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TECHNIQUES AND APPROACHES TO EPIDURAL SPACE IDENTIFICATION - REVIEW

Thuraya Abdullah Hummadi, Ebtihaj Abdo Fqiry, Yussra Omar Solan

Abstract:

Anesthesiologists need to be knowledgeable about the benefits and negative aspects of these arising technologies, to examine which methods to adopt. Additionally, expertise concerning of these more recent technologies is essential to lead future research study in this avenue. The aim of this review is to summarize the arising technologies for identifying the EDS and their possible role in the future. We performed a search using electronic databases; MEDLINE, and EMBASE, throughout 2018. Search strategies used following MeSH terms in searching: "epidural space identification", "Epidural anesthesia", "technique", "assessment". An optimal approach to recognize EDS should be simple to discover and execute, quickly reproducible with high level of sensitivity and uniqueness, and determine unintended intrathecal and intravascular catheter placements effortlessly. It is also essential to consider the accessibility of sources, clinical feasibility, and cost-benefit benefit prior to taking on any kind of new technology. Though none of the newer techniques have currently replaced conventional LOR, some have found use in unique circumstances and hence could be complimentary to LOR. Ultrasound is progressively being used as a rescue technique when a patient with difficult anatomy is experienced.

Corresponding author:
Thuraya Abdullah Hummadi,

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INTRODUCTION:

Epidural anesthesia is a commonly made use of method for ache relief which works in various setups. Identification of needle entrance into the epidural space (EDS) is done most commonly utilizing a loss of resistance (LOR) technique, which was defined in 1921 by Sicard and Forestier, and has stayed mostly unchanged since [1].

Despite its popularity, epidural analgesia is associated with a substantial failing rate [2]. Ready records a 27% and 32% failing rate for lumbar and thoracic epidural, respectively in a heterogeneous cohort of 2114 surgical patients [3]. Failing was defined as need for replacement of the epidural catheter or addition of another major technique for ache control. In another cohort of 1286 patients, Kinsella reported that 24% of patients had insufficient anesthetic when utilizing a previously put labor epidural for cesarean area [4]. Failure of epidural analgesia can occur as a result of numerous reasons consisting of a lack of ability to lead the needle through the interspinous or interlaminar gap into the EDS, false-positive identification of entrance right into the EDS, trouble ahead of time the epidural catheter right into the EDS, and malposition or succeeding dislodgement of the epidural catheter [5], [6]. Apart from the failing of analgesia/anesthesia, epidural positioning is likewise related to problems such as postdural puncture headache, inadvertent subarachnoid, subdural, [9] or epidural venous positioning, and epidural hematoma [7]. Postdural puncture headache following inadvertent dural puncture, during labor epidural positioning, is related to a much longer hospital keep and emergency clinic visits complying with discharge [8].

Throughout the last decade, newer methods for situating and confirming access into the EDS have been explored to circumvent these failures and complications. Anesthesiologists need to be knowledgeable about the benefits and negative aspects of these arising technologies, to examine which methods to adopt. Additionally, expertise concerning of these more recent technologies is essential to lead future research study in this avenue. The aim of this review is to summarize the arising technologies for identifying the EDS and their possible role in the future.

METHODOLOGY:

We performed a search using electronic databases; MEDLINE, and EMBASE, throughout 2018. Search strategies used following MeSH terms in searching: “epidural space identification”, “Epidural anesthesia”, “technique”, “assessment”. Then we also searched the bibliographies of included studies for further relevant references to our review. Studies had to be relevant to our criteria which should be review, systematic reviews, or clinical studies restriction to only English language published articles with human subject were applied in our search strategies

DISCUSSION:

- **Loss of resistance technique**

This was first explained in early 20th century and is the most commonly utilized method till present by lots of anesthesiologists. Sicard and Forestier utilized fluid as a medium for this method in 1921. Dogliotti described the principle behind it and promoted the method [9]. The advantages of this strategy are that it is very easy to find out, budget-friendly, and not cumbersome with high level of sensitivity and specificity. Individuals who have experience in valuing 'give way' feel can adopt this method. It is not a great method for the newbies. Both air and fluid can be used as a medium for this method however up-to-date the debate is going on regarding which medium transcends. Air comes to be the preferred medium with some reasons. First is historical, as up until the seventies, syringes were made from glass and were non-disposable. Fluid made the syringes sticky for this reason air changed it by preventing it. Drawbacks of using air are possibility of causing pneumocephalus, headache, cervical emphysema, patchy block, and air embolism [10]. All these problems are encountered when the amount of air exceeds the typical limits. It is important to keep in mind that, air should not be made use of as a medium after an accidental dural puncture [11]. Air is a compressible medium and high pressure cannot be accomplished when compared to no compressible matter like fluid. With the accessibility of plastic syringes fluid acquired popularity as a medium as it removed most of the problems of air as a medium. The main downsides with the use of saline are dilution of local anaesthetic agent influencing sensory blockade, and complication with cerebrospinal fluid if unintentional dural puncture occurs. Making use of more than 10 ml of normal saline in epidural room does secure venous cannulation however at the expenditure of feasible problems of the quality of analgesia. Making use of 5 ml of regular saline is related to a lower occurrence of intravascular catheter insertion and less unblocked sectors [12]. Straightforward bedside testing for temperature, glucose, protein and pH precisely distinguished between CSF and saline made use of to identify the epidural space [13]. Saline as a medium has advantages if we choose it

specifically in a parturient patient [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].

- **Hanging drop technique**

The principle in this method is based on the reality that the pressure in the epidural space is sub atmospheric. For this reason, once loss of resistance is really felt a decline of saline is placed at the hub of the syringe. Benefit is that only a drop of saline is made use of and as a result has no result on the quality of analgesia. In this strategy the epidural needle is gripped by the thumb and index finger of both hands, with the ulnar border of the hands resting on the patient's back, enabling stability and control as the needle is progressed slowly through the ligamentum flavum [15]. Due to more negative pressure in thoracic region this is the favored strategy than for the lumbar region. Still this strategy is rarely used. At the lumbar level the loss of resistance method reduces the threat of destructive dura mater compared with the hanging decrease strategy [16].

Saline infusion technique

As there is adverse pressure in the epidural space the saline from the infusion set gets in the epidural space. Baraka A reported this method [17]. The primary benefits of this method are that the needle can be grasped by both the hands and likewise directed according to the demands. It is very easy to find out especially for novices, has a high success rate, is budget-friendly, objective approach as contrasted to loss of resistance technique which is subjective. Quantity of saline going into will certainly be very little if micro infusion set is utilized thus does not impact the top quality of analgesia. Saline which enters the space makes threading the catheter really easy, and little needles can be utilized. Disadvantages may include accidental dural puncture, and complication with cerebrospinal fluid in such situations. Such downsides are marginal as both hands are used to direct the needle and manages the depth of entrance for this reason chances of dural puncture will certainly be marginal. There are chances of accidental entrance of needle right into epidural venous channels. This technique can be better utilized for thoracic epidurals, and also for the lumbar epidurals especially for the beginners.

- **Visual confirmation using the epidural needle**

The epidural needle passes through a number of tissue layers, including the skin, subcutaneous fat, supraspinous and interspinous ligaments, and the ligamentum flavum, prior to getting to the epidural space. Traditional "blind" attempts can cause failing of epidural placement and serious complications, consisting of outer nerve damages and dural puncture. Numerous techniques have been proposed to assist needle examination and have actually yielded promising results.

Optical spectroscopy

Optical spectroscopy is a measurement of tissue optical absorption using noticeable and near-infrared light that can differentiate tissues. The reasoning for this technique is based upon various tissues having different hemoglobin, lipid, and water content. Desjardins et al integrated spectroscopy fibers into the epidural needle and made use of light in the 500- 1000 nm array to get tissue ranges in a swine cadaver version [18]. The photo depth was roughly 1.2 mm for event light at 500 nm. Ting et al individually developed a comparable technique in 2010 using 532 nm and 650 nm light representation in an in vivo swine design that showed reflective optical qualities in the ligamentum flavum and epidural space [19]. Optical fibers was placed into the epidural needle and attached to a fiber optic spectrometer. This approach has been reported to have a sensitivity of 80%- 85% and a 95% success rate [20]. A portable design with a security system was created for convenience of use [20]. Interpretation of information can be difficult for those not familiar with the display, so Lin et al created an algorithm utilizing artificial intelligence that might analyze inbound measurable information from the optical fibers and classify them as most likely representing the ligamentum flavum or epidural space, or as indeterminate [21]. A success rate of 97.9% could be achieved using this technique [21]. Even more, Rathmell et al reported that use broadband optical reflectance ranges (500- 1600 nm) to determine the blood and lipid fraction boosted the precision of the technique [22].

Spectroscopy can additionally differentiate in between intravascular and subarachnoid positioning of the catheter [22]. However, contamination of the needle by blood or myoglobin in muscular tissue can disrupt the signal, which lowers the uniqueness of this approach. This issue may relapse by utilizing Raman spectroscopy, which has much better predictive accuracy for recognizing tissues and separating them from the epidural space [21]. Further, the Raman spectrum for each and every tissue was found to be

one-of-a-kind and could be determined based upon the relative amounts of albumin, actin, collagen, triolein, and phosphatidylcholine, and was not influenced by tissue thickness. However, the use of Raman spectroscopy in vivo requires to be discovered even more.

So far, spectroscopy has actually been the most exact and learnable method for determining the epidural space. Nonetheless, no research in humans has been reported.

Ultrasound

Ultrasound can be made use of in two means. Provided its excellent penetration deepness, surface ultrasound can be carried out with either a linear probe in lean patients or a curved probe in obese patients. Ultrasound offers important and trustworthy info concerning the bordering frameworks. Both the vertebral space and the dura can be recognized. Needle advice can be carried out in real-time as a two-person strategy with a high success rate. Nonetheless, placement of the epidural catheter cannot be envisioned, and a one-person technique might be difficult.

Chiang et al incorporated a 40 MHz ultrasound transducer fiber (− 6 dB fractional bandwidth 50%) right into an 18-gauge needle to obtain an A-mode image display screen. The amplitude of the ultrasound signal was displayed on the y axis and the moment required for ultrasound return was displayed on the x axis [23]. The axial resolution was 0.15 mm and the penetration were 10 mm. By showing the A-mode scan on a two-dimensional depth-reconstructed scan image, the ligamentum flavum, epidural space, and access of the needle could be visualized [24]. The ligmentum flavum was recognized on 83.3% of insertions and the dura matter on 100% of insertions. Ameri et al even more suggested that the efficacy of this technique could be improved by including A-mode imaging with two-dimensional B-mode imaging, which shows the brightness of the ultrasound signal [24]. A 2 centimeters deepness could be achieved by the B-mode needle probe, which boosted the accuracy and safety of epidural catheter positioning in animal models. Nonetheless, human researches are doing not have. Various other picking up methods, such as pulse-echo ultrasound, are being discovered.

Optical coherence tomography

Optical coherence tomography (OCT) is an optical imaging modality comparable in physical concept to ultrasound other than that it makes use of infrared light. Using OCT, it is feasible to obtain high-resolution, cross-sectional, subsurface tomographic images of tissue microstructure. Tang et al established a small-diameter (0.5 mm) onward imaging OCT system together with high-contrast Doppler flow imaging in real time [25]. The regularity domain OCT system utilizes a wavelength-swept laser that is focused at 1310 nm with a bandwidth of 100 nm. Both the side and axial resolutions are around 13 μm. This system can envision arteries, blood vessels, and differential structures layer by layer [25].

Kuo et al also defined an in-needle swept-source OCT system with high level of sensitivity and high uniqueness [26]. A two-dimensional OCT image was gotten by circumferential scanning utilizing an optical probe placed in an epidural needle with a rotational motor, which shows real-time side view images as the needle progresses right into the epidural space. The axial resolution has to do with 15 μm in tissue and the imaging depth is around 2 mm. Rather than onward imaging, they proposed that a side-looking fiber probe might much better distinguish the 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 advancement of boosting the imaging depth from 2 mm to 7 mm enhanced use of OCT further. In 2016, Ding et al used a polarization-sensitive OCT system to distinguish tissue qualities in real time [27]. Nonetheless, unlike the research by Kuo et al, their experiment was carried out making use of an explored pig spine specimen in which the different tissue layers were recognized and separated initially, and the OCT image was obtained in outdoors. Further in-needle imaging is needed before polarization-sensitive OCT can be obtained needle advice. The fiber-in-needle devices permit single-person operation and can recognize intravascular and intrathecal entry, however inexperienced visitors might locate the images difficult to translate. Quantitative imaging criteria are required for much better category of tissue types.

- **Confirmation of catheter location in epidural space**

Even with exact localization of EDS, there is no guarantee that the catheter threaded through that needle would certainly continue to be in the EDS. Second failure rates as high as 7% have actually been reported in literature [28]. Failing could result from migration of the epidural catheter out through an intervertebral foramen or from the catheter being taken out of the EDS [28].

The setting of the epidural catheter tip is a vital consider figuring out whether satisfying epidural analgesia will certainly be accomplished. An epidural catheter has been revealed to move from its preliminary position with patient movement [28]. The complying with area defines different strategies for recognizing location of the epidural catheter tip throughout epidural positioning or subsequently to check out the additional failure.

Epidural stimulation test

Tsui et al. very first defined the use of nerve stimulation to identify the proper setting of epidural catheter tip [29]. The epidural stimulation test involves electric stimulation of nerves passing through the EDS using a saline column in the epidural catheter. Electric motor or sensory response to a stimulation of 1-10 mA suggests epidural location of the catheter tip. Reported sensitivity in literary works arrays from 80% to 100% [30]. EST can also be useful in discovering unintentional subarachnoid, subdural, or intravascular positioning of the epidural catheter [29], [30]. Bilateral excitement with boosting existing <1 mA has actually related to subarachnoid position, subdural space, or is seen if the catheter is in close proximity to a nerve root. This can also be made use of to approximate the vertebral location of epidural catheter tip [32]. This is specifically handy in figuring out the extent of cephalad migration in a caudally threaded epidural catheter in babies [32]. Epidural stimulation test has been criticized for being practically difficult and cumbersome to carry out in a perioperative setting [33]. Electric stimulation is ineffective once local anesthetics are provided via the epidural catheter or after the patient obtains neuromuscular obstructing agents. Additionally, the test cannot be relied upon in patients with preexisting neuromuscular illness. Even with its advantage for caudal epidural positioning in babies, EST has actually not been adopted widely as a result of these drawbacks.

Electrocardiography guided system

Electrocardiograph (EKG) directed positioning of epidural catheter was first described by Tsui et al. in 2002 for figuring out the dermatomal location of the epidural catheter tip [34]. This technique uses a specifically designed epidural catheter, which enables its pointer to be one of the EKG leads. In addition, EKG with an additional surface electrode placed at the wanted dermatomal level is presented concurrently. Once the tip of the catheter gets to the preferred segment, both the EKG tracings would equal. In their preliminary study, Tsui et al. successfully positioned caudally threaded epidural catheters at the targeted spinal degree, in 20 children. Unlike EST, this method can additionally be utilized after management of neuromuscular blockade or after injecting local anesthetic through the epidural catheter. Nonetheless, it has just located use in pediatric populace and calls for unique devices. Though this strategy discloses the vertebral level of an epidural catheter tip, it does not confirm the existence of the catheter in EDS.

Epidurography

Epidurography entails fluoroscopy after injection of comparison dye with the epidural catheter. Precise location of the catheter is shown by common epidural spread of the dye as seen in the fluoroscopic image. Though routinely utilized in chronic pain technique, nonavailability of devices and included radiation threat have avoided regular use perioperatively. To circumvent these worries, Uchino et al. done epidurography concurrently with postoperative abdominal or spine X-rays, which were obtained as part of routine postoperative care [35]. Though this technique verifies epidural location and level of the catheter, this information would just be offered postoperatively. Epidurography can work as a tool to identify appropriate epidural placement postoperatively, prior to controling an improperly working catheter.

Epidural pressure waveform analysis

Transducing and plotting the stress determined in the EDS produces a unique and reproducible waveform, which reflects heart rate and peripheral pulse waves. These waveforms are believed to be originating from the spine and are transferred with the dura to the EDS. Thus, the visibility of these pulsatile waveforms in synchrony with heart rate, acquired on transducing the epidural catheter, would indicate epidural location of the catheter [32]. Among patients with poor postoperative analgesia, Ghia et al. located that visibility of a typical waveform highly associated with epidural place of the catheter, as validated by CT cathetergram [36]. Ability of epidural stress waveform to properly determine catheter location has actually been reported in two various other research studies [36]. Easy accessibility of stress transducers, in perioperative setup, makes this an eye-catching technique to validate epidural location of a catheter instantly after placement or later.

Near-infrared tracking system

The near-infrared tracking system contains a fiberoptic wire, positioned in an epidural catheter, which produces infrared signal allowing its visualization with

an infrared camera. Chiu et al. utilized an infrared light producing guidewire to facilitate threading of an epidural catheter to a preferred vertebral degree, in cadavers [28]. The possible advantage is the capability to assist placement of epidural catheters distantly from the needle tip, to the preferred dermatomal level. Nevertheless, the signal was diminished in overweight patients, and when the catheter passed under-lamina or diverged from midline. Its role in validating epidural setting of a catheter is also unsure.

Ultrasound

Certain investigators have utilized ultrasonography to precisely locate epidural catheter placement within the EDS, particularly among infants. Willschke et al. utilized ultrasonography to locate the placement of the catheter tip by recognizing the movement of dura, from growth of EDS, throughout local anesthetic injection via the epidural catheter [37]. On the other hand, Ueda et al. assessed the images of EDS gotten utilizing a transesophageal echocardiography probe to lead a caudally inserted epidural catheter to a desired thoracic vertebral level [38].

The use of these techniques in grownups has not been reported but would likely be hindered by poor image high quality from ossified vertebrae. However, the authors recommend that the transesophageal echocardiography probe may be able to obtain pictures via the intervertebral rooms, and hence prevent vertebral shadowing. However, its energy is limited to patients calling for intraoperative echocardiography such as for cardiac surgical procedures.

Table 1. Advantages and disadvantages of epidural space identification techniques [10-38] .

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 operator Does 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 catheter Can 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 optimal approach to recognize EDS should be simple to discover and execute, quickly reproducible with high level of sensitivity and uniqueness, and determine unintended intrathecal and intravascular catheter placements effortlessly. It is also essential to consider the accessibility of sources, clinical feasibility, and cost-benefit benefit prior to taking on any kind of new technology. Though none of the newer techniques have currently replaced conventional LOR, some have found use in unique circumstances and hence could be complimentary to LOR. Ultrasound is progressively being used as a rescue technique when a patient with difficult anatomy is experienced. Others such as EST and EKG led strategies are made use of in specific institutions to guide a caudally threaded epidural catheter in infants. However, numerous of these technologies need further characterization of security account and evidence of a favorable cost-benefit profile. Demonstration of a reduced complication rate would require larger researches, particularly since traditional strategy itself is associated with a reduced issue rate. As numerous of these technologies are in onset of development, it is difficult to have an exact understanding right into its potential. With newer developments in innovation and advancement, several of these strategies might ultimately verify to be superior to conventional approaches and therefore reduce the failure rate connected with epidural placements.

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