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APPROACHES AND TECHNIQUES TO EPIDURAL SPACE IDENTIFICATION

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Abstract

Anesthesiologists must understand the pros and drawbacks of emerging technology in order to decide which methods to use. Furthermore, knowledge of these more current technologies is required to guide future research studies in this area. The goal of this review is to outline the emerging technologies for recognizing EDS and their potential future usefulness. We searched electronic databases MEDLINE and EMBASE until the beginning of 2021. The following MeSH terms were utilized in search strategies: "epidural space identification," "epidural anesthesia," "method," and "evaluation." An ideal method for detecting EDS should be simple to discover and implement, fast replicable with a high level of sensitivity and uniqueness, and easily detect unintentional intrathecal and intravascular catheter placements. Prior to implementing any new technology, it is also critical to assess the availability of sources, clinical feasibility, and cost-benefit benefit. Though none of the novel strategies have yet to replace traditional LOR, some have found value in specific contexts and hence may be complementary to LOR. When a patient with challenging anatomy is encountered, ultrasound is increasingly being used as a rescue strategy.

Keywords: *MEDLINE and EMBASE.*

Introduction

Epidural anesthesia is a popular type of anesthesia that can be used in a variety of settings. The most popular method for identifying needle entry into the epidural space (EDS) is to use a loss of resistance (LOR) technique, which was described in 1921 by Sicard and Forestier and has remained mostly unchanged since [1].

Despite its widespread use, epidural analgesia has a high failure rate [2]. In a heterogeneous sample of 2114 surgical patients, Ready records a 27% and 32% failure rate for lumbar and 32% failure rate for thoracic epidural, respectively [3]. Failure was defined as the requirement for an epidural catheter replacement or the addition of another main strategy for pain control. Kinsella reported in another cohort of 1286 patients that 24% of patients lacked insufficient anesthesia when using a previously placed labor epidural for cesarean region [4]. Failure of epidural analgesia can occur for a variety of reasons, including a lack of ability to lead the needle through the interspinous or interlaminar gap into the EDS, false-positive identification of entrance into the EDS, difficulty inserting the epidural catheter into the EDS, and malposition or subsequent dislodgement of the epidural catheter [5], [6]. Aside from analgesia/anesthesia failure, epidural positioning is associated with complications such as postdural puncture headache, accidental subarachnoid, subdural, [9] or epidural venous location, and epidural hematoma [7]. Postdural puncture headache caused by an unintended dural puncture during labor epidural placement is associated with a substantially longer hospital stay and emergency clinic visits before discharge [8].

To avoid these failures and problems, newer ways for locating and validating access into the EDS have been investigated over the last decade. Anesthesiologists must understand the pros and drawbacks of emerging technology in order to decide which methods to use. Furthermore, knowledge of these more current technologies is required to guide future research studies in this area.

METHODOLOGY:

Throughout 2021, we conducted a search using electronic databases MEDLINE and EMBASE. The following MeSH terms were utilized in search strategies: "epidural space identification," "epidural anesthesia," "method," and "evaluation." Then we looked through the bibliographies of the included papers for further references to our review. Our search tactics restricted to only English language published articles with human subjects that were related to our criteria of review, systematic reviews, or clinical studies.

DISCUSSION:

• Loss of resistance & Hanging drop techniques This was first described in the early twentieth century and is still the most often used strategy by many anesthesiologists today. In 1921, Sicard and Forestier used fluid as a medium for this approach. Dogliotti explained the underlying notion and pushed the method [9]. The benefits of this technique are its ease of use, low cost, and low burden, as well as its high sensitivity and specificity. This strategy can be used by people who have prior experience respecting the 'give way' feeling. It is not a good method for beginners. Both air and fluid can be utilized as a medium for this approach, however there is now controversy about which media transcends. With some reasons, air becomes the chosen medium. First is historical, as up until the seventies, syringes were made from glass and were non-disposable. Because fluid made the syringes sticky, air modified it by preventing it. The disadvantages of using air include the risk of pneumocephalus, headache, cervical emphysema, patchy block, and air embolism [10]. All of these issues arise when the volume of air used exceeds the standard limitations. It is critical to remember that air should not be used as a medium following an unintentional dural puncture [11]. When compared to non-compressible materials such as fluid, air is a compressible medium and high pressure cannot be achieved. Fluid gained popularity as a medium due to the availability of plastic syringes, which eliminated most of the issues associated with air as a medium. The main disadvantages of using saline are dilution of the local anesthetic drug, which affects sensory blocking, and complications with CSF fluid if an unintended dural puncture occurs. Using more than 10 ml of normal saline in the epidural chamber secures venous cannulation, but at the expense of possible difficulties with analgesia quality. Using 5 mL of ordinary saline is associated with a decreased incidence of intravascular catheter insertion and fewer unblocked sectors [12]. Simple bedside testing for temperature, glucose, protein, and pH differentiated CSF from saline used to define the epidural area [13]. When used directly in a parturient patient, saline provides advantages [13]. Some anaesthesiologists prefer utilizing Lignocaine as a medium as opposed to regular saline as it was condemned for causing delayed start of action of local anesthetics [14].

This method's basis is based on the fact that the pressure in the epidural space is sub-atmospheric. As a result, after resistance is lost, a drop of saline is inserted at the hub of the syringe. The advantage is that only a drop of saline is used, which has no effect on the quality of analgesia. The epidural needle is grasped in this approach by the thumb and index finger of both hands, with the ulnar border of the hands resting on the patient's back, allowing stability and control as the needle is progressively advanced into the ligamentum flavum [15]. Because the thoracic region has more negative pressure than the lumbar region, this is the preferred technique. Nonetheless, this strategy is rarely employed. When compared to the hanging decrease strategy, the loss of resistance method reduces the possibility of damaging dura mater at the lumbar level [16].

Saline infusion technique

Because there is negative pressure in the epidural space, saline from the infusion set enters it. This approach was described by Baraka A [17]. The key advantages of this procedure are that the needle can be held with both hands and directed as needed. It is simple to learn, especially for beginners, has a high success rate, is inexpensive, and takes an objective approach as opposed to the subjective loss of resistance technique. If a micro infusion set is used, the amount of saline that enters will be very small, which has no effect on the quality of analgesia. The saline that enters the gap makes threading the catheter quite simple, and little needles can be used. In such cases, disadvantages may include unintentional dural puncture and complications with cerebrospinal fluid. Such disadvantages are minor because both hands are used to steer the needle and manage the depth of entry, therefore the risks of dural puncture are minimal. There is a danger that the needle will accidentally enter the epidural venous pathways. This technique is most suited for thoracic epidurals as well as lumbar epidurals, especially for novices.

Ultrasound

Ultrasound can be used in two ways. Surface ultrasonography can be performed with either a linear probe in lean patients or a curved probe in obese patients due to its good penetration depth. Ultrasound provides vital and reliable information about the surrounding structures. The vertebral space and the dura can both be identified. Needle guidance is a two- person method that may be carried out in real-time and has a high success rate. Nonetheless, epidural catheter insertion cannot be anticipated, and a one-person procedure may be challenging. Chiang et colleagues used an 18-gauge needle and a 40 MHz ultrasonic transducer fiber (6 dB fractional bandwidth 50%) to create an A-mode picture display screen. The amplitude of the ultrasound signal was shown on the y

xis, and the time necessary for the ultrasound signal to return was shown on the x axis [18]. The axial resolution and penetration were both 0.15 mm. The ligamentum flavum, epidural space, and needle access may be viewed by displaying the A-mode scan on a two-dimensional depth-reconstructed scan picture [19]. On 83.3% of insertions, the ligmentum flavum was recognized, and on 100% of insertions, the dura matter was recognized. Ameri et al. hypothesized that the usefulness of this technology could be improved even further by combining A-mode imaging with two-dimensional B-mode imaging, which displays the brightness of the ultrasound signal [19]. The B-mode needle probe could reach a depth of 2 cm, improving the precision and safety of epidural catheter positioning in animal models. Human research, on the other hand, lacks. Other methods of detection, such as pulse-echo ultrasound, are being developed.

Optical coherence tomography

Optical coherence tomography (OCT) is an optical imaging technique similar in concept to ultrasound, except that it uses infrared light. It is possible to obtain high-resolution cross-sectional subsurface tomographic pictures of tissue microstructure using OCT. Tang et colleagues developed a small-diameter (0.5 mm) forward imaging OCT device with real-time high-contrast Doppler flow imaging [20]. A wavelength-swept laser aimed at 1310 nm with a bandwidth of 100 nm is employed in the regularity domain OCT system. The axial and side resolutions are both around 13 m. Layer by layer, this technique may visualize arteries, blood vessels, and various structures [20].

Kuo et al [21] also defined an in-needle swept-source OCT device with great sensitivity and uniqueness. Circumferential scanning with an optical probe put in an epidural needle with a rotational motor, which gives real-time side view images as the needle travels right into the epidural space, yielded a two-dimensional OCT image. In tissue, the axial resolution is about 15 m, and the imaging depth is about 2 mm. Instead of forward imaging, they argued that a side-looking fiber probe may better identify tissue layers. With the OCT probe in the epidural space, a whole circular image within the epidural channel was gotten in post-processing. The technological development of increasing imaging depth from 2 mm to 7 mm increased the use of OCT even more. Ding et al. used a polarization-sensitive OCT device to differentiate tissue characteristics in real time in 2016 [22]. Nonetheless, unlike Kuo et al study their experiment used an examined pig spine specimen in which the distinct tissue layers were first identified and separated, and the OCT image was obtained outside. More in-needle imaging is required before polarization-sensitive OCT may be used to provide needle advise. The fiber-in-needle systems allow for single-person operation and can detect intravascular and intrathecal entrance, although unskilled visitors may find the images difficult to interpret. Quantitative imaging criteria are necessary for a more accurate classification of tissue types.

Epidural stimulation test

Tsui et al. pioneered the use of nerve stimulation to determine the appropriate positioning of an epidural catheter tip [23,24]. The epidural stimulation test involves inserting a saline column in the epidural catheter to stimulate nerves running through the EDS. An electric motor or sensory response to a 1-10 mA stimulation shows that the catheter tip is located in the epidural space. Sensitivity in literary works ranges from 80% to 100% [25]. EST can also be used to detect accidental subarachnoid, subdural, or intravascular epidural catheter positioning [25,26]. Bilateral stimulation with a 1 mA increase has been linked to subarachnoid position, subdural space, or is seen if the catheter is adjacent to a nerve root. This can also be used to calculate the vertebral position of the epidural catheter tip [27]. This is especially useful in determining the extent of cephalad migration in a caudally threaded epidural catheter in infants. The epidural stimulation test has been criticized for being difficult and time-consuming to perform in a perioperative context [28]. Electric stimulation is rendered useless if local anesthetics are administered through the epidural catheter or the patient receives neuromuscular obstructive drugs. Furthermore, the test cannot be used in people who already have neuromuscular disease. Despite its advantage for caudal epidural positioning in newborns, EST has not been extensively adopted due to these limitations.

Electrocardiography guided system

Tsui et al. described electrocardiograph (EKG) directed epidural catheter positioning in 2002 for determining the dermatomal location of the epidural catheter tip [29]. This method employs a specially built epidural catheter, with its pointer serving as one of the EKG leads. Concurrently, an EKG with an extra surface electrode implanted at the desired dermatomal level is shown. When the catheter's tip reaches the esired segment, the EKG tracings will be equal. Tsui et al. [29] effectively positioned caudally threaded epidural catheters at the specified spinal degree in 20 children in their exploratory investigation. Unlike EST, this approach can also be used after neuromuscular blockade management or after infusing local anesthetic through the epidural catheter. Nonetheless, it has only found utility in the pediatric population and necessitates the use of specialized instruments. Although this approach reveals the vertebral level of an epidural catheter tip, it does not prove the catheter's presence in EDS.

Epidurography

Following the injection of a comparison dye using the epidural catheter, fluoroscopy is performed. The fluoroscopic image clearly shows the catheter's precise position because to the dye's common epidural distribution. Despite being routinely used in chronic pain techniques, nonavailability of equipment and the associated radiation risk have prevented widespread use perioperatively. To alleviate these concerns, Uchino et al. performed epidurography with postoperative stomach or spine X-rays, which were taken as part of standard postoperative care [30]. Although this approach confirms the epidural position and level of the catheter, this information is only provided afterwards. Before controlling a badly working catheter, epidurography can be used to identify suitable epidural insertion postoperatively.

Epidural pressure waveform analysis

Transducing and displaying the EDS stress results in a unique and reproducible waveform that indicates heart rate and peripheral pulse pulses. These waves are thought to originate in the spine and travel through the dura to the EDS. Thus, the appearance of these pulsatile waveforms in synchrony with heart rate collected during transducing the epidural catheter would reveal the catheter's epidural position [28]. Ghia et al. discovered that visibility of a typical waveform was highly related with epidural placement of the catheter in patients with inadequate postoperative analgesia, as corroborated by CT cathetergram [31]. The ability of the epidural stress waveform to correctly assess catheter site has been documented in two earlier research investigations [32]. Because stress transducers are easily accessible in a perioperative setting, this is an eye-catching way for validating the epidural position of a catheter immediately after implantation or afterwards

Table 1. Advantages and disadvantages of epidural space identification techniques [32] .

Loss of resistance to air or saline and modification devices *Advantages* May be beneficial for beginners and can be used for demonstration purposes *Disadvantages* Additional equipment required Not proven to be superior to the loss of resistance technique performed by an experienced operatorDoes not compensate for the high false-positive rate
Visual confirmation using the epidural needle *Advantages* Real-time imaging of the ligamentum flavum, epidural space, and dura *Disadvantages* Poor penetration depth Data are difficult to interpret, and may require assistance of artificial intelligence No human studies performed to date
Confirmation of epidural catheter placement *Advantages* Can be done with existing equipment by simply linking a nerve stimulant or pressure transducer to the catheterCan be performed in babies or patients who cannot connect verbally *Disadvantages* Technically difficult to perform in the perioperative setting Confirmation after catheter placement in combination with loss of resistance technique

CONCLUSION:

An ideal method for detecting EDS should be simple to discover and implement, fast replicable with a high level of sensitivity and uniqueness, and easily detect unintentional intrathecal and intravascular catheter placements. Prior to implementing any new technology, it is also critical to assess the availability of sources, clinical feasibility, and cost-benefit benefit. Though none of the novel strategies have yet to replace traditional LOR, some have found value in specific contexts and hence may be complementary to LOR. When a patient with challenging anatomy is encountered, ultrasound is increasingly being used as a rescue strategy.

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