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Preprocedural Ultrasound for Labor Neuraxial Anesthesia: Evidence-Based Practice Recommendations

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Preprocedural Ultrasound for Labor Neuraxial Anesthesia: Evidence-Based Practice Recommendations

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Abstract

Central neuraxial blockade (CNB) is the most widely used method of anesthesia provided to laboring patients and includes epidural, spinal, combined spinal-epidural, and caudal techniques. Studies have shown that using preprocedural ultrasound is a safe and effective tool to facilitate the placement of neuraxial needles, especially in patients with predicted difficulty. With the prevalence of obesity increasing, laboring patients with predicted difficulty of neuraxial needle placement is increasing as well. In addition, the traditional method of palpation and visualization of anatomical landmarks to place neuraxial needles can produce inaccurate results due to inconsistencies between patients. Use of preprocedural ultrasound to facilitate neuraxial anesthesia is low despite evidence found in the literature describing its benefits. The project's main objective is the development and implementation of evidence-based practice (EBP) recommendations for using preprocedural ultrasound to facilitate neuraxial anesthetics provided to laboring patients. If implemented, the project has the potential to increase first-pass success rates of needle placement and decrease adverse events such as unintentional dural puncture, post dural puncture headache, and failed neuraxial block. Additional objectives for the project include developing EBP recommendations for using preprocedural ultrasound when providing neuraxial anesthesia to the laboring patient, a comprehensive plan to implement the EBP recommendations, and a method to monitor and measure the EBP recommendations. The theoretical framework for this project is the John Hopkins Evidence-Based Practice Model (JHEBP) for Nursing and Healthcare Professionals.

Keywords: Preprocedural, ultrasound, neuraxial, labor, anesthesia

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Introduction

Central neuraxial blockade (CNB) is a form of regional anesthesia that includes spinal, epidural, combined spinal-epidural (CSE), and caudal epidural techniques. Neuraxial anesthesia is the most widely used method of anesthesia administered to obstetric patients in labor (Santos et al., 2015). The Centers for Disease Control and Prevention (2022) reports that in 2020, more than 77% of births in the United States (USA) utilized epidural or spinal anesthesia during labor. With this high rate of utilization, it is imperative that techniques for CNB are based on evidence and continuously refined. Due to the vulnerability of this patient population, anesthesia techniques provided to laboring patients should continuously be evaluated and improved (Nagelhout & Elisha, 2018). The development of EBP recommendations is essential to improve labor neuraxial anesthesia.

Techniques for assessing for placement of CNB can vary. Traditionally, an anesthesia provider performs palpation of the anatomy and visualization of external surface landmarks to facilitate the placement of CNB needles (Baysinger et al., 2016; Nagelhout & Elisha, 2018). CNB can result in complications for many reasons, one of which is related to the “blind” nature of the traditional approach to needle placement (Carvalho, 2008). The relationship between anatomical landmarks, needle placement, and needle trajectory is inconsistent from patient to patient, making it a “blind” technique (Hadzic, 2017). Anatomical landmarks can sometimes be challenging to palpate and visualize in the parturient, primarily due to the natural physiological changes the body goes through during pregnancy, such as weight gain and presacral edema (Santos et al., 2015). According to Carvalho (2008):

> The somewhat unreliable nature of the [traditional] technique can lead to complications, such as patient discomfort, trauma to various structures (nerves, vessels, ligaments, and bones), [the] potential infectious risk from multiple [needle insertion] attempts, failure, and accidental dural puncture with subsequent postdural puncture headache. (p. 145)

Additionally, anesthetists who used the palpation method to identify a marked lumbar space identified them correctly in only 29% of the cases (Broadbent et al., 2000). Therefore, laboring patients receiving CNB through the traditional process of needle placement are at an increased risk of failures and complications, which warrants evidence-based improvements in the quality and safety of anesthesia providers' techniques to provide pain relief during labor and delivery.

Preprocedural ultrasound is another technique that can facilitate the placement of CNB needles. Ultrasound technology allows the anesthesia provider to assess the anatomy to provide important information such as the "needle insertion site, needle angle, and estimated depth of the epidural space" that is otherwise unavailable using the traditional method (Chestnut et al., 2020, p. 255). Ultrasound can also be used in real time to facilitate CNB placement, but this project will focus on preprocedural ultrasound. The benefits of ultrasound to guide needle placement for neuraxial anesthesia include being safe, noninvasive, simple to use, devoid of significant adverse effects, and helpful, especially for patients who are difficult to assess using the traditional approach (Hadzic, 2017). Not utilizing preprocedural ultrasound as a technique for CNB procedures may lead to the inefficient placement of neuraxial needles, leading to increased patient complications. Thus, a plan for implementing preprocedural ultrasound for neuraxial

anesthesia recommendations is needed, including the steps of EBP and quality improvement (QI).

Background

Obstetrical Neuraxial Anesthesia

Most obstetrical patients experiencing labor pain in the USA seek relief through anesthesia services. The latest National Vital Statistics Report (2022) shows that out of 3,613,647 births in the USA in 2020, 2,787,858 or more than 77% of the births involved epidural or spinal anesthesia as a method of analgesia during labor (Centers for Disease Control and Prevention, 2022). Neuraxial anesthesia in obstetrics is an intervention that allows parturients to not only receive analgesia for what otherwise would be a painful experience but also allows the mother to immediately interact with the baby after birth in cases that involve cesarean section by avoiding general anesthesia (Nagelhout & Elisha, 2018). Continual improvement in neuraxial anesthesia methods is essential in providing a desirable birthing experience.

Depending on the situation and preference, anesthesia providers perform an epidural, spinal, combined-spinal epidural (CSE), or caudal technique to provide analgesia to laboring mothers. The caudal method is unpopular due to the potential for "painful needle placement, high failure rate, potential contamination at the injection site, and risks of accidental fetal injection" (Choi et al., 2018, para. 45). Whether using preprocedural ultrasound or the traditional method for neuraxial anesthesia needle placement, spinal, epidural, and combined spinal-epidural techniques require the anesthesia provider to understand spinal anatomy to place an epidural catheter or spinal anesthesia successfully.

Epidural. For controlling labor pain, epidurals are the most common form of neuraxial anesthesia (Lee et al., 2008). The intervention of placing an epidural catheter allows for

continuous delivery of local anesthetic to provide analgesia or anesthesia, depending on the obstetrical patients' circumstances. The placement of epidural catheters occurs through a needle that enters the epidural space. To access the epidural space, the anesthesia provider must guide the needle through the skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, and ligamentum flavum. Anterior to the ligamentum flavum lies a potential epidural space just before the spinal cord's dural layer. A commonly used method to find the depth of the epidural space is the loss of resistance (LOR) technique (Chestnut et al., 2019). Once the anesthesia provider places the Tuohy needle into the fibrous ligamentum flavum, a syringe filled with air or saline is counter pulsed on while the needle is advanced slowly. The epidural space is accessed when counter pulsation of the syringe allows for injection of its contents. After confirming that there is no flow of cerebrospinal fluid (CSF), an epidural catheter can be threaded into the epidural space to administer anesthesia. The epidural catheter provides a means for the anesthesia provider to continually dose medication that delivers labor analgesia.

Spinal. Obstetrical patients undergoing a cesarean delivery commonly receive spinal anesthesia (Turkstra et al., 2017). Medications injected for a spinal technique have a quick onset and are placed on the nerves exiting the spinal cord (DeLeon & Wong, 2022). The onset of action is faster due to a spinal technique's closer proximity to the spinal nerves compared to an epidural. The use of spinal catheters is not common; instead, a single dose of medication is given to achieve anesthesia (DeLeon & Wong, 2022). To perform a spinal, the anesthesia provider may transverse the same layers required for an epidural with a smaller spinal needle but advance further through the dura mater and into the subarachnoid space where there is CSF. A single shot of anesthetic medication is injected into this space to provide neuraxial anesthesia. Prevention of spinal cord injury is imperative and achieved by placing spinal needles below the conus

medullaris (the tapered end of the spinal cord) around the area of the cauda equina (a bundle of spinal nerves and roots) (Chestnut et al., 2019). In adults, the L1 or L2 interspace correlates with the location of the conus medullaris (Broadbent et al., 2000). Thus, spinal anesthesia is performed below this interspace to prevent spinal cord injury.

Combined Spinal-Epidural. CSE technique allows the anesthesia provider to inject medication for rapid analgesia into the intrathecal space for a spinal and then place an epidural catheter into the epidural space for continuous infusion of analgesic medications to take advantage of both benefits offered by spinal and epidural techniques (Ranasinghe et al., 2018). This technique involves advancing a Tuohy needle into the ligamentum flavum. Next, the needle is advanced into the epidural space using the LOR technique. Afterward, the anesthesia provider extends a spinal needle through the Tuohy needle until CSF flows from the intrathecal space. The spinal needle allows the provider to inject preservative-free local anesthetic and opioids into the intrathecal space. The anesthesia provider removes the spinal needle while leaving the Tuohy needle in place, allowing the provider to thread an epidural catheter in the epidural space (Kenevan et al., 2018). Therefore, providing the patient with rapid spinal anesthesia and the ability for continuous epidural anesthesia.

Traditional Technique of Neuraxial Needle Placement

To provide neuraxial anesthesia with the traditional technique, anesthesia providers utilize visualization and palpation of anatomical landmarks to determine needle placement. The anatomical landmark of Tuffier's line aligns with the patient's iliac crests, which theoretically aligns with the L5 interspace of the spinal column in women (Sadeghi et al., 2021). The anesthesia provider uses visualization and palpation of the Tuffier's line, spinous processes, and vertebral interspaces to determine the needle insertion point (Carvalho, 2008). Patients with

obesity, spinal deformity, and pregnancy can make the anatomy challenging to visualize and palpate (Kenevan et al., 2018; Rana et al., 2020; Tawfik et al., 2015). In addition, once the anesthesia provider determines where the needle will go, ideally below the L3 interspace for obstetrical neuraxial anesthesia, the provider is essentially blind regarding information such as the necessary needle depth, angle of needle trajectory, and any underlying anatomical variations that present to achieve neuraxial anesthesia (Carvalho, 2008). Inaccuracies exist in determining the desired interspace for needle placement with the traditional method. One study found that when using the traditional approach, anesthesia providers identified the correct vertebral level for needle placement 29% of the time (Broadbent et al., 2000). Preprocedural ultrasound provides a method for a provider to circumvent the inaccuracies associated with the traditional method of neuraxial needle placement.

Preprocedural Ultrasound Technique of Neuraxial Needle Placement

The literature describes in depth the technique for using preprocedural ultrasound to determine the placement of neuraxial anesthesia needles. FPS of neuraxial needles "relies on having both an accurate insertion point and needle trajectory" (Chin et al., 2018, p. 472). A preprocedural ultrasound identifies lumbar anatomy and estimates "the ideal needle insertion point and depth to loss of resistance" (Spence et al., 2012, p. 225). Due to the depth of the lumbar structures, a low frequency (2-5 MHz) curved probe is necessary (Spence et al., 2012; Turkstra et al., 2017). It is essential to utilize ultrasound equipment that is suitable for neuraxial anesthesia.

Many approaches for using preprocedural ultrasound to facilitate neuraxial needle placement exist. Spence et al. (2012) used a longitudinal paramedian and a transverse plane ultrasound view to facilitate needle placement when using preprocedural ultrasound. The

following stepwise approach describes their technique in using preprocedural ultrasound to facilitate epidural catheter placement:

1. Identify the sacrum and articular processes of the spine using the longitudinal paramedian view by placing the probe 2 to 3 cm to the left or right of the midline and angled toward the center of the spine. The midline of the desired interspace can then be identified between the articular processes of the desired location (L3 to L5). Make a mark in the middle of the probe for two desired interspaces with a marker.
2. Turn the probe perpendicularly to the marked spaces for the transverse plane view. The image of the ligamentum flavum is viewed as a hypoechoic structure with an additional view of the spinal canal. Tilting the probe to attain the best image can provide information for the projected trajectory of the needle angle to enter the epidural space. Place another mark on the center of the topside of the probe.
3. Freeze the transverse plane view image. Use calipers on the ultrasound machine to gain an estimated depth from the skin to the posterior border of the ligamentum flavum that the needle will travel to achieve epidural catheter placement.
4. Draw a horizontal line from the mark created in step 1.
5. Draw a perpendicular line from the mark created in step 2. The intersection of these two lines is the indicated site for ideal needle insertion.

A study found a strong correlation between the estimated ultrasound depth of the epidural space and the actual depth (Canturk et al., 2019). The technique described is performed before creating a sterile field by placing a skin indentation at the intersected marker level before cleaning the patient (Turkstra et al., 2017). Thus, this process can be completed by an individual provider without compromising sterility.

One consideration for using preprocedural ultrasound in neuraxial anesthesia is equipment and cost (Sahin & Balaban, 2018). A concern for using preprocedural ultrasound is that it will take additional time to perform the procedure, which could cause issues in efficiency. An ultrasound machine dedicated to labor neuraxial anesthesia could mitigate some concern for efficiency issues. In their meta-analysis, Young et al. (2021) found that total procedural time for neuraxial anesthesia in obstetrics increased by one minute when preprocedural ultrasound was used compared to the traditional method. This amount of time is negligible. “Neuraxial ultrasound has few disadvantages, thus requiring only a marginal benefit to result in a favorable risk-benefit profile” (Chin et al., 2018, p. 472). Therefore, implementation of EBP recommendations pertaining to the use of preprocedural ultrasound for neuraxial labor anesthesia should be considered.

Significance of the Problem Related to Anesthesia

Anesthesia providers and healthcare systems should work to prevent patient complications that stemmed from interventions and provided procedures. During every interaction with a patient, the goal of the provider is to prevent complications and establish desirable outcomes. Neuraxial labor anesthesia creates the potential for procedural complications such as multiple needle puncture attempts, multiple needle redirections, and improperly placed needles and catheters (Hadzic, 2017). These complications can lead to adverse patient outcomes, such as inadequate anesthesia, post dural puncture headache (PDPH), infection, hematomas, and back pain (Chestnut et al., 2020). Additionally, the prevalence of obesity in pregnant patients continues to rise (CDC, 2020). This trend potentially leads to an increased number of patients with impalpable landmarks.

The traditional neuraxial needle placement method involves assessing anatomical landmarks for needle placement with palpation. Preprocedural ultrasound is a newer method to facilitate neuraxial anesthesia needle placement that is less utilized. Young et al. (2020) state, "Given the challenges and complications associated with the conduct of neuraxial blockade in obstetrics, the introduction of preprocedural ultrasound could provide additional information to facilitate the procedure" (p. 819). A study found that only 22% of obstetrical units use ultrasound for neuraxial anesthesia (Bhatia et al., 2016). Lack of utilization exists despite evidence that preprocedural ultrasound can increase first-pass success rates of needle placement compared to the traditional method (Jiang et al., 2020; Young et al., 2020). By increasing first-pass success rates of neuraxial needle placement, less trauma will occur to a patient's spinal anatomy thus potentially leading to fewer complications.

Preprocedural ultrasound is a tool that anesthesia providers can use to provide neuraxial anesthesia for a laboring parturient. As ultrasound technology continues to advance, become more affordable, and increase in use, anesthesia providers must explore its applications in their practice (American Association of Nurse Anesthesiology [AANA], 2020). The traditional method of assessing anatomical landmarks with palpation to determine needle placement for neuraxial anesthesia techniques is complicated by factors that cause impalpable anatomies such as obesity, edema, and spinal deformity (Nagelhout & Elisha, 2018). Preprocedural ultrasound to determine the site of needle placement, depth, and angle for neuraxial anesthesia techniques has emerged as a promising alternative method of needle placement (Hadzic, 2017). Therefore, anesthesia providers should consider adopting preprocedural ultrasound as a method to provide labor neuraxial anesthesia.

To use preprocedural ultrasound in neuraxial anesthesia, the anesthesia provider must be proficient in scanning the anatomy and interpreting the sonogram's information. A plan to provide initial and continuing education in neuraxial ultrasound assessment is essential to implementing recommendations for using preprocedural ultrasound. The National Institute for Health and Care Excellence (2008) created a guideline on the use of ultrasound-guided catheterization of the epidural space. Yet, the guidelines are not focused solely on preprocedural ultrasound in the clinical setting, thus providing significance to this project.

Healthcare systems can potentially improve patient outcomes by decreasing adverse events by implementing recommendations for a preprocedural ultrasound which can reduce litigation costs stemming from neuraxial procedures. Perlas et al. (2016) found that there was a reduction in traumatic neuraxial procedures by using ultrasound which may contribute to improved safety of neuraxial anesthesia. Implementing such recommendations does not come without a cost because an investment in continuing education and purchasing supplies such as additional ultrasound machines will be necessary for a successful implementation. In addition, implementing preprocedural ultrasound recommendations for neuraxial labor anesthesia requires monitoring and fine-tuning based on QI initiatives. Future research based on QI findings will be necessary to determine the continuing efficacy of preprocedural ultrasound for neuraxial labor anesthesia.

Facilities providing obstetric patients with labor and delivery anesthesia services, should seek to improve CNB placement efficiency and patient outcomes. Despite existing literature describing its benefits, anesthesia providers may not use preprocedural ultrasound to facilitate neuraxial anesthetics for laboring patients. Implementing evidence-based recommendations to use preprocedural ultrasound to assist in neuraxial labor anesthesia placement has potentially

significant implications for patients, anesthesia providers, and healthcare systems by potentially decreasing complications.

Project Objectives

The Doctor of Nursing Practice (DNP) scholar will use the scenario of looking through the lens of an anesthesia department chief CRNA to develop a final scholarly project that seeks to improve the efficiency of needle placement and patient outcomes related to neuraxial anesthesia provided to laboring patients. This final scholarly project will provide a plan to implement recommendations based on the literature's evidence and a blueprint for QI. The Johns Hopkins Nursing Evidence-Based Practice (JHNEBP) model will guide the project to completion (Dang et al., 2022). Overall, the project will integrate knowledge into practice with the following objectives:

1. Develop evidence-based practice (EBP) recommendations for using preprocedural ultrasound when providing neuraxial anesthesia to the laboring patient.
2. Develop a comprehensive plan to implement said EBP recommendations.
3. Develop a comprehensive plan to monitor and measure said EBP recommendations.

Model Identification

A model is foundational in providing direction for a project. In a rapidly changing world that continues to see significant advances in technology and informatics, anesthesia providers can easily fall behind in applying new technology and knowledge to their practice (Dang et al., 2022). Optimization of care for patients who receive anesthesia services improves by combining the best evidence in the literature, clinical expertise, and patient preference/ values to provide evidence-based anesthesia practice (American Association of Nurse Anesthesiology [AANA], n.d.). Anesthesia providers should strive to implement the latest information and technology to

improve patient outcomes. Implementing EBP is a continuous process that allows for ongoing improvements in patient care.

John Hopkins Evidence-Based Practice Model

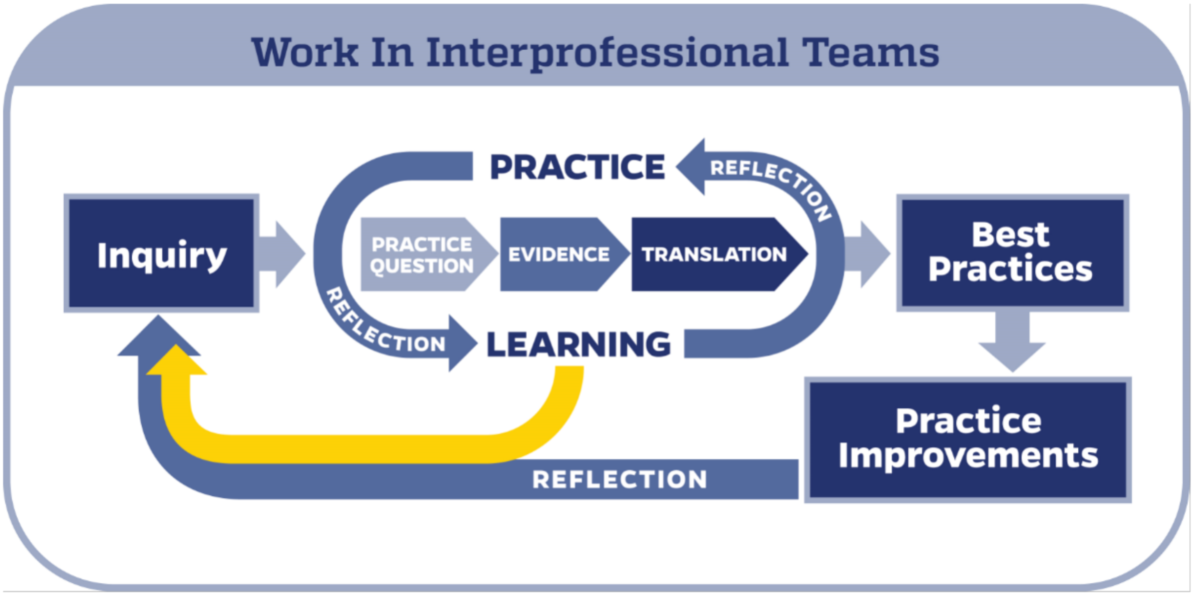
The theoretical framework for this final scholarly project is the John Hopkins Evidence-Based Practice Model (JHEBP) for Nursing and Healthcare Professionals. The JHEBP "provides a structured and systematic way for clinicians to effectively use current research and non-research evidence to determine best practices and provide safe, high-quality care" (Dang et al., 2022, Part 1). The DNP scholar obtained permission to use the JHEBP model and tools (Appendix B). The JHEBP model is a framework that uses inquiry, practice, and learning within interprofessional teams as the three major model components. (Dang et al., 2022). In addition, the model provides a three-phase process as a systematic approach to creating best practices and practice improvements. The three phases are as follows:

1. Develop a practice question.
2. Find the best evidence.
3. Translate the best evidence into practice.

The components and phases of the JHEBP model continuously flow to develop best practices leading to practice improvements (Figure 1). Developing a practice question involves seven steps (steps 1-7), finding the best evidence involves five steps (steps 8-12), and the translation phase involves eight steps (steps 13-20) (Dang et al., 2022). If an anesthesia department seeks to implement this project, the DNP scholar completed phases 1 through 2 while providing a blueprint to accomplish phase 3 with a plan for implementation and QI. All steps involved in each phase of the JHEBP model are described in the following sections of the project.

Figure 1

John Hopkins Evidence-Based Practice Model



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Phase 1: Develop a Practice Question

Step 1: Recruit Interprofessional Team

In developing a practice question, the DNP scholar recruited leadership from the following departments to the interprofessional team for creation and implementation of the project: obstetrical anesthesia, obstetrical nursing, finance, billing, information technology, and QI. If an anesthesia department wishes to implement the project, a similar interprofessional team would need to be recruited in addition to the anesthesia education department.

Step 2: Determine Responsibility for Project Leadership

Responsibility for the project included the Chief CRNA of the anesthesia department. The anesthesia department educator and anesthesia clinical staff leadership also assumed responsibility for implementation of the project.

Step 3: Schedule Team Meetings

The DNP scholar and all stakeholders determined a plan to meet quarterly. Tasks and objectives were assigned during the meetings to facilitate successful development of the project.

Step 4: Clarify and Describe the Problem

Key stakeholders identified a gap between current practice and the desired method of using preprocedural ultrasound to facilitate neuraxial anesthesia needle placement through clinical inquiry. Discussions with anesthesia providers presented anecdotal evidence that preprocedural ultrasound is not common practice for neuraxial anesthesia placement. Interviewed providers who use preprocedural ultrasound routinely provided support as proponents for such a project to have the potential to improve needle placement efficiency and patient outcomes. A review of the literature determined that evidence exists in support of using preprocedural ultrasound. A search of guidelines or recommendations at a Midwest hospital determined that guidelines and recommendations for using preprocedural ultrasound for neuraxial anesthesia do not exist.

Step 5: Develop and Refine the EBP Question

The key stakeholders created a problem, intervention, comparison, and outcome (PICO) statement that provided search strategy terms (Dang et al., 2022). Further refinement of the PICO question occurred over time to search for evidence targeted toward the desired outcomes. For instance, an outcome of the PICO question initially looked at "needle placement efficiency." The key stakeholders refined the PICO to define "placement efficiency" as "first-pass success rates of needle placement." Final PICO question: For obstetric patients who are eligible to receive neuraxial anesthesia for labor (P), would the development and implementation of an evidence-based practice guideline for preprocedural ultrasound (I) vs. the traditional approach (C) increase

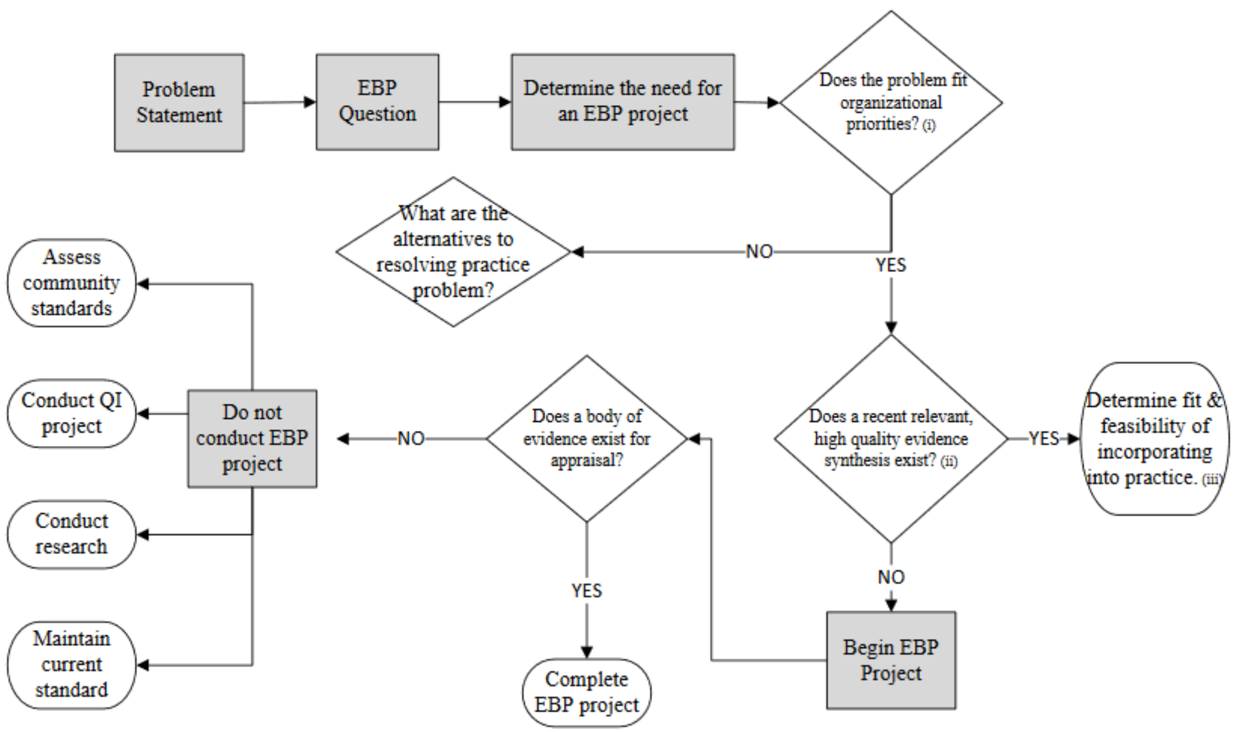
first-pass success rates of needle placement and decrease adverse events such as unintentional dural puncture, post dural puncture headache, and failed neuraxial block (O)?

Step 6: Determine the Need for an EBP Project

Laboring patients deserve continuous improvement in obstetrical anesthesia through development and implementation of EBP projects. An EBP project can begin once there is a body of sufficient evidence found in the literature. (Dang et al., 2022, Part 2). The DNP scholar and key stakeholders used the JHEBP decision tree to determine the need for an EBP project (Figure 2). Literature searches demonstrated that a body of evidence existed for appraisal to complete an EBP project.

Figure 2

JHEBP Decision Tree to Determine the Need for an EBP Project



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Step 7: Identify Stakeholders

The DNP scholar identified obstetrical patients, anesthesia providers, hospital administrators, obstetrical nursing staff, the finance department, and the billing department as relevant stakeholders for the project.

Phase 2: Find the Best Evidence

Step 8: Conduct Internal and External Search for Evidence

The literature search included internal and external investigations and considered clinical practice guidelines, opinions of internal and external experts, position statements from professional organizations, and QI data. The following contains the literature search process.

The DNP scholar thoroughly investigated the literature in July 2022. The databases searched included PubMed, Cochrane Library of Systematic Reviews (CLSR), and the Cumulative Index to Nursing and Allied Health Literature Plus with Full Text (CINAHL). The DNP scholar derived the search terms from the PICO question. The search strategy included the Boolean search phrase of "(*obstetric* OR pregnant OR labor*)* AND (*neuraxial OR spinal OR epidural OR combined spinal-epidural*) AND (*ultrasound OR sonography OR sonogram OR ultrasonography)* AND (*preprocedur*)"* on each database. Exclusion criteria included articles that only provided abstracts, descriptions of research trials without full text, and articles on irrelevant topics. The Otterbein University Courtright Library department assisted in obtaining some of the articles.

The initial search of the literature on PubMed yielded 27 hits. The DNP scholar excluded four articles from the literature review and synthesis due to irrelevance, including articles with the following topics in the title: non-pregnant patients, low cerebrospinal fluid volume, microwave thermal ablation of spinal tumors, and management of vertebral compression

fractures. These are irrelevant results of the search as they did not provide insight into neuraxial anesthesia for laboring patients. In total, the DNP scholar reviewed and synthesized 23 articles obtained in the PubMed search.

The searches on the CLSR and CINAHL databases, using the same strategy as the PubMed search, yielded 21 and 7 results, respectively. The DNP scholar discovered no new articles with full text in both additional database searches.

Step 9: Appraise the Level and Quality of Evidence

In total, the literature search of three databases resulted in the review and synthesis of 23 pieces of literature. The DNP scholar appraised the level and quality of evidence using the JHEBP Research Evidence Appraisal Tool (Dang et al., 2022). The 23 pieces of literature include three systematic reviews with meta-analysis, one systematic review without meta-analysis, ten randomized-controlled trials (RCT), one case-control study, one observational study, two literature reviews, three case reports, one narrative review, and one expert opinion piece. The appraisal of the literature using the John Hopkins Nursing Evidence-based Practice (JHNEBP) tools resulted in 14 articles with level one, one with level two, one with level three, and seven with level five evidence (Dang et al., 2022). Using the JHNEBP tools, the DNP scholar rated most of the quality of evidence with a B grade, with seven articles rated with an A (Dang et al., 2022). The appraisal is summarized in the literature summary table found in the Appendix A.

Step 10: Summarize the Individual Evidence

The DNP scholar summarized the evidence in a literature summary table found in Appendix A.

Step 11 and 12: Synthesize Findings and Develop Best Evidence Recommendations

The DNP scholar synthesized the findings in the literature review section of the project which follows in the next section. Using the Dang et al. (2022) descriptions for an overall body of evidence, the literature synthesis revealed good evidence and consistent results, which meant reliable recommendations could be created. Still, they should be evaluated for risk and organizational translation if implemented. Step 12 follows the literature review in the development of recommendations section.

Literature Review

The clinical problem of scarcity of use and lack of EBP recommendations for a preprocedural ultrasound to facilitate neuraxial anesthesia procedures for parturients at a Midwest hospital led the DNP scholar to perform the described literature search. Most articles from the literature search comparatively study preprocedural ultrasound with the traditional palpation of anatomical landmarks to facilitate neuraxial needle placement. In addition, the articles provide evidence of the problem, methods of the traditional technique and preprocedural ultrasound in neuraxial anesthesia, and insight for creating EBP recommendations.

Trends in Obstetrical Neuraxial Anesthesia

The adoption of ultrasound technology for neuraxial anesthesia is slow compared to its use for the placement of lines and regional blocks. One survey found that only 22% of obstetrical units use preprocedural ultrasound to facilitate neuraxial anesthesia (Bhatia et al., 2016). Newer anesthetists are embracing the practice of utilizing ultrasound in their approach compared to more established providers (Creaney et al., 2016). There should be a continued incline of providers who seek to use ultrasound as a tool for improving anesthesia care.

Efficacy of Preprocedural Ultrasound vs. Traditional

Most of the literature compares preprocedural ultrasound's efficacy as a method for neuraxial anesthesia placement for laboring patients to the traditional way of visualizing and palpating the anatomy. The specific outcomes this project seeks to measure include the first pass success (FPS) rate and complications encountered due to neuraxial needle placement.

First Pass Success

The definition of FPS is achieving neuraxial anesthesia with the first needle pass, including no needle redirections (Jiang et al., 2020; Young et al., 2020). In a systematic review with meta-analysis, Young et al. (2020) analyzed RCTs involving 2,462 obstetrical patients in labor who received neuraxial anesthesia using preprocedural ultrasound or the traditional method. Overall, they found that preprocedural ultrasound increased the FPS of neuraxial procedures compared with the traditional method with a risk ratio of (95%CI) of 1.46 (1.16-1.182), p = 0.001. Additionally, subgroup analysis of studies that they looked at which predicted difficulty of the neuraxial procedure indicated that preprocedural ultrasound increased FPS in the studies that predicted patients to be "difficult" or had "unspecified" descriptions with a risk ratio of (95%CI) of 1.56 (1.21-2.01), P = 0.0006 and (95%CI) of 2.7 (1.27-5.76), P = 0.01, respectively. Subgroup analysis of patients with the predicted difficulty of "easy" or "heterogeneous" descriptions in the RCTs included in the meta-analysis did not yield significant risk ratios showing an increase in FPS (p = 0.34 and p = 0.08, respectively) (Young et al., 2020).

Jiang et al. (2020) also performed a systematic review with a meta-analysis of RCTs comparing preprocedural ultrasound with the traditional method. Their analysis also found that overall preprocedural ultrasound increased FPS with a risk ratio of (95%CI), 1.49 (1.21-1.84), p = 0.0002. Likewise, their subgroup analysis of predicted difficulty for neuraxial procedures also

found that patients predicted as “difficult” had an increased FPS with a risk ratio of (95%CI), 1.40 (1.12-1.75), $p = 0.003$. In addition, patients predicted as “non-difficult” did not yield a significant risk ratio showing an increase in FPS ($p = 0.30$).

In both systematic reviews with meta-analysis, FPS increased with using preprocedural ultrasound (Young et al., 2020)(Jiang et al., 2020)(Young et al., 2020). Yet, subgroup analysis revealed that in patients with predicted “non-difficult” placement of neuraxial anesthesia needles, the use of preprocedural ultrasound did not significantly increase FPS (Jiang et al., 2020)(Young et al., 2020). The evidence presented in both studies suggests that preprocedural ultrasound may be beneficial for improving FPS, especially for obstetrical neuraxial cases predicted to be difficult.

Another systematic review with meta-analysis looked at first-attempt success rates of neuraxial needle placement, defined as “a single needle insertion with or without redirections” (Sidiropoulou et al., 2021, p. 6). In addition, they analyzed the outcome of the number of needle redirections (a backward and then the forward movement of the needle without removing it) in the RCTs they studied. While this analysis does not specifically look at this project's outcome of interest, it provides more insight into the efficacy of preprocedural ultrasound vs. the traditional method on FPS. In theory, FPS rates could potentially increase with increased first-attempt success rates and decreased needle redirections. Given the inconsistencies related to data collection, the literature outcomes are mixed. Their meta-analysis shows that preprocedural ultrasound increased the first-attempt success rate of neuraxial anesthesia with a risk ratio of 1.5 (1.22 – 1.84), $p < 0.00001$. They also did a subgroup analysis of studies that looked at patients with difficult spines and obesity and found that the first-attempt success rate was increased by a risk ratio of 1.84 (1.44 to 2.34), $p < 0.00001$ (Sidiropoulou et al., 2021).

Interestingly, preprocedural ultrasound decreased needle redirections in the analysis of all the studies considered in the meta-analysis with a risk ratio of -0.33 (-0.74 to 0.09), p = 0.04. Within the same study analysis there a subgroup with difficult spines and obese patients which did not produce a significant decrease in needle redirections with a risk ratio of -0.23 (-0.85 to 0.39), p = 0.34 (Sidiropoulou et al., 2021). As a limitation of the study concerning this project, most studies analyzed in the meta-analysis by Sidiropoulou et al. (2021) were of the obstetrical population but also included studies involving other patient populations such as orthopedics. Despite this, the meta-analysis offers insight that preprocedural ultrasound has the potential to increase first-attempt success rates and decrease redirections when placing neuraxial needles.

Chin et al. (2018) studied FPS rates in women receiving CSE anesthesia for cesarean delivery. Two hundred eighteen women were randomized to a preprocedural ultrasound group or the traditional method for neuraxial needle placement. Of 105 parturients allocated to the preprocedural ultrasound group, 63.8% of the cases achieved FPS, while only 30% of the 110 parturients assigned to the traditional method achieved FPS (p = 0.0001) (Chin et al., 2018). Additionally, they found that women in the preprocedural ultrasound group also required fewer additional needle insertions (p = 0.005) and needle redirections (p = 0.002) compared to the traditional approach (Chin et al., 2018). When stratifying the technical performance of FPS based on rated difficulties in palpating anatomical landmarks, Chin et al. (2018) found that preprocedural ultrasound increased FPS in women that had easily palpable spinous processes (p = 0.027) but not in women with moderate or difficult spinous processes or easy/moderate/difficult iliac crests. The Chin et al. (2018) study did not differentiate between epidural and spinal needle insertion FPS. Still, another RCT specifically looked at the FPS rates of spinal needle placement through an epidural needle for parturients undergoing CSE and found

that FPS was achieved in 93.8% of the preprocedural ultrasound group compared to 68.8% receiving the traditional method ($p < 0.001$) (Tao et al., 2020). Overall, these studies display that preprocedural ultrasound can potentially increase the FPS of neuraxial needles for parturients receiving CSE for cesarean delivery.

Conversely, an RCT conducted by Tawfik et al. (2017) of 108 patients receiving epidurals for cesarean delivery demonstrated that FPS was not significantly increased with the use of preprocedural ultrasound vs. the traditional technique. Compared to the meta-analysis and other RCTs described above, the sample size in this study is relatively small. Of note, though, the study demonstrated that FPS was greater in the ultrasound group compared to the traditional method by 1.5% (Tawfik et al., 2017). Another RCT of 128 patients found similar results showing no significant differences for FPS between preprocedural ultrasound and traditional method groups, with 60% and 50% success in each group, respectively (Arzola et al., 2015). Although both studies did not demonstrate statistically significant results, the FPS rate was higher in the group that performed preprocedural ultrasound in both studies.

In summary, the level one evidence found in the literature search demonstrates that preprocedural ultrasound has the potential to increase the FPS rate compared to the traditional method. Whether FPS is only increased by preprocedural ultrasound in cases where patients have impalpable spinous surfaces is debatable. RCTs with larger population sizes and varying degrees of predicted difficulty based on palpation are warranted to study the efficacy of preprocedural ultrasound vs. the traditional method on FPS.

Complications

In general, complications from neuraxial anesthesia are low. Still, risks can lead to morbidities such as post-dural puncture headache (PDPH), trauma to the anatomy of the spine,

and failed neuraxial anesthesia (Perlas et al., 2016). Due to the low rates of complications caused by neuraxial anesthesia, the evidence in the literature is limited. In theory, by preventing known mechanisms of injury by reducing multiple needle attempts and redirections and improving the accuracy of the level of the spine where the neuraxial needle is placed, complications can further be prevented (Perlas et al., 2016). “Multiple needle punctures while performing block is an independent predictor of undue complications such as paresthesia, vascular puncture, and PDPH” (Chin et al., 2018, p. 229). Even though the risks are low, preprocedural ultrasound provides additional assessment information that can further mitigate risks.

One complication discussed in the literature is unintentional dural puncture during the placement of an epidural catheter. If the epidural needle (larger than a spinal needle) is placed too deep through the dura and into the intrathecal space, cerebrospinal fluid (CSF) can leak into the epidural space. The decreased CSF due to the leak can cause a lack of support for brain structures and irritation to brain tissue (Nagelhout & Elisha, 2018). If this happens, parturients can experience a PDPH. A study found that the sonogram of the ligamentum flavum at the L3 to L4 and L4 to L5 interspace was abnormal for patients who had previously experienced an unintentional dural puncture (Lee et al., 2008). Thus, preprocedural ultrasound can be used to identify patients at higher risk for PDPH and provide additional information in choosing a spinal level for needle placement with identifiable ligamentum flavum on ultrasound. When using preprocedural ultrasound to facilitate neuraxial needle placement, Carvalho (2008) recommends avoiding “the puncture of spaces in which the ligamentum flavum is either not seen or appears abnormal on ultrasound” (Carvalho, 2008, p. 156). This suggests that PDPH incidence can be decreased using preprocedural ultrasound.

In the meta-analysis by Young et al. (2021), they found a significant decrease in post-partum headache ($p = 0.006$) but no significant decrease in unintentional dural punctures ($p = 0.670$). One potential explanation for this is that some studies may have under-reported the incidence of an unintentional dural puncture due to a lack of knowing it happened, but instead, patients felt the effects of it by experiencing a post-partum headache. Conversely, a post-partum headache could be explained by other factors unrelated to unintentional dural puncture, i.e., dehydration. In another study, the incidence of unintentional dural puncture for patients receiving preprocedural ultrasound vs. the traditional approach was 1.9% and 2.7%, respectively (Chin et al., 2018). Thus, both approaches' incidence is low, but improved outcomes using preprocedural ultrasound are demonstrated.

Every time a needle is introduced into the spinal anatomy, there is potential for trauma to occur, which could lead to backache, vascular puncture, or worse, spinal cord damage. Jiang et al. (2020) found that preprocedural ultrasound reduced the incidence of vascular puncture and backache compared to the traditional approach in their meta-analysis. While the results of the study for incidence of complications were not found to be significant due to the low rates of occurrence, Wu et al. (2018) also demonstrated fewer vascular punctures, nerve irritations, and patients demonstrating backache when patients received preprocedural ultrasound vs. palpation only.

One complication of neuraxial anesthesia that can be devastating to the obstetrical patient's experience of anesthesia is the result of failed neuraxial anesthesia placement, resulting in the necessity for a general anesthetic during cesarean delivery. General anesthesia can prevent a mother from experiencing the initial moments after the birth of their child. One case report used preprocedural ultrasound to identify a safe location for spinal placement in a parturient with

spinal metastases and prevented the need for a general anesthetic (Tawfik et al., 2015). The parturient with predicted difficulty was able to avoid general anesthesia which improved the patient's birthing experience.

Several studies also demonstrated that preprocedural ultrasound decreased the number of needle passes and attempts required for the successful placement of neuraxial needles, thus potentially causing less trauma and nerve damage (Dhanger et al., 2018; Elgueta et al., 2017; Gayathri et al., 2021; Jiang et al., 2020; Wu et al., 2021; Young et al., 2020). Dhanger et al. (2018) found that patients who received preprocedural ultrasound experienced paraesthesias in only 2% of the cases compared to 28% in the group receiving the traditional approach ($p = 0.0001$). Fewer needle passes and attempts potentially decreases nerve damage and parasthesias.

In summary, preprocedural ultrasound provides additional information to potentially prevent complications and mitigate risks involved with neuraxial anesthesia in obstetrics. As reported in the literature, the incidence of complications is low even when using the palpation method. Still, there is evidence to support that preprocedural ultrasound has the potential to decrease complications. According to Sidiropoulou et al. (2021), "A firm conclusion on the incidence of minor and major complications with or without preprocedural ultrasound is not possible, and assumptions can be based on the observed reduction in the number of needle redirections and increased first-attempt success rate" (p. 11). Any decrease in complications for neuraxial anesthesia can lead to better patient outcomes and an improved patient experience.

Training Programs

To implement preprocedural ultrasound into practice, anesthesia providers must undergo initial and continuing education to develop and maintain the technical skills involved. Sadeghi et al. (2021) suggest that using preprocedural ultrasound can improve the learning of epidural

anesthesia techniques for all learners. Despite this, there is conflicting evidence in the literature and a lack of studies determining the learning curve for using ultrasound in neuraxial anesthesia (Sahin & Balaban, 2018). Grau et al. (2003) found that the success rates of anesthesia residents who performed their first 60 obstetric epidurals using preprocedural ultrasound information such as projected needle position, depth, and angle were significantly higher than residents using only traditional methods. In addition, teaching neuraxial procedures should improve teaching by providing students with a better understanding of underlying spinal anatomy (Carvalho, 2008). Thus, preprocedural ultrasound may be a tool anesthesia programs should use to teach neuraxial anesthesia.

Spence et al. (2012) suggest anesthesia providers gain experience in a controlled setting by reviewing didactic materials and performing practice scans on volunteers before incorporating preprocedural ultrasound into clinical practice. In the clinical setting, patients predicted not to be difficult should be scanned with preprocedural ultrasound to obtain and maintain competency (Spence et al., 2012). Based on this, the DNP scholar suggests that implementing preprocedural ultrasound as the standard of care for all neuraxial anesthesia procedures in obstetrics potentially improves patient outcomes and maintains competency for the technique.

Summary

Despite a substantial amount of evidence displaying a potential to improve obstetrical neuraxial anesthesia with preprocedural ultrasound, this intervention is not the current standard of care. The literature review and synthesis found that preprocedural ultrasound increased FPS and potentially decreased complications associated with neuraxial anesthesia in obstetrics, especially in patients with impalpable landmarks. Implementing recommendations on using preprocedural ultrasound to facilitate placement of neuraxial needles will require a method for

placement that the literature described. With training and achieved competence in using preprocedural ultrasound, an anesthesia provider has the potential to improve the efficacy of neuraxial anesthesia procedures in obstetrics.

Evidenced-Based Practice Recommendations

The EBP recommendations provided in Appendix C are designed to promote improvements in the quality of patient care for laboring patients receiving neuraxial anesthesia but cannot guarantee any specific patient outcome. The recommendations should be used to implement the use of preprocedural ultrasound for facilitation of neuraxial anesthesia procedures provided to laboring patients.

Preprocedural ultrasound is not commonly used in current practice to facilitate neuraxial anesthesia procedures for laboring patients. Most providers use visualization and palpation of the anatomy to determine neuraxial needle placement (Jiang et al., 2020). This technique is considered “blind” since assessment of projected needle depth, angle of needle trajectory, and any underlying anatomical variations is unachievable. As found in the literature, preprocedural ultrasound allows the anesthesia provider to gain additional assessment information, improve FPS rates, and potentially decrease complications. The recommendations are as follows:

- Train all obstetrical anesthesia providers on how to use preprocedural ultrasound to facilitate neuraxial anesthesia placement.

A lack of formal training on using preprocedural ultrasound to facilitate neuraxial anesthesia for labor contributes to its shortage of use. Interestingly, the Council on Accreditation of Nurse Anesthesia Educational Programs (COA) (2021) approved a new minimum requirement for all student nurse anesthetists matriculating into a doctoral program after January 1, 2022, to

obtain a minimum of ten regional ultrasound cases. Using ultrasound for neuraxial procedures would meet this clinical requirement for nurse anesthetists to graduate.

As newer anesthesia providers are required to get ultrasound experience, current anesthesia providers will also need formal training to stay at the forefront of implementing technology to improve clinical practice. A CRNA's scope of practice includes the use of ultrasound in diagnosis and delivery of care (AANA, 2020a). Training considerations include providing didactic and hands on training which includes mentored patient-based scanning. All requirements for ultrasound credentialing and privileging need to be met (AANA, 2020b). Refer to federal, state, local, and facility requirements.

- Purchase an ultrasound machine to be exclusively used for neuraxial anesthesia procedures.

Purchasing an ultrasound machine exclusively for neuraxial anesthesia procedures is necessary to decrease procedure time. Depending on the number of anesthesia providers actively managing neuraxial anesthetics on a labor and delivery unit, purchasing more ultrasound machines and supplies may be warranted to prevent providers from having to wait for an available machine. The budget cost of purchasing additional equipment can be supported with this information.

- Use preprocedural ultrasound to facilitate neuraxial anesthesia provided to laboring patients who meet one or more of the following criteria: Body Mass Index (BMI) > 30, impalpable neuraxial landmarks, marked deformity of the spine, or history of difficult neuraxial anesthesia.

The use of preprocedural ultrasound was found to be especially useful in patients with predicted procedure difficulty. Rates of obesity continue to rise thus anesthesia providers will

continue to encounter more pregnant patients who have impalpable spinous landmarks which may lead to difficult neuraxial anesthesia placement. Preprocedural ultrasound allows the anesthesia provider to improve and offer neuraxial anesthetics to patients who are obese, have impalpable landmarks, have a deformity of the spine, or have a history of a previous difficult neuraxial anesthetic placement.

- Monitor staff adherence of provided clinical recommendations along with monitoring clinical outcomes including first pass success rates of neuraxial needle placement and complications associated with neuraxial anesthesia placement.

Phase 3: Translate the Best Evidence into Practice

If an anesthesia department seeks to implement the recommendations, the DNP scholar has provided a blueprint to do this. The blueprint includes a plan for implementation in addition to a plan for QI after the recommendations are implemented. Phase 3 includes steps 13 through 20 of the JHEBP model.

Step 13: Identify Practice Setting

The DNP scholar obtained feedback on the proposed recommendations from stakeholders. The input determined readiness for a practice change, the feasibility of implementation in the specific practice setting, and the available resources (Dang et al., 2022). The setting for the proposed project implementation is an urban level one trauma center in the Midwest that is also a level III maternity center that provides obstetric patients with labor and delivery anesthesia services. In the future, the provided recommendations, comprehensive implementation plan, and outcome analysis plan can be used at any facility that provides neuraxial anesthesia to laboring patients.

Step 14: Create Action Plan

A plan for implementation of the recommendations is presented. "The team must consider the who, what, when, where, how, and why when developing an action plan for a proposed change" (Dang et al., 2022, Part 2). The DNP scholar designed a plan that considers these factors to implement the provided evidence-based practice recommendations in the future.

Implementation

The Chief CRNA will first create an organizational infrastructure to implement the project. The organizational infrastructure will include building support for implementing the recommendations, providing necessary training, and acquiring the resources for successful implementation. Dang et al. (2022) recommends recruiting individuals "who are supportive of the recommended practice change and who will be able to support the project leader during the translation phase of the project" (Part 3). This team will consist of well-respected individuals of the organization from the departments of anesthesia staff, anesthesia education, biomedical engineering, information technology (IT), obstetrical nursing, and QI. The team will work as a unit to provide the organizational infrastructure described below, which will be required to implement the recommendations successfully.

Education and Training

To implement preprocedural ultrasound into practice, anesthesia staff who provide labor neuraxial anesthesia will need to be trained. Melnyk and Fineout-Overholt (2019) recommend creating a staff member who is an expert. The anesthesia staff member appointed to the preprocedural ultrasound infrastructure team should attend a reputable in-person conference. The Twin Oaks epidural and spinal conference is used as an example. Over two days, the attendee will develop spinal and epidural ultrasound skills through lectures and hands-on labs while

acquiring 16 Class A continuing education credits for CRNAs (Twin Oaks Anesthesia, n.d.-a). After the successful completion of the conference, the attendee will be labeled as the *Preprocedural Ultrasound Champion*. The *Preprocedural Ultrasound Champion* will be a resource for promoting the project and training the rest of the anesthesia staff, who will only partake in an online workshop provided by Twin Oaks Anesthesia.

Twin Oaks Anesthesia offers a Spinal & Epidural Ultrasound course through an online learning platform that provides CRNAs with 8.25 Class A continuing education credits (Twin Oaks Anesthesia, n.d.-b). Due to the online course being made up of 8 hours of video content followed by short exams, the course is estimated to take 10 hours to complete. All anesthesia staff will need to complete the course as a requirement to be able to place a neuraxial anesthetic. Margarido et al. (2010) recommend that spinal ultrasound competency be achieved with greater than twenty supervised scans and educational material.

In addition to the online course, anesthesia staff will be responsible for accomplishing greater than twenty supervised preprocedural ultrasounds for labor neuraxial anesthesia. The *Preprocedural Ultrasound Champion* will be responsible for supervising these until other staff members have reached competency. Once other staff members have reached competency, they are deemed *super users* and can be used to supervise and train additional staff. While the recommendations require a preprocedural ultrasound for patients with indicators of a predicted difficult neuraxial needle placement, competency in preprocedural ultrasound can be created and maintained through ultrasound of patients who are predicted to be easy. Competent staff members who reach the thirty supervised preprocedural ultrasounds can then supervise other anesthesia staff who have yet to achieve competency. The anesthesia educator will oversee the

tracking and maintenance of records on completion of the course and the competency standards that have been set.

Biomedical Engineering

Preprocedural ultrasound for neuraxial anesthesia requires ultrasound technology with a low-frequency (2-5 MHz) curved probe. The biomedical engineering department will be responsible for purchasing an ultrasound machine that is to be exclusively used for preprocedural ultrasound in labor and delivery suites. A quality ultrasound machine can cost around $25,000 to $100,000 depending on the condition purchased (Ultrasound Solutions Corp, 2022). The finance department should consider a machines image quality, applications, warranty, mobility, and future maintenance costs. The following is a list of brands that sell ultrasound machines but by no means is an exhaustive list of all available companies: Samsung, GE, Philips, Sonosite, Mindray, Toshiba, Siemens, and Butterfly Network. The *Preprocedural Ultrasound Champion* and the finance department representative should consult with several companies to explore the best option for an ultrasound machine to be purchased for labor neuraxial anesthesia.

Information Technology

The electronic medical record (EMR) interface will need updates to incorporate the use of preprocedural ultrasound into practice. A specialist from the Information Tecnhology (IT) department and representatives from the anesthesia and obstetrical nursing department will work together to build a functional EMR infrastructure. The EMR updates will include a charting method to identify patients who meet the recommended criteria found in Appendix C. The EMR will use the criteria to identify patients who are to receive a preprocedural ultrasound, a point and click method to record the use of preprocedural ultrasound, and a point and click method to indicate if the neuraxial needle placement is a first pass success.

Obstetrical nursing staff will be responsible for recording information such as patient weight, height, history of anatomical variations of the spine, and history of difficult neuraxial anesthesia placement. The EMR system will identify when a recommended criterion is met for the patient to receive preprocedural ultrasound by triggering a notification to the anesthesia staff reflected on the obstetrical patient summary sheet. Point and click charting can be added to the anesthesia neuraxial procedure charting interface to indicate if preprocedural ultrasound was used and to document first pass success.

Obstetrical Nursing

The obstetrical nursing department will play a key role in making the project successful. They will receive in service training on assessing the recommended preprocedural ultrasound criteria and identifying complications associated with neuraxial anesthesia. The anesthesia educator and obstetrical nursing educator will work together to create the in-service training that can be provided to nurses while on shift. When a complication is identified, the anesthesia staff will be notified so that the patient can be treated and proper documentation can be achieved.

Timeline

Implementation of the proposed evidence-based practice recommendations is estimated to take a total of twelve months, Table 1. The estimated timeline developing an organizational infrastructure, including training, purchasing equipment, and information technology upgrades to the EMR, will take a total of three months. Despite this, anesthesia providers should begin to use preprocedural ultrasound to obtain competency as soon as online training is completed and an ultrasound machine is available. Full implementation of the recommendations will begin in month four of the project, understanding that not all providers may be trained until the sixth month. A goal of having 50% of the staff trained by the fourth is reasonable. Months six through

twelve will include full implementation of the recommendations with continuous monitoring of compliance and outcomes that may warrant adjustments.

Table 1

Estimated Timeline of Implementation Plan

Task	**Month**											
	1	2	3	4	5	6	7	8	9	10	11	12
Development of Recommendations												
Training, Purchasing, and Technology												
Implement Recommendations into Practice												
Monitor Compliance and Outcomes												
Adjust the Recommendations												

Budget

The estimated expenses associated with implementing the recommendations include IT labor costs for the EMR infrastructure, training, purchasing technology, and QI costs. Table 2 provides a summary of the estimated project budget.

Table 2

Estimated Project Budget

Expense	Estimated Cost
Information Technology	$552
Twin Oaks Spinal and Epidural Conference	$4,027
Twin Oaks Spinal and Epidural Online Training	$25,100
Ultrasound Machine	$100,000
Quality Improvement	$416
Total Estimated Cost	$130,095

The IT EMR infrastructure is estimated to take twelve hours to build. Average salary of a healthcare information technology specialist is $34 per hour (ZipRecruiter, 2022b). Thus, the information technology costs of the project are estimated to be $552.

Costs associated with Preprocedural Ultrasound Champion training include room and board for two nights stay for the Twin Oaks Anesthesia conference. Room and board are estimated to be $600 which includes $200 per night at a hotel and $100 per day for food and beverage. Travel expenses will also need to be considered and estimated round trip flight is $600. Cost of the conference is $1,099. In addition, the conference attendee will be paid sixteen total hours. With the average CRNA salary reported at $108 per hour, the estimated salary cost to attend the conference is $1,728 (ZipRecruiter, 2022a). In total, costs to train the Preprocedural Ultrasound Champion is estimated to be $4,027. The online course for additional CRNAs is estimated to take ten hours per provider to complete and each class costs $175 per provider. For twenty CRNAs to complete the online training it is estimated to cost $25,100.

The cost to purchase an ultrasound capable for implementing this project can vary greatly including the cost of maintenance and warranty. The estimated cost to purchase an ultrasound machine exclusively for labor neuraxial anesthesia is $100,000 (Ultrasound Solutions Corp, 2022). Monitoring the compliance of following the recommendations and outcomes associated with preprocedural ultrasound is estimated to take two hours monthly by a QI specialist. The average salary for a QI specialist is $26 per hour, so the total cost for eight months of monitoring is $416 (ZipRecruiter, 2022b). The total budget for the project is estimated to be $130,095.

Return on Investment

Realization of a return on investment may take time. Most insurance carriers will not reimburse for preprocedural ultrasound for neuraxial anesthetics because placement of the

neuraxial needle is not guided in real-time (Kline, 2011). Despite this, implementing the evidence-based practice recommendations provides a potential opportunity for a return on the significant investment to be made through mitigation of medicolegal risks.

The most common injuries involved permanent neurological deficit and post dural puncture headache. In an analysis of medicolegal issues in obstetric anesthesia between 2005 and 2015 Kovacheva et al. (2019) found that maternal nerve injuries from neuraxial anesthesia were the most frequent cause of closed claims. The settlement amounts for maternal nerve injury ranged from $8,724 to $227,468 with legal expenses ranging from $0 to $307,487 (Kovacheva et al., 2019). Greater than 50% of the maternal injury closed claims involved injury to the spinal cord thus providing an emphasis on accurately identifying the lowest interspace to provide a safe neuraxial anesthetic. Preprocedural ultrasound allows for the provider to accurately identify the lumbar interspaces which lowers the risks associated with the traditional method of neuraxial needle placement.

Additionally, obstetric patients are at a higher risk of having a difficult airway (Chestnut et al., 2020). Failed airway management can lead to maternal and fetal death or brain injury, leading to settlement payments ranging from $13,597 to $5,665,292 (Kovacheva et al., 2019). With improvements in neuraxial needle placement using preprocedural ultrasound, general anesthesia can potentially be avoided, thus mitigating the medicolegal risks. Due to ultrasound being safe and void of harmful effects, there is only potential for a decrease in litigation risk involved with labor anesthesia.

Work Flow

Patients admitted to the labor and delivery department will require a height and weight to calculate a BMI. BMI is a recommended indicator to trigger the use of preprocedural ultrasound.

In addition, anesthesia staff will assess for other indicators including impalpable neuraxial landmarks, marked spine deformity, and a history of difficult neuraxial anesthesia. If one or more of the recommended indicators is found true during the patient assessment, preprocedural ultrasound will be required if a neuraxial anesthetic is desired. As part of the EMR infrastructure, additional assessment questions to identify the indicators may be required for the admission assessment with point and click questions that the obstetrical nursing staff will ask. For example, the point and click assessment of the indicators by the obstetrical nursing assessment staff is found to be true or the BMI is greater than 30. In that case, the EMR infrastructure should alert the anesthesia provider that preprocedural ultrasound should be used for patients who consent for neuraxial anesthesia.

After a patient is identified as requiring preprocedural ultrasound for a neuraxial anesthetic, anesthesia staff will consent the patient for the procedure. After consent is received, a trained anesthesia provider will scan the patient before creating a sterile field. A skin marker will be used to mark two eligible interspaces and midline for those spaces. Needle trajectory and measured ultrasound depth of the desired spinal structures will be noted. A sterile field will then be created, and the neuraxial anesthetic will be placed at one of the marked interspaces. If placement at the first attempted interspace fails, the second marked interspace can be used without having to break the sterile field. Upon successful placement of the neuraxial anesthetic, the anesthesia provider should document details about the use of preprocedural ultrasound.

The EMR infrastructure will require additional features including a point and click option to indicate that preprocedural ultrasound was used to facilitate the placement of the neuraxial anesthetic. Suppose this point and click option is selected. In that case, additional assessment information for preprocedural ultrasound will populate including the exact vertebral interspace,

measured depth, and needle trajectory used to place the neuraxial needle. Click and point options to indicate first pass success of needle placement will also be required if not already available. Documentation of first pass success of needle placement will be key for future monitoring and adjustment of QI for the project.

The standard of care for neuraxial anesthetics requires continuous monitoring of the effectiveness of the blocks. Suppose the patient experiences complications including a failed neuraxial block, postdural puncture headache, and backache after the removal or discontinuation of a neuraxial anesthetic. In that case, the EMR should have click and point options to document these occurrences so they can be tracked.

Labor Impact

The labor impact caused by implementing the recommendations is estimated to be minimal for anesthesia providers. Obstetrical nursing staff will play a key role in assessing and identifying neuraxial procedure complications, including failed neuraxial block, postdural puncture headache, and backache. An in-service training can be used to stress the assessment indicators for these complications. The anesthesia provider should be notified if the nursing staff assesses a complication so that it can be addressed through additional interventions and appropriately documented.

Phase 3: Translate the Best Evidence into Practice Continued

Step 15: Secure Support and Resources to Implement Action Plan

Training for anesthesia staff on using preprocedural ultrasound for neuraxial anesthesia will require resources and a plan to implement and maintain proposed recommendations. Practice settings will also need additional supplies such as ultrasound machines and gel available in laboring suites of the obstetrical department.

Step 16: Implement Action Plan

A comprehensive plan to implement this project is provided in the implementation section.

Step 17: If Change is Implemented, Evaluate Outcomes to Determine Whether Improvements Have Been Made

The DNP scholar will not implement this project due to academic time constraints, but rather the project provides a blueprint for implementation and QI. The following section of the project provides said blueprint for QI if the implementation plan is used.

Quality Improvement

Monitoring the Recommendations

Recommendation #4 includes monitoring staff adherence to the recommendations, FPS rates of neuraxial needle placement, and complications associated with neuraxial anesthesia, including failed neuraxial block, postdural puncture headache, and backache. The QI department will monitor this recommendation and report to the Chief CRNA and the interprofessional team recruited to translate the recommendations into practice. Starting on the 5th month, after one month of full implementation of the recommendations, the QI department will audit patient charts who received neuraxial anesthetics for labor monthly. The IT and QI departments will work together to form a seamless auditing system that allows reports to be created to monitor the recommendations. The EMR will play a key role in monitoring the recommendations. The IT department will include additional features in the EMR to identify the recommended indicators to trigger preprocedural ultrasound use and document the first-pass success of needle placement and associated complications.

Staff Adherence

An audit report feature should be included so the QI department can monitor the staff's adherence to the recommendations. This will include monitoring compliance of using preprocedural ultrasound for patients who meet the indicators. The goal is for 100% of patients with predicted difficulty indicators to receive a preprocedural ultrasound to facilitate labor neuraxial anesthesia. The QI department will report compliance rates for this goal to the Chief CRNA monthly.

First Pass Success

The outcome of placing a neuraxial needle with the first pass will also be tracked through chart audits of the EMR. The IT department will provide an option to chart this and provide a method for the QI department to run an audit to determine FPS rates. Suppose the previous charting before implementing the recommendations on FPS rates is available. In that case, a retroactive chart review should be conducted to determine the FPS rates of all the labor neuraxial anesthetics in the previous year to determine a facility benchmark for the outcome. The meta-analysis by Young et al. (2021) found that first pass success was achieved at a rate of 58% for the neuraxial labor anesthetics with predicted difficulty. Additionally, the meta-analysis by Jiang et al. (2020) found that first pass success was achieved at a rate of 60% for the neuraxial labor anesthetics with predicted difficulty. If facility benchmark data is unavailable through retroactive chart review, a benchmark goal of greater than 60% of labor neuraxial anesthetics with predicted difficulty should be used. Rates of first-pass success will be reported to the Chief CRNA monthly.

Complications

A chart audit for the incidence of unintentional dural punctures, post dural puncture headaches, and failed neuraxial block should be conducted to determine complications over the previous year before implementing the recommendations. The goal for these complications should be zero incidences after the recommendations are implemented. The preprocedural ultrasound team should review complications incidences to determine improvement areas. Incidence of complications will be reported to the Chief CRNA and preprocedural ultrasound team monthly.

Adjusting the Recommendations in the Future

A potential barrier to implementing the recommendations is anesthesia non-compliance due to preprocedural ultrasound creating extra work. Preprocedural ultrasound should not take additional time compared to the traditional technique thus additional staff education instilling this evidence may be necessary. It is also possible that training on preprocedural ultrasound is inadequate, which will require increasing the amount of supervised neuraxial anesthetics placed with ultrasound. This adjustment to training requirements can also be used if FPS rates are not increased or incidence of complications is not decreased. If anesthesia staff finds it difficult to obtain an ultrasound machine quickly to facilitate a neuraxial anesthetic, purchasing additional ultrasound machines may be necessary.

Phase 3: Translate the Best Evidence into Practice Continued

Step 18: Report Results to Stakeholders

Results were not reported to stakeholders for this project due to the project not being implemented. Rather, the project will be disseminated to the anesthesia and academic community.

Step 19: Identify Next Steps

The DNP scholar has prepared a blueprint to be used if an obstetrical unit desires to implement the provided recommendations pertaining to preprocedural ultrasound in neuraxial anesthesia in the future.

Step 20: Disseminate Findings

The DNP scholar will disseminate the project to an urban level one trauma center in the Midwest that is also a level III maternity center that provides obstetric patients with labor and delivery anesthesia services. A poster describing the EBP project will be created and displayed in a high traffic area for anesthesia personnel to disseminate the plan. If this project is implemented in the future, findings should be disseminated to other providers of neuraxial anesthesia.

Conclusion

Neuraxial anesthesia is a cornerstone of providing comfort and relief to laboring patients. Anesthesia providers can experience challenges in placing neuraxial anesthesia needles, especially in patients with predicted difficulty indicators. Ultrasound technology is increasingly used for regional anesthesia but is not a standard of care in labor neuraxial anesthesia. The evidence found in the literature shows that first-pass success rates of neuraxial needle placement are increased, and complications are decreased using preprocedural ultrasound, especially for patients with predicted difficulty. As adoption of the EBP recommendations occurs, additional evidence for the use of preprocedural ultrasound in labor neuraxial anesthesia can be generated. Implementation of the recommendations provided, and use of the QI plan is intended to improve labor neuraxial anesthesia. In the future, using preprocedural ultrasound as a method to provide neuraxial anesthesia to laboring patients with predicted difficulty has the potential to become a standard of care.

References

American Association of Nurse Anesthesiology. (2020a). https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/professional-practice-manual/scope-of-nurse-anesthesia-practice.pdf?sfvrsn=250049b1_10

American Association of Nurse Anesthesiology. (2020b). *Point-of-care ultrasound in anesthesia care practice considerations*. American association of nurse anesthesiology. https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/professional-practice-manual/pocus-in-anesthesia-care-practice-considerations.pdf?sfvrsn=a3259e3e_4

American Society of Anesthesiologists. (2021). *Guidelines for neuraxial analgesia or anesthesia in obstetrics*. https://www.asahq.org/-/media/sites/asahq/files/public/resources/standards-guidelines/guidelines-for-neuraxial-analgesia-or-anesthesia-in-obstetrics.pdf?la=en%26hash=655A96C7455F4581773DF05E5DD1277AC25FD50A#:~:text=GUIDELINE%20III%20Neuraxial%20analgesia%20or,and%20the%20progress%20of%20labor

Arzola, C., Mikhael, R., Margarido, C., & Carvalho, J. C. (2015). Spinal ultrasound versus palpation for epidural catheter insertion in labour. *European Journal of Anaesthesiology*, *32*(7), 499–505. https://doi.org/10.1097/eja.0000000000000119

Baysinger, C., Bucklin, B., & Gambling, D. (2016). *A practical approach to obstetric anesthesia* (2nd ed.). Wolters Kluwer.

Bhatia, K., Kochhar, P., Clegg, I., & Maguire, S. (2016). The availability and use of ultrasound in uk obstetric anaesthesia. *International Journal of Obstetric Anesthesia*, *25*, 91–92. https://doi.org/10.1016/j.ijoa.2015.10.001

Broadbent, C. R., Maxwell, W. B., Ferrie, R., Wilson, D. J., Gawne-Cain, M., & Russell, R. (2000). Ability of anaesthetists to identify a marked lumbar interspace. *Anaesthesia*, *55*(11), 1122–1126. https://doi.org/10.1046/j.1365-2044.2000.01547-4.x

Canturk, M., Karbancioglu Canturk, F., Kocaoglu, N., & Hakki, M. (2019). Abdominal girth has a strong correlation with ultrasound-estimated epidural depth in parturients: A prospective observational study. *Journal of Anesthesia*, *33*(2), 273–278. https://doi.org/10.1007/s00540-019-02621-9

Carvalho, J. (2008). Ultrasound-facilitated epidurals and spinals in obstetrics. *Anesthesiology Clinics*, *26*(1), 145–158. https://doi.org/10.1016/j.anclin.2007.11.007

Centers for Disease Control and Prevention. (2020). *Increases in prepregnancy obesity: United States, 2016 - 2019*. https://www.cdc.gov/nchs/products/databriefs/db392.htm#:~:text=System%2C%20Natality%20file.-,Summary,levels%20shown%20in%20this%20report.

Centers for Disease Control and Prevention. (2022). *National vital statistics reports* (Vol. 70, No. 17) [Report]. https://www.cdc.gov/nchs/data/nvsr/nvsr70/nvsr70-17-tables.pdf

Chestnut, D. H., Wong, C. A., Tsen, L. C., Ngan Kee, W. D., Beilin, Y., Mhyre, J. M., & Bateman, B. T. (2020). *Chestnut's obstetric anesthesia principles and practice* (6th ed.). Elsevier.

Chin, A., Crooke, B., Heywood, L., Brijball, R., Pelecanos, A. M., & Abeypala, W. (2018). A randomised controlled trial comparing needle movements during combined spinal-epidural anaesthesia with and without ultrasound assistance. *Anaesthesia*, *73*(4), 466–473. https://doi.org/10.1111/anae.14206

Choi, J., Germond, L., & Santos, A. (2018). *Obstetric regional anesthesia - nysora*. NYSORA. https://www.nysora.com/topics/sub-specialties/obstetric/obstetric-regional-anesthesia/

Council on Accreditation of Nurse Anesthesia Educational Programs. (2021). *Approved revisions to the accreditation standards* [PDF]. https://www.coacrna.org/wp-content/uploads/2021/02/COA-Presentation-on-Revisions-to-Standards-and-Policies.pdf

Creaney, M., Mullane, D., Casby, C., & Tan, T. (2016). Ultrasound to identify the lumbar space in women with impalpable bony landmarks presenting for elective caesarean delivery under spinal anaesthesia: A randomised trial. *International Journal of Obstetric Anesthesia*, *28*, 12–16. https://doi.org/10.1016/j.ijoa.2016.07.007

Dang, D., Dearholt, S., Bissett, K., Ascenzi, J., & Whalen, M. (2022). *John Hopkins evidence-based practice for nurses and healthcare professional: Model and guidelines* (4th ed.). Sigma Theta Tau International. https://www.r2library.com/Resource/Title/1948057875/ch0001s0009

DeLeon, A. M., & Wong, C. A. (2022). Spinal anesthesia: Technique (R. Maniker & M. Crowley, Eds.). *UpToDate*. Retrieved July 22, 2022, from https://www.uptodate.com/contents/spinal-anesthesia-technique

Dhanger, S., Vinayagam, S., Vaidhyanathan, B., Rajesh, I., & Tripathy, D. (2018). Comparison of landmark versus pre-procedural ultrasonography-assisted midline approach for identification of subarachnoid space in elective caesarean section: A randomised controlled trial. *Indian Journal of Anaesthesia*, *62*(4), 280. https://doi.org/10.4103/ija.ija_488_17

Elgueta, M. F., Duong, S., Finlayson, R. J., & Tran, D. Q. (2017). Ultrasonography for neuraxial blocks: A review of the evidence. *Minerva Anestesiologica*, *83*(5). https://doi.org/10.23736/s0375-9393.16.11650-5

Gayathri, B., Swetha Ramani, C. K., Urkavalan, K., Pushparani, A., & Rajendran, A. (2021). Comparison of the time taken for subarachnoid block using ultrasound-guided method versus landmark technique for cesarean section – a randomized controlled study. *Journal of Anaesthesiology Clinical Pharmacology*, *37*(2), 205. https://doi.org/10.4103/joacp.joacp_35_20

Hadzic, A. (2017). *Hadzic's textbook of regional anesthesia and acute pain management* (2nd ed.). McGraw-Hill Education/Medical.

Jiang, L., Zhang, F., Wei, N., Lv, J., Chen, W., & Dai, Z. (2020). Could preprocedural ultrasound increase the first-pass success rate of neuraxial anesthesia in obstetrics? a systematic review and meta-analysis of randomized controlled trials. *Journal of Anesthesia*, *34*(3), 434–444. https://doi.org/10.1007/s00540-020-02750-6

Kenevan, M. R., Smith, H. M., Olsen, D. A., & Sharpe, E. E. (2018). Ultrasound-assisted combined spinal-epidural anesthesia for cesarean delivery in a parturient with currarino triad: A case report. *A&A Practice*, *12*(11), 393–395. https://doi.org/10.1213/xaa.0000000000000941

Kline, J. (2011). *Ultrasound guidance in anesthesia*. American Association of Nurse Anesthesiology. https://www.aana.com/docs/default-source/aana-journal-web-documents-1/ultrasound_0611_p209-217b77f37731dff6ddbb37cff0000940c19.pdf?sfvrsn=53805ab1_6

Kovacheva, V. P., Brovman, E. Y., Greenberg, P., Song, E., Palanisamy, A., & Urman, R. D. (2019). A contemporary analysis of medicolegal issues in obstetric anesthesia between 2005 and 2015. *Anesthesia & Analgesia*, *128*(6), 1199–1207. https://doi.org/10.1213/ane.0000000000003395

Lee, Y., Tanaka, M., & Carvalho, J. (2008). Sonoanatomy of the lumbar spine in patients with previous unintentional dural punctures during labor epidurals. *Regional Anesthesia and Pain Medicine*, *33*(3), 266–270. https://doi.org/10.1016/j.rapm.2007.12.002

Margarido, C. B., Arzola, C., Balki, M., & Carvalho, J. A. (2009). Anesthesiologists' learning curves for ultrasound assessment of the lumbar spine. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie*, *57*(2), 120–126. https://doi.org/10.1007/s12630-009-9219-2

Melnyk, B., & Fineout-Overholt, E. (2019). *Evidence-based practice in nursing & healthcare: A guide to best practice* (4th ed.). LWW.

Nagelhout, J. J., & Elisha, S. (2018). *Nurse anesthesia* (6th ed.). Saunders.

National Institute for Health and Care Excellence. (2008). *Ultrasound-guided catheterisation of the epidural space interventional procedures guidance*. https://www.nice.org.uk/guidance/ipg249/resources/ultrasoundguided-catheterisation-of-the-epidural-space-pdf-1899865404843973

Perlas, A., Chaparro, L. E., & Chin, K. J. (2016). Lumbar neuraxial ultrasound for spinal and epidural anesthesia: a systematic review and meta-analysis. *Regional Anesthesia and Pain Medicine*, *41*(2), 251–260. https://doi.org/10.1097/AAP.0000000000000184

Perna, P., Gioia, A., Ragazzi, R., Volta, C. A., & Innamorato, M. (2017). Can pre-procedure neuroaxial ultrasound improve the identification of the potential epidural space when

compared with anatomical landmarks? a prospective randomized study. *Minerva Anestesiologica*, *83*(1). https://doi.org/10.23736/s0375-9393.16.11399-9

Rana, S., Gupta, B., Verma, A., & Awasthi, H. (2020). Ultrasound-assisted subarachnoid block in obese parturient: Need of the hour. *Saudi Journal of Anaesthesia*, *14*(2), 228. https://doi.org/10.4103/sja.sja_619_19

Sadeghi, A., Patel, R., & Carvalho, J. (2021). Ultrasound-facilitated neuraxial anaesthesia in obstetrics. *BJA Education*, *21*(10), 369–375. https://doi.org/10.1016/j.bjae.2021.06.003

Sahin, T., & Balaban, O. (2018). Lumbar ultrasonography for obstetric neuraxial blocks: Sonoanatomy and literature review. *Turkish Journal of Anesthesia and Reanimation*, *46*(4), 257–267. https://doi.org/10.5152/tjar.2018.90277

Santos, A., Epstein, J., & Chaudhuri, K. (2015). *Obstetric anesthesia*. McGraw-Hill Education / Medical.

Sidiropoulou, T., Christodoulaki, K., & Siristatidis, C. (2021). Pre-procedural lumbar neuraxial ultrasound—a systematic review of randomized controlled trials and meta-analysis. *Healthcare*, *9*(4), 479. https://doi.org/10.3390/healthcare9040479

Spence, D., Nations, R., Rivera, O., Bowdoin, S., Hazen, B., Orgill, R., & Maye, J. (2012). Update for nurse anesthetists evidence-based anesthesia: The use of preprocedural ultrasonography during labor to facilitate placement of an epidural catheter. *AANA Journal*, *80*(3), 223–230.

Tao, B., Liu, K., Ding, M., Xue, H., Li, X., & Zhao, P. (2020). Ultrasound increases the success rate of spinal needle placement through the epidural needle during combined spinal-epidural anaesthesia. *European Journal of Anaesthesiology*, *38*(3), 251–258. https://doi.org/10.1097/eja.0000000000001380

Tawfik, M., Atallah, M., Elkharboutly, W., Allakkany, N., & Abdelkhalek, M. (2017). Does preprocedural ultrasound increase the first-pass success rate of epidural catheterization before cesarean delivery? a randomized controlled trial. *Anesthesia & Analgesia*, *124*(3), 851–856. https://doi.org/10.1213/ane.0000000000001325

Tawfik, M. M., Elrefaey, A. A., Abdelkhalek, M., & Makroum, A. A. (2015). Ultrasound-guided spinal anesthesia for cesarean section in a parturient with spinal metastases. *Journal of Clinical Monitoring and Computing*, *30*(6), 857–858. https://doi.org/10.1007/s10877-015-9785-5

Turkstra, T. P., Marmai, K. L., Armstrong, K. P., Kumar, K., & Singh, S. (2017). Preprocedural ultrasound assessment does not improve trainee performance of spinal anesthesia for obstetrical patients: A randomized controlled trial. *Journal of Clinical Anesthesia*, *37*, 21–24. https://doi.org/10.1016/j.jclinane.2016.10.034

Twin Oaks Anesthesia. (n.d.-a). CRNA Conferences - Twin Oaks Anesthesia. https://www.twinoaksanesthesia.com/courses

Twin Oaks Anesthesia. (n.d.-b). *Spinal & epidural ultrasound*. Twin Oaks CEs Online. https://www.twinoaksceonline.com/courses/spinal-epidural-ultrasound

Ultrasound Solutions Corp. (2022). *How much does an ultrasound machine cost*. Ultrasound Solutions Corp.. https://www.uscultrasound.com/blog/ultrasound-machine-cost/#:~:text=Ultrasound%20machine%20prices%20vary%20depending,for%20between%20%2420%2C000%20and%20%2475%2C000.

Wu, J.-P., Tang, Y.-Z., He, L.-L., Zhao, W.-X., An, J.-X., & Ni, J.-X. (2021). Preprocedure ultrasound imaging combined with palpation technique in epidural labor analgesia. *World Journal of Clinical Cases*, *9*(21), 5900–5908. https://doi.org/10.12998/wjcc.v9.i21.5900

Young, B., Onwochei, D., & Desai, N. (2020). Conventional landmark palpation vs. preprocedural ultrasound for neuraxial analgesia and anaesthesia in obstetrics – a systematic review and meta-analysis with trial sequential analyses. *Anaesthesia*, *76*(6), 818–831. https://doi.org/10.1111/anae.15255

ZipRecruiter. (2022a). *CRNA salary*. https://www.ziprecruiter.com/Salaries/CRNA-Salary#:~:text=%2485.82%20is%20the%2025th%20percentile,Wages%20below%20this%20are%20outliers.&text=%24125.00%20is%20the%2075th%20percentile,Wages%20above%20this%20are%20outliers.

ZipRecruiter. (2022b). *Health information technology specialist*. Retrieved September 29, 2022, from https://www.ziprecruiter.com/Salaries/Health-Information-Technology-Specialist-Salary

ZipRecruiter. (2022c). *Quality improvement specialist salary*. https://www.ziprecruiter.com/Salaries/Quality-Improvement-Specialist-Salary#:~:text=As%20of%20Sep%206%2C%202022,%2Fweek%20or%20%244%2C482%2Fmonth.

Appendix A

Literature Summary Table

Citation	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables; Definitions	Outcome Measurement	Data Analysis	Findings	Level of Evidence	Quality of Evidence
Arzola, C., Mikhael, R., Margarido, C., & Carvalho, J. C. (2015). Spinal ultrasound versus palpation for epidural catheter insertion in labour. European Journal of Anaesthesiology, 32(7), 499–505. https://doi.org/10.1097/eja.0000000000000119	To determine if preprocedural ultrasound improves the ease of insertion of labor epidural catheters compared to palpation technique following a training program in ultrasound assessment of the spine for a group of anesthesia residents and fellows.	RCT	164 parturients requesting epidural for labor at an academic hospital in Toronto, Canada assessed for eligibility. 36 parturients didn't meet inclusion criteria or declined to participate. 128 parturients randomized for study (84 epidurals performed by 17 residents and 44 epidurals performed by 5 fellows) Inclusion criteria = full-term parturients with easily palpable lumbar spines. Exclusion criteria = patients with contraindications to epidural anesthesia	IV = The intervention of interest was preprocedural ultrasound compared to the control of palpation as a method for neuraxial anesthesia placement. DV = time taken to insert epidural catheter, number of interspace levels attempted (need to attempt a second interspace), number of needle passes, total procedure	Outcome data collected on dependent variables by a blinded research assistant. In addition, a Patient Satisfaction Questionnaire on a 5-point scale was used.	Student's t-test or Wilcoxon Rank Sum test and Pearson's Chi-square or Fisher's exact test were used to analyze continuous and categorical variables. Multivariable analysis was used to analyze duration of procedures.	No difference in epidural insertion time between U/S and palpation group P = 0.14. No significant difference in palpation vs U/S respectively in FPS (50% vs 60%, P=0.26), number of interspace levels attempted (4/68 vs 2/60, P = 0.68), number of	I	B Study is limited due to a smaller sample size, varying degrees of anesthesia experience (resident vs fellow), and the study only includes the use of preprocedural U/S on patients with easily palpable spines. In addition, the patient satisfaction questionnaire was not validated.

			and patients with previous spinal surgery, trauma, or spinal deformity.	time (assessment + insertion time), first pass success rate, number of attempts required to thread epidural catheter, failure of epidural, patient satisfaction			needles passes (P =0.43), number of threading attempts (P = 0.93, and patient satisfaction. No failures of epidural analgesia occurred.		
Canturk, M., Karbancioglu Canturk, F., Kocaoglu, N., & Hakki, M. (2019). Abdominal girth has a strong correlation with ultrasound-estimated epidural depth in parturients: A prospective observational study. Journal of Anesthesia, 33(2), 273–	To determine if there is a correlation between U/S estimated epidural depth with abdominal girth, body mass index (BMI), weight, height, and age in parturients.	Prospective, Observational study	130 parturients scheduled for elective cesarean section with combined spinal epidurals (CSE). ASA status of II-III, singleton term pregnancy, aged 18-45. Exclusions included parturients with neurological diseases, vertebral column anomalies, history of spinal surgery, abnormal fetal presentations, multiple pregnancies, history of complicated	IV = patient characteristics such as age, weight, height, BMI, abdominal girth (AG) DV = skin to epidural depth	Patient age, height, weight, and BMI recorded. AG measured at umbilicus in the sitting position	Bivariate linear correlation and linear regression analysis used for testing correlation between U/S estimated skin to epidural depth in the transverse median plane (TP) and paramedian sagittal oblique	Statistically significant results (p <0.05) that showed epidural depth measured by U/S correlates with actual epidural depth in the TP and PSO view. In addition, estimated epidural depth strongly	III	B Study limited due to not considering ethnicity of patient sample. Height and weight ratios were also not considered for correlation.

278. https://doi.org/10.1007/s00540-019-02621-9			pregnancies, and contraindications to CSE.			(PSO) plane with age, weight, height, AG, and BMI	correlated with AG, BMI, and weight but not for age and height.		
Carvalho, J. (2008). Ultrasound-facilitated epidurals and spinals in obstetrics. Anesthesiology Clinics, 26(1), 145–158. https://doi.org/10.1016/j.anclin.2007.11.007	Provides expert opinion, method of intervention, and a summary of research and theoretical literature on using U/S to facilitate epidurals and spinals in obstetrics.	Expert opinion based on experience and literature.	N/A	N/A	N/A	N/A	Provides methodology for using preprocedural U/S in neuraxial anesthesia. Provides positive expert opinion for using preprocedural U/S.	V	B Expertise appears to be credible, but credibility cannot be confirmed as evident.
Chin, A., Crooke, B., Heywood, L., Brijball, R., Pelecanos, A. M., & Abeypala, W. (2018). A randomised controlled trial comparing needle	To determine the efficacy of preprocedural ultrasound for CSE compared to the traditional approach.	RCT	218 parturients undergoing CSE for cesarean delivery were randomized in the study to U/S group (n=106) or the control group (n = 112). Each group had 1 participant excluded from analysis due to missing data. 99	IV = The intervention of interest was preprocedural ultrasound compared to the control of palpation as a method for neuraxial anesthesia placement.	A study investigator observing the CSE procedure recorded outcomes related to FPS and needle movemen	Descriptive statistics used to calculate patient characteristic and outcomes. Pearson Chi-squared test used to test association	Statistically significant results showing that respectively in the U/S group vs control group FPS was achieved in 67	I	B Separate operators were used in the study in performing preprocedural U/S and the CSE procedure itself which may

movements during combined spinal-epidural anaesthesia with and without ultrasound assistance. Anaesthesia, 73(4), 466–473. https://doi.org/10.1111/anae.14206			participants were excluded from original assessment for eligibility due to no scanner available, no patient consent, and not meeting inclusion criteria of age > 18 years, > 37 weeks gestation, and scheduled elective caesarean section without complications.	DV = FPS (single insertion with no needle redirections), difficulty of the CSE procedure, needle movements, block quality, and patient pain and satisfaction during CSE placement	ts. A verbal numerical rating scale was used for the patient to rate pain. To rate satisfaction, 5-point Likert scale was used.	between categorical variables. Fischer's exact test used when Chi-square assumptions not met. Student's t-test used to show differences between groups for parametric continuous variables. Mann Whitney U-tests used for non-parametric continuous variables.	participants (63.8%) vs 42 (38.2%) (adjusted p = 0.001), CSE was difficult in 19 (18.1%) vs 33 (30.0%) (unadjusted p =0.042), additional needle insertions in 20 (19%) vs 42 (38.2%) (adjusted p = 0.005), and needle redirections of 36 (34.3%) vs 64 (58.2%) (adjusted p = 0.002). There were no statistically significant differences in the other outcomes.		underestimate the benefits of U/S. Study size for multiple variables is small such as when looking at different difficulties of palpation.

Creaney, M., Mullane, D., Casby, C., & Tan, T. (2016). Ultrasound to identify the lumbar space in women with impalpable bony landmarks presenting for elective caesarean delivery under spinal anaesthesia: A randomised trial. *International Journal of Obstetric Anesthesia*, *28*, 12–16. https://doi.org/10.1016/j.ijoa.2016.07.007	To compare the efficacy of preprocedural ultrasound to landmark palpation as a method of spinal anesthesia for parturients presenting for elective caesarean delivery who have impalpable spinous processes.	RCT	20 parturients randomized evenly between intervention and control group. Inclusion requirements included ASA status I to II, singleton pregnancy, impalpable spinous processes, and presenting for elective cesarean delivery.	IV = Intervention of interest was preprocedural ultrasound vs the control group of palpation only. DV = number of needle redirections (any ventral advancement of needle or introducer and/or any new intervertebral space attempted), procedural time (insertion site identification, needle insertion, and overall procedure time), patient satisfaction score	Outcomes were recorded. A 5-point Likert scale used to assess patient satisfaction	Statistical analysis performed with Prism 5 for Mac v 5.0a. Student t-test used to analyze patient demographic and parametric data. Wilcoxon's ranked sum test used for non-parametric data analysis between group comparisons.	Statistically significant results displayed a mean of fewer needle redirections in U/S (3) vs control group (5.5) ($p = 0.03$). Mean time in seconds to mark insertion point of needle was significantly longer in U/S (91.8) vs control group (32.6) ($p < 0.001$) but total time in procedure was about even with a mean around 192 ($p = 0.99$). No difference in	I	B Sample size is small. Palpability of spines is subjective between anesthesia providers. Blinding was not attempted.

							patient satisfaction.		
Dhanger, S., Vinayagam, S., Vaidhyanathan, B., Rajesh, I., & Tripathy, D. (2018). Comparison of landmark versus pre-procedural ultrasonography-assisted midline approach for identification of subarachnoid space in elective caesarean section: A randomised controlled trial. Indian Journal of Anaesthesia, 62(4), 280. https://doi.org/10.4103/ija.ija_488_17	To study the efficacy of preprocedural ultrasound vs landmark guided spinal anesthesia in parturients undergoing elective caesarean deliveries.	RCT	100 parturients undergoing elective caesarean deliveries. Exclusions included history of spinal surgery or spinal deformity and contraindications to spinal anesthesia.	IV = Intervention of interest was preprocedural ultrasound vs the control group of assessing anatomical landmarks only. DV = number of insertion attempts (number of times needle was withdrawn from the skin and reinserted), needle passes (number of times needle was withdrawn and redirected without exiting the skin), distance between skin and dura mater, and time taken	Outcomes measured during the procedure and recorded.	Statistical analysis completed using SPSS software. Shapiro-Wilk, Chi-square, Fisher exact, and Student t-test used for analysis.	Number of attempts, needle redirections, and total time of procedure significantly decreased in U/S group ($p < 0.001$). Although, time to identify interspace was significantly higher in U/S vs control group ($p < 0.001$).	I	B Sample size is small. Demographics such as ethnicity were not studied. Authors admit to difficulty in blinding anesthesia providers for the study group.

				to identify interspace					
Elgueta, M. F., Duong, S., Finlayson, R. J., & Tran, D. Q. (2017). Ultrasonography for neuraxial blocks: A review of the evidence. Minerva Anestesiologica, 83(5). https://doi.org/10.23736/s0375-9393.16.11650-5	To review and summarize evidence from RCTs that involve the use of U/S for neuraxial blocks.	NR	Reviewed studies pertaining to U/S use separately for epidural, spinal, and caudal techniques. 11 RCTs were used to assess its use in epidural anesthesia. 5 RCTS were reviewed for spinal anesthesia. 1 study was used for caudal anesthesia.	N/A	N/A	N/A	In summary, preprocedural U/S increases first pass success rate of neuraxial needle placement especially in patients with difficult spinal anatomy.	V	B Evidence is spread between different populations.
Gayathri, B., Swetha Ramani, C. K., Urkavalan, K., Pushparani, A., & Rajendran, A. (2021). Comparison of the time taken for subarachnoid	To determine the efficacy of preprocedural ultrasound vs landmark technique for spinal anesthesia for parturients	RCT	60 pregnant patients with ASA status II and BMI between 24-34 kg/m^2 undergoing elective cesarean section. Patient with contraindications to spinal anesthesia were excluded from the study.	IV = preprocedural U/S vs traditional landmark technique DV = Procedural time, preparation time (identify	Outcome were measured during the procedure. Satisfaction was assessed post-surgery.	A Likert scale was used to assess patient satisfaction.	The study found statistically significant results ($p < 0.05$) showing that preprocedural ultrasound compared to traditional landmark	I	B Small sample size. Authors of study admit to difficulty in blinding patients and observers.

block using ultrasound-guided method versus landmark technique for cesarean section – a randomized controlled study. Journal of Anaesthesiology Clinical Pharmacology, 37(2), 205. https://doi.org/10.4103/joacp.joacp_35_20	undergoing cesarean section.			interspace), number of attempts, number of attempts in same interspace, number of attempts in different space, number of needle passes, patient satisfaction			technique decreased number of attempts, number of reattempts in same interspace, number of reattempts in different interspace, number of needle passes, patient, and overall procedure time. Patient satisfaction scores were increased in U/S group (p < 0.0001) but overall preparation time was increased.		
Jiang, L., Zhang, F., Wei, N., Lv, J., Chen, W., & Dai, Z.	Systematically searched, reviewed, and analyzed the literature	SR & MA	18 RCTs with a total of 1844 participants were included. Only RCTs comparing	IV = intervention of preprocedural U/S vs control	Data was extracted from the studies by two	Meta-analysis was completed on outcomes with Review	Preprocedural ultrasound could improve FPS in parturients	I	A Actual level of experience of anesthesia

(2020). Could preprocedural ultrasound increase the first-pass success rate of neuraxial anesthesia in obstetrics? a systematic review and meta-analysis of randomized controlled trials. Journal of Anesthesia, 34(3), 434–444. https://doi.org/10.1007/s00540-020-02750-6	of RCTs to compare the effects of preprocedural U/S vs palpation method of neuraxial anesthesia placements in obstetrical patients.		preprocedural ultrasound vs landmark location for placement of neuraxial anesthesia in obstetrics were used. Studies were excluded if they included patients pregnant with twins, scheduled for emergency cesarean deliveries, had unobtainable data, or included patients with contraindications to neuraxial anesthesia.	of palpation technique DV = FPS, number of redirections, number of punctures, identification and procedure time, incidence of failed puncture, adverse events	independent authors. Quality of studies was assessed using Cochrane Collaborations Risk of Bias Tool.	Manager 5.2 software.	with predicted difficulty but not in non-difficult cases. It could also decrease number of redirections, number of punctures, and identification time. Adverse events such as vascular puncture and backache could also be decreased.		providers was difficult to assess which is a potential limitation.
Kenevan, M. R., Smith, H. M., Olsen, D. A., & Sharpe, E. E. (2018). Ultrasound-assisted combined spinal-epidural anesthesia for cesarean	To present a case report where preprocedural U/S was used on a patient to provide neuraxial anesthesia who	Case report	A 37-year-old gravida 2 para 1 parturient with Currarino syndrome, obesity, and previous history of failed spinal anesthesia for labor.	N/A	N/A	N/A	Preprocedural U/S was found to be useful in providing safe and effective neuraxial anesthesia to a laboring patient with	V	B

delivery in a parturient with currarino triad: A case report. *A&A Practice*, *12*(11), 393–395. https://doi.org/10.1213/xaa.0000000000000941	presented with Currarino triad.						spinal deformity.		
Lee, Y., Tanaka, M., & Carvalho, J. (2008). Sonoanatomy of the lumbar spine in patients with previous unintentional dural punctures during labor epidurals. Regional Anesthesia and Pain Medicine, 33(3), 266–270. https://doi.org/	To determine if U/S imaging of patients with a history of unintentional dural puncture is abnormal and associated with increased complications compared to patients with a history of uneventful epidural placement	Case-control study	94 patients with previous unintentional dural puncture (UDP) were selected from a database. Exclusions included patients with history of spine surgery and spinal deformities. Inclusion required that all UDP occurred with a midline approach. Only 18 of the patients selected from the database became part of the study. 18 volunteers without UDP history were also	IV = Cases = History of UDP Control = No history of UDP DV = presence of an abnormal ligamentum flavum, measurement of ligamentum flavum depth, and symmetry of neuraxial structures	L1-S1 U/S of the spine was completed by 3 investigators. Images were saved for each interspace. Anatomy was reviewed by all 3 investigators and rated/measured	Data was analyzed with P values and confidence intervals of the odds ratios for abnormal outcomes discovered. Additional statistical analysis was completed on the data.	Abnormal U/S imaging of the ligamentum flavum was found to be significantly higher in the patients with a history of UDP, especially in the L4-5 and L3-4 interspace levels ($P < 0.0001$). This gives potential in possibly detecting	II	B Small sample size. Investigators were not blinded between case and control groups.

10.1016/j.rapm.2007.12.002	for labor neuraxial anesthesia.		selected from the staff as the control group.		for the dependent variables.		patients at risk of UDP.		
Perna, P., Gioia, A., Ragazzi, R., Volta, C. A., & Innamorato, M. (2017). Can pre-procedure neuroaxial ultrasound improve the identification of the potential epidural space when compared with anatomical landmarks? a prospective randomized study. Minerva Anestesiologica, 83(1). https://doi.org/10.23736/s0375-9393.16.11399-9	To determine if preprocedural U/S vs palpation of anatomical landmarks reduces needle insertion attempts.	RCT	60 parturients receiving epidural analgesia for labor at a labor ward of the Operative Unit of Anesthesia of S. Maria delle Croci Hospital, Ravenna.	IV = preprocedural ultrasound or palpation of anatomical landmarks for neuraxial anesthesia placement DV = number of needle insertion attempts, needle skin-to-tip distance of epidural space and measured U/S depth to epidural space.	One experienced anesthetist performed all the epidurals of the study. Each needle redirection was considered a needle insertion attempt.	Data calculations completed using Microsoft Excel® 2010, SPSS Statistics® v.20 and MedCalc®. X^2 and Student's t-test were used for analysis in addition to nonparametric K-sample tests. Bland-Altman analysis and Pearson's correlation were also used.	Number of needle redirections, repositions, and total attempts were significantly decreased in the preprocedural U/S group (respectively, $P < 0.024$, $P < 0.018$, $P < 0.019$). There is a strong correlation between real epidural depth and estimated depth by U/S.	I	A

Rana, S., Gupta, B., Verma, A., & Awasthi, H. (2020). Ultrasound-assisted subarachnoid block in obese parturient: Need of the hour. Saudi Journal of Anaesthesia, 14(2), 228. https://doi.org/10.4103/sja.sja_619_19	A case report of a parturient with a history of postdural puncture headache and anticipated difficulty in performing neuraxial anesthesia. Preprocedural U/S used and reported on.	Case report	A 28-year-old, 95 kg (BMI = 39.1 kg/m2) who is scheduled for elective caesarean section under a spinal block.	N/A	N/A	N/A	It is the authors opinion that preprocedural U/S is useful for neuraxial anesthesia placement especially in patients with impalpable spine anatomy or obese parturients.	V	B
Sadeghi, A., Patel, R., & Carvalho, J. (2021). Ultrasound-facilitated neuraxial anaesthesia in obstetrics. BJA Education, 21(10), 369–375. https://doi.org/	To provide steps in performing preprocedural U/S as a method for neuraxial anesthesia placement in obstetrics and provide a literature review on the subject.	Literature review	N/A	N/A	N/A	N/A	Recommends the use of preprocedural U/S in obstetrics to improve neuraxial anesthesia outcomes. Authors also recommend routine use and training of U/S to	V	A

10.1016/j.bjae.2021.06.003							maintain skills.		
Sahin, T., & Balaban, O. (2018). Lumbar ultrasonography for obstetric neuraxial blocks: Sonoanatomy and literature review. Turkish Journal of Anesthesia and Reanimation, 46(4), 257–267. https://doi.org/10.5152/tjar.2018.90277	To evaluate preprocedural U/S use, technique, impact, and limitations with a review of the literature.	Literature review	N/A	N/A	N/A	N/A	Despite limitations provided, the authors believe preprocedural U/S could be strongly recommended.	V	B Fairly definitive conclusion and recommendations provided.
Sidiropoulou, T., Christodoulaki, K., & Siristatidis, C. (2021). Pre-procedural lumbar neuraxial ultrasound—a	To systematically review RCTs that study the use of preprocedural U/S vs non ultrasound assisted	SR & MA	32 RCTS met inclusion criteria which involved 3,439 adult patients receiving neuraxial procedures. The RCTs were not limited to only obstetrical patients.	IV = preprocedural U/S vs non ultrasound assisted neuraxial anesthesia placement	Two independent authors extracted relevant data from the studies and a	Review Manager software was used to perform meta-analysis.	Preprocedural U/S reduces failure rate, number of needle redirections, and increases first attempt	I	A

systematic review of randomized controlled trials and meta-analysis. Healthcare, 9(4), 479. https://doi.org/10.3390/healthcare9040479	neuraxial anesthesia placement and make recommendations based on meta-analysis.			DV = technical failure rate, number of needle redirections, total procedure time, needling time,	third resolved discrepancies found. Several tools were used to assess for limitations and risk of bias.		success rate. Time of procedure is not increased.		
Spence, D., Nations, R., Rivera, O., Bowdoin, S., Hazen, B., Orgill, R., & Maye, J. (2012). Update for nurse anesthetists evidence-based anesthesia: The use of preprocedural ultrasonography during labor to facilitate placement of an epidural	To describe technique for preprocedural U/S use in neuraxial aensthesia for patients in labor, systematically review the literature, and discuss how preprocedural U/S can be integrated into practice.	SR	16 studies. 1 SR, 5 RCTs, 1 cohort study, 1 case-control study, and 8 descriptive-correlational studies.	N/A	N/A	N/A	Preprocedural U/S may reduce number of puncture attempts, interspace determinations, and catheter insertions for epidural placement. Practical tips on the use of U/S are provided.	I	A

catheter. AANA Journal, 80(3), 223–230.									
Tao, B., Liu, K., Ding, M., Xue, H., Li, X., & Zhao, P. (2020). Ultrasound increases the success rate of spinal needle placement through the epidural needle during combined spinal-epidural anaesthesia. European Journal of Anaesthesiology, 38(3), 251–258. https://doi.org/10.1097/eja.0000000000001380	To determine if preprocedural ultrasound can increase FPS of spinal needle placement through the epidural needle during combined spinal-epidural anesthesia.	RCT	140 randomized paturients with inclusion criteria of age 24-52, ASA status II-III, and 38-40 weeks gestation scheduled for elective caesarean section with combined spinal-epidural anesthesia at a hospital in China.	IV = preprocedural ultrasound vs traditional technique DV = FPS, total duration of procedure, needle redirections, complications, and patient satisfaction	Outcomes measured during the procedure. A 5-point Likert scale used for patient satisfaction. Postoperative data collected on complications.	Kolmogorov-Smirnov test, student's t-test, Mann-Whitney U, x^2, Fisher's exact, and p value used for statistical analysis using GraphPad Prism 8 for macOS.	FPS was significantly higher in the U/S group P < 0.001. Duration of total combined spinal-epidural (p < 0.0015) and spinal procedure (p < 0.0003) were significantly less.	I	B Small sample size.
Tawfik, M., Atallah, M., Elkharboutly, W.,	To determine differences in	RCT	108 parturients (53 in U/S group and 55 in palpation group). Inclusion	IV = preprocedural U/S vs palpation	A blinded investigator entered the room	Data analyzed with Kolmogorov	Study found no significant differences	I	B Small sample size. Only 1

Allakkany, N., & Abdelkhalek, M. (2017). Does preprocedural ultrasound increase the first-pass success rate of epidural catheterization before cesarean delivery? a randomized controlled trial. Anesthesia & Analgesia, 124(3), 851–856. https://doi.org/10.1213/ane.0000000000001325	preprocedural U/S vs palpation method on FPS, number of needle passes, skin punctures, duration of procedure, patient satisfaction, and complications.		criteria = age 19-40 years, BMI < 35, ASA status II, full term singleton pregnancy, elective cesarean delivery with combined spinal-epidural anesthesia.	method for neuraxial anesthesia placement DV = FPS, number of needle pass and skin punctures, duration of procedure, patient satisfaction, and complications from procedure	to record outcomes.	-Smirnov test, means +/- SD, Student t-test, median, Mann Whitney U test, x^2 or Fisher exact test, p values using R software.	in FPS, number of needle passes and skin punctures, or patient satisfaction.		investigator performed the procedures so generalizability could be low.
Tawfik, M. M., Elrefaey, A. A., Abdelkhalek, M., & Makroum, A. A. (2015).	To provide a case report on a parturient with multiple metastatic	Case report	37-year-old woman, 33 weeks gestation, with cervical and lumbar metastatic lesions.	N/A	N/A	N/A	Per the case report, preprocedural U/S increased the safety of neuraxial	V	B

Ultrasound-guided spinal anesthesia for cesarean section in a parturient with spinal metastases. Journal of Clinical Monitoring and Computing, 30(6), 857–858. https://doi.org/10.1007/s10877-015-9785-5	cervical and lumbar lesions who presented for neuraxial anesthesia placement for a scheduled cesarean delivery with the anesthesia team utilizing U/S for neuraxial anesthesia placement.						anesthesia placement for the patient described in the report.		
Turkstra, T. P., Marmai, K. L., Armstrong, K. P., Kumar, K., & Singh, S. (2017). Preprocedural ultrasound assessment does not improve trainee performance of spinal anesthesia for	To determine efficacy of preprocedural ultrasound on spinal anesthesia placement by trainee residents.	RCT	80 parturients with inclusion criteria of being scheduled for elective cesarean delivery under spinal anesthesia, BMI <40, single gestation, and with no history of scoliosis, previous spinal surgery, or previous failed spinal. Study location at 2	IV = preprocedural U/S vs traditional landmark technique DV = number of attempts, placement duration, block height, incidence of need for staff intervention,	A blinded attending anesthesiologist recorded all outcomes.	Mann-Whiney U or log rank test, fisher exact test or x2, and p value were used to analyze data by a blinded statistician.	There were no statistically significant outcomes discovered in the study.	I	B Residents performing the procedure were aware of the primary outcomes and blinding was not ensured. Sample size was small.

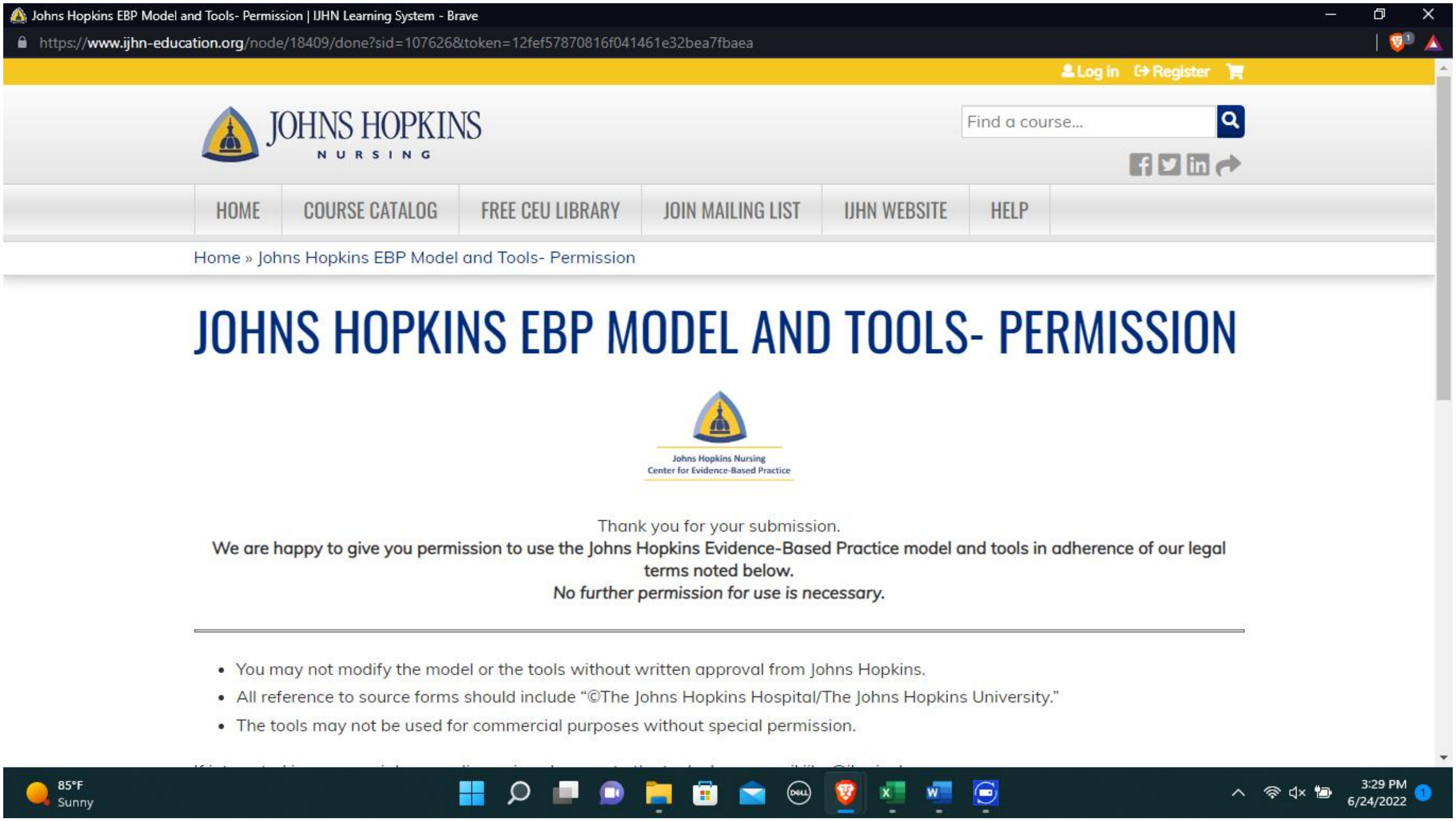
obstetrical patients: A randomized controlled trial. Journal of Clinical Anesthesia, 37, 21–24. https://doi.org/10.1016/j.jclinane.2016.10.034			obstetrical teaching hospitals in Canada.	paresthesia, and bloody taps					
Wu, J.-P., Tang, Y.-Z., He, L.-L., Zhao, W.-X., An, J.-X., & Ni, J.-X. (2021). Preprocedure ultrasound imaging combined with palpation technique in epidural labor analgesia. World Journal of Clinical Cases, 9(21), 5900–5908. https://doi.org/	The study aimed to evaluate utility of preprocedural ultrasound for parturients receiving an epidural.	RCT	72 parturients with inclusion criteria of healthy pregnancy, age 18-40 years, ASA status II or above, active labor, no history of caesarean for dystocia, absence of contraindications to neuraxial anesthesia, absence of mental health history and/or substance abuse, BMI <35 kg/m^2, and no history of hypertension, diabetes, heart failure, or previous caesarean section.	IV = combined preprocedural U/S and palpation method vs palpation only DV = total duration of procedure, time to perform epidural puncture and catheterization, number of needle passes, number of skin punctures, FPS, depth from skin to epidural	Assisting nursing staff recorded outcomes intra and post procedure.	Means +/- SD, x^2 test, and P value were used to analyze the data using SPSS 19.0 software.	Study found that time to perform epidural puncture and catheterization as significantly less in the combined group ($p < 0.001$). Number of needle passes was statistically less in combined group ($P < 0.001$). FPS was	I	A

10.12998/wjcc.v9.i21.5900				space, and complications			statistically higher in combined group (P < 0.045). All other outcomes found to not be statistically significant.		
Young, B., Onwochei, D., & Desai, N. (2020). Conventional landmark palpation vs. preprocedural ultrasound for neuraxial analgesia and anaesthesia in obstetrics – a systematic review and meta-analysis with trial sequential analyses. Anaesthesia, 76(6), 818–831.	To compare the efficacy of preprocedural U/S vs landmark technique with a systematic review and meta-analysis of the literature.	SR & MA	22 RCTs were included with a total of 2,462 parturients.	IV = preprocedural U/S vs landmark palpation DV = FPS, total procedure time (identification of needle insertion site + neuraxial procedure time), additional efficacy outcomes, complications, and adverse effects	Two authors independently screened and assessed for bias with Cochran Collaboration tools for all eligible articles.	Review Manager software was used to perform meta-analysis.	Study found that preprocedural U/S increases the FPS and decreases complications without increasing total procedure time.	I	A

https://doi.org/10.1111/anae.15255									

Appendix B

JHNEBP Model Permission



Appendix C

RECOMMENDATIONS FOR USING PREPROCEDURAL ULTRASOUND TO FACILITATE LABOR NEURAXIAL ANESTHESIA

CURRENT PRACTICE

- ☐ Preprocedural ultrasound is not commonly used to facilitate neuraxial anesthesia procedures for laboring patients. Most providers use visualization and palpation of the anatomy to determine neuraxial needle placement. This technique is considered "blind" since assessment of projected needle depth, angle of needle trajectory, and any underlying anatomical variations is unachievable.

RECOMMENDATION #1

Train all obstetrical anesthesia providers on how to use preprocedural ultrasound to facilitate neuraxial anesthesia placement.

- ☐ Training on preprocedural ultrasound to facilitate neuraxial procedures provides the anesthesia provider with an additional method of placing neuraxial needles which has potential to increase first pass success rates and decrease complications.

RECOMMENDATION #2

Purchase an ultrasound machine to be exclusively used for neuraxial anesthesia procedures.

- ☐ Availability of an ultrasound machine in each labor suite will reduce time required to use preprocedural ultrasound to facilitate neuraxial anesthesia procedures.

RECOMMENDATION #3

Use preprocedural ultrasound to facilitate neuraxial anesthesia provided to laboring patients who meet one or more of the following criteria: BMI >30, impalpable neuraxial landmarks, marked deformity of the spine, or history of difficult neuraxial anesthesia.

- ☐ Preprocedural ultrasound has the potential to increase first pass success rates and decrease complications especially for patients with the criteria above associated with the predicted difficulty of the neuraxial procedure.

RECOMMENDATION #4

Monitor staff adherence of provided clinical recommendations along with monitoring clinical outcomes including first pass success rates of neuraxial needle placement and complications associated with neuraxial anesthesia placement.

- ☐ Implementation of preprocedural ultrasound will require monitoring of outcomes and adjustments to the project.