to improve spinal procedures in infants. But the traditional approach in some cases may not be reliable because these surface landmarks may be absent, unclear, or distorted in the presence of obesity, previous spinal surgery, deformities, or degenerative changes. Manual palpation may be inaccurate, and placement of the needle at or above the level of the conus medullaris can lead to complications, including neurological injury. Although rare, spinal cord injury resulting from direct needle trauma or intramedullary injection of local anesthetic can be potentially fatal. Ultrasonography makes it possible to more accurately select the appropriate intervertebral space for spinal anesthesia, reduce the technical complexity of neuraxial blockade, and minimize the number of attempts at lumbar puncture. Multiple attempts at needle insertion may increase the risk of complications such as post-puncture headache and back pain.*

Keywords*: ultrasound imaging, spinal anesthesia, central neuraxial blocks, local anesthetics, childhood, regional anesthesia.*

Introduction. The use of ultrasound (ultrasound) in the practice of anesthesiologists has greatly facilitated the performance of a number of invasive manipulations and has become a common accessory. The use of preprocedural scanning increases the technical efficiency of central neuraxial block (CNB), facilitating accurate identification of the underlying anatomical structures [1, 2]. It can be used as an adjunct to central venous catheterizations and general vascular access, airway management, bedside imaging of the heart, lungs and abdomen, point-of-care ultrasound for rapid diagnosis and monitoring of cerebral problems, and has recently proven itself as an adjunct to regional anesthesia (RA).

The use of ultrasound can improve the success of procedures, increase safety and effectiveness in routine clinical practice, and aid in therapeutic and diagnostic interventions [3]. A Cochrane review demonstrated that sonographically guided regional anesthesia is more successful than guided techniques in reducing block time and thus increasing the number of needle passes [4].

The use of ultrasound when performing neuraxial blockades provides visualization of nerves and surrounding structures in real time optimizes the proximity of the injection of local anesthetic (LA) to the target nerve structures, which allows reducing the volume of injected local anesthetic, thereby reducing the risk of toxicity, which is of no little importance in pediatric practice.

Purpose of the work: to analyze scientific publications on the effectiveness of using ultrasound guidance in spinal anesthesia.

Materials and methods

When searching for publications on the use of ultrasound guidance during spinal anesthesia, the following keywords were used: spinal anesthesia, ultrasound guidance, neuraxial blockades, local anesthetics, ultrasound imaging. A comparative analysis of 46 publications was carried out, including the results of original and review articles, of which the most informative were 31 works that formed the basis of our review.

Exclusion criteria included unreliable evidence without prospective registration and sample size justification. Searches were carried out in databases/scientific electronic libraries eLibrary.ru (RISC), PubMed (MEDLINE), Cohrane, Clinicaltrials.gov, Google Scholar and Science Direct for the period from 2021 to March 2024. Despite an extensive literature search, Level of Evidence remains limited to date due to the lack of randomized controlled trials.

Discussion

In newborns and infants, the spinal cord ends at L2–L3, in children it ends at T12–L1 and the lower third of L1, in adolescents it ends at the middle third of L1 and L1–L2, and in young adults the spinal cord ends at L1– L2. The spinal cord was not located caudal to the L3 vertebral body. The thecal sac in newborns ends at the level of S3 and the spinal cord at the level of L3 and does not reach the “adult” S2 and L1, respectively, until the 2nd year of life. Thus, it is advisable to use a low approach (L4–L5 or L5–S1) to prevent spinal cord injury [5,6].

The subarachnoid space in newborns is narrower (6–8 mm), and the cerebrospinal fluid pressure is lower, which requires more careful execution and avoidance of lateral deviation of the needle [7,8]. Thoracic kyphosis is less pronounced due to greater flexibility of the spine, which facilitates the cranial spread of the anesthetic and greater severity of sensory block [9,10]. All this should be taken into account when using the traditional method of performing spinal anesthesia in children. Ultrasound imaging of the nervous system in children (especially infants under 6 months of age) is easier than in adults due to the fact that the back of the spine is primarily cartilaginous. It is still considered an advanced imaging modality due to the limited ultrasound window.

The absence of ossification associated with aging significantly increases the penetration of the ultrasound beam, thereby creating a clearer image of neuraxial structures. In infants, structures that are not usually visible on scans of the adult nervous system (spinal cord, conus medullaris, cauda equina, vertebral body) and even extension of local anesthetic into the subarachnoid space may be visualized [11]. Although ultrasound images of neuraxial structures become more limited with age due to ossification of the posterior elements, they can still be useful in identifying structures of interest in older children [12].

Bone does not penetrate ultrasound and casts a dense acoustic shadow. Thus, the contours of the posterior bony surfaces of the lumbar vertebra have characteristic patterns of acoustic shadowing that are key to the interpretation of the sonoanatomy of the lumbar spine. Visualization of the spinal canal is possible only through soft tissue acoustic windows of the interlaminar and interspinous spaces.

There are five main ultrasound views of the spine that can be systematically acquired: the parasagittal oblique (interlaminar) view (PSO view) and the transverse interlaminar/interspinous view (TI view) are the most important views in clinical practice because they provide images of the spine. neuraxial structures through acoustic windows. These structures include: ligamentum flavum, posterior dura mater, spinal canal, anterior dura mater, and posterior longitudinal ligament [13].

Pre-procedural ultrasound scanning technique.

Ultrasound examination of the spine involves visualization of structures covered by a complex, articulated shell of bones. The ultrasound beam needs to penetrate very narrow acoustic windows within this bone complex to obtain the best view [14].

The structures are located deeper on the surface of the skin compared to those we visualize with ultrasound during peripheral nerve blocks and vascular access placement. The ultrasound probe used to evaluate the spine should be a low frequency (2–5 MHz) curved probe, which has lower image resolution but penetrates deeper compared to a high frequency (10–15 MHz) linear probe, which in turn better resolution, but less penetrating.

In spinal ultrasound, two access planes allow the ultrasound beam to penetrate two narrow acoustic windows. These are longitudinal paramedian oblique approach and transverse approach; the images seen on these planes have been described as the “saw sign” and “bat”, respectively [15,16].

The longitudinal paramedian oblique approach is performed by placing the ultrasound probe vertically in line with the long axis of the spine. The transducer is placed in the sacral region 1 to 3 cm to the left of the midline and then tilted medially to target the center of the spine until a continuous hyperechoic (bright) linea alba (sacrum) is visible.

The transducer is then moved cranially until a hyperechoic sawtooth image appears. The “saw” represents the vertebral plates (saw teeth) and interstices (spaces between the teeth) where the ligamentum flavum and posterior dura mater (posterior complex) are located, and this approach also allows visualization of the anterior dura mater, posterior longitudinal ligament and vertebral body (anterior complex). The exact level of the spaces, starting from L5–S1, above the sacrum can then be counted and marked.

The transverse approach is achieved by placing the ultrasound transducer horizontally, perpendicular to the long axis of the spine, at the marked levels obtained in the longitudinal paramedian oblique projection. Assuming that the spine is aligned and there is no scoliosis, the midline of the spine can be identified by a small hyperechoic signal just under the skin (spinous process), which continues as a long triangular hypoechoic (dark) acoustic shadow.

The transducer is moved cranially or caudally until the acoustic window detects the interstitial space. Within the gap, two hyperechoic lines (the "equal sign") will be visible, corresponding to the anterior and posterior complexes, as well as the articular processes (bat ears) and transverse processes (bat wings), creating the image of a "bat". It is important to note that the angle at which the transducer is pressed against the skin to provide an optimal view of the bat is also the angle at which the needle should subsequently be inserted.

Now the middle of the sensor can be marked on the skin along the horizontal and vertical edges, corresponding to the midline and interdimensional level, respectively. The ultrasound image can be frozen and the distance from the skin to the subarachnoid space can be measured using a built-in caliper. The needle puncture site is determined by the intersection of these two marks on the skin.

Thus, prepuncture ultrasound scanning provides accurate and reliable information about several important landmarks necessary for successful intrathecal needle placement. This is exactly the interval (level) at which the puncture will be made; the intermediate space with the most clear sonoanatomy; middle line; optimal insertion point; optimal angle of needle insertion; depth of the subarachnoid space; and any anomalies of the spine and spinal cord (Klippel-Feil syndrome, diastematomyelia, syringomyelia, Spina bifida, etc.) [17].

Broadbent and colleagues studied the ability of anesthesiologists to accurately identify a prominent lumbar gap by palpation. They found that experienced anesthesiologists misidentified gaps 71% of the time when confirmed by MRI. The identified intervening space was often higher than the actual intervening space, usually by one or two levels.

Their report even reported a case in which an obese patient had an actual gap that was four gaps higher. This was confirmed by a study in term pregnant women, where the intercrystalline line, determined by palpation, was identified above the L4–L5 space in all cases when assessed with ultrasound. The level of intersection varied from the level directly above L1–L2 to L4–L5. In contrast to palpation, the use of ultrasound identification of the L3–L4 space has been found to correlate more accurately (~71–76%) with spinal imaging and further supports ultrasound as a useful adjunct to safe intrathecal “acupuncture” [18].

Reynolds' case report highlights spinal cord injury following spinal or combined spinal-epidural anesthesia when anesthesiologists believed the needle was inserted in the L2-L3 space. The author concluded that when performing neuraxial blocks, the likelihood of inaccurate determination of the lumbar spaces and the variability of the position of the cone in children should be taken into account.

And therefore, the intrathecal needle should not be inserted above the L3 level. In a subsequent editorial, Bogod supported this recommendation and described the area below L2–L3 as the “Reynold's zone” as the safest site for intrathecal needle insertion. He reiterated that relying on Tuffier's line to be at L4 or below could lead to errors in selecting a higher puncture interval, which could result in spinal cord injury. It should be noted that all these recommendations become meaningless if neuraxial anesthesia is practiced without ultrasound assistance, given the inaccuracy of palpation technique [19].

Young and colleagues reported an increased success rate when performing ultrasound before neuraxial anesthesia. According to the results of their study, preprocedural ultrasound reduced the incidence of complications, including: technical impossibility of performing the neuraxial technique; failure of analgesia or anesthesia; "blood tap" or vascular cannulation; postpartum back pain and headache [19].

A randomized clinical trial by Grau and colleagues found that trainees who performed their first regional blocks under ultrasound guidance (versus landmark palpation) had a significantly higher success rate at all stages of the study. A systematic review of the literature on trainee training in neuraxial anesthesia highlighted the need for further research in this area and concluded that ultrasound should be considered as a first-line training tool for novice trainees.

Conclusions.

The ability to visualize neuraxial structures with preprocedural ultrasound assessment may help to safely access the subarachnoid space.

The ability to accurately determine the correct intervertebral level, the optimal point and trajectory of needle insertion. This technique is especially useful in cases where anatomical landmarks may be difficult, such as obesity, scoliosis, or previous spinal surgery.

Ultrasound is noninvasive, safe, can be performed quickly, has no radiation exposure, provides real-time images, and has no side effects.

Detailed knowledge of lumbar spine anatomy and sonoanatomy is required to interpret neuraxial ultrasound images. Ultrasound is an excellent teaching tool for demonstrating spinal anatomy and improves the learning process for performing regional blocks.

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