A Patient-Centered Data-Driven Analysis of Epidural Anesthesia

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INTRODUCTION

According to the 2019 Center for Diseases Control and Prevention birth statistics, of the 3.75 million newborns delivered in the United States, about 31.7% were delivered by Cesarean section (C-section).

Epidural anesthesia provides regional anesthesia for C-section. This local anesthetic is injected into an area of the lower back just outside the spinal-fluid sac. It takes about 15 to 20 minutes to work, and the anesthesiologist can leave the catheter in place to allow for top-offs.

The potential consequences of failed or misplaced epidural needles are well known to obstetric anesthesiologists. A well-documented epidural complication, a "wet tap," results in a headache and possible total spinal anesthesia/block, requiring immediate maintenance of the patient's airway and blood pressure. The inadvertent intravenous injection of local anesthetic into a vein in the epidural space leads to seizures and fatal cardiac arrhythmias. Equally worrisome is the inadequate epidural block leading to complications during a C-section. These complications include an emergency general anesthetic, resulting in airway loss, hypoxemia, hypercarbia and death (Cheng et al. 2015; Dunham et al, 2014; Liu et al., 2015). However, to date, limited research has been performed regarding standardization of the epidural analgesia procedure to avoid practice variance and ensure minimal complications.

In this chapter, we report on an in-depth study of epidural process to capture practice variance and quantify the time and dose required to achieve the desired sensory level. Using a data-driven and machine learning approach, we establish a safe and quickly effective epidural dose that can be administered through the epidural needle prior to the insertion of the epidural catheter. Based on clinical results, we quantify complications for a dose as large as 20 ml that is injected through the epidural needle. We contrast the proficiency of physician practice and provide insights on their preference in medication (including use of opioid-type drug) and dosage. Understanding the causes and effects of such variation can help providers avoid practices that negatively impact outcomes. The machine learning analysis reveals practice characteristics that result in the best outcome with the fewest complications. Our findings facilitate the establishment of improved clinical practice guidelines (CPG) for care outcome and delivery improvement.

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BACKGROUND

Traditionally, the epidural catheter is placed, aspirated, and a test dose of medication is given to detect the possibility of an intravascular (IV) or intrathecal (IT) catheter prior to administering additional doses of local anesthetic and opioids. More rapid injection is often possible through the epidural needle given the relatively larger gauge and shorter length compared to a catheter (Omote et al., 1992), which could potentially enhance the spread of medication within the epidural space. However, there have been very few studies in which anesthesia providers have initiated labor analgesia by injecting medications through the epidural needle immediately after loss of resistance to achieve faster onset of pain relief (Gambling et al., 2013). The rationale for potentially improved analgesia onset with epidural needle injection is uncertain. In addition to faster onset of analgesia, it has been reported that dosing through the epidural needle may result in improved quality of epidural anesthesia compared to dosing through the catheter (Cesur et al., 2005). However, other investigations in obstetric (Husain et al., 1997) and non-obstetric (Yun et al., 2004) patients receiving epidural anesthesia have observed a similar onset and quality of surgical anesthesia as well as a similar level of sensory blockade when dosing through the needle versus the catheter. In a small double-blind prospective investigation (n=60), Raster et al. 2017 directly compared needle and catheter injection of epidural medications for the initiation of labor analgesia. Their results showed that epidural needle and catheter injection of medications result in similar onset of analgesia and sensory blockade, quality of labor analgesia, patient satisfaction, and complication rates. To date little is known regarding practice and patient outcome related to large doses of local anesthetic injected through the epidural needle.

MATERIALS AND METHODS

The study design involves five major steps: 1) Develop process maps of patient and epidural service workflow via objective process observations and structured interviews. 2) Perform time-motion studies of epidural processes, record complications and practice variance, and analyze hospital data. 3) Perform statistical analysis of collected data, conduct system analysis on practice variance, and quantify effective dose-sensory level achievement, 4) Develop a machine-learning model to predict patient/outcome characteristics. 5) Develop a computerized simulation-optimization system to simulate current performance, optimize systems, and estimate anticipated global improvement. 6) Report findings and establish practice guideline recommendations for improved quality of care.

Epidural Workflow and Services

Figure 1 summarizes the observed epidural process performed by anesthesiologists. The green denotes the observed practice variance. Anesthesiologists choose one of three basic techniques of loss of resistance (or a combination thereof) to identify the proper epidural space: air, saline, or local anesthetic. Medication dosages vary by provider, with most injecting as much as 20 ml through the epidural needle prior to inserting the epidural catheter.