Automated Method for Confirming Epidural Catheter Location

Authors: Zachary D. Walton, M.D., Ph.D.; Ferne R. Braveman, M.D.; Denis Snegovskikh, M.D.
Department of Anesthesiology, Yale-New Haven Hospital, New Haven, CT 06510

Introduction: Inadequate epidural analgesia or anesthesia among parturients has been reported to be as high as 17%, with the most common reason for failure being improper location of the catheter tip [1]. Malposition of the catheter increases the risk of serious complications. These complications can include a high spinal with intrathecal placement and local anesthetic toxicity with intravascular placement. There is currently no convenient and reliable method of confirming proper position of the tip of the epidural catheter.

As a first step in improving safety and efficacy of epidural analgesia/anesthesia, we have developed a new method for detecting migration of the epidural catheter, from the epidural space, into the subcutaneous tissue. Our method is based on a technique known as epidural pressure waveform analysis (EPWA). With this technique, a transducer is connected to the hub of the epidural catheter. A pulsatile pressure wave synchronous with the cardiac pulse suggests that the catheter is in the epidural space; lack of pulsatility suggests that the catheter is in not in the epidural space [2,3,4]. The epidural pressure wave measured through the catheter is low amplitude (1-5 mmHg). Distinguishing pulsatility from noise is difficult, leading to limitations in sensitivity and specificity (sensitivities in the above citations range between 55.6% and 88.9%). Previous investigators have only used human judgment to decide if a pressure waveform is pulsatile or not. Here we report the results of our effort to use digital signal processing to automate the EPWA technique.

Methods: We collected waveforms on 20 obstetric patients who all had successful epidural analgesia/anesthesia. At the time of epidural catheter removal, we connected a standard disposable transducer to the epidural catheter and made a digital recording of the pressure wave as the catheter was removed. The catheter was withdrawn incrementally, approximately 1 cm every 30 seconds. Later on, we analyzed the digital pressure waveform by first attempting to visually identify the transition between pulsatility (catheter tip in the epidural space) and no pulsatility (catheter tip in the subcutaneous tissue). We applied a digital signal processing algorithm which was designed to automatically detect this loss of pulsatility. The algorithm works by analyzing a moving 30-second window of data. For each 30-second window, the algorithm uses time domain analysis to extract a single number (i.e., the Epidural Pulsatility Index [EPI]), which is low for a pulsatile signal (the pressure waveform in the epidural space) and high for a signal with nonpulsatile noise (the pressure waveform in the subcutaneous tissue). By plotting EPI versus time, we attempt to identify the moment the epidural catheter leaves the epidural space by associating it with a transition between low EPI and high EPI.

Results: Upon visual inspection, 14 of the 20 waveforms showed a clear transition between pulsatility and no pulsatility. An example of this transition is shown in Fig. 1. Figure 2 shows the EPI versus time for the 14 waveforms that were found to have the clear transition in pulsatility by visual inspection.

Conclusions: Our algorithm for automated confirmation of epidural catheter location worked in the sense that for each waveform, with a visually identifiable transition between pulsatility and nonpulsatility, the EPI makes a clear transition across a threshold value (EPI=40), as seen in Figure 2. It is interesting to speculate why only 14 of the 20 waveforms showed pulsatility, given that all of the catheters were successfully used for epidural analgesia/anesthesia. One possibility is that the catheters were dislodged between the time of delivery and catheter removal (which sometimes occurred the following day). We hypothesize that by modifying the design of our algorithm based on a large library of waveforms and associated clinical outcomes (i.e., failure/success of the epidural), this automated technique will be able to achieve higher sensitivity and specificity than simple human judgment.

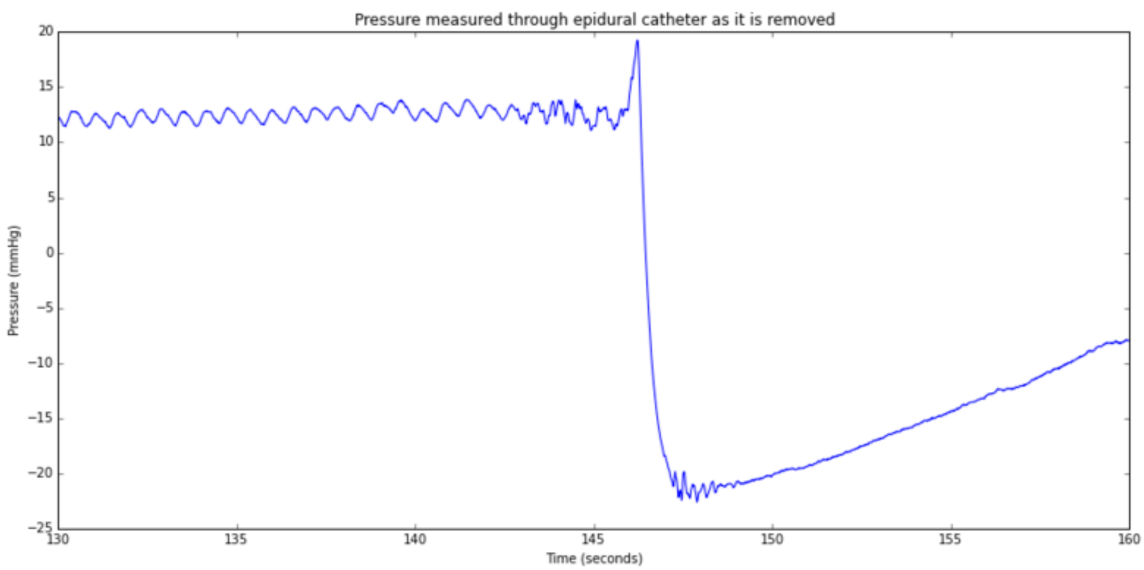

Figure 1. Pressure wave measured through the epidural catheter as it is removed.

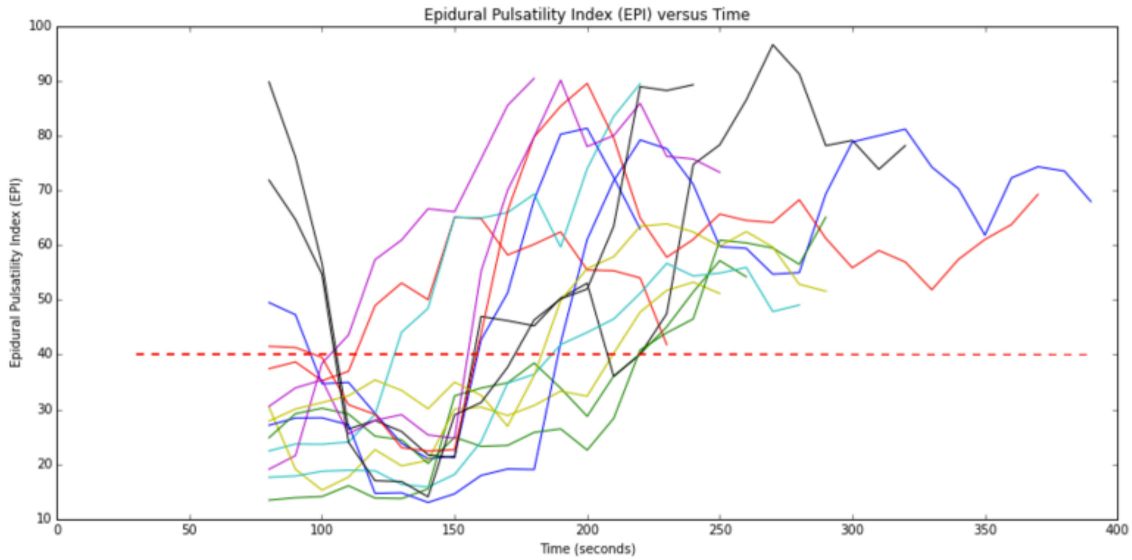

Figure 2: Epidural Pulsatility Index (EPI) for 14 epidural catheters as they are removed. EPI=40 is a threshold that provides reasonable discrimination between low EPI (epidural space) and high EPI (subcutaneous space).

References:

[1] Crosby, Edward T. "Epidural catheter migration during labour: an hypothesis for inadequate analgesia." *Canadian Journal of Anaesthesia* 37.7 (1990): 789-793.

[2] Ghia, J. N., et al. "Confirmation of location of epidural catheters by epidural pressure waveform and computed tomography cathetergram." *Regional anesthesia and pain medicine* 26.4 (2001): 337-341.

[3] De Medicis, Etienne, et al. "A prospective comparative study of two indirect methods for confirming the localization of an epidural catheter for postoperative analgesia." *Anesthesia & Analgesia* 101.6 (2005): 1830-1833.

[4] Lennox, Pamela H., et al. "A pulsatile pressure waveform is a sensitive marker for confirming the location of the thoracic epidural space." *Journal of cardiothoracic and vascular anesthesia* 20.5 (2006): 659-663.