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Final Scholarly Project: Evidence-based Practice Guidelines for the Perioperative Management of Blood Glucose Levels in the Cardiac Surgery Patient

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Abstract

Cardiovascular disease is the leading cause of mortality worldwide, necessitating a high demand for cardiac surgery. A unique stressor for cardiac surgery is an increased surgical stress response involving hyperglycemia. Perioperative hyperglycemia contributes to adverse postoperative outcomes following cardiac surgery. Current evidence examines blood glucose control and its effect on adverse postoperative outcomes, including sternal wound infections, acute kidney injury, prolonged mechanical ventilation, and an increased length of stay in the intensive care unit. Despite the link between hyperglycemia and poor postoperative outcomes, most facilities lack standardized guidelines for the perioperative management of blood glucose levels in cardiac surgery patients. This project aims to have anesthesia providers implement blood glucose management guidelines in adult cardiac surgery patients during the perioperative setting. The Johns Hopkins Evidence-based Practice model guided the project through initial research, planning, implementation, and dissemination. A literature synthesis and analysis were conducted to synthesize current evidence supporting the development of guidelines to decrease adverse postoperative outcomes after cardiac surgery. The project team educated critical stakeholders, including anesthesia providers, and implemented blood glucose management guidelines based on current evidence. Outcomes following the implementation of the blood glucose guidelines will be compared to pre-implementation outcomes. The project team will analyze the post-implementation outcomes, including sternal wound infections, acute kidney injury, prolonged mechanical ventilation, and an increased length of stay in the intensive care unit, for improvements to assess whether the guidelines can be disseminated, or adjustments are needed.

Keywords: cardiac surgery, blood glucose, guidelines, complications, perioperative, hyperglycemia, anesthesia

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Introduction

Cardiovascular disease is the leading cause of death globally (World Health Organization (WHO), 2021). According to the WHO (2021), cardiovascular disease will remain the leading cause of mortality over the next decade. Treatment options for cardiovascular disease include lifestyle changes, implementing medications should lifestyle changes not be sufficient, and surgical intervention (Mayo Clinic, 2022). With cardiovascular disease as the leading cause of mortality and advances in medical techniques, the demand for cardiac surgery will remain high. Nearly 500,000 people in the United States had cardiac surgery in 2018 (Cleveland Clinic, 2022). Cardiac surgery can occur for many reasons, including improving blood flow due to blocked coronary vessels of the heart, repairing or replacing valves within the heart, regulating abnormal rhythms, fixing a dilated blood vessel, or performing a heart transplant (Cleveland Clinic, 2022). While cardiac surgery may be needed for differing reasons, each surgical experience provides a unique stressor for cardiac surgery patients.

Due to the surgical stress response during cardiac surgery, this patient population is at an increased risk for complications. Surgical stress, inotropic medications, corticosteroids, and glucose-containing solutions administered during surgery place cardiac surgery patients at a higher risk for hyperglycemia (Matsumoto et al., 2022). Matsumoto et al. (2022) state that over 60% of cardiac surgery patients experience hyperglycemia. Hyperglycemia is an issue due to the inflammatory response it induces, and it can contribute to postoperative organ dysfunction (Matsumoto et al., 2022).

The prevalence of cardiac disease ensures a continuing necessity for cardiac surgery, and advanced practice providers should implement practices to avoid preventable complications. Cardiac surgery induces a stress response that can increase blood glucose levels and cause inflammation (Matsumoto et al., 2022). Adequate blood glucose management during the perioperative period will prevent undesired postoperative outcomes. Anesthesia providers are responsible for regulating blood glucose levels during the perioperative period. However, there is variability in best practices on the optimal blood glucose level to maintain and the best mechanism to achieve the desired blood glucose level. The literature evaluates strict blood glucose control compared to more liberal control of blood glucose levels. Overall, the literature notes the wide variability in practice and points toward favored outcomes with optimal blood glucose control. This project aims to optimize perioperative blood glucose management to minimize adverse postoperative outcomes.

Background

When a patient undergoes general anesthesia, there is a disruption to normal physiological processes where the body cannot adequately regulate blood glucose levels. Typically, there is a balance between the body's glucose production and utilization to maintain glucose levels between 70 and 100 mg/dL (Duggan et al., 2017). However, general anesthesia and surgery cause a surge of circulating hormones, including catecholamines, cortisol, and glucagon, which increase baseline blood glucose levels (Duggan et al., 2017). Consequently, the body cannot produce adequate insulin, and patients often develop insulin resistance (Duggan et al., 2017). According to Duggan et al. (2017), these processes are most pronounced on the first postoperative day and can last up to 21 days following surgery. Therefore, it is imperative to adequately manage blood glucose levels intraoperatively to prevent hyperglycemia's lasting effects long after surgery.

Some of the lasting effects of hyperglycemia occurring in cardiac surgery patients are organ damage, including acute kidney injury (AKI), the need for prolonged mechanical ventilation, and an increased length of stay in the intensive care unit (ICU) (Matsumoto et al., 2022). A study by Moitra et al. (2017) explains that prolonged mechanical ventilation and increased length of stay in the ICU lead to a higher incidence of mortality. During an extended ICU stay, complications can occur, such as hospital-acquired infections, malnutrition, immune suppression, posttraumatic stress disorder, and dysfunction of the brain (Moitra et al., 2017). Another complication contributing to morbidity and mortality among cardiac surgery patients is sternal wound infections (SWI) (de Vries et al., 2017). SWIs can be connected to the incidence and degree of hyperglycemia. Therefore, maintaining normal blood glucose levels is imperative.

Elevated blood glucose levels can contribute to the incidence of postoperative AKI and SWI, increased duration of mechanical ventilation, and increased length of ICU stay. According to Haga et al. (2011), hyperglycemia additionally contributes to SWI by impairing white blood cell activity, thus depressing the immune system. Additionally, hyperglycemia contributes to endothelial cell dysfunction, cerebral ischemia, and postoperative sepsis, which contribute to adverse postoperative outcomes (Emam et al., 2010).

Differing complications from elevated blood glucose levels appeared in the literature but were much less consistent. Hua et al. (2012) included 30-day mortality rates as a dependent variable. Jin et al. (2020) included mortality and atrial fibrillation in the outcomes examined. Additionally, Matsumoto et al. (2022) generalized adverse outcomes with the phrase postoperative end-organ dysfunction (PEOD). PEOD included outcomes such as delirium and myocardial injury (Matsumoto et al., 2022). Lastly, Wahby et al. (2016) included the need for inotropic support as an adverse outcome, and Zadeh and Azemati (2020) included cardiac arrhythmias and cerebrovascular accidents as adverse outcomes. The author excluded these complications from consideration because of the lack of prevalence in the literature.

Cardiac surgery patients provide a unique challenge for hyperglycemia treatment due to the severity of surgical stimulation. According to Duggan et al. (2017), 20-40% of general surgery patients experience hyperglycemia, while around 80% of cardiac surgery patients experience hyperglycemia. A contributor to hyperglycemia in cardiac surgery patients is the glucose levels in the priming solution for cardiopulmonary bypass, which often creates a challenging environment for glucose management (Pereira et al., 2017). Additionally, when patients are placed on cardiopulmonary bypass, there is an increased risk of hypothermia, which directly inhibits insulin secretion, resulting in the patient becoming hypoglycemic (Pereira et al., 2017). Due to the inability to produce insulin, there should be frequent monitoring and interventions during surgery by the anesthesia provider to manage blood glucose levels.

While surgical intervention places patients at an increased risk for hyperglycemia, an added challenge for anesthesia providers is the rising number of diabetic patients encountered during practice. For example, around 40% of patients undergoing coronary artery bypass graft surgery (CABG) have diabetes or intolerance to glucose (Siddiqui et al., 2019). Additionally, many patients undergoing surgical procedures have an unknown glucose intolerance or meet the criteria for diabetes without already having a preexisting diagnosis (Duggan et al., 2017). Therefore, with the development and implementation of blood glucose management guidelines for cardiac surgery patients, the anesthesia provider will be better equipped to manage hyperglycemia.

Significance to the Profession

Postoperative complications resulting from hyperglycemia can be connected to the anesthetic management of blood glucose levels during the perioperative period. The active management and medical intervention of blood glucose is typically based on anesthesia provider preference and traditional methods rather than guidelines based on the most recent evidence. According to Crowley et al. (2023), there are numerous variations in guidelines for best practices for managing intraoperative hyperglycemia. Guidelines are often based on expert opinions or consensus, resulting in differing approaches between facilities (Crowley et al., 2023). Blood glucose management guidelines may be present on medical floors but often vary within operating rooms (OR). Therefore, facilities would benefit from guidelines for anesthesia providers to utilize and manage patient blood glucose levels. Implementing blood glucose guidelines by certified registered nurse anesthetists (CRNA) during the perioperative period would decrease adverse events in the postoperative period.

PICO(T) Question

By reviewing the current literature, patients undergoing cardiac surgery who become hyperglycemic often experience adverse postoperative outcomes. This scholarly project will address the following question: In open heart surgical patients undergoing general anesthesia (P), would the development and implementation of evidence-based practice (EBP) guidelines for blood glucose management (I), compared to a traditional approach (C), affect clinical outcomes such as acute kidney injury (AKI), sternal wound infection (SWI), the need for prolonged mechanical ventilation, and an increased length of stay in the ICU (O) within 96 hours during the postoperative period (T)?

Project Objectives

Standardizing blood glucose management will allow anesthesia providers to provide consistent treatment to improve patient outcomes. Recent evidence shows that maintaining blood glucose levels near the normal range, between 70 and 110 mg/dL, improves postoperative patient outcomes (Siddiqui et al., 2019). However, implementing guidelines for blood glucose management will require financial resources, planning for implementation, and adjusting guidelines if outcomes are not optimal.

This Doctor of Nursing Practice (DNP) scholarly project aims to implement guidelines for blood glucose management of cardiac surgery patients based on current EBP research. Establishing blood glucose control guidelines based on EBP aims to improve patient outcomes. Therefore, the objectives of this DNP project are as follows:

- Develop EBP guidelines for blood glucose management for cardiac surgery patients in the perioperative setting;
- Develop a comprehensive plan to implement the blood glucose management guidelines in the perioperative setting;
- Develop a comprehensive plan on how to monitor and measure the use of the blood glucose management guidelines;
- Develop a comprehensive plan to adjust the guidelines if the outcomes are less than desirable.

Conclusively, adequate blood glucose management in cardiac surgery patients will promote safety and reduce adverse outcomes. Although anesthesia providers regularly treat blood glucose levels with conventional methods, they are insufficient and can lead to adverse postoperative outcomes. Standardization of blood glucose management into guidelines for anesthesia providers is necessary.

Literature Analysis & Synthesis

Databases

The practice gap guided the literature search and utilized Otterbein University's OneSearch from the Courtright Memorial Library. OneSearch offers multiple databases, including but not limited to Cumulative Index to Nursing and Allied Health Literature (CINAHL), Academic Search Complete, Cochrane Library, and Open Access Journal (Otterbein University, 2023). Approximately 90 percent of library databases are included within OneSearch, offering a comprehensive literature search to find the best and most current evidence (Otterbein University, 2023).

Within OneSearch, there is an option for advanced settings to enable the selection of a date range, ensure full-text articles are available, and only show scholarly, peer-reviewed articles. Boolean operators between phrases were used to narrow results and exclude non-related material. The author searched for current evidence on perioperative blood glucose management practices for cardiac surgery patients. Once a general search was conducted and the results narrowed, the author examined the articles to ensure they were directly related to the PICOT question.

Literature Search Terms

The initial search results from the phrase "intraoperative blood glucose management" on OneSearch yielded 25,878 results. To further narrow results, advanced settings ensured articles were available in full-text options and were scholarly peer-reviewed articles, which generated 10,252 results. To further narrow the search and ensure the inclusion of the correct population, the Boolean operator "AND" was used, and the phrase "adult cardiac surgery patients" was added to the search. In addition, the selection of the year range of 2010 and 2023 yielded 7,999 results. Two articles were exceptions to the date range being slightly before 2010. Even though these articles were slightly older, in conjunction with additional evidence, they proved significant to the project. Finally, the other search phrase, "postoperative outcomes," with the Boolean operator "AND" was added, resulting in 134 articles.

Several articles removed from consideration focused on non-cardiac surgery patients despite the search including "cardiac surgery patients." Additional articles focused on pediatric cardiac surgery patients under 18 years of age, thus, could not be used. Articles discussing preoperative or postoperative glucose management within the ICU did not meet the criteria of the PICOT question. Some articles discussed the preoperative use of diabetic medications on blood glucose levels during cardiac surgery and did not focus on perioperative management of blood glucose levels and were subsequently left out of consideration. Other articles excluded included those focusing on lab results besides blood glucose levels. After a rigorous review of the search results, the author selected 13 of the 134 articles as evidence directly relating to the PICOT question. A synthesis of the evidence gathered in this project can be seen in Appendix A.

Literature Analysis

Management of Perioperative Blood Glucose Levels

Due to the various management protocols within hospital systems, by focusing on best practice guidelines, there will be a consensus on best practices to avoid adverse postoperative outcomes. Frequently, perioperative glucose management is deferred to the discretion of the anesthesia provider. Due to the lack of a standardized blood glucose management approach, the frequency at which anesthesia providers monitor blood glucose levels varies. A common theme is a form of stricter blood glucose control, typically through continuous intravenous insulin drips, compared to a more liberal form of blood glucose control that allows higher blood glucose levels. For example, Emam et al. (2010) evaluated tight glycemic control to maintain blood glucose levels between 100 and 150 mg/dL versus liberal glycemic control to maintain blood glucose levels less than 200 mg/dL and the effect on postoperative outcomes. Tight glycemic control was associated with a decrease in adverse postoperative outcomes compared to liberal glycemic control.

Several systematic reviews and meta-analyses, including de Vries et al. (2017), Haga et al. (2011), Hua et al. (2012), Jin et al. (2020), and Thiessen et al. (2015) examined the effect of tight glycemic control versus liberal glycemic control or conventional methods. While studies evaluated differed on exact management and target blood glucose levels, there was a trend between intervention groups kept at lower blood glucose targets and allowance of higher blood glucose targets. For example, a meta-analysis by de Vries et al. (2017) examined 15 randomized controlled trials (RCT) on cardiac surgery patients that underwent either intensive blood glucose control or conventional methods, often left to the provider's discretion.

Other meta-analyses were more specific in blood glucose control and interventions to achieve such targets. A systematic review by Gandhi et al. (2008) examined 26 RCTs on cardiac surgery patients managed with either perioperative insulin infusion to maintain blood glucose levels less than 150 mg/dL or conventional methods. Conventional methods were inconsistent between RCTs and included blood glucose control through insulin infusion, subcutaneous insulin, or another standard of care to maintain blood glucose levels (Gandhi et al., 2008).

A randomized prospective study by Emam et al. (2010) compared the intervention of blood glucose control between 100 and 150 mg/dL to liberal glycemic control to maintain blood glucose levels less than 200 mg/dL. The intervention group's blood glucose levels were managed with a protocol utilizing an insulin drip, and the control group's levels were maintained with subcutaneous insulin via a sliding scale (Emam et al., 2010). Similarly, Lazar et al. (2009) conducted a retrospective cohort study evaluating the difference in outcomes between tight glucose control to maintain levels less than 180 mg/dL versus conventional methods. Siddiqui et al. (2019) conducted a retrospective cohort study that evaluated the use of intraoperative insulin during cardiac surgery versus no insulin use at all. According to Duggan et al. (2017), patients undergoing cardiac surgery often experience hemodynamic changes, temperature changes, inotropic medications, vast fluid shifts, and lengthy operative times, which may impact subcutaneous insulin absorption; thus, intravenous insulin use is more feasible.

An RCT by Wahby et al. (2016) evaluated the effect of tight glycemic control versus moderate glycemic control on cardiac surgery patients during coronary artery bypass graft (CABG) surgery. Tight glycemic control was defined as blood glucose levels between 110 and 149 mg/dL and moderate glycemic control between 150 and 180 mg/dL (Wahby et al., 2016). Another RCT by Zadeh and Azemati (2020) evaluated a more considerable difference in blood glucose levels between groups. One group's blood glucose levels were maintained between 100 and 120 mg/dL, while the others were less than 200 mg/dL.

A retrospective cohort study that differed slightly looked at C-reactive protein (CRP) levels combined with blood glucose levels during cardiac surgery and the effect on the incidence of AKI and length of ICU stay (Lee et al., 2021). Blood glucose levels were kept at less than 140 mg/dL, or a higher blood glucose level was allowed (Lee et al., 2021). Matsumoto et al. (2022) also utilized a separate blood glucose measurement method within a retrospective observational study. The blood glucose exposure index (GE index) evaluates both the severity and duration of hyperglycemia during the perioperative period for cardiac surgery patients (Matsumoto et al., 2022). According to Matsumoto et al. (2022), the GE index is the combination of the magnitude and duration of blood glucose levels greater than 180 mg/dL. The study evaluated patients with lower GE indexes versus those with higher GE indexes and the effect on postoperative outcomes (Matsumoto et al., 2022). While the measurement methods differ slightly, they examine liberal blood glucose levels compared to stricter levels and the effect on postoperative outcomes.

Adverse Effect of Tight Blood Glucose Control

A potential downside to strict blood glucose control is the potential for hypoglycemia. According to Wahby et al. (2016), hypoglycemia was increased when blood glucose levels were maintained between 80 and 110 mg/dL, with no significant improvement in postoperative outcomes. Hypoglycemia is especially dangerous because if blood glucose levels become too low, the brain will not receive enough glucose and will not function correctly (American Diabetes Association, 2024). If hypoglycemia occurs for long periods, this may lead to seizures, coma, and even death (American Diabetes Association, 2024). Therefore, while stricter blood glucose control improves postoperative outcomes, management should be structured to avoid hypoglycemia. Guidelines should include treatment options for hypoglycemia and ensure prompt recognition of hypoglycemia should it occur.

A meta-analysis by de Vries et al. (2017) found an increased incidence of hypoglycemia within the strict blood glucose control group. However, the hypoglycemic incidences were without an increased risk of stroke or death (de Vries et al., 2017). For example, in the systematic review by Gandhi et al. (2008), hypoglycemia occurred when the overcorrection of elevated blood glucose levels occurred. The intervention group in this study had blood glucose levels maintained at less than 150 mg/dL (Gandhi et al., 2008). If a lower limit to blood glucose management is implemented as a guide, providers might be better able to avoid hypoglycemia as a complication of stricter blood glucose management.

Outcomes of Blood Glucose Management

Sternal Wound Infection.

Most articles found that with blood glucose levels kept below 180 mg/dL, there was a decreased incidence of SWI. Meta-analyses and systematic reviews by de Vries et al. (2017), Gandhi et al. (2008), Hua et al. (2012), Jin et al. (2020), and Thiessen et al. (2015) observed decreases in SWIs in cardiac surgery patients undergoing stricter blood glucose control, with levels between 140 and 180 mg/dL, during the perioperative period. A randomized prospective study by Emam et al. (2010) saw no SWIs in the tight glycemic control group, while the liberal glycemic control group experienced five wound infections. Additionally, retrospective cohort studies by Lazar et al. (2009) and Siddiqui et al. (2019) reported a reduction in SWIs in the tight glucose control groups compared to those managed with conventional methods. Both RCTs by Wahby et al. (2016) and Zadeh and Azemati (2020) saw a decreased incidence of SWIs in the intervention group. Evidence strongly correlates with a decreased risk of SWI when stricter blood glucose levels were maintained during the perioperative period.

Acute Kidney Injury.

AKI was discussed in retrospective cohort studies by Lee et al. (2021) and Matsumoto et al. (2022). AKI was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria based on serum creatinine levels (Matsumoto et al., 2022). A rise in serum creatinine greater than 1.5 times the baseline level was an AKI (Matsumoto et al., 2022). Lee et al. (2021) evaluated blood glucose levels and found a decreased incidence of AKI in normoglycemic patients. As previously stated, Matsumoto et al. (2022) evaluated glucose levels based on the patient's GE index. Patients with higher GE indexes experienced an increased incidence of AKI (Matsumoto et al., 2022). RCTs conducted by Wahby et al. (2016) and Zadeh and Azemati (2020) also evaluated AKI. Wahby et al. (2016) saw a reduction in the occurrence of AKI in the tight glycemic control group, while Zadeh and Azemati (2020) saw no statistical difference in the incidence of AKI between the intervention group and control group. While there is an outlier in the RCT conducted by Zadeh and Azemati (2020), where there was no statistical difference in AKI between groups, there was an overall reduction in the incidence of AKI with tighter blood glucose control in the additional evidence.

Prolonged Mechanical Ventilation.

Prolonged mechanical ventilation is an adverse outcome of hyperglycemia during the perioperative period. Haga et al. (2011) saw a decreased length of mechanical ventilation in patients managed with tight glycemic control. The systemic review and meta-analysis by Haga et al. (2011) evaluated around 1500 patients, proving significant due to the number of studies and patients evaluated. A retrospective observational study by Matsumoto et al. (2022) evaluating 553 patients saw an increased duration of mechanical ventilation in patients with higher GE indexes. Prolonged mechanical ventilation was defined as failure to wean from the ventilator within 24 hours (Matsumoto et al., 2022). The RCT conducted by Wahby et al. (2016) saw a shorter duration of mechanical ventilation, defined as less than 24 hours, with tight glycemic control compared to moderate glycemic control.

Conversely, Siddiqui et al. (2019) saw a minor increase in the duration of mechanical ventilation with the use of insulin during the perioperative period. While one study conflicts with most evidence, the retrospective study by Siddiqui et al. (2019) consisted of only 129 patients.

More robust levels of evidence still support maintaining tighter blood glucose levels, resulting in decreased days spent on mechanical ventilation.

Increased Length of Stay in the Intensive Care Unit.

The length of time spent in the ICU relating to blood glucose management was frequently considered in the literature. Randomized prospective studies by Emam et al. (2010) and Lee et al. (2021) saw shorter ICU stay lengths in patients with tighter blood glucose levels. Studies by Gandhi et al. (2008), Haga et al. (2011), and Thiessen et al. (2015) saw a decreased length of stay in the ICU in patients managed with tight blood glucose control during the perioperative period compared to more liberal blood glucose control methods. Most studies saw lengths of stay decrease to less than 48 hours in intervention groups. The RCT conducted by Zadeh and Azemati (2020) saw no statistical difference in the length of ICU stays between the tight glycemic control group and the liberal control group. While the RCT by Zadeh and Azemati (2020) saw no statistical evidence, most articles found a decreased length of stay in the ICU with tighter blood glucose control. Decreasing ICU stay length is imperative for cardiac surgery patients to decrease overall morbidity and mortality (Moitra et al., 2017).

Literature Synthesis

The lack of standardized blood glucose management in the perioperative period for adult cardiac surgery patients presents a problem for anesthesia providers. According to Matsumoto et al. (2021), hyperglycemia during the perioperative period is associated with an increased incidence of adverse postoperative outcomes. Patients with lower blood glucose levels during the perioperative period experienced fewer adverse postoperative outcomes (Matsumoto et al., 2021). By looking at current evidence, this project aims to implement guidelines for anesthesia providers to follow during cardiac surgery to optimize patient outcomes in the postoperative period.

Evidence shows a direct correlation between elevated blood glucose levels and adverse postoperative outcomes, including AKI, SWI, prolonged mechanical ventilation, and increased length of stay in the ICU. The articles discussed show that stricter blood glucose control, compared to more liberal blood glucose control or conventional methods, leads to a decreased incidence of adverse outcomes in the postoperative period. Managing elevated blood glucose levels is critical because any patient undergoing cardiac surgery is already at an increased risk for hyperglycemia due to the surgical stress response. Another essential factor to consider is the high number of patients undergoing cardiac surgery concurrently with diabetes mellitus (Wahby et al., 2016).

Studies frequently set the upper blood glucose level around 150 mg/dL or 180 mg/dL, such as the study by Emam et al. (2010) that had blood glucose levels in the tight glycemic control group maintained between 100 and 150 mg/dL. A clear benefit is evident when blood glucose levels are less than 150 mg/dL. While it is crucial for guidelines for blood glucose management during the perioperative period to maintain blood glucose levels lower than 180 mg/dL, it is also critical to avoid hypoglycemia as a complication. Setting a lower limit to blood glucose control will aid in the avoidance of hypoglycemia. Therefore, blood glucose guidelines to maintain levels between 100 and 150 mg/dL will provide optimal management of cardiac surgery patients and decrease adverse postoperative outcomes.

Evidence-based Practice Model

Johns Hopkins Evidence-Based Practice Model

The Johns Hopkins Evidence-Based Practice (JHEBP) model guides nurses and healthcare professionals through the EBP process. Within the model are multiple user-friendly tools designed to assist professionals in decision-making and problem-solving (Dang et al., 2022). Within the model is the PET process, which stands for practice question, evidence, and translation (Dang et al., 2022). The model begins by asking a clinical question, proceeds to analyze current evidence, and finally translates the evidence to improve clinical practice, as seen in Appendix B (Dang et al., 2022). Within each step, a reflection is crucial to the success of the project (Dang et al., 2022). According to Dang et al. (2022), as the JHEBP model evolves, the goal remains constant: to provide a system to incorporate best practices into routine clinical care. Permission to utilize the JHEBP model was obtained on June 23, 2022, by an online request to Johns Hopkins Hospital, as seen in Appendix C.

Practice Question

The JHEBP model states to succinctly define the practice question stemming directly from a clinical problem (Dang et al., 2022). Defining the practice question begins with gathering an interprofessional team (Upstate Medical University, 2023). The clinical problem should come from healthcare professionals directly involved, such as anesthesia providers. A variety of perspectives allows for an all-encompassing approach to the problem and assists in identifying key stakeholders (Upstate Medical University, 2023).

According to Ascenzi et al. (2021), the PICOT question guides clinical problem-solving. The clinical problem for this scholarly project is the need for standardized guidelines for blood glucose management in adult cardiac surgery patients during the perioperative period. Refining the clinical problem into an EBP question leads to relevant results when searching the literature (Upstate Medical University, 2023). The practice question for this clinical problem is in the following PICOT format: In open heart surgical patients undergoing general anesthesia (P), would the development and implementation of EBP guidelines for blood glucose management (I), compared to a traditional approach (C), affect clinical outcomes such as acute kidney injury (AKI), sternal wound infection (SWI), the need for prolonged mechanical ventilation, and an increased length of stay in the intensive care unit (ICU) (O) within 96 hours during the postoperative period (T)?

Key stakeholders' participation in the project is paramount to successful implementation. A stakeholder is a person or group that carries out the process in question or will be affected by the change (Upstate Medical University, 2023). Stakeholders involved in implementing the guidelines include anesthesia providers, cardiothoracic surgeons, information technology (IT), hospital pharmacy, and OR nursing staff. In this process, anesthesia providers will be directly involved in blood glucose level measurement and management while implementing the guidelines.

Stakeholders must all participate in the process, but the project's success relies on choosing an appropriate leader (Upstate Medical University, 2023). The project leader is an anesthesia provider directly involved with the care of the patient and the implementation of the guidelines. The provider should have experience with EBP and be able to coordinate between the interprofessional teams involved. The scholarly author will assist the project team leader with all aspects of the project, including identifying the practice gap, gathering and synthesizing evidence, translating the evidence into guidelines, and implementing the process.

Cooperation from IT to incorporate the guidelines within the electronic medical record is necessary. Quick access to the guidelines by the anesthesia provider is essential for successful implementation. Cardiac surgery anesthesia is rigorous and requires diligent care from the anesthesia provider. The guidelines should be readily available to the anesthesia provider for successful implementation, with reminders throughout the case to ensure compliance.

Additionally, the hospital pharmacy must be aware of the guidelines and ensure an adequate supply of insulin drips is available for providers during cardiac surgery. Cardiac surgery often occurs within an OR designated explicitly for these cases. The pharmacy can supply insulin drips within the medication dispenser available to ensure ease of implementation.

In addition, cardiothoracic surgeons are actively involved in the care of their patients. Working with cardiothoracic surgeons to form guidelines that align with current EBP is essential to provide a smooth transition into implementation. With the implementation of EBP guidelines, cardiothoracic surgeons and the project team will strive to decrease adverse outcomes, including AKIs, SWIs, length of stay in the ICU, and length of mechanical ventilation.

Nursing staff will also be integral to the project's success. Perioperative nurses play a crucial role in patient care throughout the operative course. The nurses are responsible for checking patients' blood glucose levels, whether at a set time interval or when asked by the provider. Nurses are accountable for maintaining glucose monitoring equipment and supplies while caring for patients alongside the providers. Finally, laboratory services will be involved in the project by ensuring timely blood glucose readings. A singular source of monitoring should be utilized to ensure validity and consistency. Glucometers offer a quick solution to monitoring blood glucose levels, and laboratory services will be able to ensure supplies are available, along with timely results.

Meetings occur weekly once there are crucial stakeholders and the team leader. Teams that meet frequently and consistently are more likely to ensure the implementation of EBP guidelines to completion (Upstate Medical University, 2023). Within the meetings, the project team can have conversations about potential changes to the process and evaluate outcomes along the way.

Evidence

The next step within the JHEBP model is gathering evidence. According to Ascenzi et al. (2021), the author describes a clinical problem, explains its significance, and must search and critically appraise the best evidence to propose a strategy to fix the problem. According to Upstate Medical University (2023), searches are guided based on terms in the PICOT question and continue to revise and refine results. The scholarly author reviewed and analyzed current literature, described in the literature search and analysis section, to establish existing evidence and best practices regarding the clinical problem. The evidence was evaluated for current practice trends and best glucose management practices. Based on the PICOT question, a search for best practice research was compiled practices.

A consistent step within the JHEBP model is continuous evaluation of the level of evidence in the literature to ensure that the data utilized for this project provides quality recommendations supported by EBP. The JHEBP model assists the author in separating the quality of evidence (Ascenzi et al., 2021). Some evidence may be opinion pieces, while others are peer-reviewed and contain high-quality evidence applicable to the project. Higher levels of evidence, such as systematic reviews and meta-analyses, were utilized, along with supportive evidence from randomized controlled trials and prospective studies.

Summarizing gathered evidence allowed the author to view trends and utilize best practices to establish guidelines for managing blood glucose levels for cardiac surgery patients. The level of evidence should be synthesized to ensure high-quality evidence is used and consistency between findings (Upstate Medical University, 2023). Throughout the literature search process, the evidence consistently pointed towards utilizing EBP blood glucose management guidelines to prevent adverse patient outcomes. A summary of the current evidence, along with the decreased incidence of adverse outcomes, can be seen in the literature review table in Appendix A.

Translation

After analyzing and synthesizing the current literature, the evidence was translated into guidelines for clinical practice implementation. The target level was a blood glucose goal between 140 and 180 mg/dL. Interventions within the guidelines guided anesthesia providers to manage blood glucose levels during the perioperative period. The author should have a plan to perform the project within the selected facility (Upstate Medical University, 2023). Resources, such as glucometers, insulin drips, and posters, must be available, and there must be a readiness for change and an overall benefit to implementation (Upstate Medical University, 2023).

Translation to practice will require an action plan and consideration of all stakeholders involved (Dang et al., 2022). Additionally, consideration of the strengths and limitations of the action plan must occur, and alternative strategies should be in place if the desired outcome is not achieved (Dang et al., 2022). Suppose patient outcomes, including AKIs, SWIs, length of stay in the ICU, and length of mechanical ventilation, are not improving throughout the process. In that case, real-time adjustments to the amount of insulin given will need to occur. Additionally, if adverse outcomes, such as hypoglycemia, occur in multiple patients and are not easily corrected with the corrective actions listed, the guidelines must be shifted to be less strict. Participation and feedback from each group involved will be pertinent to successfully implementing the blood glucose management guidelines. Feedback should be elicited throughout the implementation phase in weekly meetings and during the evaluation phase.

A proposal of the EBP guidelines will be made available to all parties involved to gather support staff participating in implementation and resource allocation, including supplies needed for blood glucose checks. Securing support is critical to implementing the action plan. It should be accomplished by educating stakeholders on the need for change through staff meetings, along with emails updating stakeholders on when the process will begin and what will be required of them. Questions for the project team to answer should be encouraged within staff meetings and emails. Those involved will need time to process how their work will change, so the proposal should occur a month before implementation. Anesthesia providers must understand their role in implementing the guidelines, how often they need to check blood glucose levels, and the treatment for blood glucose levels within the guidelines. Cardiothoracic surgeons will need to understand the EBP guidelines and monitor the outcomes of cardiac surgery patients. Information technology will need adequate time to implement the guidelines within the electronic medical record. The hospital pharmacy must allocate insulin drips to the ORs where cardiac surgery occurs. Nursing staff should be aware of how patient care will alter, including the frequency of blood glucose monitoring and ensuring adequate supplies are available. Laboratory services must ensure adequate glucometers, control solutions, and blood glucose test strips are available for monitoring.

Evaluating outcomes and updating anesthesia providers, cardiothoracic surgeons, perioperative nursing staff, information technology, and the hospital pharmacy will assist in revising the EBP guidelines. Gathering opinions and feedback from stakeholders will allow for the proper adjustment of guidelines to ensure a smooth transition (Upstate Medical University, 2023). Opinions and feedback from key stakeholders can occur during weekly meetings, where anyone involved will be invited to attend. Stakeholders should also be encouraged to send feedback over email if they cannot attend a weekly meeting. Anticipated feedback may include satisfaction or dissatisfaction with the guidelines and possible changes to make implementation easier. Finally, once implementation is complete and improvements are seen, the author can disseminate findings through statistics displayed during staff meetings, in email format, and posters hung up in critical places, such as staff breakrooms and locker rooms. Statistics should be displayed in an easy-to-understand manner, such as tables or charts, allowing easy comparison of pre-implementation and post-implementation results. Key stakeholders will be updated on the project's success, adjustments to the amount of insulin given, and how implementation will be carried out. The implementation may continue with the guidelines as written, or another implementation phase may be needed after adjustments to the guidelines are made.

Methodology & Project Design

The practice gap of the lack of consistent blood glucose management guidelines guided the search for evidence to improve adverse outcomes following cardiac surgery. Based on the literature search and analysis of the evidence, stricter control of blood glucose levels during the perioperative period correlates with a decreased incidence of adverse outcomes, including AKIs, SWIs, length of mechanical ventilation, and length of stay in the ICU. As a result, clinical guidelines should maintain blood glucose levels between 140 and 180 mg/dL in cardiac surgery patients. This project will implement blood glucose guidelines and gather quantitative data to analyze the results.

Quantitative Data

Quantitative data will assess the number of AKIs, SWIs, length of mechanical ventilation, and length of stay in the ICU. Secondarily, compliance with cardiac surgery patients' blood glucose management guidelines during the perioperative period will be monitored. Data will come from patients' electronic medical records (EMR). Quantitative data should be collected before and after implementation to compare the results from the clinical guidelines to pre-implementation values. Pre-implementation data will include the outcomes stated in the PICOT question, including the incidences of SWI and AKI, length of mechanical ventilation, and length of stay in the ICU. Based on individual studies in the literature, assessing implementation on 50 patients is sufficient. Data should be collected from 50 cardiac surgery patients to be compared to the same number of patients post-implementation.

Data collection after implementation should include all the previously stated data points and ensure the clinical guidelines are followed. Blood glucose measurement frequency should occur hourly according to the guidelines, and the appropriate adjustment of insulin to achieve the desired blood glucose levels should be collected to ensure compliance with the guidelines. Collecting data pre-implementation and post-implementation will ensure a direct comparison between previous conventional blood glucose control and management with the new guidelines. Pre-implementation data should be collected once a month in advance from 50 adult cardiac surgery patients who had surgery in the past year. Post-implementation data should be collected within one month after completion of the implementation phase and should include 50 adult cardiac surgery patients. All data will be stored in an Excel spreadsheet on the project team leader's computer with a secure network to ensure data security.

Implementation Plan

Implementing blood glucose guidelines within cardiac surgery will include three steps: pre-implementation, trial implementation, and post-implementation. Pre-implementation will involve seeking approval to implement changes, trial implementation will carry out the guidelines, and post-implementation will assess the results.

Sample Setting & Target Population

The implementation facility of interest is an academic, level-one trauma hospital in the Midwest region where cardiac surgery occurs. CRNAs and anesthesiologists care for cardiac surgery patients during the perioperative setting and directly manage blood glucose levels perioperatively. The blood glucose management guidelines would apply to patients between 18 and 75 undergoing cardiac surgery.

Pre-implementation

First, the project team should seek approval from the correct institutional review board (IRB). Next, the project team should seek approval from the Chief CRNA and key stakeholders to implement practice changes during pre-implementation. A department meeting will occur with anesthesia providers to introduce the guidelines while providing education on the EBP guidelines. Anesthesia providers will be educated on the evidence guiding the blood glucose target between 140 and 180 mg/dL, the insulin drip rate required with each measurement, and actions to take to avoid hypoglycemia. The education will occur over an hour in the form of a PowerPoint and outline improved outcomes from studies found during the literature search portion of this project. Education for all anesthesia providers providing anesthesia for adult cardiac surgery patients will be made mandatory. The PowerPoint should highlight all stakeholder roles, including perioperative nursing staff, cardiothoracic surgeons, information technology, and hospital pharmacy. Supplies that must be readily available within the OR are glucometers and maintenance accessories, such as quality control solutions. Agreement from each stakeholder group must occur to ensure the guidelines are implemented as designed.

The project team should choose professionals from the quality-improvement (QI) team at the selected facility for data collection before implementation. The members of the QI team should gather data, listed within the quantitative section, from 50 previous cardiac surgery patients within the past year for comparison to future patients undergoing implementation of the new guidelines.

The project team used the EBP literature to decide upon blood glucose management guidelines for managing blood glucose levels in cardiac surgery patients to support the reduction of adverse postoperative outcomes, including SWIs, AKIs, length of mechanical ventilation, and length of stay in the ICU. Utilizing the guidelines determined by the literature, the project team correlated better outcomes with tighter blood glucose control. The guidelines will include an intravenous insulin infusion for consistency and reliability in treatment. Utilization of the insulin infusion guide, adapted from Duggan et al. (2017), will allow blood glucose levels within the target between 140 and 180 mg/dL, as seen in Appendix D. The anesthesia provider should monitor blood glucose levels hourly to adjust to the targeted levels. The guidelines also accounted for possible hypoglycemia and listed treatment options to avoid adverse effects.

Trial Implementation

During trial implementation, an in-service education with the presentation of the PowerPoint to the staff involved should occur. There will be one-hour-long staff meetings that will discuss the clinical problem, including perioperative hyperglycemia in cardiac surgery patients leading to an increased incidence of adverse postoperative outcomes stated in the PICOT question. Separate staff meetings will need to be provided for each stakeholder group involved, including the anesthesia department, cardiac surgeons, OR nursing staff, information technology, and pharmacy. Each meeting will be tailored to the department receiving education. For example, the project team should explain the new EBP guidelines to anesthesia providers. At the same time, the pharmacy will be notified of the guidelines focusing on the need for insulin infusions in the perioperative area. Additional time should be allotted for questions and concerns regarding implementation. Along with education in staff meetings, posters with details of the guidelines should be printed and hung in high-traffic areas. If there are inadequate supplies, purchasing will occur with funds received for the project, as described later in the budget section.

Once education has occurred, cardiac surgery patients will begin to undergo implementation of the blood glucose management guidelines. The guidelines should be implemented for 50 patients, and outcomes should be gathered for 96 hours postoperatively. Anesthesia providers should have access to the blood glucose guidelines seen within Appendix D via implementation into the EMR by IT. Additionally, the guidelines should be available in written format within the cardiac ORs for easy access. Providers should follow the guidelines precisely while maintaining vigilant patient care. Suppose a provider feels it is necessary to deviate from the blood glucose management guidelines. In that case, there will be an opportunity to provide documentation, and a follow-up will occur post-implementation.

Additionally, the project team and key stakeholders should meet weekly throughout the implementation phase to discuss observations and challenges of implementation. Possible challenges include hypoglycemia, lack of adequate supplies, technological issues with the guidelines not loading into the electronic medical record (EMR), etc. Hypoglycemia will be managed with the actions within the guidelines. IT must ensure the guidelines work correctly within the EMR if technological errors occur.

Post-implementation

Finally, after trial implementation, patient data collection gathered throughout the process will be compared to pre-implementation data. The outcomes will be averaged for easy side-by-side comparison. Along with monitoring outcomes, compliance monitoring should occur to ensure anesthesia providers correctly and adequately implement the guidelines. The goal is to view fewer adverse postoperative outcomes in cardiac surgery patients by implementing the new blood glucose management guidelines. Based on the literature, the project team should anticipate a 5% decrease in adverse outcomes for the project to be statistically significant in improving the incidence of AKIs, SWIs, prolonged mechanical ventilation, and prolonged stay in the ICU. If there is no decrease in adverse effects, the project should be adjusted or aborted to optimize patient outcomes following cardiac surgery. Possible adjustments to the project include modifying the amount of insulin given for certain blood glucose levels and modifying the treatment if hypoglycemia occurs.

If findings are sufficient and there are outcome improvements, then dissemination through emails and staff meetings should occur to ensure the continuation of implementation. After implementation, a survey will be presented to the stakeholders involved to provide feedback and gather opinions for possible areas of improvement, as seen in Appendix E.

Data Collection & Analysis

After implementation, data collection from 50 patient charts via the EMR will occur. Data collected includes the incidence of the outcomes in the PICOT question, including SWI, AKI, length of mechanical ventilation, and length of stay in the ICU for cardiac recovery. Secondary information to be collected includes the amount of insulin utilized during the perioperative period, perioperative blood glucose measurements, and how frequently they were collected. The anticipated results will reveal a decrease in the rate of postoperative outcomes when compared to blood glucose control via conventional methods. Compliance with the blood glucose management guidelines should reach a threshold of 90% to be included in the implementation evaluation.

Timeline & Budget

Timeline for Implementation

The timeline for this project would take approximately nine months to complete. Pre-implementation includes assessing current practices at the facility regarding perioperative blood glucose management during cardiac surgery. Current practices must be assessed to evaluate the changes needed to implement the new guidelines. The QI team will collect this information, which will take approximately two weeks. During this period, the project team can also inquire about supplies available within cardiac surgery ORs, such as glucometers necessary for blood glucose measurements. If the supplies for implementation are unavailable, the project team will need to acquire all the necessary equipment. The team should allocate 5-10 business days for shipping necessary equipment.

Additionally, during pre-implementation, team members of the QI team will collect retrospective data from previous patients at the facility undergoing cardiac surgery. The project team must collect the retrospective data before implementing the new guidelines. Retrospective data collection will take approximately two weeks to gather and synthesize into a presentable format.

During implementation, the guidelines will be presented via staff meetings and emails. Communication with managers and the heads of specific departments will be critical to ensure the required staff can attend meetings. The meetings should be spaced out over two weeks to ensure all involved staff can attend. Follow-up emails will be crucial to ensure that the information is disseminated appropriately to all parties involved. Overall, pre-implementation will take approximately one month. The project team should communicate with each stakeholder to ensure education is completed, data from previous patients is collected promptly, and supplies are prepared for implementation.

Once education is complete, the project team will set a date for implementing the new blood glucose management guidelines. The rollout of the guidelines will occur over seven months, with chart audits occurring at one, four, and seven-month periods. There will be a goal of 50 patient charts to match the pre-implementation audits of 50 charts for comparison. If 50 patient charts cannot be collected during this period, the project team must adjust the timeline appropriately by extending the implementation phase to match pre-implementation data. Synthesizing the statistics will occur by the end of the implementation period in the same form as the pre-implementation data.

After data collection, the project team can compare post-implementation data with pre-implementation data. The project team can assess whether improvements in outcomes, including AKIs, SWIs, length of mechanical ventilation, and length of stay in the ICU, have been made and whether to continue the implementation of the blood glucose management guidelines. If outcomes are less than desirable, the guidelines should be adjusted, such as adjusting the amount of insulin utilized or the blood glucose parameters. The post-implementation process will take approximately one month, and the guidelines can be finalized.

Budget

Considerations for the budget include the number of cardiac surgery-specific ORs within the selected facility and the availability of glucometers within the OR. The project team must also include glucometer accessories in the budget, such as control solutions and glucometer strips for reading blood glucose results. The cost of each blood glucose result must be added to the budget. Anesthesia providers can obtain blood samples from arterial lines with available syringes in the OR, which will be an additional cost to the department. Insulin infusions will already be available within the hospital; however, allocation of insulin to the cardiac OR medication dispenser will be available for easy use. The insulin drip will also be an additional cost to the patient. Intravenous pumps are available within cardiac ORs to titrate medications, including vasopressors, sedatives, and intravenous fluids. The anesthesia provider should ensure there are adequate channels on the intravenous pump for medications, along with the insulin drip required according to the guidelines.

While staff compensation must occur for their education time, staff meetings can occur during work hours, so no additional funds are required. However, there must be appropriate compensation for the CRNA coordinating and implementing this project. For proper compensation, the CRNA should log the total hours outside the regular shift required to work on this project. Additionally, the budget should include the cost of paper and ink to print signage of the blood glucose management guidelines. A layout of the potential budget is in Appendix F.

Outcomes & Analysis

Once implementation is complete, data collected from 50 patients who underwent implementation of the blood glucose guidelines will be compared to data collected from 50 patients pre-implementation. The project team will evaluate the number of postoperative outcomes within each group. The goal is a decline in adverse postoperative outcomes, including SWI, AKI, the length of mechanical ventilation, and the length of stay in the ICU. The project team should monitor for a decrease in the number of outcomes, and they will determine the success of implementation. A successful implementation will be a decrease in the number of each of the outcomes outlined. The project team should reevaluate the guidelines if there is no improvement or no change in adverse postoperative outcomes.

Suppose there is a decrease in the number of adverse postoperative outcomes. In that case, the project team should proceed with disseminating the findings and continue the implementation of the blood glucose management guidelines. The dissemination of findings will occur similarly to the introduction of the guidelines. Follow-up staff meetings with all stakeholders involved should occur to explain the improvement in outcomes following the implementation of the guidelines. Additionally, the findings should be reiterated via emails to staff and signage printed in high-traffic areas.

If reevaluation is necessary, the project team should discuss compliance with the guidelines by the providers. The QI team should look at the chart of each patient included and examine the actions of the anesthesia provider to ensure the blood glucose guidelines were followed appropriately. Additionally, the project team should evaluate feedback received via staff meetings and emails to assess overall satisfaction and potential hurdles encountered with the implementation process. The project team should discuss adjusting the guidelines if compliance issues are not encountered. If there is no decrease in the number of adverse postoperative outcomes, the project's overall goal will not have been met. The blood glucose target may need to be lower to maintain adequate glucose control to optimize postoperative outcomes. Following the proper adjustment of the blood glucose target, the project team will need to begin the implementation phases again with the updated guidelines.

Project Limitations

A limitation includes the financial means to obtain the necessary equipment to implement the blood glucose management guidelines. However, in most hospital settings, the supplies mentioned in the budget section are readily available, and reallocating resources may be the solution. While there may be minor costs upfront, additional costs can be avoided later due to resources saved with a decreased incidence of adverse postoperative outcomes. An additional limitation is potential staff non-compliance or dissatisfaction with the guidelines. Anesthesia providers may resist change within the practice and may not appreciate adding extra steps to blood glucose management. Nevertheless, with proper education, anesthesia providers should understand the potential benefits for cardiac surgery patients. This project will be cost-effective and improve cardiac surgery patients' outcomes.

Conclusion

Cardiovascular disease is the leading cause of mortality worldwide and is expected to remain as such for the next decade (WHO, 2021). The prevalence of cardiovascular disease directly correlates to the large number of cardiac surgeries that occur in the United States. A challenge of general anesthesia, heightened by cardiac surgery, is hyperglycemia (Matsumoto et al., 2022). Hyperglycemia is linked to adverse postoperative outcomes, including SWI, AKI, prolonged mechanical ventilation, and increased length of stay in the ICU. Thus, controlling blood glucose levels during cardiac surgery is essential.

Anesthesia providers lack consistency of blood glucose management, and the implementation of guidelines will allow for guidance during the perioperative period. The guidelines outlined in this project are EBP and linked to improving the incidence of SWI, AKI, prolonged mechanical ventilation, and increased length of stay in the ICU. Although hyperglycemia is expected in the perioperative period in cardiac surgery patients, blood glucose management guidelines can assist anesthesia providers with inadequate blood glucose control and decrease the incidence of adverse outcomes.

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Appendix A

APA Citation:
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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***
Theoretical basis for the study: N/A	Meta-analysis	**Number of Characteristics:** 15 RCTs comparing IV intensive glucose control versus a more conventional method Studies between January 1990-2015 Surgical site infection (SSI) as a complication **Exclusion Criteria:** Language was restricted to English, Spanish, and French **Attrition:** 12 articles excluded for not including SSI **Setting:** RCTs within differing hospital settings	**Independent variables:** **IV1=** conventional blood glucose control **IV2=** strict blood glucose control **Dependent variables:** SSI, wound infection	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):** Risk of bias was analyzed for each RCT	**Statistical tests, if any:** Number of surgical site infections and patients that experienced hypoglycemia. Review Manager version 5.3 was utilized with a random effect model **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Less incidence of surgical site infection in strict blood glucose control groups Increased risk of hypoglycemia with strict control but without increased incidence of stroke or death **Qualitative findings, if any:** N/A	Level 1	**Strengths:** High level of evidence **Limitations:** 9 out of 15 RCTs are cardiac surgery patients **Risk or harm if implemented:** Some studies with lower blood glucose targets had more patients experience hypoglycemia. **Feasibility of use in the project practice area:** Feasible using data collected from cardiac surgery studies and adjusting guidelines per hypoglycemic events.

Annotated Bibliography statement:
This meta-analysis evaluated the effect of intravenous intensive glucose control versus conventional methods in surgical patients and the effect on the incidence of surgical site infections and wound infections. A total of 15 randomized controlled trials were in the study, meeting criteria to include cardiac

surgery patients, surgical site infection (SSI) as a complication, and the intervention of intensive glucose control. The authors concluded that patients undergoing intensive glucose control had a decreased incidence of SSI. There was an increase in the incidence of hypoglycemia in the intensive glucose control group; however, this was without an increase in stroke or overall mortality. This article is the highest level of evidence and will provide helpful information in creating blood glucose management guidelines.

Thematic Analysis
Key Themes or FSP related significance:
1. Decreased SSIs with implementation of intensive blood glucose control
2. Nine out of fifteen RCTs were conducted on cardiac patients and noted a lower incidence of SSIs with intensive glucose control
3. Increased risk of hypoglycemia with intensive blood glucose control
4. Adjustment of blood glucose guidelines can be made to decrease incidence of hypoglycemia

APA Citation:
Emam, I. A., Allan, A., Eskander, K., Dhanraj, K., Farag, el-S., El-Kadi, Y., Khalaf, W., Riad, S. R., & Somia, R. (2010). Our experience of controlling diabetes in the peri-operative period of patients who underwent cardiac surgery. *Diabetes research and clinical practice*, *88*(3), 242–246. https://doi.org/10.1016/j.diabres.2010.03.002

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***
Theoretical basis for the study: N/A	Randomized prospective study	**Number of Characteristics:** 120 adults with diabetes undergoing cardiac surgery Between 2005-2008 **Exclusion Criteria:** Non-diabetic patients Non-cardiac surgery patients **Attrition:** 0 patients **Setting:** King Fahd Medical Complex	**Independent variables:** **IV1=** tight glycemic control (BG between 100-150 mg/dL) **IV2=** liberal glycemic control (BG < 200 mg/dL) **Dependent variables:** Stay in the cardiac intensive care unit (CICU), the total length of stay in the hospital, wound infection	**Scale(s) used:** Braithwaite protocol for strict glycemic control and insulin sliding scale for liberal glycemic control **Reliability information (*alphas*, if any):** N/A	**Statistical tests, if any:** SPSS t-Test at a 95% confidence level **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Tight glycemic control group had a shorter length of stay in the CICU, a shorter length of stay in the hospital, and experienced no wound infections, while the liberal glycemic control group experienced 5 wound infections	Level 4	**Strengths:** Patients were split via randomization No patient in either group experienced hypoglycemic events **Limitations:** Small group of patients studied within one hospital system **Risk or harm if implemented:** N/A **Feasibility of use in the project practice area:** Study strongly points to stricter

						Qualitative findings, if any: N/A		glycemic control as beneficial

Annotated Bibliography statement:
This randomized prospective study evaluated the effect of tight blood glucose control versus liberal blood glucose control on postoperative outcomes, including length of stay in the intensive care unit (ICU), total length of stay in the hospital, and wound infections. One hundred twenty cardiac surgery patients with diabetes were randomly placed into control and intervention groups. The intervention group was treated with tight glycemic control to keep blood glucose levels between 100 and 150 mg/dL. In comparison, the control group was treated with liberal glycemic control to maintain blood glucose levels under 200 mg/dL. The intervention group that underwent tight glycemic control experienced shorter lengths of stay in the ICU and hospital and experienced no wound infections. The control group experienced five wound infections. While this study is a lower level of evidence conducted within one hospital system, it still shows that tighter glycemic control leads to decreased adverse postoperative outcomes.

Thematic Analysis
Key Themes or FSP related significance:
1. Decreased length of stay in ICU and hospital with tighter blood glucose control
2. Decreased incidence of wound infections with tighter blood glucose control
3. Further evidence needed to support single study in one hospital system

APA Citation:
Gandhi, G. Y., Murad, M. H., Flynn, D. N., Erwin, P. J., Cavalcante, A. B., Nielsen, H. B., Capes, S. E., Thorlund, K., Montori, V. M., & Devereaux, P. J. (2008). Effect of perioperative insulin infusion on surgical morbidity and mortality: Systematic review and meta-analysis of randomized trials. *Mayo Clinic Proceedings,* 83(4), 418-430. https://doi.org/10.4065/83.4.418

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***
Theoretical basis for the study: N/A	Systematic review and meta-analysis	**Number of Characteristics:** RCTs evaluating the effects of an insulin infusion for any surgery 2552 patients in the control group 2598 patients in the intervention group Insulin infusion started during surgery	**Independent variables:** **IV1=** perioperative insulin infusion to maintain blood glucose < 150 mg/dL **IV2=** conventional methods: insulin infusion, SQ insulin, or other standard care to maintain higher	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):** Adherence with the Quality of Reporting of Meta-analyses standards Independent reviewers with reliability were utilized	**Statistical tests, if any:** DerSimonian and Laird random effects model **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Small reductions in SWI, length of ICU stay, and length of hospital stay **Qualitative findings, if any:** N/A	Level 1	**Strengths:** High level of evidence **Limitations:** 26 out of 34 RCTs were on cardiac surgery patients 12 of 34 RCTs were not truly blind **Risk or harm if implemented:** Risk of hypoglycemia with certain

		Exclusion Criteria: Excluded patients randomized to insulin infusion after experiencing myocardial infarction or cardiac arrest Excluded studies not performed in randomized fashion **Attrition:** N/A **Setting:** Various hospital settings and surgical settings	blood glucose target **Dependent variables:** Sternal wound infection (SWI), length of ICU stay, length of hospital stay					mechanisms of glucose control **Feasibility of use in the project practice area:** Overall, perioperative insulin infusion decreased mortality

Annotated Bibliography statement:
The authors listed conducted a systemic review and meta-analysis to evaluate the effect of utilizing an insulin infusion to maintain a surgical patient's blood glucose levels less than 150 mg/dL, compared to conventional methods, on postoperative outcomes. Outcomes explored include sternal wound infection (SWI), length of stay in the intensive care unit (ICU), and overall length of stay in the hospital. In total, 34 randomized controlled trials (RCT) were in the meta-analysis, and 26 were on cardiac surgery patients. Of the RCTs conducted on cardiac surgery patients, the stricter blood glucose control groups experienced small reductions in the incidence of SWIs. They had decreased lengths of stay in both the ICU and hospital. Overall, this is a high level of evidence pointing to stricter blood glucose control being beneficial in the cardiac surgery population; however, there is an added risk of hypoglycemia.

Thematic Analysis
Key Themes or FSP related significance:
1. Blood glucose control with intravenous insulin infusion leads to decreased SWIs and length of stay in the ICU and hospital
2. There is a risk of hypoglycemia if elevated blood glucose levels are overcorrected
3. Studies conducted on non-cardiac surgery patients should be excluded from consideration

APA Citation:
Haga, K. K., McClymont, K. L., Clarke, S., Grounds, R. S., Ng, K. Y. B., Glyde, D. W., Loveless, R. J., Carter, G. H., & Alston, R. P. (2011). The effect of tight glycaemic control, during and after cardiac surgery, on patient mortality and morbidity: A systematic review and meta-analysis. *Journal of Cardiothoracic Surgery*, *6*(1), 1–10. https://doi.org/10.1186/1749-8090-6-3

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***

Theoretical basis for the study: N/A	Systematic review and meta-analysis	**Number of Characteristics:** Cardiac surgery patients Compared tight glycemic control to normal control Original study data or extracted from larger systematic review Randomly assigned to groups **Exclusion Criteria:** Limited to articles published in the English language Non-cardiac surgery patients Only evaluated glucose control and not outcomes No extractable data **Attrition:** 44 potential studies were excluded **Setting:** Various surgical settings	**Independent variables:** **IV1=** Tight glycemic control **IV2=** Conventional glycemic control **Dependent variables:** Length of time in intensive care unit (ICU), length of time on mechanical ventilation	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):** RCTs were independently reviewed twice	**Statistical tests, if any:** Meta-analysis performed using RevMan5 software 95% confidence interval used **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Decreased time of mechanical ventilation Decreased length of stay in ICU **Qualitative findings, if any:** N/A	Level 1	**Strengths:** High level of evidence High volume at almost 1500 patients **Limitations:** **Risk or harm if implemented:** Risk of hypoglycemia with strict glycemic control Trials included relatively small numbers of patients **Feasibility of use in the project practice area:** Feasible considering overall significant reduction in mortality utilizing tight glycemic control

Annotated Bibliography statement:
Haga et al. (2011) conducted a systematic review and meta-analysis on cardiac surgery patients to compare perioperative tight and conventional glycemic control and the effect on length of stay in the intensive care unit (ICU) and time on mechanical ventilation. The intervention group underwent tight glycemic control and experienced a decreased length of stay in the ICU and decreased time on mechanical ventilation. The study is a high level of evidence, including almost 1500 patients, and points to a significant reduction in mortality when utilizing tight glycemic control.

Thematic Analysis
Key Themes or FSP related significance:
1. High level of evidence exemplifying benefits of tight glycemic control including decreased mechanical ventilation time and decreased length ICU stay
2. Some patients on strict glycemic control experienced hypoglycemia
3. Conventional glycemic control resulted in a higher number of adverse postoperative outcomes.

APA Citation:
Hua, J., Chen, G., Li, H., Fu, S., Zhang, L. M., Scott, M., & Li, Q. (2012). Intensive intraoperative insulin therapy versus conventional insulin therapy during cardiac surgery: a meta-analysis. *Journal of cardiothoracic and vascular anesthesia*, *26*(5), 829–834. https://doi.org/10.1053/j.jvca.2011.12.016

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***
Theoretical basis for the study: N/A	Meta-analysis	**Number of Characteristics:** Studies in any language Intraoperative insulin therapy Cardiac surgery patients Adults Between January 1966-February 2011 **Exclusion Criteria:** Not RCTs **Attrition:** 436 of 441 potential RCTs excluded **Setting:** Various cardiac surgery settings	**Independent variables:** **IV1=** Intensive insulin control **IV2=** Conventional methods **Dependent variables:** 30-day mortality and infection rates	**Scale(s) used:** **Reliability information (*alphas*, if any):** Two authors independently screened all articles	**Statistical tests, if any:** Random effects model and fixed-effects model Review Manager 5.0.0 95% confidence intervals **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Infection rates much lower in intensive insulin control group **Qualitative findings, if any:** N/A	Level 1	**Strengths:** High level of evidence **Limitations:** Limited number of RCTs included **Risk or harm if implemented:** Risk of hypoglycemia with intensive insulin control **Feasibility of use in the project practice area:** Overall decrease in infection rates prove valuable for the project, although no statistical significance seen in 30-day mortality

Annotated Bibliography statement:
The authors conducted a meta-analysis on adult cardiac surgery patients to evaluate perioperative intensive insulin control versus conventional methods to treat elevated blood glucose levels. The outcomes evaluated in this study included 30-day mortality and infection rates. The results concluded that infection rates were much lower in the intensive insulin control group, with no significant statistical difference in 30-day mortality rates. The study is a high level of evidence evaluating five randomized controlled trials. However, along with other similar studies, there is an increased risk of hypoglycemia in the intensive insulin control group.

Thematic Analysis
Key Themes or FSP related significance:
1. Intensive insulin control groups experienced fewer infections compared to groups utilizing conventional methods

2. There is no significant statistical difference of 30-day mortality rates between groups **3.** Increased risk of hypoglycemia with intensive insulin control

APA Citation:
Jin, X., Wang, J., Ma, Y., Li, X., An, P., Wang, J., Mao, W., Mu, Y., Chen, Y., & Chen, K. (2020). Association between perioperative glycemic control strategy and mortality in patients with diabetes undergoing cardiac surgery: A Systematic Review and Meta-Analysis. *Frontiers in Endocrinology*, *11*. https://doi.org/10.3389/fendo.2020.513073

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***
Theoretical basis for the study: N/A	Systematic review and meta-analysis	**Number of Characteristics:** Patients with diabetes Adults Heart surgery At least 2 different perioperative glycemic controls RCTs or cohort studies Between 2004-2016 **Exclusion Criteria:** Non-diabetic patients Non-cardiac surgery Missing concerned outcomes **Attrition:** 5,685 of 5,691 studies excluded	**Independent variables:** **IV1=** Strict glycemic control **IV2=** Moderate glycemic control **Dependent variables:** Mortality, stroke, atrial fibrillation, and sternal wound infection (SWI)	**Scale(s) used:** NOS checklist to asses for bias **Reliability information (*alphas*, if any):** 2 independent authors extracted data Disagreements settled by a discussion with a third independent researcher Risk of bias evaluated	**Statistical tests, if any:** Random or fixed effects model 95% confidence intervals **Qualitative analysis, if any:** Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system based on study design, execution limitations, inconsistency, indirectness, imprecision of results, and publication bias	**Statistical findings, if any:** No significant difference in mortality between groups No significant difference in the incidence of stroke Strict glycemic control correlated with decreased incidence of atrial fibrillation Significant reduction in the incidence of SWI with strict glycemic control **Qualitative findings, if any:** One study was an open-labeled trial	Level 1	**Strengths:** Level of evidence No significant difference in episodes of hypoglycemia between the groups **Limitations:** Limited number of RCTs - 6 **Risk or harm if implemented:** N/A **Feasibility of use in the project practice area:** Significant reduction in SWI in the strict glycemic control group makes this strong evidence to support the project

		Setting: Various cardiac surgical settings				All 6 did not report blinding of outcome assessment		

Annotated Bibliography statement:
Jin et al. (2020) conducted a systematic review and meta-analysis of randomized controlled trials (RCT) and cohort studies on adult cardiac surgery patients with diabetes between 2004 and 2016. The authors evaluated the use of strict glycemic control compared to moderate glycemic control and the effect on postoperative outcomes, including mortality, stroke, atrial fibrillation, and sternal wound infection (SWI). There was no statistical difference in mortality and incidence of stroke between the two groups. However, there was a decreased incidence of atrial fibrillation and SWIs when utilizing strict glycemic control. This study is a high level of evidence evaluating six RCTs and shows strong evidence to support tight glycemic control.

Thematic Analysis
Key Themes or FSP related significance:
1. Tight glycemic control led to a decreased incidence of SWI in cardiac surgery patients with diabetes
2. There was no significant statistical difference in mortality and the incidence of stroke between the tight and moderate glycemic control groups
3. High level of evidence supporting use of strict glycemic control

APA Citation:
Lazar, H. L., McDonnel, M., Chipkin, S. R., Furnary, A. P., Engelman, R. M., Sadhu, A. R., Bridges, C. R., Haan, C. K., Svedjeholm, R., Taegtmeyer, H., Shemin, R. J. (2009). The society of thoracic surgeons practice guideline series: Blood glucose management during adult cardiac surgery. *The Annals of Thoracic Surgery,* 87(2), 663-669. https://doi.org/10.1016/j.athoracsur.2008.11.011

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***
Theoretical basis for the study: N/A	Retrospective cohort study	**Number of Characteristics:** Cardiac surgery patients Adults **Exclusion Criteria:** None **Attrition:** N/A **Setting:** Various cardiac surgical settings	**Independent variables:** **IV1=** Tight glucose control (BG < 180 mg/dL) **IV2=** Conventional methods **Dependent variables:** SWI, length of hospital stay, morbidity, and mortality	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):** N/A	**Statistical tests, if any:** N/A **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Tight glycemic control experienced less SWI, decreased length of stay, and decreased morbidity and mortality **Qualitative findings, if any:** N/A	Level 4	**Strengths:** Large number of patients evaluated – 6,280 **Limitations:** Optimal glucose range and insulin protocols vary per study **Risk or harm if implemented:** Risk of hypoglycemia with certain protocols

								Feasibility of use in the project practice area: Decreased adverse effects with tighter blood glucose control makes this article feasible for the project

Annotated Bibliography statement:
This retrospective cohort study compared tight glucose control to maintain blood glucose levels less than 180 mg/dL to conventional methods on adult cardiac surgery patients to evaluate the effect on postoperative outcomes. Outcomes assessed in the study included sternal wound infection (SWI), length of hospital stay, morbidity, and mortality. Groups treated with tight glycemic control experienced a decreased incidence of SWIs, decreased length of stay in the hospital, and decreased morbidity and mortality. While this study is a lower level of evidence, a strength is the total number of patients evaluated, equaling 6,280 cardiac surgery patients. The study points towards decreased adverse outcomes with tight blood glucose control in the postoperative period.

Thematic Analysis
Key Themes or FSP related significance:
1. Decreased incidence of SWI and length of hospital stay with tight blood glucose control
2. Lower level of evidence but high number of patients evaluated
3. Risk of hypoglycemia seen with certain protocols to maintain tight blood glucose control

APA Citation:
Lee, S., Nam, S., Bae, J., Cho, Y. J., Jeon, Y., & Nam, K. (2021). Intraoperative hyperglycemia in patients with an elevated preoperative C-reactive protein level may increase the risk of acute kidney injury after cardiac surgery. *Journal of Anesthesia*, *35*(1), 10–19. https://doi.org/10.1007/s00540-020-02849-w

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***
Theoretical basis for the study: N/A	Retrospective cohort study	**Number of Characteristics:** Adult patients Cardiac surgery patients with or without cardiopulmonary bypass	**Independent variables:** **IV1=** Elevated CRP and hyperglycemia **IV2=** Normal CRP and normoglycemia	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):**	**Statistical tests, if any:** One-way analysis of variance or Kuskal-Wallis test Logistics regression	**Statistical findings, if any:** Lower incidence of AKI in normoglycemia and low CRP group Decreased length of stay in	Level 4	**Strengths:** Large number of patients in study – 3,625 **Limitations:** Subjects all within 1 hospital system

		Studies between January 1, 2008-December 31, 2018 **Exclusion Criteria:** Patients having more than 1 cardiac surgery Patients with end-stage renal disease, on renal replacement therapy, history of kidney transplant, or with low baseline GFR Patients with < 6 intraoperative glucose measurements **Attrition:** 2,702 of 6,327 patients **Setting:** Seoul National University Hospital in Seoul, Korea	**Dependent variables:** Acute kidney injury (AKI) within 7 days of surgery, in-hospital mortality, lengths of stay in the ICU and hospital		**Qualitative analysis, if any:** N/A	ICU and hospital in normoglycemia and low CRP group **Qualitative findings, if any:** N/A		**Risk or harm if implemented:** None **Feasibility of use in the project practice area:** CRP will not be evaluate within the project, however, normoglycemia provides strong evidence with correlation of decrease in AKI

Annotated Bibliography statement:
Lee et al. (2021) conducted a retrospective cohort study of adult cardiac surgery patients within one hospital system to evaluate C-reactive protein (CRP) levels and blood glucose levels and their effect on postoperative outcomes. Outcomes included acute kidney injury (AKI) within seven days of surgery, in-hospital mortality, and length of stay in the intensive care unit (ICU) and hospital. Patients selected had surgery between January 1, 2008 and December 1, 2018. Patients excluded included those with more than one cardiac surgery, patients with end-stage renal disease, those on renal replacement therapy, those with a history of a kidney transplant, patients with low baseline glomerular filtration rates, and patients with less than six perioperative blood glucose measurements. Overall, there was a lower incidence of AKI and decreased length of stay in the ICU in the group with normoglycemia and normal CRP levels. While this study was limited to one hospital system, the study included many patients.

Thematic Analysis
Key Themes or FSP related significance:
1. Decreased incidence of AKI and length of ICU stay in patients with normoglycemia and normal CRP levels
2. Only one hospital system evaluated, yet 3,625 patients included

3. CRP levels will not be evaluated in this final scholarly project, yet glucose levels evaluated provides evidence to support normoglycemia contribution to decreased adverse postoperative outcomes

APA Citation:
Matsumoto, S., Omiya, H., Fujinaka, W., & Morimatsu, H. (2022). Association between intraoperative hyperglycemia and postoperative end-organ dysfunctions after cardiac surgery: a retrospective observational study. *Journal of Anesthesia*, *36*(2), 174–184. https://doi.org/10.1007/s00540-021-03024-5

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*
Theoretical basis for the study: N/A	Retrospective observational study	**Number of Characteristics:** Cardiac surgery patients on cardiopulmonary bypass Between May 2015-December 2019 Patients > 20 years old **Exclusion Criteria:** Surgery with circulatory arrest Use of ECMO or LVAD Kidney disease requiring preoperative renal replacement therapy Transcatheter aortic valve replacement Pregnancy Missing primary outcomes	**Independent variables:** **IV1=** Lower GE index **IV2=** Higher GE index **Dependent variables:** Postoperative end-organ damage (PEOD) including AKI, delirium, myocardial injury, and prolonged mechanical ventilation within 72 hours following surgery	**Scale(s) used:** GE index (calculated by magnitude and duration of BG > 180 mg/dL) **Reliability information (*alphas*, if any):** Ethical Review Committee of Hiroshima City Hiroshima Citizens Hospital provided ethical approval	**Statistical tests, if any:** Mean + standard deviation or median with interquartile range Univariate analysis **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** PEOD more common in patients with greater GE indexes **Qualitative findings, if any:** N/A	Level 4	**Strengths:** Large number of patients evaluated – 553 patients **Limitations:** Study conducted at one specialized tertiary hospital **Risk or harm if implemented:** None **Feasibility of use in the project practice area:** This study supports that increased magnitude and length of hyperglycemia correlates with increased PEOD making it feasible to support the project

		Attrition: 807 of 1360 patients **Setting:** Hiroshima City Hiroshima Citizens Hospital						

Annotated Bibliography statement:
Matsumoto et al. (2022) conducted a retrospective observational study on cardiac surgery patients on cardiopulmonary bypass. The study evaluated the effect of a higher blood glucose exposure index (GE index) versus a lower GE index. The GE index was calculated by taking the magnitude and duration of blood glucose levels greater than 180 mg/dL and served to mark the severity of hyperglycemia. The authors assessed the effects of the GE index on postoperative end-organ damage, including acute kidney injury (AKI), delirium, myocardial injury, and prolonged mechanical ventilation within 72 hours of surgery. The study found that patients with a higher GE index experienced more postoperative end-organ damage. The study was limited to one specialized tertiary hospital yet included 553 patients.

Thematic Analysis
Key Themes or FSP related significance:
1. An increased magnitude and duration of hyperglycemia contributes to poor postoperative outcomes including AKI and prolonged mechanical ventilation
2. Lower level of evidence, yet still examined 553 patients
3. More studies needed to support these findings and strengthen evidence

APA Citation:
Siddiqui, K., Asghar, M., Khan, M., Khan, F., Siddiqui, K. M., Asghar, M. A., Khan, M. F., & Khan, F. H. (2019). Perioperative glycemic control and its outcome in patients following open heart surgery. *Annals of Cardiac Anaesthesia*, *22*(3), 260–264. https://doi.org/10.4103/aca.ACA_82_18

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***
Theoretical basis for the study: N/A	Retrospective observational study	**Number of Characteristics:** Open heart surgery patients Patients with diabetes Between January 2015 and December 2016 **Exclusion Criteria:** Nondiabetic patients	**Independent variables:** **IV1=** Patients receiving no insulin **IV2=** Patients receiving insulin **Dependent variables:** Cardiac arrhythmias, deep sternal infection, length of prolonged	**Scale(s) used:** N/A **Reliability information (*alphas*, if any):** Evaluated for bias by ethical committee within hospital	**Statistical tests, if any:** Statistical Packages for Social Science version 19 Mean and standard deviation were computed and analyzed by sample t-test Chi-square test	**Statistical findings, if any:** Incidence of cardiac arrhythmias and prolonged mechanical ventilation slightly increased with use of insulin Sternal infections decreased with	Level 4	**Strengths:** Thorough study evaluating multiple variables encountered during the surgical period **Limitations:** Low number of patients evaluated – 129 Study took place within single hospital system

		Emergency surgery Off-pump bypass surgery < 18 years old On dialysis History of stroke within the past 6 months **Attrition:** None **Setting:** Aga Khan Unviersity, Karachi, Pakistan	mechanical ventilation		**Qualitative analysis, if any:** N/A	the use of insulin **Qualitative findings, if any:** N/A		**Risk or harm if implemented:** Risk of hypoglycemia **Feasibility of use in the project practice area:** Lower level of evidence but still supports favored outcomes with better glucose control

Annotated Bibliography statement:
The authors conducted a retrospective observational study on open-heart surgery patients with diabetes to compare receiving no insulin in the perioperative period to receiving insulin for the treatment of hyperglycemia. Patients included had surgery between January 2015 and December 2016. Exclusion criteria included nondiabetic patients, emergency surgeries, surgeries without cardiopulmonary bypass, patients less than 18 years old, patients on dialysis, and patients with a history of a stroke within the past six months. The outcomes analyzed in this study were cardiac arrhythmias, deep sternal infections, and length of mechanical ventilation. The study concluded that patients treated with insulin in the perioperative period experienced a decreased incidence of sternal wound infections; however, they experienced a slightly increased incidence of cardiac arrhythmias and prolonged mechanical ventilation. Limitations to this study include the level of evidence, the fact that this study took place in one hospital setting, and the low number of patients evaluated. There was an increased risk of hypoglycemia for those treated with insulin compared to those without insulin.

Thematic Analysis
Key Themes or FSP related significance:
1. Incidence of sternal wound infections decreased with insulin utilization during the perioperative period
2. Lower level of evidence limited to one hospital system and smaller number of patients included compared to other studies
3. Increased risk of hypoglycemia in the insulin treatment group

APA Citation:
Thiessen, S., Vanhorebeek, I., & Van den Berghe, G. (2015). Glycemic control and outcome related to cardiopulmonary bypass. *Best Practice & Research Clinical Anaesthesiology*, *29*(2), 177–187. https://doi.org/10.1016/j.bpa.2015.03.003

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***
Theoretical basis for the study: N/A	Meta-analysis	**Number of Characteristics:**	**Independent variables:**	**Scale(s) used: Reliability information**	**Statistical tests, if any:** Not noted	**Statistical findings, if any:** 2 studies	Level 1	**Strengths:** High level of evidence

		Cardiac surgery patients Adult patients Pediatric patients **Exclusion Criteria:** Non-cardiac surgery **Attrition:** Not listed **Setting:** Various cardiac surgery settings	**IV1=** Strict blood glucose control **IV2=** Conventional methods **Dependent variables:** Sternal wound infection (SWI), increased length of hospital stay, length of stay in the ICU, duration of ventilatory support, mortality	**(*alphas*, if any):** No conflicts of interest	**Qualitative analysis, if any:** N/A	found a decrease in SWI, length of hospital stays, and mortality 1 study (prospective study) found no significant statistical difference **Qualitative findings, if any:** N/A		Large number of patients within 2 RCTs **Limitations:** Exclusion of RCTs involving pediatric patients **Risk or harm if implemented:** Increased incidence of hypoglycemia **Feasibility of use in the project practice area:** Stronger evidence (2 RCTs) support stricter blood glucose monitoring, making this article feasible for the project

Annotated Bibliography statement:
Thiessen et al. (2015) conducted a meta-analysis that evaluated the effect of strict blood glucose control compared to conventional methods on postoperative outcomes in cardiac surgery patients. Outcomes assessed included sternal wound infections (SWI), length of stay in the intensive care unit (ICU), duration of mechanical ventilation, and mortality. Three studies within this article were conducted on adult cardiac surgery patients, while the rest were on pediatric cardiac surgery patients. Two randomized controlled trials (RCT) found that strict blood glucose control decreased the incidence of SWIs, decreased the length of ICU stays, and decreased mortality. One prospective study found no significant statistical difference in outcomes between the two groups. This study is a high level of evidence, with many patients included in the RCTs. Pediatric patient studies must be excluded for use in the final scholarly project. The study also found an increased risk of hypoglycemia in patients treated with strict blood glucose control.

Thematic Analysis
Key Themes or FSP related significance:
1. Strict blood glucose control led to decreased SWI, length of stay in the ICU, and mortality
2. There is an increased risk of hypoglycemia in patients undergoing strict blood glucose control
3. Studies on pediatric patients within this meta-analysis will need to be excluded

APA Citation:
Wahby, E. A., Abo Elnasr, M. M., Eissa, M. I., & Mahmoud, S. M. (2016). Perioperative glycemic control in diabetic patients undergoing coronary artery bypass graft surgery. *Journal of the Egyptian Society of Cardio-Thoracic Surgery*, *24*(2), 143–149. https://doi.org/10.1016/j.jescts.2016.05.007

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***
Theoretical basis for the study: N/A	RCT	**Number of Characteristics:** CABG surgery patients Between January 2013-January 2015 **Exclusion Criteria:** Emergency CABG Off-pump surgery Combined valve and CABG surgery **Attrition:** None **Setting:** Tanta University Hospital and National Heart Institute	**Independent variables:** **IV1=** Tight glycemic control: BG between 110-149 mg/dL **IV2=** Moderate glycemic control: BG between 150-180 mg/dL **Dependent variables:** SWI, leg wound infection, need for inotropic support, AKI, prolonged mechanical ventilation	**Scale(s) used:** None listed **Reliability information (*alphas*, if any):** None listed	**Statistical tests, if any:** Patients randomly assigned via computer allocated generation table (graph pad software) Analysis performed using Statistical Package for Social Science (SPSS version 16) Chi-sqaure test **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Tight glycemic control group had decreased incidence of SWI, AKI, need for inotropic support, prolonged mechanical ventilation, and leg wound infection **Qualitative findings, if any:** N/A	Level 2	**Strengths:** Higher level of evidence **Limitations:** Takes place within 1 hospital setting **Risk or harm if implemented:** Slightly higher risk of hypoglycemia in tight glycemia control group **Feasibility of use in the project practice area:** Feasible due to considerable decrease in postoperative adverse outcomes in the tight glycemic control group

Annotated Bibliography statement:
The authors of this randomized controlled trial (RCT) assessed the effect of tight glycemic control to maintain blood glucose levels between 110 and 149 mg/dL versus moderate glycemic control to maintain blood glucose levels between 150 and 180 mg/dL in coronary artery bypass graft (CABG) surgery patients. Patients undergoing CABG surgery within one hospital setting between January 2013 and January 2015 were included in this study. Exclusion criteria included patients having emergency surgery, CABG surgery without cardiopulmonary bypass, and CABG surgery combined with cardiac valve surgery. Postoperative outcomes evaluated included sternal wound infections (SWI), leg wound infections, the need for inotropic support, acute kidney injury (AKI), and the length of mechanical ventilation. The study concluded that patients treated with tight glycemic control had a decreased incidence of SWIs, leg wound infections, AKIs, need for inotropic support, and a decreased length of mechanical ventilation. This study is a high level of evidence, yet it only takes place within one hospital setting. The study also found an increased risk of hypoglycemia in the tight glycemic control group.

Thematic Analysis
Key Themes or FSP related significance:

1. Decreased incidence of SWI, AKI, and length of mechanical ventilation in patients treated with strict glycemic control **2.** Higher incidence of hypoglycemia in the strict glycemic control group **3.** Higher level of evidence study

APA Citation:
Zadeh, J. & Azemati, S. (2020). Adjusted tight control blood glucose management in diabetic patients undergoing on pump coronary artery bypass graft. A randomized clinical trial. *Journal of Diabetes & Metabolic Disorders*, *19*(1), 423–430. https://doi.org/10.1007/s40200-020-00494-4

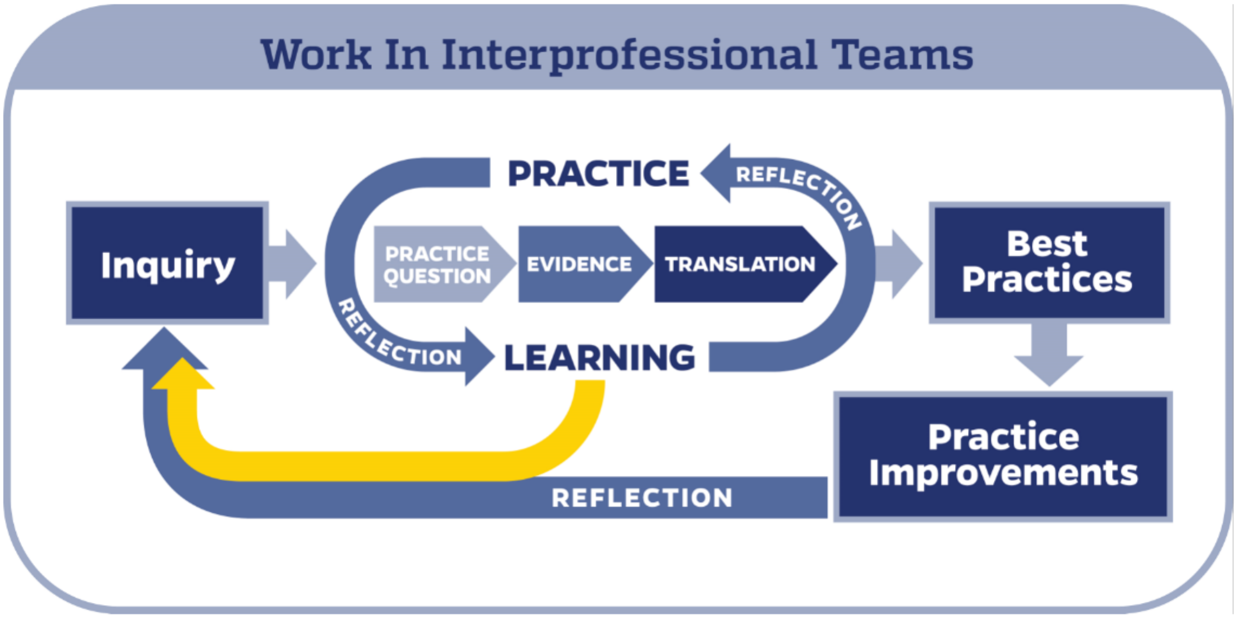
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions, if any***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
Theoretical basis for the study: N/A	RCT	**Number of Characteristics:** Patients with diabetes that are non-insulin dependent Age 18-70 years old CABG surgery patients ASA status II-III Ejection Fraction > 30% Between September 2017-March 2018 **Exclusion Criteria:** Ketoacidosis or hyperosmolar coma Redo surgery History of CVA or TIA Liver or kidney disease **Attrition:** 5 patients from	**Independent variables:** **IV1=** BG maintained between 100-120 mg/dL **IV2=** BG maintained < 200 mg/dL **Dependent variables:** SWI, mortality, cardiac arrhythmias, AKI, CVA, duration of mechanical ventilation, and length of ICU stay	**Scale(s) used:** Memorial Delirium Assessment Scale (MDAS) **Reliability information (*alphas*, if any):** None listed	**Statistical tests, if any:** Randomization via computer-generated random digits **Qualitative analysis, if any:** N/A	**Statistical findings, if any:** Decreased incidence of SWI found in the intervention group No statistical significance seen between the groups with other outcomes. **Qualitative findings, if any:** N/A	Level 2	**Strengths:** Double-blind randomized control trial **Limitations:** Study took place within 1 hospital location **Risk or harm if implemented:** Hypokalemia was experienced more frequently in the intervention group **Feasibility of use in the project practice area:** Decreased incidence of SWI makes this article feasible for use in the project

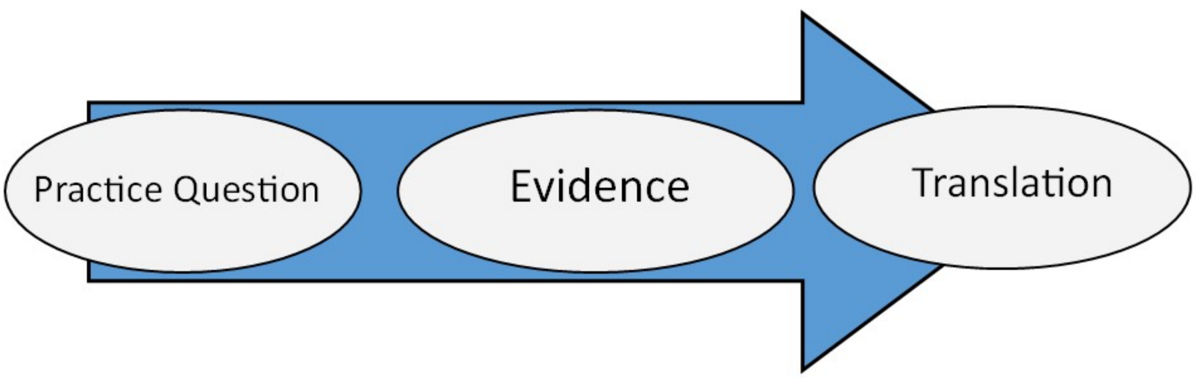
		each group excluded due to cancelled procedures **Setting:** Shahid Faghihi Hospital in Shiraz, Iran						

Annotated Bibliography:
Zadeh and Azemati (2020) conducted a randomized controlled trial (RCT) on non-insulin-dependent patients with diabetes undergoing coronary artery bypass graft (CABG) surgery. The study compared blood glucose control between 100 and 120 mg/dL to blood glucose levels maintained less than 200 mg/dL. Patients were between 18 and 70 years old, had an American Society of Anesthesiologists (ASA) status of two or three, and had an ejection fraction greater than 30 percent. The authors assessed outcomes, including sternal wound infections (SWI), mortality, cardiac arrhythmias, acute kidney injuries (AKI), cerebrovascular accidents (CVA), the duration of mechanical ventilation, and the length of stay in the intensive care unit (ICU). The group with stricter blood glucose control had a decreased incidence of SWIs, yet no statistical significance occurred between the groups concerning the other outcomes. This study's limitations are that it took place within one hospital system. Risks to the strict blood glucose control group included a higher incidence of hypokalemia.

Thematic Analysis
Key Themes or FSP related significance:
1. Decreased incidence of SWIs in the strict blood glucose control group
2. No statistical significance seen with other outcomes analyzed
3. Study took place within one hospital system and further studies to confirm findings are needed

Appendix B


Work In Interprofessional Teams
Inquiry
PRACTICE
REFLECTION
PRACTICE QUESTION
EVIDENCE
TRANSLATION
REFLECTION
LEARNING
Best Practices
Practice Improvements
REFLECTION


Practice Question
Evidence
Translation

Appendix C

JOHNS HOPKINS EBP MODEL AND TOOLS- PERMISSION

Thank you for your submission.
We are happy to give you permission to use the Johns Hopkins Evidence-Based Practice model and tools to adhere to our legal terms noted below.
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Appendix D

EBP Guidelines for the Perioperative Management of Blood Glucose Levels in the Cardiac Surgery Patient	
Developed Date: 09/05/2023	**Effective Date:** 02/01/2024
Developed By: Chelsey Benner, SRNA	**Reviewed Date:** 02/01/2024
Reviewed By: Dr. Brian Garrett	**Approved By:** Dr. Brian Garrett

STATEMENT OF PURPOSE:

In multiple studies, blood glucose levels maintained at certain levels during cardiac surgery patients have reduced adverse postoperative outcomes. Implementing evidence-based practice (EBP) guidelines will allow for more favorable outcomes in the cardiac surgery population. These guidelines are to be followed by all staff involved in the care of patients undergoing cardiac surgery. Clinical judgment should not be overlooked if provider judgment warrants deviation from the guidelines for patient safety. However, compliance with the guidelines will be monitored, and clarification should be given if the guidelines are not followed.

GUIDELINES:

These guidelines are to be utilized during the intraoperative period by anesthesia providers.

Blood glucose (BG) (mg/dL)	**BG increased from previous measurement**	**BG decreased from previous measurement by less than 30 mg/dL**	**BG decreased from previous measurement by > 30 mg/dL**
>241	Increase rate by 3 U/hr	Increase rate by 3 U/hr	No change in rate
211 - 240	Increase rate by 2 U/hr	Increase rate by 2 U/hr	No change in rate
181 - 210	Increase rate by 1 U/hr	Increase rate by 1 U/hr	No change in rate
141 - 180	No change in rate	No change in rate	No change in rate
110 - 140	No change in rate	Decrease rate by ½ U/hr	Hold insulin infusion
100 - 109	1. Hold insulin infusion 2. Recheck BG hourly Restart infusion at ½ previous dose if BG > 180 mg/dL		
71 - 99	1. Hold insulin infusion 2. Recheck BG every 30 minutes until BG > 100 mg/dL 3. Resume BG checks hourly Restart infusion at ½ previous dose if BG > 180 mg/dL		
70 or lower	If BG = 50-70 mg/dL 1. Give 25 mL D50W 2. Repeat BG checks every 30 minutes until BG > 100 mg/dL If BG < 50 mg/dL 1. Give 50 mL D50W 2. Repeat BG every 15 minutes until BG > 70 mg/dL		

	3. When BG > 70 mg/dL, repeat BG every 30 minutes until > 100 mg/dL -repeat D50 dose if BG < 50 mg/dL a second time and start D10 infusion 4. After BG > 100 mg/dL, resume hourly BG check -restart infusion at ½ previous dose if BG > 180 mg/dL

Perioperative target blood glucose (BG) 140 to 180 mg/dL

1. If BG > 180 mg/dL, start insulin infusion.
2. Start rate at BG/100 = U/hr
3. Check BG hourly and correct per table

D10 = 10% dextrose solution; D50 = 50% dextrose solution

Appendix E

Post Implementation Follow-Up

Statements	Yes	No
The guidelines were easy to understand and implement during the perioperative period.		
I was compliant in measuring blood glucose levels hourly in cardiac surgery patients.		
I treated blood glucose levels to the desired targets with little difficulty.		
I utilized an intravenous insulin drip to treat elevated blood glucose levels.		
My patients experienced little to no incidences of hypoglycemia with the targeted blood glucose levels.		
Education for these guidelines was sufficient and effective.		
I recommend the continued use of these guidelines for cardiac surgery patients.		

Please leave any additional comments below:

Appendix F

Operating Budget

Product	Cost	Amount
CRNA hourly salary	$107 per hour	X hours required
Glucometer Reading	$4.19	X required number of readings

(ZipRecruiter, 2023). (Mathew et al., 2023).

Capital Budget

Product	Cost	Amount
Glucometers	$125.49	X 1 per OR
Glucometer control solutions	$62.74	X 10 units
Glucometer strips	$42.28	X 50 units
Printing of Signage	$12.50 per poster	X 10 posters

(ATC Medical, 2023). (Staples, 2023).