Final Scholarly Project: Implementation Guidelines of Ultrasound-Guided Regional Anesthesia in Pediatric Cardiac Surgical Patients

Matthew Hall, BSN, RN, CCRN

Department of Nursing, Otterbein University

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DNP Final Scholarly Project Team:

Dr. Brian Garret, DNP, CRNA, Team Leader

Dr. Ruth Chavez, DNP, NP, Team Leader

Dr. Danielle Winch, DNP, CRNA, Team Member

Dr. Amy Bishop, DNP, AGCNS, Team Member

Approved by: Brian Garrett, CRNA

Author Note

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Correspondence concerning this article should be addressed to Dr. Brian Garret, 1 South Grove Street, Westerville, OH 43081. bgarrett@otterbein.edu

Abstract

In the United States, around 40,000 surgeries are conducted on pediatric patients yearly to address congenital heart disease. These surgeries involve a variety of complications beyond cardiovascular problems, including pain management. Traditional pain management involving intravenous opioids has drawbacks such as sedation, respiratory depression, and prolonged recovery times. As the healthcare industry moves away from opioid-centric pain management, the use of multimodal analgesia, including ultrasound-guided regional anesthesia, is being utilized. Regional anesthesia techniques, such as the transversus thoracis muscle plane block and the thoracic erector spinae block, are being considered for the ability to provide adequate pain relief while reducing opioid usage. The goal of using ultrasound blocks for congenital heart patients is to decrease postoperative opioid consumption and decrease the time to extubation in pediatric cardiac surgical patients in the first 24 hours postoperatively. A 12-month timeline outlines the development of guidelines, staff training, and clinical practice change integration. The project follows the Iowa Model for Evidence-Based Practice to guide its implementation, focusing on reducing opioid use, improving postoperative outcomes, and enhancing patient safety.

Keywords: ultrasound, transversus thoracis muscle, serratus anterior, regional, anesthesia, pediatrics, open-heart, surgery

Implementation Guidelines of Ultrasound-Guided Regional Anesthesia in Pediatric Cardiac Surgical Patients

Introduction of the Problem

Pediatric cardiac surgery is a complex, high-risk procedure that is required to surgically repair congenital birth defects that affect the function of the heart. The incidence of congenital heart defects (CHD) is steadily increasing, with recent reports indicating approximately 12-14 cases per 1000 live births worldwide (Javed et al., 2021). Each year, about 40,000 surgeries are performed for CHD in pediatric patients in the United States (Pasquali et al., 2020). Depending on the severity of the CHDs, these patients will require surgical intervention to repair the deficiencies, which can occur anytime during childhood and adolescence. The procedures are invasive, requiring the thoracic cavity to be open to the air, exposing the heart to the optimum field of view for surgery. Due to the invasiveness of this procedure, postoperative analgesia for pain management and discomfort is often required to support the children after surgery.

Adequate pain control is managed differently between some surgeons and anesthesia providers due to diverse training, which can bring about overprescribing and can result in harmful side effects. Aggressive use of analgesic products can produce undesirable side effects such as sedation, respiratory depression, and extubation failure postoperatively (Saini et al., 2020). There is a significant occurrence of newly established and persistent opioid use in children who have not been exposed to opioids before, following surgery, with reported rates reaching up to 20% (Kelly-Quon et al., 2021). Therefore, exploring innovative multimodal approaches, such as ultrasound-guided (US) regional anesthesia (RA) and early recovery after surgery (ERAS), to reduce analgesic consumption while maintaining optimal pain control is an important aspect to consider.

Although most initial ERAS efforts focused on adult surgical patients, the practice increasingly has become embraced within pediatric surgical subspecialties to optimize care. These principles have been established within congenital heart surgery to promote decreased opioid use, improved pain scores, early extubation (EE), decreased intensive care unit (ICU) and hospital length of stay, and reduced costs (Townsley, 2020). This project aims to develop guidelines for US RA use for pediatric cardiac patients to improve patient outcomes.

Background

Congenital Heart Defects

CHDs are among the most prevalent forms of congenital malformations globally, with surgical intervention as the primary method of repair. The surgical intervention for open-heart surgery (OHS) is a sternotomy. Within the area of the incision, there are numerous nerves, muscles, tendons, and vasculature, which are separated by an incision. Management of postoperative pain after sternotomy presents distinct challenges related to the abundant innervation of the thorax (Kaushal et al., 2018). Due to this disruption, some complications can arise with the cardiovascular and non-cardiovascular systems. Cardiovascular complications consist of cardiac arrest (17.7%), arrhythmias (16.9%), excessive bleeding (19.2%), and emergency need to reopen the chest (9.2%) (Javed et al., 2021). Non-cardiovascular complications include sepsis (17.7%), thoracic/pleural effusion (20.8%), hepatic/gastrointestinal (4.6%), neurological (6.2%), or renal injury (6.2%) (Javed et al., 2021). The surgical intervention, while essential for repairing congenital heart defects, can lead to various complications affecting both cardiovascular and non-cardiovascular systems. Attention to these challenges is crucial for optimizing patient outcomes and ensuring a successful recovery process.

Current Methods

Along with the variety of postoperative complications, pain can inhibit a child's recovery throughout the perioperative period. Pain in the postoperative period can arise from many different sources, including the surgical procedure and various diagnostic and therapeutic procedures. These may include endotracheal intubation, suctioning, and intravenous (IV) placement. Inadequate pain management can lead to complications such as prolonged immobilization, hypertension, hypoxia, pulmonary hypertensive crisis, tachyarrhythmia, and the inability to cough due to median sternotomy (Zhang et al., 2022).

Current methods to treat pain in OHS patients include non-steroidal anti-inflammatories (NSAIDs) and opioids. These methods are administered to the patient either orally or through the IV. Opioids can have adverse effects on both short-term and long-term health outcomes. In the short term, children may experience physiological changes similar to adults, such as decreased respiratory drive, delayed intestinal motility, and sedation, all of which can lead to a prolonged hospital stay (Archer et al., 2022). Therefore, it is essential to explore alternative strategies that minimize reliance on opioids and provide effective pain relief while minimizing adverse effects. Traditionally, IV opioids have been utilized for acute postoperative pain management. Even though IV opioids are effective in controlling postoperative pain, it is not without side effects, such as sedation, respiratory depression, and ileus, that can affect postoperative recovery (Archer et al., 2022). The strict use of opioids for postoperative pain management has yielded appropriate pain management, but the opioid-related side effects have prevented a reduction in recovery time (Hamed et al., 2022).

From 1999 to 2016, pediatric overdoses rose from 0.08/100,000 children to a high of 0.19/100,000, with opioids accounting for the increase in mortality (Kelly et al., 2021). It is

crucial to weigh the benefits of pain relief against the possible adverse effects and to monitor patients closely to ensure their safety. When administering opioids to pediatric patients, considering the potential risks associated with breakthrough pain in the intraoperative and postoperative periods and IV opioid administration is essential to deliver effective care. Finding a balance that will provide the necessary pain relief without causing undue stress on the body or unwanted side effects is essential. (Raj, 2019). This highlights the need for efforts to promote opioid stewardship among surgical and medical professionals caring for children. These efforts are vital considering the recent increase in opioid-associated deaths in the pediatric population.

ERAS

ERAS initiatives involving a multimodal approach to treating surgical patients are linked to significant improvements in clinical outcomes and cost (Townsley, 2020). At its core, ERAS revolves around the concept that patient outcomes can be improved through multiple incremental steps acting synergistically throughout the perioperative period to modulate the physiologic response to surgical stress (Townsley, 2020). Positive pressure ventilation harms pulmonary blood flow in Fontan physiology patients, so transitioning to spontaneous breathing improves pulmonary blood flow and hemodynamics (Baehner et al., 2022). One component of ERAS is the utilization of EE in pediatric cardiac surgical patients in the postoperative period. Different groups have varying definitions of early extubation (EE), which means removing the endotracheal tube in the operating room. In contrast, others use a cut-off of 6 or even 24 hours to define EE (Montoro et al., 2020). Due to advancements in modern medicine, short-acting anesthetics such as remifentanil, dexmedetomidine, and propofol, as well as various regional techniques like intrathecal or caudal morphine, it is now possible to extubate patients early and immediately after longer surgeries involving complex repairs (Tirotta et al., 2020). Including

ERAS as part of a multimodal approach to treat perioperative and postoperative pain leads to improved patient outcomes in the postoperative period.

Significance of the Problem to Nurse Anesthesia

Controlling postoperative pain in pediatric cardiac patients is paramount to providing positive clinical outcomes and reducing potential adverse events. Cardiac surgery has slowly adopted RA techniques in pediatric and adult patients due to bleeding concerns at RA needle sites in heparinized patients (Monahan et al., 2019). Bleeding complications (e.g., spinal epidural hematoma) were a principal concern regarding the use of thoracic epidural anesthesia and land-marked-based paravertebral blocks, owing to why cardiac specialties were delayed in implementing RA protocols (Balan et al., 2021). There are also concerns around landmark-based RA that can lead to venous puncture resulting in infiltration of the LA into blood vessels and causing side effects such as agitation, confusion, and cardiovascular toxicity (NYSORA, 2024). Compared to landmark-based paravertebral blocks, US-guided paravertebral blocks are more consistent and safer (Balan et al., 2021). Understanding and proficiency in US techniques is a vital skill anesthesia providers must possess to administer regional anesthesia effectively.

Receiving an RA block can improve pain scores compared to not receiving a block and can be efficacious when placed properly by a well-trained provider. Postoperative pain scores using the Face-Legs-Activity-Cry-Consolability (FLACC) score were significantly lower in patients receiving a thoracic paravertebral block than those patients without a block at the 6, 12, and 24-hour intervals ($p < 0.001$) (Feng et al., 2023). Administering NMB agents before the first incision has been shown by literature to be an effective proactive measure for reducing analgesic requirements (Yamamoto et al., 2020). US NMB is essential for nurse anesthetists caring for pediatric cardiac surgical patients as it enhances RA techniques' precision, safety, and

effectiveness. It allows for tailored pain management and reduces the need for systemic medications, optimizing patient care and outcomes. It is important to note that the cost implications of US NMB can vary depending on factors such as institutional pricing, resource availability, and local healthcare systems. While there may be some initial investment and procedure time considerations, the potential benefits of improved patient outcomes, reduced complications, and optimized pain management may outweigh the associated costs in the long run.

PICO(T) Question

Using the clinical question format, the PICO(T) question guiding this project is: (P) in pediatric cardiac surgical patients (I), would the development of US-guided NMB guidelines and implementation (C) compared to traditional pain management (O) decrease the use of breakthrough analgesic products and decrease time to extubation (T) in the 24-hour postoperative period?

Project Objectives

The first objective of the Doctor of Nursing Practice (DNP) project includes developing evidence-based practice (EBP) guidelines for using US RA on pediatric cardiac surgical patients to improve postoperative outcomes. A second objective includes developing strategic and operational plans to implement the US RA guidelines as established. The third objective consists of developing a comprehensive plan to monitor and measure the US RA guidelines as implemented, including mandatory reporting and data collection through chart reviews. A fourth objective is to create a thorough plan to adjust the guidelines based on recorded outcomes and barriers to implementation.

Literature Synthesis and Analysis

Literature Review

Literature Search

Otterbein OneSearch was used to collect the most up-to-date literature. Otterbein OneSearch is maintained through the Otterbein University Courtright Memorial Library and searches 299 resources for literature using the EBSCO Discovery Service. Literature abstracts were searched using OneSearch and EBSCO, with the operators neuromuscular blockade AND ultrasound-guided AND pediatric AND cardiac AND surgery. They were limited to peer-reviewed literature published in the preceding five years. The initial search resulted in 72 article hits. After the literature was systematically reviewed, with inclusion criteria consisting of types of NMB, study size, and how recently the study was performed, 20 articles were selected.

Literature Synthesis

Regional Anesthesia Added to General Anesthesia. Many medical practitioners embrace RA techniques in cardiac interventions. These techniques aim to facilitate early extubation, minimize postoperative complications, curtail the length of hospital stays, and reduce overall care expenses for patients with CHD (Monahan et al., 2019). Comparatively, in the 24 hours following surgery, patients who underwent RA exhibited lower pain scores than those who solely received systemic analgesia, according to (Monahan et al., 2019). The use of US RA in pediatric cardiac surgical patients resulted in an average reduction of 2.9 points on the Modified Objective Pain Score (MOPS) scale, highlighting the potential benefits of this approach (Monahan et al., 2019). For pediatric open heart patients who received RA, the time to extubation was significantly reduced compared to those who did not receive RA preoperatively or perioperatively (Gams et al., 2023).

Regional Anesthesia. As new research strays from IV opioid use for postoperative pain management increases, implementing multimodal analgesia, including RA and US, becomes more mainstream (Monahan et al., 2019). RA has become a popular alternative to traditional drug-based anesthesia strategies, as it overcomes many of the limitations of opioid analgesia, such as respiratory depression, short half-lives, and risk of addiction. Monahan et al. (2019) describe that RA techniques have reduced IV opioid use in the first 24 hours after surgery for pediatric cardiac surgical patients with a standard difference of 2.1 on a modified objective pain scale. With the advancement of technology such as bedside US, the ease of use can be rapidly incorporated into many pediatric specialties, primarily in critical care and emergency medicine, with interest in the perioperative application quickly expanding due to the ability to perform precise neuromuscular blockade (NMB) (Adler et al., 2019).

Precise imaging of the underlying anatomy provided by US, allows for the advancement in anesthesia techniques to improve, such as the peripheral, epidural, and caudal nerve blocks that are performed safely in the pediatric population with minimal rates of complications (Monahan et al., 2019). Conventional neuraxial techniques included thoracic epidural anesthesia, and land-marked-based paravertebral blocks comprised the standard regional approach to establish chest wall pain analgesia before US practically transformed RA (Balan et al., 2021). Fascial plane blocks have been introduced to help place the blockade closer to the surgery site without a catheter in the epidural space (Raj, 2019). Fascial nerve blockade sites most commonly practiced are the serratus anterior plane block and the pectoral nerve block, also known as PECS I and PECS II (Jack et al., 2020). The PECS I block involves injecting a local anesthetic between the pectoralis major and minor muscles. At the same time, the PECS II incorporates the PECS I and the serratus anterior block, providing improved anesthetic coverage (Jack et al., 2020).

Bilateral erector spinae blocks have begun to be incorporated into regional anesthesia for pediatric patients, as evidence shows that the blocks may improve postoperative pain in adults (Roy et al., 2020).

Utilizing local anesthetics to provide pain relief, along with an ERAS protocol, in the postoperative period helps to decrease the number of opioids consumed by patients. It reduces the length of stay in the ICU and overall hospital stay. After bilateral erector spinae blocks were placed at the end of a cardiac surgical procedure, oral morphine equivalents of patients with blocks were 0.89 ± 0.06 mg/kg versus 1.05 ± 0.06 mg/kg for patients not receiving the block (Roy et al., 2021). 14% of patients who received bilateral US-guided thoracic erector spinae blocks needed rescue analgesia compared to 41% of patients without blocks (Macaire et al., 2020). As US RA is implemented into the pain management of pediatric cardiac surgical patients, the significance of controlling pain is an important aspect that nurse anesthetists have to consider when caring for the pediatric population.

Transversus Thoracis Muscle Plane Block. Multiple RA techniques have been employed to administer NMB to improve pain management and patient outcomes in the pediatric population. Such methods include the transversus thoracis muscle plane block (TTPB), erector spinae block, serratus anterior block, pectoral nerve block, and thoracic paravertebral block. The TTPB is a relatively new block technique developed to place local anesthetics close to the sternum and block several intercostal muscles (Abdelbaser & Mageed, 2020; Cakmak & Isik, 2021; Hamed et al., 2022). Using US probes to visualize the precise area for block placement in the post-induction period, two randomized controlled studies performed the TTPB similarly (Abdelbaser & Mageed, 2020; Hamed et al., 2022). The US probe was placed between the fourth and fifth costal cartilage, then the transversus thoracis and intercostal muscles were identified

(Abdelbaser & Mageed, 2020; Hamed et al., 2022). Once the anatomical structures were identified, 0.25% bupivacaine (0.2-0.4 mL/kg) was injected into the interfascial plane between the intercostal muscle and the transversus thoracis muscle between the fourth and fifth costal cartilages on each side of the sternum (Abdelbaser & Mageed, 2020; Hamed et al., 2022).

Application of the TTPB before incision showed improved pain scores and reduced fentanyl consumption during the perioperative, along with the first 24-hour postoperative period (Hamed et al., 2022). Additionally, TTPB has been associated with a lower incidence of non-sternal wound chest pain (Elbardan et al., 2023). Abdelbaser & Mageed (2020) showed that there was a significant reduction in fentanyl consumption in the 24 hours post-extubation, with an average fentanyl use of 9.892 mcg/kg compared to the non-block group with a moderate use of 18.5 mcg/kg. In the first 24 hours postoperative period, Hamed et al. (2022) discovered that the average fentanyl consumption of the TTPB group was 205.7 mcg/kg compared to the non-block group at 390.9 mcg/kg with a mean difference of -185.143 mcg/kg.

Thoracic Erector Spinae Block. The erector spinae plane block (ESPB) is a relatively new RA technique first described by Forero et al. (2016). ESPB is an interfascial plane block that involves the injection of a local anesthetic (LA) beneath the iliocostalis, longissimus, and spinalis muscles (Macaire et al., 2020). Utilizing a US probe, the third and fourth thoracic vertebrae transverse process' is visualized, where the needle tip is placed close to the third thoracic vertebrae transverse process (Macaire et al., 2020). The effect of the ESPB is achieved through the spread of the LA close to the paravertebral space, providing chest wall or abdominal wall analgesia (Roy et al., 2021). The LA is administered through a single shot of ropivacaine (0.1%/0.2%) followed by a programmed intermittent bolus (PIB) of ropivacaine (0.1%/0.2%) for 48 hours (Macaire et al., 2020).

In the first 24 hours, postoperative pain scores decreased significantly in patients receiving ESPB with ropivacaine after extubation and chest tube removal (Macaire et al., 2020; Luo et al., 2021). Macaire et al. (2020) discovered in a randomized controlled study that 41% of patients in the saline infusion group required a total dose of 512 $\pm$ 560 mcg/kg of morphine in the first 48 hours, while 14% of the ropivacaine infusion group required 120 $\pm$ 320 mcg/kg of morphine. The use of US ESPB resulted in lower pain scores and less opioid usage compared to those who did not receive the block, despite all patients following a multimodal pain regimen guideline in an ERAS protocol (Roy et al., 2021). Time to extubation, pediatric intensive care unit (PICU) length of stay, and overall hospital stay were not statistically different between the variable and control groups (Luo et al., 2021; Macaire et al., 2020; Roy et al., 2021).

Using ESPB does not always produce improved outcomes, as Luo et al. (2021) discovered that differences in pain scores were not statistically significant at the 12 and 24-hour marks between the control and variable groups but did reduce the amount of rescue analgesics required in the postoperative period. Concerns with ESPB focus on catheter displacement and the extent of the spread of the LA. Displacement of the catheter is of concern in the pediatric population, as patients are more likely to move around and not follow directions (Luo et al., 2021; Macaire et al., 2020). There is also concern that if the catheter is dislodged, the PIB of ropivacaine is not as effective in providing adequate analgesia (Macaire et al., 2020). The area of LA spread in the vertebral region is still debated, with concerns that LA could extend at least three to four vertebral levels cranially and caudally from the injection site (Macaire et al., 2020).

Serratus Anterior Plane Block. Serratus anterior plane block (SAPB) is a relatively new plane block that is being incorporated into pediatric cardiac surgery. SAPB requires that the patient be placed in a lateral decubitus position and utilize a US probe to facilitate identifying

anatomical structures in the chest (Kaushal et al., 2019; Jack et al., 2020). Compared to other methods for performing NMB in the anterior thoracic region, SAPB has shown lower pain scores and opioid requirements (Jack et al., 2020; Kaushal et al., 2019). Compared to an intercostal nerve block, SAPB reduces the amount of rescue fentanyl used in the postoperative period by 1.47 ± 0.47 mcg/kg versus 2.12 ± 0.63 mcg/kg (Kaushal et al., 2019). Jack et al. (2020) discovered that combining SAPB with pectoral nerves II blocks improved pain control compared to single-block administration. The SAPB and PECS II blocks are becoming popular alternatives for pain relief, as the blocks can be performed in a supine position, and the injection site is away from structures that could cause hemodynamic instability (Jack et al., 2020).

Thoracic Paravertebral Block. Thoracic paravertebral blocks (TPVB) are another regional technique that has been shown to reduce analgesia requirements for pediatric cardiac surgical patients. The TPVB is performed by placing the patient in the lateral decubitus position after anesthesia induction (Feng et al., 2023). At hours six, 12, and 24, pain scores were decreased in the TPVB group compared to the group that only received PNCA (Feng et al., 2023). Within 24 hours postoperatively, infants and children receiving TPVB and PNCA had significantly lower total and invalid PCA attempts and decreased intraoperative sufentanil consumption (Feng et al., 2023). Time to extubation for TPVB and PNCA patients was reduced compared to the group that did not receive TPVB. There was no statistically significant difference in the ICU and overall hospital length of stay (Feng et al., 2023).

Summary of Literature. After reviewing the literature, TTPB and ESPB have proven effective in alleviating pain in pediatric patients undergoing open heart surgery. The literature review indicates that ESPBs have been successfully carried out on hundreds of children without any reported complications (Holland & Bosenberg, 2019). Moreover, TTPB has been

demonstrated to provide longer-lasting pain relief and reduce the need for opioid analgesics during the perioperative period. The use of TTPB has also resulted in lower pain scores, less postoperative breakthrough pain, and increased patient satisfaction. Reducing the number of opioids the patient requires, and EE in pediatric open-heart patients is crucial in promoting comfort, facilitating faster recovery, optimizing respiratory function, improving outcomes, and enhancing patient satisfaction. Based on the literature review and available data, the TTPB has been selected for incorporation into the proposed guidelines.

Evidence-Based Practice Model

The Iowa Model has emerged as a highly regarded framework that healthcare researchers and practitioners use to implement evidence-based interventions. Originating in the 1990s, it was developed by nurses at the University of Iowa Hospitals as a multi-step process for promoting quality care through implementing EBP (Buckwalter et al., 2017). The model is grounded in the Diffusion of Innovations theory, which explains how new ideas and technology disseminate (Melnyk & Fineout-Overholt, 2018). The Iowa Model is an appropriate framework for implementing US-guided NMB in pediatric cardiac patients in the perioperative and postoperative periods.

The Iowa Model has evolved to keep up with the ever-changing healthcare landscape and the increasing need for EBP. The current version of the Iowa Model employs a 10-step, multiphase approach to implementing EBP in healthcare, which involves three key decision points (Appendix A). Buckwalter et al. (2017) found that specific steps, including topic prioritization, critique, pilot, and institute change, were particularly challenging for participants. Based on these findings, the authors revised the model to address these issues, and it is now in its current state.

Design and Methods

Step 1: Identifying the Triggering Issues/Opportunities

The practice problem is related to the urgent need to decrease the amount of opioid medication prescribed to pediatric cardiac surgical patients during surgical or interventional procedures. This must be done while also improving pain management for these patients. The issue is especially challenging due to the high-risk nature of these procedures. However, it requires attention to ensure that these patients receive the best possible care.

Step 2: State the Question or Purpose

This project aims to meet the predetermined objectives and create a set of guidelines for the implementation of utilizing US RA to benefit pediatric cardiac surgical patients. The data identified the pediatric population at risk for decreased pain control and extended time to extubation through traditional anesthesia techniques. The data helps to define the project, but the EBP model will help maintain the project's focus and determine how to implement and evaluate the EBP initiative. Buckwalter et al. (2017) emphasize the importance of using a PICOT question in EBP, as it provides a clear and concise way to structure the research process. By utilizing this framework, healthcare professionals can ensure that their EBP initiatives are effective, safe, and evidence-based.

Step 3: Decision Point 1 – Is This a Priority?

The process of selecting the EBP project topic can be overwhelming, given the many available options. Buckwalter et al. (2017) suggest that patient safety, feasibility, and leadership support are some indicators that should guide the decision-making process. When starting the project, it is essential to identify the individuals who care for the pediatric population and

oversee the care where the issue occurs. Identification will help narrow the scope of inquiry and ensure that the project is feasible and relevant.

Step 4: Form A Team

It is crucial to involve key stakeholders early in the EBP process to ensure the program's success. As Cullen et al. (2017) suggest, starting with the right people can make all the difference. Buckwalter et al. (2017) also emphasize the importance of gaining stakeholder buy-in, even from those who may initially oppose the project. Project leaders should also consider recruiting informal team members who can offer valuable insights, help secure resources, and facilitate implementation. By working collaboratively with all stakeholders, the EBP process can be more effective in achieving its goals.

Before implementing any clinical practice changes, obtaining buy-in from the Chief Anesthesiologist, Chief Certified Registered Nurse Anesthetist (CRNA), Surgeons, nurses, anesthesia technicians, pharmacy, material supplies, or other administrative faculty is essential. Buy-in can be done through a presentation of clinical guidelines, a plan for implementation, a plan for monitoring the project's effects, and a strategy for adjusting the program based on outcome analysis. Clear written or verbal communication and collaboration are essential to implement any clinical practice change successfully. It is also crucial for other healthcare team members, such as pre-operative nursing staff, to understand the purpose of the change and how it may affect their respective roles.

Collaborating with representatives from the billing department can prove extremely valuable when obtaining information on coding for US-guided NMB. The billing department can guide the appropriate coding, such as Current Procedural Terminology (CPT) codes, modifiers, and documentation requirements for accurate billing and reimbursement. Revenue generation

from billable procedures and patient safety drives clinical practice change (Lee et al., 2019). This consideration can strengthen support for program implementation, especially among administrators who focus on daily budget evaluation. By showcasing the potential financial return on investment, which includes revenue generated from the procedure, stakeholders can justify expenses related to US machines, additional training hours, and requisite staff tasks. This approach helps address concerns about unproductive costs and underscores the program's value in terms of both patient safety and financial benefits.

It is essential to assess whether the current US machines can cover the additional procedures or if there is a need to invest in more USs. Biomedical engineering can help us make this determination through analysis. Once this analysis is complete, the purchasing department can assist in acquiring US machines for the anesthesia department. Representatives from information technology (IT) are beneficial stakeholders, as they can provide the tools necessary to develop an algorithm to search and collect data pertinent to the project.

Nurses from informatics, quality assurance/quality improvement (QA/QI), and post-anesthesia care unit (PACU) nurses are essential in this process. Establishing an average of medications administered and time to extubation is crucial to effectively monitor the program's progress following implementation. Involving risk or legal department staff in monitoring outcomes for the target facility is highly recommended. QA/QI can provide valuable information about past litigation resulting from inadequate pain control, complications from overuse of opioids, and aspiration after extubation. Considering the potential negative impact of any clinical practice change on patients is crucial, so it is essential to involve these team members.

Step 5: Assemble, Appraise, and Synthesize the Body of Evidence

See the literature review, analysis, and synthesis described earlier in the project. Additional information can also be found in the literature table in Appendix F.

Step 7: Decision Point 2 – Is There Sufficient Evidence?

Pediatric cardiac surgery is an invasive procedure that produces significant pain due to the nature of the process, which must be managed appropriately. Inadequate pain control can lead to severe complications, including prolonged intubation, surgical site infection, surgical stress, prolonged hospital stay, vomiting, and opioid-induced respiratory depression (Feng et al., 2023; Macaire et al., 2020; Roy et al., 2021). RA techniques, such as TTPB, ESPB, SAPB, and TPVB, have shown promise in reducing postoperative pain and opioid usage in pediatric cardiac surgery patients. However, some variations in results and concerns about specific techniques warrant further investigation and research to optimize their effectiveness and safety. TTPB has shown the most promise in the reviewed literature and is incorporated into this doctoral project.

Step 8: Design and Pilot the Practice Change

Setting. The implementation setting is a large children's hospital in the midwestern United States. The surgical population consists mainly of pediatric patients, with some adults due to CHD that pediatric cardiologists still manage. An inpatient setting is also required as the procedures requiring NMB necessitate prolonged hospital stays.

Step 9: Decision Point 3 – Is Change Appropriate for Adoption in Practice?

Please see the literature review section and conclusion summary explaining why the TTPB was selected as the block of choice for this project.

Step 10: Integrate and Sustain Practice Change

Proposed Timeline

The timeline for project implementation covers 12 months, with an additional month at the beginning for project review and approval from the hospital institutional review board (IRB) department. During the first month, project review and IRB approval will take place. IRB approval may take time, requiring the timeline to be adjusted to accommodate the increased approval time. The second month will consist of developing guidelines and an implementation timeline. During the third month, staff will be trained in TTPB techniques and the required block medications. Also, during the third month, OR staff will be educated on intraoperative care of the blocks, while PACU staff and cardiac recovery nurses will be educated on postoperative care.

Implementation is proposed to occur over seven months, incorporating the regional techniques in the intraoperative and postoperative periods. During the sixth month, data collection will begin through chart reviews of the selected patients. The seventh month will commence with the data analysis with the QI department's help. Data evaluation will begin during the eight months, and staff involved with the project will be surveyed. Evaluation continues into the 10th month, with any changes needed regarding the project, such as when the blocks are administered, who places the blocks, or what NMB agents are used, will be instituted. The final month convenes a meeting between key stakeholders to discuss the project findings and possible future applications. The timeline covers all project phases, from developing guidelines, staff training, and integrating clinical practice change to monitoring progress and outcomes. The timeline will allow for the seamless execution of the project, achievement of our goals, and delivery of the desired results.

Implementation

In the first month, a comprehensive three-page guideline was developed that includes all the relevant data, imaging, and other pertinent information about the criteria and inclusion of perioperative US imaging (Appendix D). The document was shared during an informational meeting with the chief anesthesiologist, CRNA, and other key stakeholders who will assist in facilitating the integration of this technology into clinical practice. Moreover, IT, biomedical engineering, and billing department representatives ensure seamless integration of US technology with the electronic medical record (EMR) for chart auditing and imaging uploads. The legal department is involved in reviewing the proposed project to determine if there are any legal ramifications to the implementation. This approach will ensure that perioperative US imaging integrates smoothly and efficiently into clinical practice.

During the second month, all anesthesia providers are trained in the necessary RA techniques for effective NMB using ultrasound for precise placement. The NMB guidelines document is distributed electronically and as a physical printout during training sessions. Training sessions cover the aspects of the US machine, from probe selection to optimized imaging. Training availability will take place over two weeks, three days a week, for two hours, as an in-service that providers will only need to complete once. This allows for providers to have the flexibility to train based on schedules. Locating the structures included in the TTPB will also be included during the training.

Appropriate selection of anesthetic is covered, specifically using 0.2% ropivacaine when placing the block and the volume amounts needed to ensure the nerve is adequately bathed in anesthetic. Ropivacaine, an emerging amide local anesthetic, is increasingly favored in pediatric surgery due to its superior safety profile compared to bupivacaine (NYSORA, 2022). As an

l-enantiomer, it exhibits reduced cardiovascular and central nervous system side effects and some vasoconstrictive properties due to a longer time to peak drug concentration (NYSORA, 2022). The maximum dose of ropivacaine is 2.5 mg/kg, with 3 to 5 mL required for each side of the sternum for the TTPB (NYSORA, 2022; Yamamoto et al., 2020). The training sessions also cover guidance for appropriately charting the RA and techniques used.

Implementation of a brief electronic education piece (e.g., HealthStream) is utilized to train perioperative nursing staff and anesthesia technicians. The electronic piece will cover the basics of the block, why the block was selected, its purpose, and the equipment and supplies needed by the anesthesiologist or CRNA for the procedure. Other aspects covered include assisting the provider and preparing the patient for the procedure. Training these team members is necessary to ensure the proper equipment is available in the operating room and to minimize delays.

The guidelines will be fully integrated into daily practice in months three through six as part of the study phase. While some challenges are anticipated, intervention may be required to smooth the transition process. By the end of month six, nurses from the quality improvement department observe daily processes to ensure compliance with these guidelines. Anesthesia staff will be asked for feedback on the US RA implementation of TTPB in an accessible text format supplied to them through email. Feedback from stakeholders and those caring for pediatric patients about concerns with project implementation, including time spent in the OR for block completion, adherence to guidelines, ease of block placement, staff satisfaction, and patient experience, is crucial in understanding the project's efficacy.

At the end of the final month, the informatics department organizes data and reviews it with stakeholders. Critical data to be examined are the number of cardiac surgeries, the number

of regional blocks placed, the amounts of neuromuscular blocking agent used, postoperative pain scores (face, legs, activity, cry, and consolability (FLACC)), Wong-Baker, and scale from one to ten), and time to extubation (Appendices B & C). Other essential data points include extra analgesia coverage in the PACU and required analgesia types.

Proposed Budget

The associated costs with the quality improvement project are detailed in Appendix E. The total estimated budget for this project is $*75,008.33*. The main expenses for the project are the need for an additional US in the operating rooms, training time for staff, and staff involved in data collection and review. The project will require review from the legal department and the hospital policy review committee, each requiring reimbursement for time spent on the project. The legal review will occur through one hospital attorney and will take four hours. The hospital policy review committee comprises members from all areas of the hospital to determine the project's feasibility, which will require three hours. The education department will create the electronic education portion of the training, and the IT department will update the EMR for functional charting. For the initial EMR integration and education creation, three weeks or 120 working hours have been allotted.

The QI department will provide all-encompassing support for outcome monitoring. The initial data collection is estimated to take two weeks or 80 working hours. Continuous monitoring will require about twelve hours monthly from the QI department, with 160 paid working hours for the entire project. Biomedical engineering and materials supply departments will require about eight hours of paid time each to determine the needs for the project and what materials are essential for project completion. Finally, the billing department will require about 16 hours of paid time to ensure that all billing codes are correct for each block performed.

Monitoring Outcomes

To evaluate the effectiveness of RA in the proposed population, the QI department employs a range of statistical and qualitative tools to analyze the data collected during the project. Outcomes that the QI department examines are pain scores using the FLAAC, Wong-Baker, and 0-10 pain scales and time to extubation after surgery based on the individual blocks. The first tool the QI department uses is descriptive statistics. The QI department uses a calculated mean of opioids required for patients who received TTPB and the mean of time to extubation for these same patients. The data set is then compared to patients who did not receive the TTPB to determine the effectiveness of the block on the examined outcomes.

Upon determining the calculated mean, the QI department employs standard deviation to measure the variability of the pain scores and time to extubate around the mean. The team calculates the standard deviation for opioid use and time to extubation between TTPB and the traditional pain management method. Through this, the QI department quantifies the variability of required opioids and the time to extubation between the TTPB and the traditional pain management method. In comparing the data of the TTPB and the traditional pain management method, the team can speculate that the block is effective and leads to consistent reductions in required opioids and time to extubation if the standard deviation decreases following the intervention. In contrast, if the standard deviation increases or remains high after the intervention, this indicates that individual responses to the block are variable.

As part of their analysis, the QI department plans to use a paired t-test to compare the outcomes between TTPB and the traditional pain management method. This statistical method will allow the team to determine whether there is a significant difference in the effectiveness of the two interventions concerning opioids required and time to extubation. The paired t-test is a

powerful tool that enables the QI department to investigate the impact of the TTPB block and identify if it is effective in managing pain and reducing the time to extubation. In this statistical analysis, an alpha level of 0.05, a standard threshold used in many scientific studies to determine whether a difference is statistically significant, has been set. The QI department will use the test results to obtain significant statistical evidence to support the intervention by calculating the mean, standard deviation, and alpha score. This approach will provide a more detailed and accurate assessment of the effectiveness of the intervention and enable the QI team to make informed recommendations for pain management in pediatric cardiac surgical patients.

Adjustment Plan

The fourth objective of this project is to develop a comprehensive plan to adjust the guidelines if the outcomes could be more desirable. The three foremost indicators of the need for guideline modification are maintained or increased opioid requirements, maintained or decreased time to extubation, and feedback from anesthesia providers, surgeons, perioperative staff, and postoperative staff about the usefulness of the implemented guidelines. If there is maintenance or increased opioid requirements and time to extubation, RA blocks may have been placed incorrectly, or the wrong NMB medication may be utilized. The program may need to be halted for patient safety concerns related to increased bleeding or adverse reactions to NMB agents, and collaboration with the risk management and legal teams is necessary. Upon review of survey results from all staff involved, adjustments may also need to be made. Anticipating all issues that may occur is difficult to ascertain, but suggestions from survey respondents may improve the project and guidelines.

Step 11: Disseminate Results (Plan for Dissemination)

After conducting a pilot evaluation and measuring the outcomes, the data is compiled and presented to the Chief Anesthesiologist and Chief CRNA in an in-person setting. The dissemination within the organization will include all the crucial details, such as the project title, project director, and team member names and credentials. Organization dissemination of information will occur as an in-person presentation to the department chairpersons of the stakeholders involved, with the data and presentation sent out to all staff via email. The purpose and rationale of the project are also explained, along with a brief synthesis of the evidence. The practice change, implementation strategies, and evaluation results will also be shared.

Limitations

The current project faces several limitations. Firstly, the age range of children studied in the literature varied between the different studies, with most studying age two and above, necessitating further research to encompass younger children, utilizing alternative pain assessment tools such as the Neonatal Infant Pain Scale (NIPS). Secondly, there needs to be more clarity regarding the appropriate dosage and concentration of local anesthetics for the TTPB in pediatric patients. While Zhang et al. (2020) utilized 0.75 mL/kg of 0.2% ropivacaine, Yamamoto et al. (2020) incorporated a max dose of 3mg/kg of 0.1% to 0.375% ropivacaine in a single block. Drawing definitive recommendations based solely on these cases can be challenging. Thirdly, the duration of analgesia provided by single-shot blocks was limited. Therefore, future studies should explore the efficacy of continuous local anesthetic infusion through catheter insertion in the fascial plane between the internal intercostal and transversus thoracis muscles for prolonged postoperative pain relief.

Barriers

Implementation of the TTPB in pediatric open-heart surgery presents several hurdles. Firstly, there needs to be more standardized protocols tailored to pediatric patients, complicating dosage determination and administration of local anesthetics. Secondly, pediatric patients exhibit physiological variations, necessitating meticulous consideration of age, weight, and comorbidities for personalized pain management strategies. Additionally, more research is needed on the safety and efficacy of TTPB, specifically in pediatric cardiac surgery, heightening concerns among practitioners. Procedural intricacies and anatomical differences in pediatric patients demand specialized skills and training for accurate block placement, amplifying the learning curve for healthcare providers and increasing time to implementation.

Institutional barriers such as resource constraints and institutional protocols may impede the adoption of TTPB in pediatric cardiac surgery cases. Lastly, apprehensions regarding potential complications and adverse events associated with RA in pediatric cardiac patients pose significant barriers to widespread implementation. Overcoming these challenges requires collaborative efforts, including further research, specialized training programs, interdisciplinary teamwork, and establishing standardized protocols to ensure safe and effective integration of TTPB into pediatric OHS practice.

Future Direction

The future direction of TTPB in pediatric OHS involves further research to improve the block's efficacy, address provider knowledge gaps, and accessibility, and integrate it into clinical practice. Additional research is required to develop regional medication types and dosing for the block so that providers can use it in future administration. As the use of US for RA continues to expand, dedicated training for US applications may need to be incorporated into yearly education

to keep providers' skills proficient. Future directions also include exploring multimodal approaches to enhance pain management, investigating novel formulations for prolonged analgesia, and integrating TTPB into standardized protocols for pediatric cardiac care. Another area of study may be incorporating additional blocks with the TTPB, which may help improve pain management and decrease the time to extubation, providing more excellent coverage of the chest and back.

Conclusion

TTPB used during cardiac surgery via median sternotomy in children has several beneficial effects. Firstly, TTPB reduces the need for perioperative opioid analgesics, which can have harmful side effects and lead to addiction in some cases. By blocking the nerves in the intercostal space, TTPB provides effective pain relief, reducing the need for opioid analgesics. Secondly, TTPB reduces pain intensity within the first 24 hours following surgery, which is a crucial period for the patient's recovery. This is achieved by providing effective pain relief without the harmful side effects of opioid analgesics. The reduced pain intensity allows the patient to breathe deeply, cough, and move around more comfortably, which is essential for preventing postoperative complications such as pneumonia and thrombosis.

Lastly, TTPB enables earlier endotracheal extubation, leading to a faster recovery. This is achieved by reducing pain and maintaining hemodynamics, which allows the patient to be extubated earlier. Earlier extubation leads to a shorter stay in the intensive care unit, reduced risk of ventilator-associated pneumonia, and faster recovery. The technique of TTPB is straightforward and uncomplicated, posing a minimal risk of severe complications such as internal mammary artery injury or pneumothorax. Therefore, it is a safe and effective method to manage pain and improve cardiac surgery outcomes in children.

Summary

In summary, using TTPB during OH pediatric surgery presents a significant opportunity to improve pain management and decrease the time to extubation. Although challenges to overcome in refining dosing, ensuring safety, and integrating TTPB into standardized protocols, advancements in US guidance, multimodal analgesic approaches, and innovative formulations offer hope for addressing these obstacles. TTPB could become an essential aspect of comprehensive pain management strategies in pediatric cardiac care by continuing to investigate and collaborate among clinicians, researchers, and regulatory bodies. Ultimately, this could enhance the recovery process and long-term well-being of young patients undergoing open-heart surgery.

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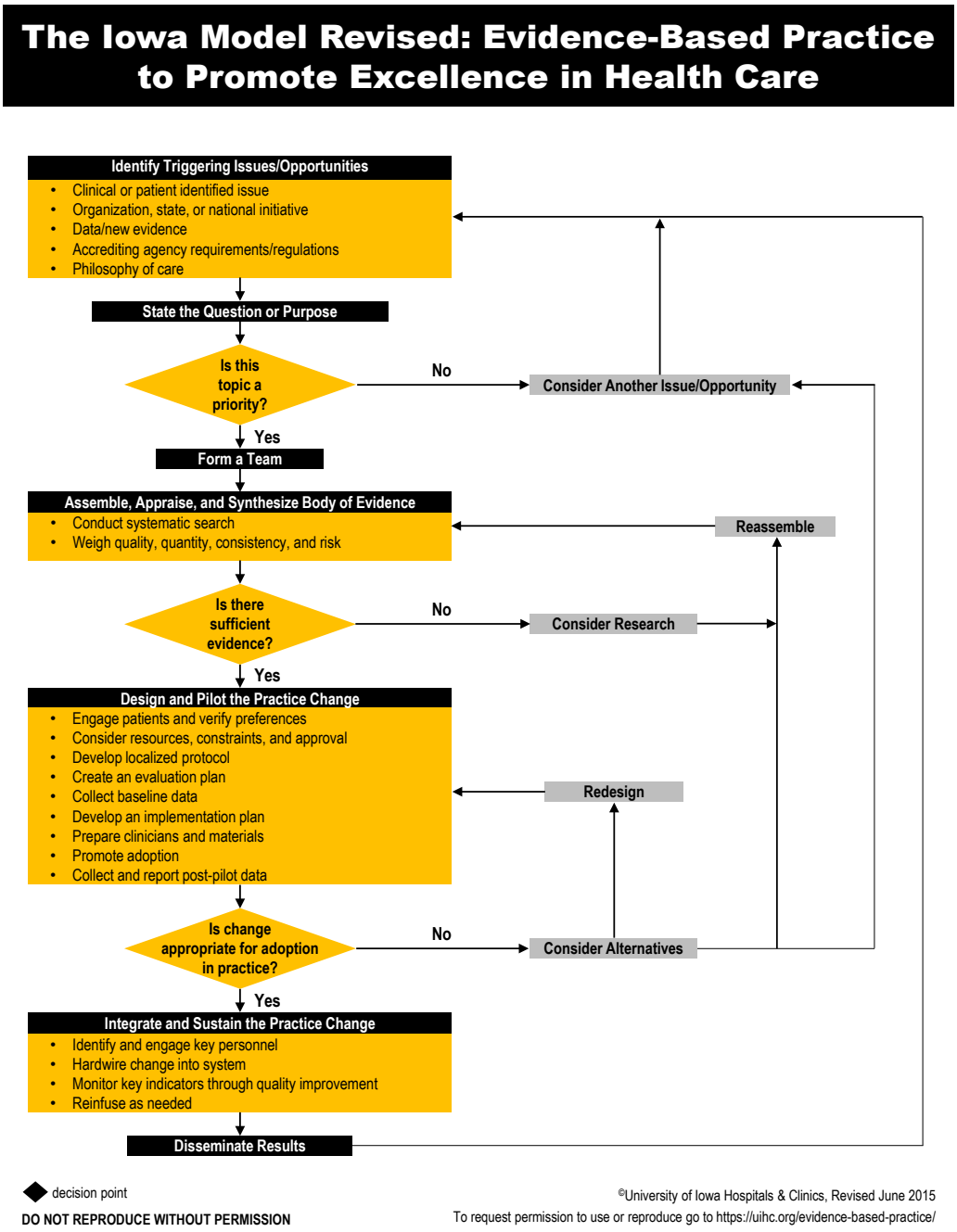
Appendix A



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Appendix B

Criteria	Finding	Points
Crying	none consolable not consolable	0 1 2
Movement	none restless thrashing	0 1 2
Agitation	asleep/calm mild hysterical	0 1 2
Posture	normal flexed holds injury site	0 1 2
Verbal	asleep/no complaint complains/cannot localize complains/can localize	0 1 2

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Wong-Baker FACES® Pain Rating Scale

Instructions for Usage

Explain to the person that each face represents a person who has no pain (hurt), or some, or a lot of pain.

Face 0 doesn't hurt at all. Face 2 hurts just a little bit. Face 4 hurts a little bit more. Face 6 hurts even more. Face 8 hurt a whole lot. Face 10 hurts as much as you can imagine, although you don't have to be crying to have this worst pain.

Ask the person to choose the face that best depicts the pain they are experiencing.

Appendix C


0-10 SCALE OF PAIN SEVERITY
SEVERITY
DESCRIPTION OF EXPERIENCE
10 UNABLE TO MOVE
I am in bed and can't move due to my pain. I need someone to take me to the emergency room to get help for my pain.
9 SEVERE
My pain is all that I can think about. I can barely talk or move because of the pain.
8 INTENSE
My pain is so severe that it is hard to think of anything else. Talking and listening are difficult.
7 UNMANAGEABLE
I am in pain all the time. It keeps me from doing most activities.
6 DISTRESSING
I think about my pain all of the time. I give up many activities because of my pain.
5 DISTRACTING
I think about my pain most of the time. I cannot do some of the activities I need to do each day because of the pain.
4 MODERATE
I am constantly aware of my pain but I can continue most activities.
3 UNCOMFORTABLE
My pain bothers me, but I can ignore it most of the time.
2 MILD
I have a low level of pain. I am aware of my pain only when I pay attention to it.
1 MINIMAL
My pain is hardly noticeable.
0 NO PAIN
I have no pain.

Appendix D

TRANSVERSUS THORACIS MUSCLE PLANE BLOCK GUIDELINES

Pre-Intervention Scan

1. Induction of general anesthesia
2. Bilateral parasternal intercostal spaces are scanned
    a. A linear ultrasound probe at a frequency of 8 to 15 Hz and a depth of 3 to 5 cm
    b. Not performed in a sterile fashion
3. The ultrasound probe is moved longitudinally along the edge of the sterum (Fig 1, A).
4. The intercostal muscular layer between the costal cartilages and the underlying transverse thoracis muscle and the pericardium and pleura are found.
    a. The intercostal layer consists of 3 layers:
        i. External costal muscle
        ii. Internal costal muscle
        iii. Innermost costal muscle
5. The target layer for the TTPB is located between the intercostal muscle layer and the transverse thoracic muscle, identified as a white line on the ultrasound (Fig 1, B & C)

Ultrasound-Guided TTPB Procedure

1. The procedure is performed in a sterile fashion
    a. The puncture site is sterillized
    b. The provider dons sterile gloves
    c. A sterile ultrasound probe cover is placed over the probe
2. A 22-guage regional nerve block needle is prepared
    a. Puncture needle can vary based on provider preference
3. A 10 mL syringe is filled with 0.2% ropivacaine and attached to the needle via microbore tubing.
4. The needle is inserted via the long-axis approach, with the needle point monitored until it reaches the target layer (Fig 2, A).
5. An aspiration test is performed and ropivacaine is injected into the target layer
    a. Local anesthestic spread across the intercostal spaces, along with the downward movement of the transverse thoracic muscle and the pericardium (Fig 2, C)
6. 3 - 5 mL of ropivacaine is a sufficient dose for each side of the sterum, with a max dose of 2.5 mg/kg
7. Once sufficient spread is noted on the ultrasound, the needle may be withdrawn and the procedure performed on the other side.

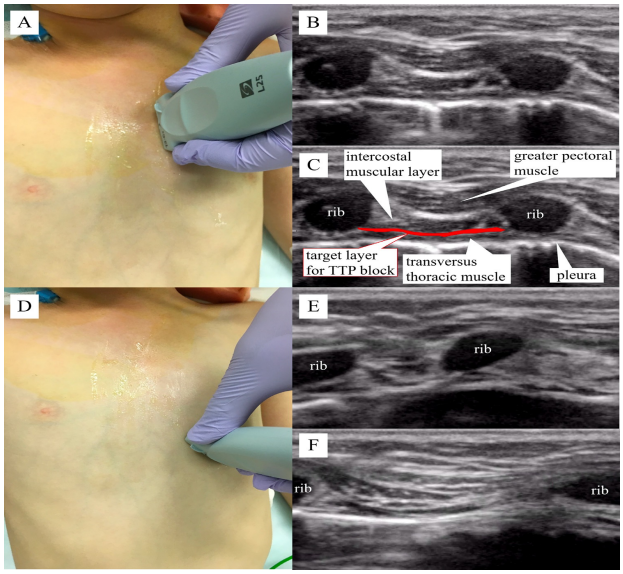

Fig 1

Postoperative Care

1. Monitor the injection sites for any bleeding or erythema
2. Monitor for any signs of local anesthetic systemic toxicity (LAST)
    a. Manifestations include:
        i. Neurological symptoms
            1. Circumoral numbness
            2. Altered mental status
            3. Seizures
        ii. Cardiac arrest
        iii. Death
3. Monitor for any signs or symptoms of pneomothorax
4. Provide breakthrough analgesia as needed during the case or postoperatively.

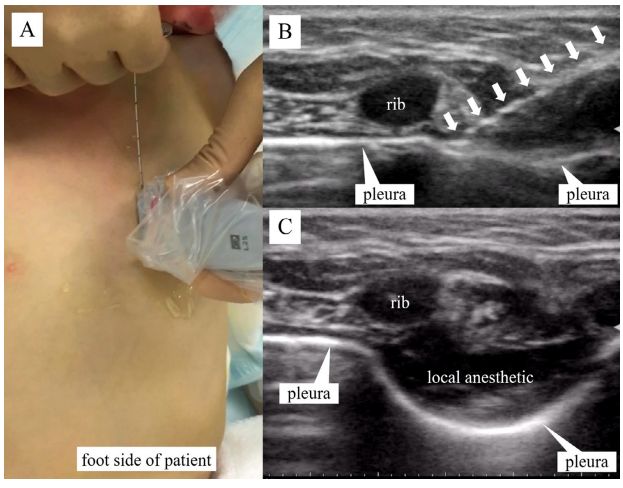

Fig 2

Appendix E

Proposed Budget

Summary of costs associated with project implementation

Item	**Cost**	**Multiplier**	**Total**
Anesthesiologist	$165/hr	3 hours x 30 Anesthesiologists	$14,850
CRNA/AA	$95/hr	3 hours x 45 CRNA/AA	$12,825
Anesthesia Techs	$40/hr	1 hour x 15 Techs	$600
Staff RN	$35/hr	1 hour x 65 RNs	$2,275
Trainer	$95/hr	3 hours x 10 days	$2,850
Policy Review Committee	$335/hr	3 hours	$1,005
Legal Review	$100/hr	4 hours	$400
Information Technology Department	$50/hr	120 hours	$6,000
Quality Improvement Department	$40/hr	*160* hours	$*12,800*
Biomedical Engineering	$45/hr	8 hours	$360
Billing Department	$30/hr	16 hours	$480
Materials & Supply Department	$35/hr	8 hours	$280
Tuohy needles	$407.93	1 case	$407.93
Quincke needles	$151.95	1 case	$151.95
Saline Solution	$5.65	10 bottles	$56.50
Ultrasound gel	$29.95	1 case	$29.95
Syringes	$87.00	1 case	$87
Handouts	$1.00	150	$150
Capital Funds			
Ultrasound Machine	$20,000	1 unit	$20,000
			$*75,008.33*

Appendix F

Evidence Review Worksheet								
APA Citation: Abdelbaser, I. I., & Mageed, N. A. (2020). Analgesic efficacy of ultrasound-guided bilateral transversus thoracis muscle plane block in pediatric cardiac surgery: A randomized, double-blind, controlled study. *Journal of Clinical Anesthesia*, *67*, 110002. https://doi.org/10.1016/j.jclinane.2020.110002								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Randomized, double-blind, controlled study	**Sample Size:** 80 **Number of Characteristics:** 5 – pediatric patients of either sex, aged 2 to 12, left to right intracardiac shunt (atrial septal defect, ventricular septal defect, and common atrioventricular canal), elective open-heart surgery, and median sternotomy. **Exclusion Criteria:**	**Independent variables:** **IV1=** Block group **Dependent variables:** Non-block group	The primary outcome was the total dose of fentanyl consumption in the first postoperative 24 hours. Secondary outcomes included postoperative pain score at rest, heart rate, and mean arterial pressure before and after induction of anesthesia, after skin incision, after sternotomy, 15 min after cardiopulmonary bypass, and after	**Statistical tests, if any:** Data were tested for normality using the Kolmogorov-Smirnov test and Shapiro-Wilk test. Mann-Whitney *U*-test analyzed patient age and modified objective pain score. **Qualitative analysis, if any:** An unpaired *t*-test was used to compare the	**Statistical findings, if any:** Postoperative fentanyl consumption in the first 24 hours after extubation = Block group – 9.892 $\pm$ 3.397 µg/kg and Non-block group 18.500 $\pm$ 3.401 µg/kg. Total intraoperative fentanyl requirements = Block group – 8.27 $\pm$ 1.170 µg/kg and Non-block	Level 2	**Strengths:** Randomized control study. Decreased fentanyl consumption during the first 24 hours postoperatively. Decreased time to extubation and ICU length of stay. **Limitations:** **Risk or harm if implemented:** No serious complications were noted during the study. Same precautions for any regional

		Refusal to participate, redo or urgent cardiac surgery, infection of the skin at the needle puncture site, allergy to bupivacaine, coagulation disorders, liver or kidney disease, heart failure, and moderate to severe pulmonary hypertension. **Attrition:** 7 patients **Setting:** Monsoura University Childrens Hospital, between October 2019 to May 2020.		the sternum closure.	means of two groups. The Chi-square test was used for the analysis of categorical data. $p < 0.05$ CI 95%	group – 13.72 $\pm$ 1.186 μg/kg. Time to first rescue analgesia = Block group – 5.57 $\pm$ 1.625 hours and Non-block group – 1.58 $\pm$ 0.500 hours. Time to extubation = Block group – 2.05 $\pm$ 1.433 hours and Non-block group – 5.96 $\pm$ 1.117 hours. ICU length of stay = Block group – 26.32 $\pm$ 1.082 hours and Non-block group – 32.06 $\pm$ 2.927 hours.		anesthetic administration. Pruritis and vomiting were similar in both groups. **Feasibility of use in the project practice area:** Would be feasible to implement in the OR or post-op, with the use of ultra-sound.
Annotated Bibliography Table								
Annotated Bibliography statement (may be several sentences summarizing the article based upon the information above using professional APA writing style): A study aimed to evaluate the effectiveness of transversus thoracis plane (TTP) block in providing pain relief for pediatric patients undergoing								

cardiac surgery. The study design was a randomized, double-blind, controlled trial conducted at Mansoura University Children Hospital in Egypt. Eighty pediatric patients aged 2-12 years undergoing cardiac surgery were divided into two groups: a control group and a TTP block group. The control group received fentanyl for pain control, while the TTP block group received the TTP block intervention. The primary outcome measured was the total dose of fentanyl consumed in the first 24 hours after extubation, and secondary outcomes included pain scores, intraoperative fentanyl consumption, time to extubation, and ICU length of stay. The results showed that the TTP block group had significantly lower fentanyl consumption both during the first 24 hours postoperatively and intraoperatively compared to the control group. Additionally, the TTP block group reported lower pain scores throughout the study period. In conclusion, the TTP block technique reduced fentanyl consumption and alleviated postoperative pain intensity in pediatric cardiac surgery patients.
Thematic Analysis: Key Themes or FSP related significance: **1.** The study's main objective is to address the importance of adequate pain management during and after cardiac surgery in pediatric patients. **2.** The study focuses on assessing the effectiveness of TTP block as an analgesic technique specifically in pediatric cardiac surgery. **3.** The study utilized a randomized, double-blind, controlled design and included eighty pediatric patients aged 2-12 years undergoing cardiac surgery via median sternotomy. **4.** The primary outcome measured was the total dose of fentanyl consumed un the first 24-hours after extubation. Secondary outcomes included postoperative pain scores, intraoperative fentanyl consumption, time to extubation, and ICU length of stay. **5.** The TTP block group demonstrated significantly lower fentanyl consumption both during the first 24-hours postoperatively and intraoperatively compared to the control group. Additionally, the TTP block group reported lower pain scores throughout the study period.

Evidence Review Worksheet								
APA Citation: Cakmak, M., & Isik, O. (2021). Transversus thoracic muscle plane block for analgesia after pediatric cardiac surgery. *Journal of Cardiothoracic and Vascular Anesthesia*, *35*(1), 130–136. https://doi.org/10.1053/j.jvca.2020.07.053								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Retrospective Study	**Inclusion Criteria:** Patients aged between 2 months and 12 years who underwent congenital heart surgery with median	**Independent variables:** **IV1 =** Patients who received transversus thoracic muscle plane block (TTPB) TTPB Group.	Primary Outcomes: The effects of TTPB on perioperative fentanyl consumption, FLACC scores during the first 24 hours, and	**Statistical tests:** Normality was evaluated by using the Kolmogorov-Smirnov test, and the Levene test was used to	**Statistical findings:** Total intraoperative and postoperative 24-hour fentanyl consumption was significantly	Level IV	**Strengths:** Decreased total fentanyl consumption in the first 24-hour period. **Limitations:** The study was an audit that could have

		sternotomy and cardiopulmonary bypass (CPBP) and had an American Society of Anesthesiologists (ASA) score II or III. **Exclusion Criteria:** Patients intubated preoperatively or remained intubated longer than 24 hours postoperatively, patients who underwent complex surgical procedures, and patients who received nitric oxide treatment due to severe pulmonary hypertension. **Setting:** A tertiary teaching hospital between January 2018 and March 2019.	**Dependent variables:** Patients who did not receive TTPB, non-TTPB Group.	time to extubation. Secondary Outcome: Reduction in ICU length of stay.	evaluate the homogeneity of the group variance. Mann-Whitney U test was used to determine whether there was any difference between the groups. The Pearson chi-square test or Fisher-Freeman-Halton Exact test was used for the analysis of categorical data. Statistical analysis was performed using IBM SPSS version 22 software. **Qualitative analysis, if any:**	lower in the TTPB Group vs the non-TTPB Group = $p < 0.001$. **Qualitative findings, if any:**		been affected by inherent weaknesses stemming from the study design. Caregivers and anesthesiologists were not blinded. Exclusion of patients undergoing complex cardiac surgeries. **Risk or harm if implemented:** Anticipated postoperative nausea and vomiting. **Feasibility of use in the project practice area:** Feasibility is uncertain as further studies may be needed before implementing in the practice project area.
Annotated Bibliography								

Annotated Bibliography statement: The was study conducted at a tertiary care teaching hospital aimed to evaluate the effectiveness of transversus thoracic muscle plane block (TTPB) as a novel technique for postoperative pain relief in pediatric cardiac surgery patients. The study, which was retrospective in design, included children who underwent congenital heart surgery through median sternotomy between January 2018 and March 2019. The study found that the TTPB group had significantly lower pain scores compared to the non-TTPB group, indicating that TTPB is an effective technique for postoperative pain relief in pediatric cardiac surgery patients. The TTPB group also required lower doses of fentanyl intraoperatively and a lower total fentanyl dose during the 24-hour period. Additionally, the TTPB group had a faster time to extubation compared to the non-TTPB group. In conclusion, the study demonstrated that TTPB is an effective technique for postoperative pain relief in pediatric cardiac surgery patients undergoing median sternotomy.
Thematic Analysis: Key Themes or FSP related significance: **1.** The study aims to assess the effectiveness of transversus thoracic muscle plane block (TTPB) as a novel technique for postoperative analgesia in pediatric cardiac surgery. **2.** The study is retrospective in nature and was conducted at a tertiary care teaching hospital. **3.** The study included children who underwent congenital heart surgery through median sternotomy between January 2018 and March 2019. **4.** Bilateral ultrasound-guided TTPB was performed as a single-shot technique before the sternal incision, with a specific dose of bupivacaine injected. The study compared the TTPB group (received the intervention) and the non-TTPB group (did not receive the intervention). **5.** The study found that the TTPB group had significantly lower pain scores compared to the non-TTPB group. Intraoperatively, the non-TTPB group required higher doses of fentanyl, and the total fentanyl dose administered during the 24-hour period was higher in the non-TTPB group. The TTPB group also had a significantly shorter time to extubation.

Evidence Review Worksheet								
APA Citation: Feng, J., Wang, H., Peng, L., Xu, H., & Song, X. (2023). Effects of thoracic paravertebral block on postoperative analgesia in infants and small children undergoing ultra-fast track cardiac anesthesia: A randomized controlled trial. *Journal of Cardiothoracic and Vascular Anesthesia*, *37*(4), 539–546. https://doi.org/10.1053/j.jvca.2022.12.006								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Single-center, prospective, randomized,	**Sample Size:** 200 **Inclusion Criteria:** Patients	**Independent variables:** **IV1=** Bilateral thoracic paravertebral	Primary Outcome: Postoperative pain scores using the Face, Legs, Activity,	**Statistical tests:** Analysis performed using the SPSS 20.0 for	**Statistical findings:** Pain scores were significantly lower in Group T vs	Level 2	**Strengths:** Decreased pain scores with the intervention. The trial is reproducible as

	controlled study.	scheduled to undergo cardiac surgery via midline sternotomy using cardiopulmonary bypass. American Society of Anesthesiologists (ASA) grades I to III, risk adjustment for congenital heart surgery (RACHS) grades 1 to 3, age between 1 month and 3 years, and weighing >5 kg. **Exclusion Criteria:** Neonates, ASA grades IV to V, RACHS grades 4 to 6, weighing <5 kg, children undergoing emergency surgery, severe pneumonia prior to surgery, severe liver or kidney dysfunction, severe central	block and parent- and/or nurse-controlled intravenous analgesia (PNCA) (Group T) **Dependent variables:** Parent- and/or nurse-controlled intravenous analgesia only (Group P)	Cry, and Consolability (FLACC) scale to evaluate the pain scores for infants and small children. Secondary Outcomes: intraoperative consumption of sufentanil, time to extubation, use of neostigmine cumulative total and invalid PCA attempts at 24 and 48 hours after surgery, hospitalization characteristics, perioperative blood glucose, postoperative arterial oxygen partial pressure (PaO2), arterial carbon dioxide partial pressure (PaCO2), and brain natriuretic peptide (BNP).	Windows. The continuous variables are presented as mean ± standard deviation (SD) and assessed using an unpaired Student's t-test. Categorical variables are presented as numbers (n) and assessed using a chi-square test.	Group P at 6, 12, and 24 hours = (1.98 ± 0.69 *v* 3.07 ± 0.92 at 6 hours; 1.65 ± 0.80 *v* 2.61 ± 0.71 at 12 hours; 1.24 ± 0.78 *v* 1.85 ± 0.86 at 24 hours; p< 0.001).		the study is well-defined. **Limitations:** The randomized controlled trial was conducted at a single medical center with a small sample size. Postoperative analgesia follow-up is only for 2 days after surgery. A continuous catheter may provide protracted postoperative analgesia. **Risk or harm if implemented:** Postoperative nausea and vomiting. **Feasibility of use in the project practice area:** The trial can be used in the project practice area, but with effective training and implementation.

		nervous system disease, atrioventricular block, or an allergy to amide local anesthetics. **Attrition:** 20 **Setting:** A tertiary children's medical center						
Annotated Bibliography								
Annotated Bibliography statement: A recent study was conducted to determine whether a preoperative bilateral thoracic paravertebral block (TPVB) would improve postoperative pain relief in infants and small children undergoing open cardiac surgery within an ultra-fast track cardiac anesthesia (UFTCA) protocol. The study included 180 children aged 1 month to 3 years undergoing cardiac surgery. The patients were randomly assigned to either the TPVB and parent- and/or nurse-controlled intravenous analgesia (PNCA) group (Group T) or the PNCA group (Group P). The study found that the combination of bilateral single dose TPVB and PNCA pain management was superior to PNCA alone. Within 24 hours postoperatively, Group T had significantly lower postoperative pain scores, intraoperative sufentanil consumption, total and invalid PCA attempts, perioperative blood glucose levels, and BNP levels compared to Group P. The time to extubation, use of neostigmine, and PaCO2 at the sixth hour postoperatively were also significantly lower in Group T. However, there were no significant differences in hospitalizations between the two groups. This combination approach led to better postoperative pain relief, reduced sufentanil consumption, faster recovery with shorter extubation time, and improved perioperative outcomes.								
Thematic Analysis: Key Themes or FSP related significance: **1.** The study aims to assess whether a preoperative bilateral thoracic paravertebral block (TPVB) improves postoperative analgesia in infants and small children undergoing open cardiac surgery within an ultra-fast track cardiac anesthesia (UFTCA) protocol. **2.** The study included a total of 180 children aged 1 month to 3 years who were undergoing cardiac surgery. **3.** The primary outcome measured was postoperative pain scores. Secondary outcomes included intraoperative sufentanil consumption, time to extubation, use of neostigmine, cumulative total and invalid patient-controlled analgesia (PCA) attempts, hospitalization characteristics, perioperative blood glucose levels, arterial oxygen partial pressure, arterial carbon dioxide partial pressure (PaCO2), and brain natriuretic peptide (BNP) levels. **4.** A combination of bilateral TPVB and PNCA pain management is superior to PNCA alone in infants and small children undergoing open cardiac surgery within the UFTCA protocol. This combined approach results in better postoperative pain relief, reduced sufentanil consumption, faster recovery with shorter extubation time, and improved perioperative outcomes.								

Evidence Review Worksheet								
APA Citation: Hamed, M. A., Boules, M. L., Sobhy, M. M., & Abdelhady, M. A. (2022). The analgesic efficacy of ultrasound-guided bilateral transversus thoracic muscle plane block after open-heart surgeries: A randomized controlled study. *Journal of Pain Research*, *Volume 15*, 675–682. https://doi.org/10.2147/jpr.s355231								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Prospective, randomized, observer-blind study	**Sample Size:** 70 **Number of Characteristics:** 3 – 18 years or older, elective cardiac surgery for valve replacement or adult congenital ventricular septal defect or atrial septal defect **Exclusion Criteria:** Emergency surgeries, re-do surgery, coagulopathy, preoperative poor left ventricular function (EF < 35%), systemic	**Independent variables:** **IV1=** Block group (35) **Dependent variables:** Non-block group	The primary outcome was the total fentanyl consumption during the first 24 hours after surgery. Secondary outcomes included time of extubation, ICU stay, and hospital stay.	Two-sample *t*-test to compare mean values of age, BMI, and fentanyl consumption between the two groups. A Mann-Whitney *U*-test compared medians for skewed endpoints. A chi-square test was used to determine significance. CI = 95% $p < 0.0001$	Mean total fentanyl consumption in first 24 hours = Block group – 205.7 μg vs No block group – 390.9 μg, with a mean difference of -185.143. Median estimate time for first analgesic request = Block group – 14 hours, no block group – 3 hours. At-rest pain scores = 1.86	Level 2	**Strengths:** Significantly decreased fentanyl use in the first 24 hours and prolonged time to first analgesic request. Randomized trial. **Limitations:** Chest tubes and visceral pain were not considered, only post-sternotomy pain. Dependence on nurse-controlled analgesia. Ethnicity of population. CABG surgeries were not included due to anatomical considerations.

		infections, infection at site of injection, neuromuscular disease, psychiatric illness, narcotic dependency, allergy to drug used, prolonged ICU stay for reasons as heart failure and reoperation for hemostasis **Attrition:** 0 **Setting:** Fayoum University Hospital from December 2019 to February 2021				units lower in Block group. Pain score with cough = 3.29 units lower in Block group.		Limited prior research. **Risk or harm if implemented:** No risk or harm noted during the trial and all segments completed without complications. **Feasibility of use in the project practice area:** Would be feasible to implement in the OR or post-op, with the use of ultra-sound.
Annotated Bibliography								
Annotated Bibliography statement: In a recent study, researchers aimed to evaluate the effectiveness of ultrasound-guided bilateral transversus thoracic muscle plane block for pain relief after open-heart surgeries. The study included seventy patients above 18 years old undergoing valve replacement or adult congenital surgeries via median sternotomy, randomly assigned to either the block group (receiving the muscle plane block) or the control group (receiving a sham block). The primary outcome measured was total fentanyl consumption in the first 24 hours. The results showed that the block group had significantly lower fentanyl consumption in the first 24 hours compared to the control group. Although the time to the first analgesic request was shorter in the control group, postoperative pain scores at rest and with cough were significantly lower in the block group. The study concludes that bilateral transversus thoracic muscle plane block is a promising and effective technique for reducing opioid consumption and controlling post-sternotomy pain after open-heart surgery via median sternotomy.								
Thematic Analysis: Key Themes or FSP-related significance: **1.** The study aimed to evaluate the analgesic efficacy of ultrasound-guided bilateral transversus thoracic muscle plane block after open-heart surgeries.								

2. The study included 70 patients aged above 18 years undergoing valve replacement or adult congenital surgeries via median sternotomy.
3. The primary outcome measured was the total fentanyl consumption in the first 24 hours. Secondary outcomes included pain score, time to their first analgesic request, time to extubation, ICU stays, and hospital stay.
4. The block group had significantly lower fentanyl consumption in the first 24-hours compared to the control group. The time to the first analgesic request was shorter in the control group. Pain scores at rest and with cough were significantly lower in the block group.
5. The study concludes that bilateral transversus thoracic muscle plane block is a promising and effective technique for reducing opioid consumption and controlling post-sternotomy pain after open-heart surgery via median sternotomy.

Evidence Review Worksheet

APA Citation: Jack, J. M., McLellan, E., Versyck, B., Englesakis, M. F., & Chin, K. J. (2020). The role of serratus anterior plane and pectoral nerves blocks in cardiac surgery, Thoracic Surgery and trauma: A qualitative systematic review. Anaesthesia, 75(10), 1372–1385. https://doi.org/10.1111/anae.15000

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Qualitative Systematic Review – MEDLINE, Medline In-process/ePubs, Embase, Cochrane Central Register of Controlled Trials, and Cochrane Database of Systematic Reviews.	**Characteristics:** Any study reporting applications of Pecs 1, Pecs 2, or serratus anterior plane block in thoracic trauma or in elective cardiac or thoracic surgical procedures. Eligible studies included: randomized controlled trials (RCTs), prospective non-	Resting and dynamic pain scores, intra-operative and postoperative analgesic requirements, time to first postoperative analgesic administration, duration of postoperative ventilatory support, changes	Resting and dynamic pain scores, intra-operative and postoperative analgesic requirements, time to first postoperative analgesic administration, duration of postoperative ventilatory support, changes	Assessed the methodological quality of included RCTs using the Cochrane Collaboration's risk of bias summary tool. Non-randomized cohort studies were assessed using the Newcastle-Ottawa Scale. Data analysis was stratified by type of	**Qualitative findings:** Lower pain scores and opioid requirements with serratus anterior plane block (SAPB). Superior pain scores and opioid consumption at 12-24 hours with thoracic paravertebral block.	Level 3	**Strengths:** Analysis and assessment of articles covering different levels of evidence. The review is reproducible. **Limitations:** Small number of RCTs involving just over 600 patients. Majority of literature comprises of small cohort studies, case series, and case

		randomized comparative studies, retrospective comparative and cohort studies, prospective observational cohort studies, and case series or reports. **Exclusion Criteria:** None noted **Setting:** June 2019	in hemodynamic parameters, length of intensive care unit (ICU) stays, length of hospital stay, patient satisfaction, adverse effects, and complications	in hemodynamic parameters, length of intensive care unit (ICU) stays, length of hospital stay, patient satisfaction, adverse effects, and complications	intervention and comparator. Qualitative analysis and summary of study findings.			reports. Some publications appeared in conference proceedings rather than in peer-reviewed journals. **Risk or harm if implemented:** Analysis assessed no increased risk or harm with implemented blocks. **Feasibility of use in the project practice area:** This article helps to increase the understanding of the available literature on the project.
Annotated Bibliography								
Annotated Bibliography statement (may be several sentences summarizing the article based upon the information above using professional APA writing style): After conducting a systematic review, it was found that serratus anterior plane and pectoral nerves blocks have an analgesic role in cardiothoracic surgery, cardiac-related interventional procedures, and chest trauma. A total of 51 studies were identified, including randomized control trials, cohort studies, case series, and case reports. The majority of randomized controlled trials focused on the serratus anterior plane block in thoracotomy or video-assisted thoracoscopic surgery, with fewer studies on pectoral nerves blocks. Evidence in thoracic trauma was primarily based on case series and reports. The results suggest that these blocks can reduce pain scores and opioid consumption compared to systemic analgesia alone for approximately 6-12 hours. The duration of action of these blocks may be longer than intercostal nerve blocks but shorter than thoracic paravertebral blockade. Continuous catheter technique							

can prolong block duration, potentially achieving similar results to thoracic epidural analgesia. It is important to note that no complications were reported, and the risk of hemodynamic instability appears to be low. The current evidence, although limited, supports the efficacy and safety of these blocks as analgesic options in cardiothoracic surgery.
Thematic Analysis: Key Themes or FSP related significance: **1.** The majority of randomized controlled trials focused on the serratus anterior plane block in thoracotomy or video-assisted thoracoscopic surgery, while fewer studies examined pectoral nerves blocks. The evidence suggested that these blocks reduce pain scores and opioid consumption compared to systemic analgesia alone in cardiothoracic surgery, cardiac-related interventional procedures, and chest trauma for approximately 6-12 hours. **2.** The duration of action of these blocks was reported to be longer than intercostal nerve blocks but potentially shorter than thoracic paravertebral blockade. Continuous catheter technique was mentioned as a way to prolong the block duration. **3.** No complications were reported, and the risk of hemodynamic instability was noted to be low. **4.** The current evidence, although limited, supports the efficacy and safety of serratus anterior plane and pectoral nerves blocks as analgesic options in cardiothoracic surgery.

Evidence Review Worksheet								
APA Citation: Kaushal, B., Chauhan, S., Saini, K., Bhoi, D., Bisoi, A. K., Sangdup, T., & Khan, M. A. (2019). Comparison of the efficacy of ultrasound-guided serratus anterior plane block, pectoral nerves II block, and intercostal nerve block for the management of postoperative thoracotomy pain after pediatric cardiac surgery. Journal of Cardiothoracic and Vascular Anesthesia, 33(2), 418–425. https://doi.org/10.1053/j.jvca.2018.08.209								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Single-center, randomized, prospective, single-blind, comparative study.	**Sample Size:** 108 – ages 6 months to 10 years. **Inclusion Criteria:** Children undergoing cardiac	**Independent variables:** **IV1=** Serratus anterior plane block (SAPB) group	**Scale(s) used:** MOPS – Modified Objective Pain Score **Outcomes:** Primary	Analysis performed using Strat software, Version 14 Continuous data is	Postoperative rescue fentanyl requirements: ICNB – 2.12 $\pm$ 0.63 μg/kg SAPB – 1.47 $\pm$ 0.47 μg/kg	Level 1	**Strengths:** This study can be reproduced at other institutions based on the methods used. The article is transparent in the methods and data

		surgery through a thoracotomy incision. **Exclusion Criteria:** Children requiring sternotomy or emergency surgery, allergy to ropivacaine, infection at the site of injection, deranged coagulation profile, previous thoracotomy, and prolonged extubation > 2 hours after surgery. **Attrition:** 0 **Setting:** Single-institution tertiary referral cardiac center in New Delhi, India.	**IV2=** Pectoral nerves (Pecs) II block **Dependent variables:** Well-established intercostal nerve block (ICNB)	outcome was post-thoracotomy pain as adjusted by the MOPS on a scale of 0 to 10. Secondary outcomes included time from arrival to the ICU to extubation, postoperative cumulative fentanyl dosage (μg/kg) up to 12 hours, and any adverse effects (related to blocks or opioids). An estimated sample size of 36 children per children was required to ensure 90% power at α = 0.05	expressed as mean and standard deviation. Qualitative data are expressed as frequency and percentage. Chi-square and the Fisher exact tests were used to examine the association among qualitative variables. One-way analysis of variance followed by Bonferroni correction was performed for comparison among groups.	Pecs II – 1.65 $\pm$ 0.79 μg/kg p-Value for Pairwise Comparison: SAPB vs Pecs II – 0.968 SAPB vs ICNB – 0.002 Pecs II vs ICNB – 0.037		analysis, documenting improvements and data that do not support the initial hypothesis. **Limitations:** Lack of a traditional control group, difficulty in assessing block in the pediatric age group due to the inability to appropriately report sensations and temperature. Rescue fentanyl administration could have compounded the MOPS assessment. **Risk or harm if implemented:** Risk of allergic reaction to local anesthetic. **Feasibility of use in the project practice area:** The proposed methods in the paper would be feasible to

								reproduce in the practice area.

Annotated Bibliography

Annotated Bibliography statement: This recent study compared the efficacy of three different blocks for managing post-thoracotomy pain in pediatric cardiac surgery: ultrasound-guided serratus anterior plane block (SAPB), pectoral nerves (Pecs) II block, and intercostal nerve block (ICNB). The study involved 108 children with congenital heart disease undergoing thoracotomy, who were randomly assigned to one of the three groups: SAPB, Pecs II, or ICNB. All groups received ropivacaine for the block. The study found that the SAPB and Pecs II blocks were equally effective as ICNB for post-thoracotomy pain management in pediatric cardiac surgery. They provided longer-lasting pain relief and were as easily performed as the traditional ICNB. The early pain scores were similar among the three groups at 1, 2, and 4 hours post-extubation. However, the SAPB group had significantly lower late pain scores compared to the ICNB group. The Pecs II group also had lower pain scores than the ICNB group at 6, 8, and 10 hours. The requirement for rescue fentanyl was higher in the ICNB group compared to the SAPB and Pecs II groups.

Thematic Analysis

Key Themes or FSP related significance:

1. The objective of the study was to compare the efficacy of different blocks (SAPB, Pecs II, and ICNB) for managing post-thoracotomy pain in pediatric cardiac surgery.

2. The study included 108 children with congenital heart disease undergoing thoracotomy.

3. The children were randomly assigned to one of the three groups (SAPB, Pecs II, or ICNB) and received ropivacaine for the ultrasound-guided block.

4. Pain scores were assessed using a modified objective pain score (MOPS) at various time intervals post-extubation. The SAPB and Pecs II groups showed lower pain scores compared to the ICNB group, particularly during the later hours. The requirement for rescue fentanyl was higher in the ICNB group.

5. SAPB and Pecs II blocks were found to be equally efficacious as ICNB for post-thoracotomy pain management in pediatric cardiac surgery. Additionally, SAPB and Pecs II blocks provided longer-lasting pain relief and were as easily performed as the traditional ICNB.

Evidence Review Worksheet								
APA Citation: Luo, R., Tong, X., Yan, W., Liu, H., Yang, L., & Zuo, Y. (2021). Effects of erector spinae plane block on postoperative pain in children undergoing surgery: A systematic review and meta-analysis of randomized controlled trials. *Pediatric Anesthesia*, *31*(10), 1046–1055. https://doi.org/10.1111/pan.14255								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Systematic Review and Meta-Analysis of Randomized Controlled Trials (RCTs)	**Inclusion Characteristics:** All RCTs that compared the analgesic efficacy of erector spinae plane block (ESPB) with no block and other types of blocks in children under 18 years undergoing surgeries. **Exclusion Criteria:** Irrelevant and duplicate studies. Ongoing trials. **Setting:** 2020, West China Hospital,	**Independent variables:** **IV1=** Patients receiving ESPB **Dependent variables:** Patients not receiving a block or other types of blocks that were not ESPBs.	Primary Outcomes: Pain intensity at rest within 24 hours postoperatively and the number of patients requiring rescue analgesics. Secondary outcomes: time to first rescue analgesic, number of patients with adverse events, including postoperative nausea and vomiting, block related complications or side effects, time to extubation,	**Statistical tests, if any:** RevMan software version 5.3. For continuous data, the inverse variance model was used and for dichotomous data, the Mantel-Haenszel model was used. Statistical heterogeneity was tested using the chi-square test and I^2 statistic. **Qualitative analysis, if any:**	**Statistical findings, if any:** Patients' scores were lower at the following intervals: 0 hours (SMD: -1.07; 95% CI: -1.6 to -0.54; I^2 = 52%) and 6 hours (SMD: -0.82; 95% CI: -1.39 to -0.25; I^2 = 79%). No significant difference at hours 12 and 24.	Level 1	**Strengths:** Extensive literature search and inclusion/exclusion criteria. Review and meta-analysis are reproducible based on the description in the article. **Limitations:** All trials included small sample sizes, sensitivity analysis was not performed, and outcomes of postoperative opioid consumption were not assessed due to inconsistencies in the reported data and time points used. **Risk or harm if implemented:** Post-op nausea and vomiting was the most reported side effect.

		Chengdu, Sichuan, China.		duration of ICU stay, and length of hospital stay.	Methodological quality of each individual trial was assessed according to the Cochrane Risk of Bias Tool and Jadad score. Bias was assessed using six domains: allocation generation, allocation concealment, blinding, completeness of outcome data, possible selected outcome reporting, and any other potential sources of bias.	Time to first rescue analgesic compared to no block group (SMD: 4.86; 95% CI: -5.39 to 5.39). **Qualitative findings, if any:**		**Feasibility of use in the project practice area:** This article would be helpful in creating a proposed outline of protocols to implement ESPBs in the postoperative period.
Annotated Bibliography								
Annotated Bibliography statement: According to this systematic review and meta-analysis, the erector spinae plane (ESP) block may provide some pain relief for children undergoing surgery. The review examined seven randomized controlled trials and found that the ESP block slightly reduced pain scores at 0 and 6 hours postoperatively at rest compared to no block. Additionally, it significantly reduced the need for rescue analgesics. However, evidence comparing the ESP block with other regional blocks is limited, and further research is needed to establish its comparative effectiveness and safety. These findings suggest that the ESP block may hold promise for postoperative pain relief in children, but more research is needed to fully understand its potential benefits.								
Thematic Analysis **Key Themes or FSP related significance:** **1.** The article discusses the use of ESP block as a regional anesthetic technique in children and highlights the need to assess its efficacy for postoperative pain relief.								

2. The results of the reviewed trials indicate that ESP block shows a slight reduction in pain scores at different postoperative time points and significantly reduces the need for rescue analgesics compared to no block. The analgesic effects of ESP block are also compared to other regional blocks in some trials.
3. The article acknowledges the limited data available and the low-quality evidence for ESP block in children. It emphasizes the need for future well-designed and larger-scale randomized controlled trials to clarify the comparative effectiveness of ESP block with other regional blocks.
4. The article suggests the potential of ESP block as a superior analgesic option in children compared to no block. However, it highlights the importance of further research to establish its efficacy, safety, and comparative effectiveness with other regional blocks in pediatric patients.

Evidence Review Worksheet

APA Citation: Macaire, P., Ho, N., Nguyen, V., Phan Van, H., Dinh Nguyen Thien, K., Bringuier, S., & Capdevila, X. (2020). Bilateral ultrasound-guided thoracic erector spinae plane blocks using a programmed intermittent bolus improve opioid-sparing postoperative analgesia in pediatric patients after open cardiac surgery: a randomized, double-blind, placebo-controlled trial. *Regional Anesthesia & Pain Medicine*, *45*(10), 805–812. https://doi.org/10.1136/rapm-2020-101496

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Randomized, double-blind, placebo-controlled study	**Sample Size:** 104 **Number of Characteristics:** Children scheduled for cardiac surgical procedures through a midline sternotomy. **Exclusion Criteria:** Patient's family refusal, a perioperative ejection fraction	**Independent variables:** **IV1 =** Patients receiving a programmed intermittent bolus (PIB) regimen of 0.1%/0.2% ropivacaine for 48 hours. **Dependent variables:** Patients receiving a regimen of PIB of normal saline	The primary outcome was decreased total opioid consumption 48 hours after surgery, and experience improved postoperative pain relief. Secondary outcomes included the COMFORT score and FLACC scale, the number of	The Shapiro-Wilk test for normality of continuous variables. Univariate analysis was performed between continuous variables with the Student's *t*-test or the Mann-Whitney test for non-Gaussian variables.	41% of patients in the saline group = 512 $\pm$ 560 μm/kg of morphine in the first 48 hours, while 14% of the ropivacaine group total dose = 120 $\pm$ 320 μg/kg of morphine in the first 48 hours.	Level 2	**Strengths:** Findings supported the hypothesis. There was a total reduction of opioid use in patients that received the ropivacaine PIB. **Limitations:** Small sample size, pediatric patients did not enter an anesthesia fast-track with on-table extubation.

		< 35%, ventricular arrhythmia/ dysrhythmia, perioperative inotropic support, redo or emergency surgical procedures, and an allergy to amide-type local anesthetics. **Attrition:** 54 **Setting:** Vinmec Central Park International Hospital, Ho Chi Minh City, Vietnam, from August 2018 to March 2019.	for 48 hours. Patients also received the same induction single-shot bilateral erector spinae plane block (ESPB)as the IV1 group.	patients receiving morphine, the number free of intravenous morphine within the 48-hour period, time to extubation, ICU length of stay, and incidence of adverse events.	Categorical variables were compared the Chi-square test or Fisher's exact test. A linear regression model was applied to include the impact of repeated measures in the same patients with mixed effects.	p = 0.03 CI = 95%		Initial bolus masked the difference in time to extubation and ICU length of stay. Dermatomal sensory blockade was not assessed. **Risk or harm if implemented:** Accidental removal of the catheter from site, precautions with the use of local anesthetics. **Feasibility of use in the project practice area:** This could be implemented in the practice area, but with a need to educate staff on how to care for and administer the medication.
Annotated Bibliography								
Annotated Bibliography statement: This study investigated the effectiveness of using bilateral erector spinae plane blocks (ESPB) with a programmed intermittent bolus regimen for postoperative pain management in children undergoing cardiac surgery. The study found that using ESPB with ropivacaine significantly reduced the total dose of morphine consumed in 48 hours compared to the control group. Patients in the ropivacaine group also had improved								

pain scores at various postoperative time points and reduced FLACC scale levels. These results suggest that using ESPB with ropivacaine is an effective method for managing postoperative pain in pediatric cardiac surgery.

Thematic Analysis

Key Themes or FSP related significance:

1. The article focuses on the issue of managing pain experienced by children after cardiac surgery

2. The article introduces ESPBs as a regional anesthesia technique that is being explored for postoperative pain relief in pediatric cardiac surgery.

3. The study divided the patients into two groups, one receiving bilateral ESPB with ropivacaine and the other receiving a control saline infusion. The effects of the treatment on morphine consumption, pain scores, and other measures were evaluated.

4. The study found that bilateral ESPB with ropivacaine resulted in significantly reduced morphine consumption, lower rates of rescue analgesia, improved pain scores, and decreased vomiting episodes compared to the control group. The study concludes that bilateral ESPB with ropivacaine provides better postoperative analgesia in pediatric cardiac surgery.

Evidence Review Worksheet

APA Citation: Monahan, A., Guay, J., Hajduk, J., & Suresh, S. (2019). Regional analgesia added to general anesthesia compared with general anesthesia plus systemic analgesia for cardiac surgery in children. *Anesthesia & Analgesia*, *128*(1), 130–136. https://doi.org/10.1213/ane.0000000000003831

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Systematic review/Meta-Analysis	**Search Characteristics:** Randomized clinical trials comparing regional anesthesia (RA) techniques with systemic analgesia in children undergoing	**Independent variables:** **IV1 =** Any type of RA technique, including neuraxial blocks (spinal, epidural, caudal) peripheral nerve blocks intrapleural	Pain scores (up to 5 days after surgery, with any ascending or descending scale), nausea and vomiting, blood loss, resources utilization (duration of mechanical	**Statistical tests, if any:** Data were analyzed with Review Manager (The Cochrane, Copenhagen, Denmark) and Comprehensive Meta-analysis	**Statistical findings, if any:** RA reduces pain at 6-8 hours after surgery: SMD, -0.81 (95% CI, -1.22 to -0.40).	Level 1	**Strengths:** **Limitations:** Systematic review of the literature. The study is reproducible through the methods described in the analysis.

		cardiac surgery. Ages 0-18 included. **Exclusion Criteria:** Observational studies, quasi-randomized trials, crossover trials, cluster-randomized trials, and retrospective trials were excluded. **Attrition:** 41 articles initially found, with 26 ultimately excluded. **Setting:** Electronic search completed in May 2018 in PubMed, Embase, and the Cochrane Central Register of Controlled Trials.	analgesia, wound infiltration, or IV lidocaine infusion. **Dependent variables:** Any type of systemic analgesia (opioids or others) by any route (IV, intramuscular, or subcutaneous) and with or without self-administration or proxy-controlled method.	ventilation, ICU length of stay, hospital length of stay), infections, reoperation, death (up to 1 year), and complications from the analgesic techniques (respiratory depression, systemic local anesthetic toxicity, transient, or lasting [> 1 month] neurological complications.	software with fixed- ($I^2 <$ 25%) or random-effects models ($I^2 \geq$ 25%). Dichotomous data were analyzed as risk ration. Continuous data were analyzed as mean differences or standardized mean differences (SMD, different scales or data that could be extracted only as *P* values).	RA reduces pain at 12-16 hours after surgery: SMD, -0.61 (95% CI, -1.04 to -0.17).		**Risk or harm if implemented:** None noted. **Feasibility of use in the project practice area:** This article would be feasible in the practice setting to guide the protocols for implementation.
Annotated Bibliography								
Annotated Bibliography statement: According to this recent systematic review, regional analgesic (RA) techniques are effective in reducing postoperative pain in children undergoing cardiac surgery for up to 24 hours after the procedure. The review analyzed 14 randomized controlled trials involving 605								

participants. The findings also revealed that there was no significant difference between RA and systemic analgesia in terms of nausea and vomiting, duration of tracheal intubation, intensive care unit and hospital length of stay, reoperation, death, and respiratory depression. Although no major complications were reported with the use of RA techniques, the studies analyzed were small and heterogeneous, indicating a need for further research to obtain more conclusive results.
Thematic Analysis **Key Themes or FSP related significance:** **1.** The article compared the effects of these two approaches on postoperative pain, nausea and vomiting, resources utilization, reoperation, death, and complications in children undergoing cardiac surgery. **2.** The article revealed that RA techniques were successful in reducing pain up to 24 hours after surgery. **3.** While RA techniques showed benefits in pain reduction, there were no notable differences between RA and systemic analgesia in terms of nausea and vomiting, duration of tracheal intubation, intensive care unit and hospital length of stay, reoperation, death, and respiratory depression. **4.** The trials did not report any signs of local anesthetic toxicity or lasting neurological or infectious complications related to the use of RA techniques. However, one trial mentioned a transient episode of diaphragmatic paralysis that resolved after discontinuation of local anesthetic administration. **5.** The results of this systematic review were based on a meta-analysis of small and heterogeneous studies. Therefore, there is a need for additional research to provide more conclusive evidence and a better understanding of the impact of RA techniques on pediatric cardiac surgery outcomes.

Evidence Review Worksheet								
APA Citation: Roy, N., Brown, M. L., Parra, M. F., Sleeper, L. A., Alrayashi, W., Nasr, V. G., Eklund, S. E., Cravero, J. P., del Nido, P. J., & Brusseau, R. (2021). Bilateral erector spinae blocks decrease perioperative opioid use after pediatric cardiac surgery. *Journal of Cardiothoracic and Vascular Anesthesia*, *35*(7), 2082–2087. https://doi.org/10.1053/j.jvca.2020.10.009								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Prospective cohort study	**Sample Size:** 10 **Number of Characteristics:** Children ages 5 to 17 years of age, undergoing elective cardiac surgery requiring cardiopulmonary	**Independent variables:** **IV1=** Patients receiving bilateral erector spinae blocks (BESB) using a ropivacaine infusion until	Evaluate the safety and feasibility of performing BESB after congenital cardiac surgery and decreased opioid use in the	Wilcoxon rank-sum test is used to compare non-normally distributed variables. Exact conditional logistic regression was	The median time to complete the blocks was 16.0 minutes. The total additional operating room	Level 2	**Strengths:** Pilot study looking at the efficacy and feasibility of BESB. Decreased opioid use in the first 48 hours for the BESB cohort. **Limitations:** An unblinded

		bypass, ERAS cardiac surgical program, primary sternotomy **Exclusion Criteria:** Patients undergoing redo procedure, significant scoliosis or other anatomic contraindication to erector spinae blocks, previous bleeding diathesis, therapeutic anticoagulation at time of block, significant hemodynamic instability or bleedin, severe developmental delay, previous chronic pain syndromes, history of opioid treatment at any point in the past 2 months before surgery, lack of parental consent.	chest tube removal **Dependent variables:** Patients in an ERAS cardiac program, not receiving BESB.	first 48 hours postoperatively. VAS – Visual Analog Scale NRS – Numeric Rating Scale INRS – Individualized Numeric Rating Scale FLACC – Face, Legs, Activity, Cry, and Consolability	used to compare dichotomous outcomes between the BESB and the ERAS control cohorts. A generalized linear model was used for continuous measures. Fisher exact or chi-square test was used to compare patient characteristics of the two cohorts.	time was 24.0 minutes. The median infusion time was 47.5 hours. Oral morphine equivalents (OME) during the first 48 hours: BESB patients – 0.81mg/kg and ERADS patients – 1.10 mg/kg. p=0.04 Median total postoperative opioid use: BESB – OME 1.34 mg/kg and ERAS – OME 1.51 mg/kg. Not statistically significant p=0.18.		observational cohort study with a potential bias for the administration of opioids. Small sample size, designed to ensure feasibility. **Risk or harm if implemented:** Concerns for catheter displacement once placed. **Feasibility of use in the project practice area:** Potentially feasible in the practice setting, with larger studies needed to determine efficacy.

		Attrition: 0 **Setting:** Quaternary children's hospital, university setting from October 1, 2018 to September 30, 2019.						

Annotated Bibliography

Annotated Bibliography statement: This study was conducted in a children's hospital to assess the feasibility and effectiveness of continuous bilateral erector spinae blocks for managing post-sternotomy pain in pediatric cardiac surgery. The study included ten children between the ages of five and 17 who underwent elective cardiac surgery and were matched with control patients. The bilateral blocks were performed using ultrasound guidance and were completed in a median time of 16.0 minutes without any major adverse events. Pain scores were low in both groups, but patients who received the blocks had significantly reduced opioid use at 48 hours post-surgery compared to the control group. There were no significant differences in recovery metrics, length of stay, or complications between the two groups. The study concluded that bilateral erector spinae blocks were associated with decreased opioid use, which may lead to improved recovery and patient satisfaction. However, larger studies are needed to confirm these findings.

Thematic Analysis

Key Themes or FSP related significance:

1. The study aimed to evaluate the feasibility and efficacy of continuous bilateral erector spinae blocks for managing post-sternotomy pain in pediatric cardiac surgery.

2. The study was a prospective cohort study conducted in a quaternary children's hospital. Patients who received bilateral blocks were compared to a matched control group. Conditional logistic regression and generalized linear models were used for analysis.

3. Ultrasound-guided bilateral erector spinae blocks were performed at the conclusion of the cardiac surgical procedure. The blocks involved the infusion of ropivacaine until chest tube removal. Standardized postoperative management guidelines were followed.

4. The bilateral blocks were feasible to perform, with a median completion time of 16.0 minutes and no major adverse events identified.

5. Pain scores were low in both the bilateral blocks group and the control group.

6. Patients who received the bilateral blocks had significantly reduced opioid use (measured as oral morphine equivalents) at 48 hours post-surgery compared to the control group. There were no significant differences in recovery metrics, length of stay, or complications between the two groups.