Implementation of a Spinal-Induced Hypotension Bundle in Total Hip Arthroplasty Patients

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Abstract

Problem: An estimated 85% of patients undergoing a total hip arthroplasty (THA) were experiencing spinal-induced hypotension (SIH) at a small community hospital in Maryland. Additionally, 100% of patients who received a THA at this community hospital were over age 60 and were known to experience SIH at higher rates. **Purpose:** The purpose of this quality improvement (QI) project was to reduce the incidence of SIH among elderly patients over the age of 60 undergoing a THA at a small community hospital in Maryland by implementing an SIH bundle including a crystalloid co-load of 10ml/kg, 4 mg of intravenous ondansetron administered five minutes before the spinal anesthetic, and a low- dose, weight-based phenylephrine infusion started at the time of the spinal anesthetic. **Methods:** The Project Lead constructed a three-part SIH bundle approved by the anesthesia department leadership and the clinical site representative (CSR). Bundle education was provided in person and virtually for all 37 anesthesia providers. Immediately following education, anesthesia staff administered the three-part bundle, including a 10ml/kg crystalloid fluid co-load, 4 mg of intravenous ondansetron administered five minutes before the spinal anesthetic, and a low dose weight-based phenylephrine infusion started at the time of the spinal anesthetic. Bundle compliance with each intervention was measured via retrospective chart audits by the Project Lead and disseminated weekly to staff. All THA patients over 18 receiving spinal anesthesia are included in the data collection. **Results:** To date, 191 patients were eligible for inclusion in the project data. Providers were fully compliant with all three interventions on 44 patients. The intervention with the lowest median compliance rate of 17.5%, was the initiation of the phenylephrine drip. Implementation of the 10ml/mg crystalloid co-load and the administration of 4mg of ondansetron five minutes before the spinal significantly reduced the need to initiate the phenylephrine drip. By the conclusion of the project implementation, overall SIH bundle compliance rates achieved a median rate of 71.5%. **Conclusions:** The findings suggest implementing an SIH bundle was feasible. The SIH bundle, concurrently implemented with stakeholder buy-in and effective implementation strategies, sustained a successful evidence-based practice change.

Keywords: *Spinal Induced Hypotension (SIH), total hip arthroplasty (THA), ondansetron, phenylephrine, crystalloid co-load*

Implementation of a Spinal-Induced Hypotension Bundle in Total Hip Arthroplasty Patients

According to the American College of Rheumatology, an estimated 544,000 total hip arthroplasties (THAs) are performed annually in the United States (Ray, 2024). Spinal anesthesia is the favorable anesthetic for a THA and is associated with reduced pain scores, morphine consumption, postoperative nausea and vomiting (PONV), and 30-day complication rates (Warren et al., 2020). After spinal anesthesia, patients commonly experience spinal-induced hypotension (SIH), which occurs at a rate of 40-70% in non-obstetric adult patients (Mendonça et al., 2021; Owczuk et al., 2015). The mechanism of SIH includes the sympathetic blockade of cardio-accelerator nerve fibers resulting in arterial and venodilation, pooling, reduced venous return, and bradycardia (Tubog et al., 2017).

Problem Description

At a community hospital in the state of Maryland, an estimated 85% of patients undergoing a THA experienced SIH, according to baseline chart review data. 100% of patients getting a total hip arthroplasty at this community hospital were over age 60 and were known to experience SIH at increased rates (Mendonça et al., 2021; Mostafa & Attia, 2021).

A root cause analysis was performed to further explore the factors affecting the problem; see Figure 1. The purpose of this QI project was to investigate the best practices to reduce the incidence of SIH in elderly patients over the age of 60 undergoing a THA at a community hospital in Maryland. This project focused on optimizing spinal anesthetic administration with limited cost to the organization through the implementation of a SIH bundle including the administration of a 10ml/kg crystalloid co-load, 4 mg of IV ondansetron within five minutes of the spinal anesthetic, and initiation of a low-dose weight-based phenylephrine drip.

Available Knowledge & Specific Aims

An extensive evidence search, review, and synthesis were conducted to identify the best practices for mitigating SIH. The evidence search was conducted in the PubMed database using Boolean search phrases: (spinal anesthesia) AND (hypotension). Inclusion criteria of Human subjects, the English language, and Publication dates 2016-2024 were applied yielding 608 results. After applying the following filters: systematic review, meta-analysis, and randomized control trial (RCT) 261 studies remained. Out of the remaining studies, 252 were eliminated due to irrelevance to the topic. Abstracts of the remaining nine citations were reviewed and seven were retained as they were the highest level of evidence. See Figure 2 for the detailed PubMed search history. See Figure 3 for a Preferred Reporting Items Systematic Reviews and Meta-Analysis (PRISMA) diagram of the search history.

After reviewing three randomized controlled trials (RCT)s and four systematic reviews with meta-analysis all study treatment protocols used a combination of a fluid co-load, vasopressor, or ondansetron in addition to their intervention to attenuate SIH. Ferre et al., (2016), Mendonca et al., (2021), and Tubog & Bramble (2022) implemented their interventions in the non-obstetric population indicating strong, generalizable results in other populations receiving a spinal anesthetic. Mendonca et al., (2021), Tubog & Bramble (2022), and Xiao et al., (2020) all conclude prophylactic administration of ondansetron five minutes before the spinal anesthetic had a significant reduction in vasopressor requirements. Chooi et al. (2020), Riijs et al. (2020), and Tubog & Bramble (2022) reduced the grading and quality of evidence due to small sample sizes, unclear randomization, and bias.

Chooi et al., (2020) conducted the largest systematic review that suggests that a combination of practices will have a greater impact on the reduction of SIH than just one

intervention alone. Based on the body of evidence, the combination of interventions including; a crystalloid co-load of 8-10mls/kg, ondansetron administration five minutes before the spinal anesthetic, and phenylephrine infusions combined will have a significant reduction in SIH.

Overall, the evidence is considered level 1A representing strong, compelling high-quality RCTs and systematic review with meta-analysis (Dang et al, 2022). See Tables 1 and 2 for a detailed evidence review and synthesis to support this practice change.

Rationale

The Promoting Action on Research Implementation in Health Services (PARiHS) framework was the theoretical implementation framework for this QI project as it lays the foundation for successful evidence-based change. The key elements addressed within the framework include the clarity and quality of supporting evidence, the quality of the context in which the change was implemented, and the type of facilitation at the site needed to ensure successful changes (White et al., 2021). This model not only accounts for the rigorous body of evidence related to SIH but, more importantly, the context of the organization with specific attention to organizational culture, leadership, and evaluation strategies.

Contextual factors at the site included leadership that embraces evidence-based changes. Through regular evaluation practices, department leadership recognized that they needed assistance in reducing the downstream effects of intraoperative hypotension. Preventable downstream effects such as acute kidney injury, stroke, and heart attacks prove to be costly to the organization and healthcare system (Nanji et al., 2021). The chief anesthesiologist made this goal a priority, which proved to be a major facilitator to the concept of the SIH bundle and its implementation. His ability to demonstrate to staff that change was inevitable and crucial to improving patient outcomes. Department leadership made a generous difference in the

facilitation of the project. Examples set forth by strong leadership allowed staff to embrace the upcoming changes. Context and facilitation were equally as important as the quality of evidence when seeking successful organizational change and quality improvement. See *Figure 4* for a visual representation of the PARiHS framework.

Methods

Context

The context was evaluated by the Clinical Site Representative (CSR), Chief Anesthesiologist, and Chief Certified Registered Nurse Anesthetist (CRNA) using the Context Assessment Index (CAI) Tool (McCormack et al., 2009). The CAI tool was used to determine the department's receptiveness to change before the implementation of the new evidence-based SIH bundle. The CAI tool analyzed culture, leadership, and evaluation methods. The department scored 88% in culture, 93% in leadership, and 82% in evaluation techniques. The overall score of the CAI assessment was 88%, indicating a strong cultural context to implement evidence-based change. See Table 3 for the full results of the CAI tool.

The following organizational resources were assessed: equipment available for providing spinal anesthetics, the number of THAs performed monthly, and medication availability in the operating room (OR). The site obtained new intravenous (IV) infusion pumps, and all supplies were widely available to initiate the SIH bundle. A cost analysis determined that the purchase of 0.5% bupivacaine spinal kits was not feasible. See Figure 5 for a process map of the previous practice. The SIH bundle optimized the current spinal anesthetic workflow by having the appropriate spinal kits, sterile gloves, and spinal needles set out on a Mayo stand with room turnover, initiating the fluid co-loading of crystalloid fluids earlier in the pre-operative area, administering ondansetron with midazolam five minutes before the local anesthetic injection, and

starting a phenylephrine drip earlier in addition to administering phenylephrine boluses as needed. See Figure 6 for the desired process map. The desired process improved efficiency from preop to discharge and patient satisfaction by reducing pain and PONV with no cost to the organization.

Intervention

Proper planning by the QI project lead and collaboration with site CSR were crucial to a successful implementation phase. By the end of spring 2024, all key background information, team members, responsibilities, and goals were outlined. By the end of summer 2024, the project implementation and teaching plan were solidified. By the project implementation date in the fall of 2024, 100% of anesthesia technicians ensured two IV pumps and spinal supplies were in every OR performing THAs. Within two weeks of implementation start, in the fall of 2024, 100% of anesthesia providers were educated and expressed knowledge of the SIH bundle. Immediately after the provider education sessions were completed, 100% of providers administered a 10ml/kg crystalloid co-load, four milligrams of IV ondansetron within five minutes of the spinal anesthetic, and a low-dose weight-based phenylephrine drip. By the end of spring 2025, data was reviewed and disseminated to the community in a timely fashion. See Figure 7 for the GANTT chart on the project timeline.

To ensure the success of this QI project, the ABCDE tactics and strategies by Bingham & Main, 2010 & Powell et al., 2015, were implemented to achieve project goals. To ensure the structure goals were achieved, a sense of accountability and changes to the physical structure and equipment were created. Formal commitments from key stakeholders were obtained regarding the availability of appropriate supplies for a phenylephrine drip by the start of implementation (Bingham & Main, 2010 & Powell et al., 2015). To ensure the success of the project's process

goals, early adopters and change champions were identified. Educational meetings regarding the new SIH bundle were conducted at the beginning of implementation and as needed. Supervision from the project lead and CSR remained ongoing throughout implementation via weekly communication between the project lead and site CSR and dissemination of data audits via posters related to project success (Bingham & Main, 2010 & Powell et al., 2015).

Measures

The measurement plan for the QI project was divided into structure and process measurements. The following two structures: 0.5% isobaric bupivacaine kits and two IV pumps present in the OR were measured as complete or incomplete and did not require a validated tool for measurement. A Research Electronic Data Capture (RedCap) structure audit tool was created to ensure these structure goals were met (Appendix A). The tool was used to conduct random audits throughout the implementation phase of the project.

Measurement of the process goals included adherence to the bundled SIH interventions and completion of provider education. The number of anesthesia providers who attended the education session was divided by the total number of anesthesia providers in the department. The Project lead provided a Post Education RedCap survey with a Quick Response (QR) code for data collection at each education session (Appendix B). Measurement of the three process goals: 100% of providers will administer a 10ml/kg crystalloid co-load, 100% of providers will administer ondansetron five minutes before the spinal anesthetic, and 100% of providers will administer a low-dose phenylephrine drip, were assessed by dividing the number of patients with the documented SIH mitigation strategy out of the total number of patients who received a spinal anesthetic for their THA. Each goal was measured for individual compliance, as well as overall bundle compliance. This data was collected by the project lead through chart documentation

audits with an IT-generated report. A RedCap SIH Process Audit tool was created for data collection on the IT-generated report (Appendix C).

Analysis

Data analysis was completed throughout the implementation phase of the project. Both quantitative and qualitative were analyzed. Quantitative data was analyzed weekly via run charts pre- and post-implementation. The run chart demonstrated the percentage of providers who completed each intervention from the SIH bundle on the y-axis over time in weeks on the x-axis. The median was calculated for comparison against all run chart data points. Consecutive runs, astronomical data points, positive or negative shifts in data points against the median line, and upward or downward trends in data points will be observed. This assisted in identifying the differences in random variation of data points or special cause variation related to the implementation of the project interventions.

Qualitative data collected weekly assisted in identifying special cause variations to the run charts. The qualitative data was assessed via the project process audit tool's written response sections and the structure audit tool's completion. Weekly conversations with key stakeholders on any ongoing problems with completing the interventions helped to interpret shifts and trend variations in the data. Common themes were extracted from quantitative data for review and compared against the qualitative data in the run chart.

Ethical Considerations

Before project implementation at the site, the project lead obtained training regarding the Health Insurance Portability and Accountability Act (HIPAA) and Collaborative Institutional Training Initiative (CITI) training, which was maintained for the duration of the QI project. The University of Maryland School of Medicine (UMSOM) Institutional Review Board (IRB) and

Human Research Protection Office (HRPO) reviewed this QI project to determine its qualification as Non-Human Subjects Research. This QI project was conducted ethically and ensured the protection of privacy and confidentiality for all participants. Data was only collected and accessed in a private location on password-protected computers via the dual authenticated Virtual Private Network (VPN) network. Chart audits were completed by using the side-by-side screen method via RedCap Audit tools, in which personal information was de-identified to provide confidentiality, including the date of the THA and the last four digits of the medical record number. To ensure inclusion in the project and intervention equity, all adult patients over the age of eighteen undergoing a spinal anesthetic for a THA were included in the project intervention. Patients who received a general anesthetic for a THA were not eligible for inclusion. There were no conflicts of interest to disclose for the duration of the project and all privacy and safety measures set forth by the site were abided by.

Results

Education was provided during weeks one to three of the project implementation, in which 51% (n=19) of individuals attended the in-person staff education session (Figure 8). The rest were educated virtually or via printed versions of the education session left in the break rooms. To date, 191 patients were eligible for inclusion in the project data. Providers fully complied with all three interventions on 23% of patients (n=44), see Figure 9.

The intervention with the lowest weekly adherence rate was the initiation of the phenylephrine infusion, with a median rate of 17.5 %, see Figure 10. The run chart depicts two positive runs in the data points between weeks five and six and again between weeks 11 and 12. An increase in phenylephrine infusion usage was expressly noted just after the national intravenous fluid shortage following Hurricane Helen and Milton, correlating with week nine of

implementation. Adherence rates with the phenylephrine infusion also varied based on the reliability and usability of the IV pumps in the operating room as noted in the qualitative analysis.

Adherence rates for the four milligrams of IV ondansetron administered five minutes before the spinal ranged from 88% to 100% between weeks four and 16, with a median rate of 100%, see Figure 11. Weeks five, nine, and 14 depicted negative astronomical data points and were considered outliers.

The adherence rate for the fluid co-load ranged from 69% to 100% between weeks four and 16, with a median rate of 85%. A positive trend in the data points was observed between weeks four and nine, followed by two negative runs between weeks 10-12 and weeks 14-16. The decrease in fluid co-loads was seen just after the national intravenous fluid shortage began in week nine, see Figure 12.

By the end of the implementation time frame, overall SIH bundle compliance had a range of 0-83% with a median rate of 71.5%, see Figure 13. A positive trend in the data was noted between weeks four and seven, with many of the data points hovering on the median line between weeks eight to 13.

From week one to 16, an upward, positive run in the data is seen in overall SIH bundle compliance, as depicted in Figure 13. By weeks nine to 13, the data points remained consistently at the median, as week nine began the national fluid shortage extending throughout the remaining data collection, as seen in Figure 13. After week nine, the overall compliance rate remains at the median line; Figure 10 depicts the increased use of phenylephrine drips during the fluid shortage. The data points on each run chart depict an overall positive shift from the baseline against the median.

The data on the structure goals were omitted as the 0.5% bupivacaine kits could not be stocked in time for implementation. The structure measures remained at 50%, as two IV pumps remained in the operating rooms for the duration of the project.

Discussion

After reviewing the weekly run chart data from each intervention separately and the overall bundle run chart, the key findings suggest that implementing the 10ml/kg crystalloid co-load and the administration of 4mg of ondansetron five minutes before the spinal significantly reduced the need to initiate the phenylephrine infusion. This can explain the low overall compliance rate ranging from 0-50% on the phenylephrine infusion, which is consistent with the current body of evidence (Choi et al, 2020, Tubog & Bramble, 2022, Xiao et al., 2020). Xiao et al., 2020 observed a 26% reduction in the effective dose of phenylephrine infusions just by administering four milligrams of IV ondansetron alone. The overall findings are supported overwhelmingly by the evidence in Choi et al., 2020 which conducted the most significant systemic review on SIH, that one intervention alone is not enough to eliminate SIH, but rather multiple interventions together will have a greater impact. Also of note, all studies included a minimum of two SIH attenuation measures in their intervention protocol, further aligning with the final QI outcomes.

Anesthesia providers who implement a bundle of interventions to combat SIH reduce their patient's risk of developing serious adverse medical events after surgery along with additional costs to the healthcare system. This project was implemented at no additional cost or significant increases in workload to the institution and will help to reduce extraneous costs related to adverse medical events such as acute kidney injury, stroke, and myocardial infarction, estimated to cost anywhere from $17000 - $21,300 per case (Nanji et al., 2021). This project can be easily

sustained within the department as meaningful changes to workflow and awareness to prevent adverse medical events have been made a priority in the department's culture.

Limitations to the project included initial resistance to the phenylephrine drips as the risk of intraoperative blood loss is significantly higher in a THA when a tourniquet cannot be used. Additionally, provider discretion was encouraged regarding vasopressor initiation, as not every patient experienced clinically significant hypotension. It was anticipated that overall compliance with this intervention would be much lower than the other two interventions. The national IV fluid shortage began during week 9, with the damages from Hurricane Helene & Milton to major fluid manufacturing plants in North Carolina and Florida, limiting the ability to perform the 10ml/kg crystalloid co-load. Technical difficulties related to infusion pump malfunctions limited the provider's ability to initiate a phenylephrine drip; however, frequent boluses of phenylephrine were used and accounted for in the project data. The inability to secure the 0.5% isobaric bupivacaine kits was a minor issue that did not make a difference in the bundle workflow.

Conclusion

The SIH bundle, implemented concurrently with stakeholder buy-in and effective strategies, has sustained a successful evidence-based practice change. The SIH bundle enhances spinal anesthetic workflow while significantly reducing adverse medical events related to intraoperative hypotension. This will potentially save the institution hundreds of thousands of dollars annually. All interventions are even more accessible to staff due to the addition of new IV infusion pumps. The department chair plans to maintain this SIH bundle and ensure that all new providers are educated about it upon hire. This project can easily be expanded to any other population receiving spinal anesthetic within the institution at no additional costs.

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Table 1

Evidence Appraisal

Citation: Chooi, C., Cox, J. J., Lumb, R. S., Middleton, P., Chemali, M., Emmett, R. S., Simmons, S. W., & Cyna, A. M. (2020). Techniques for preventing hypotension during spinal anaesthesia for caesarean section. *Cochrane Database of Systematic Reviews*, *2020*(7). https://doi.org/10.1002/14651858.CD002251.pub4	**Level and Quality** I-B
Purpose	**Purpose:** To assess the effects of prophylactic interventions for hypotension following spinal anesthesia for caesarean section.
Research Design	Systematic Review and Meta-Analysis of randomized controlled trials
Sample - Population, Size, Setting	**Sampling technique:** Systematic electronic searches of Cochrane Pregnancy and Childbirth Trials Register, which included detailed search strategies for CENTRAL, MEDLINE, Embase, and CINAHL. **Population Included:** All published or unpublished randomized controlled trials that compare an intervention to prevent hypotension with a placebo or alternative treatment in women having spinal anesthesia for cesarean section. **Population Excluded:** Studies were excluded if hypotension was not an outcome measure or was not clearly defined before administering a rescue treatment, inadequate or no randomization, use of a combined spinal-epidural anesthesia, or study intervention was implemented as a response to a fall in blood pressure and not in prevention to hypotension. **Size**: 125 studies involving 9469 women were included in the review. **Setting**: Hospital settings in Australia, Europe, India, North America, and the Middle East during cesarean section
Intervention Procedures	**Interventions assessed included:** 1) Administration of Fluids: Colloids & Crystalloids 2) Drugs: ephedrine, metaraminol, phenylephrine & ondansetron 3) Physical methods: Leg bindings, Compression stockings, Other maneuvers
Primary Outcome and Measures	**Primary outcome:** The incidence of maternal hypotension requiring pharmacological intervention (after intrathecal injection and before delivery). **Measure:** Hypotension-a certain decrease in systolic or mean blood pressure, as defined and measured by the authors of included studies.
Results Conclusions	**Statistical Results: (see summary and analysis tables within the article for more robust statistical data)** 1) Crystalloid: rapid co-load versus preload: A rapid crystalloid co-load was associated with a lower incidence of hypotension than a preload (average RR 0.70, 95% CI 0.59 to 0.83, 5 studies, 384 women) 2) Phenylephrine infusion vs bolus: There was insufficient evidence to determine whether there was a difference between the groups (RR 1.40, 95% CI 0.50 to 3.92, 1 study, 60 women). 3) Ondansetron vs control: There was a lower incidence of hypotension in the ondansetron group (average RR 0.67, 95% CI 0.54 to 0.83, 8 studies, 740 women, $I^2 = 35\%$, $Tau^2 = 0.05$, low-quality evidence). **Conclusion:** Some interventions assessed in this review can reduce the incidence of hypotension after spinal anesthesia, but no single intervention eliminates the need to treat hypotension during spinal anesthesia. One or more interventions combined in practice are likely the most effective. All evidence was rated low quality as the reviewed studies had small sample sizes, and their lack of detail in reporting led to an unclear risk of bias in the method of randomization, allocation concealment, and blinding.

Citation: Ferré, F., Marty, P., Bruneteau, L., Merlet, V., Bataille, B., Ferrier, A., Gris, C., Kurrek, M., Fourcade, O., Minville, V., & Sommet, A. (2016). Prophylactic phenylephrine infusion for the prevention of hypotension after spinal anesthesia in the elderly: A randomized controlled clinical trial. *Journal of Clinical Anesthesia*, *35*, 99–106. https://doi.org/10.1016/j.jclinane.2016.07.020	**Level and Quality** I-A
Purpose	**Purpose:** The objective of this study was to evaluate the efficacy and safety of prophylactic infusion of phenylephrine after spinal anesthesia (SA) for orthopedic surgery in the elderly.
Research Design	prospective, randomized, double-blind, and placebo-controlled study
Sample - Population, Size, Setting	**Sampling technique:** convenience sampling **Population Included:** Patients older than 60 years undergoing spinal anesthesia for elective orthopedic surgery on the lower extremities. **Population Excluded:** patients with uncontrolled hypertension, hyperthyroidism, dementia, symptomatic coronary artery disease, anemia with a hemoglobin <10 g/dL, or any contraindications to SA or administration of vasoconstrictors. **Size**: 57 participants randomized into two groups of 29 & 28 respectively **Setting**: tertiary care hospital in France, during orthopedic surgery **Power Analysis:** 26 patients were needed in each group to achieve a power of 90% and an alpha of 0.05- Power analysis met. **Group Homogeneity:** no significant difference among groups
Intervention Procedures	**Group P:** intervention group received 100-µg/mL solution of phenylephrine solution at 1 mL/min after placement of SA **Group C:** control group received 0.9% isotonic sodium chloride solution **Intervention fidelity:** Before placement of spinal anesthesia, all patients received an IV bolus of 8 mL/kg of Lactated Ringer's solution. An independent co-investigator carried out the randomization by sealed envelopes and prepared the syringes containing either 100 µg/mL of phenylephrine (group P) or 0.9% isotonic sodium chloride solution (group C). Neither the anesthesiologist of the case nor the patient knew the results of the randomization. Spinal anesthesia was performed in the lateral decubitus position and the infusion of phenylephrine or saline was started immediately after intrathecal injection. Patients remained in the lateral decubitus position for 5 minutes and then turned supine.
Primary Outcome and Measures	**Primary outcome:** Mean arterial pressure, time to first hypotensive episode and number of hypotensive episodes. **Measure:** Hypotension was defined by a 20% decrease and hypertension as a 20% increase from baseline MAP. Bradycardia was defined as a heart rate lower than 50 beats per minute
Results Conclusions	**Statistical Results:** The following results are considered statistically significant according to the P values. MAP was higher in group P than in group C (P< .001). The number of hypotensive episodes per patient was significantly higher in group C vs group P (P= <.01). Time until the first hypotensive episode was shorter in the control group than in the phenylephrine group (P= .004) **Conclusion:** Prophylactic phenylephrine infusion is an effective method of reducing SA-induced hypotension in the elderly. Compared with a control group, it delays the time to onset of hypotension and decreases the number of hypotensive episodes per patient.

Citation: Mendonça, F. T., Crepaldi Junior, L. C., Gersanti, R. C., & De Araújo, K. C. (2021). Effect of ondansetron on spinal anesthesia-induced hypotension in non-obstetric surgeries: A randomized, double-blind and placebo-controlled trial. *Brazilian Journal of Anesthesiology (English Edition)*, *71*(3), 233–240. https://doi.org/10.1016/j.bjane.2020.12.028	**Level and Quality** I-A

Purpose or Hypothesis	**Purpose:** To compare the effect of ondansetron and placebo before spinal block on the incidence of hypotension in patients having non-obstetric surgeries. **Hypothesis:** Treatment with ondansetron would result in a 30% risk difference in the rate hypotension compared to placebo (15% vs. 45%)
Research Design	prospective, randomized, parallel-group, superiority placebo-controlled trial with a 1:1 allocation ratio
Sample - Population, Size, Setting	**Sampling technique:** convenience **Population Included:** Patients scheduled for urgent or elective surgical procedures requiring spinal anesthesia, 18 years of age and older, with an ASA status I, II, or III. **Population Excluded:** Patients with any contraindication or history of hypersensitivity to the drugs used in the study, use of clonidine during the spinal, patients using prophylactic or therapeutic anticoagulation treatments, patients with AV block, diagnosed with cardiac arrhythmias, heart failure, kidney disease, liver disease, or any type of suspected systemic or localized infection at the puncture site, or contraindication to the neuraxial anesthesia. **Size**: 144 patients, randomized into 72 patients per group **Setting**: Tertiary care hospital in Brazil, during non-obstetric surgeries **Power Analysis:** 140 patients required to meet power of 90% and alpha of 0.05, assuming a 20% drop out rate- power analysis met **Group Homogeneity:** no significant difference among groups
Intervention Procedures	**Group 1:** received 20 mL of a placebo 5 minutes prior to spinal anesthesia. **Group 2** received 20 mL of ondansetron (8mg) prior to spinal anesthesia. **Intervention fidelity:** All patients received standard monitoring, which included electrocardiography, pulse oxygen saturation, noninvasive blood pressure monitoring, and body temperature. After venous access, patients received 0.05 mg.kg−1 of midazolam Intravenous (IV). Crystalloids were administered at a volume of 10 mL.kg−1 before to spinal anesthesia. Medication syringes were prepared by an investigator not involved in the patient's surgery or follow-up. Syringes were deidentified to allow for blinding. All medications were administered 5 minutes before spinal.
Primary Outcome and Measures	**Primary outcome:** hypotension during surgery. Hypotension was defined as a systolic blood pressure below 80% of baseline or below 90 mmHg. **Measure:** Baseline blood pressure was recorded, as well as after anxiolysis, 5 minutes, 10 minutes, 20 minutes, and 30 minutes after spinal anesthesia.
Results Conclusions	**Statistical Results:** The risk of hypotension was 27.8% in the ondansetron group and 50% in the placebo group, demonstrating a significant difference (p=0.007). **Conclusion:** Prophylactic intravenous administration of ondansetron results in significantly lower rates of spinal induced hypotension, especially in patients aged 60 years old or older. Results indicate not only that the prophylactic use of ondansetron can reduce the usage of ephedrine during general non-obstetric surgical procedures that require spinal anesthesia, but also that ondansetron may help to limit the side effects related to spinal block particularly in elderly patients.

Citation: Rijs, K., Mercier, F. J., Lucas, D. N., Rossaint, R., Klimek, M., & Heesen, M. (2020). Fluid loading therapy to prevent spinal hypotension in women undergoing elective caesarean section: Network meta-analysis, trial sequential analysis and meta-regression. *European Journal of Anaesthesiology*, *37*(12), 1126–1142. https://doi.org/10.1097/EJA.0000000000001371	**Level and Quality** I-B
Purpose	**Purpose:** To evaluate the current evidence on fluid loading in the prevention of spinal anesthesia-induced hypotension.
Research Design	Systematic review and network meta-analysis with trial sequential analysis and meta-regression.
Sample - Population, Size, Setting	**Sampling technique:** databases Medline, Epub, Embase.com (Embase and Medline), Cochrane Central, Web of Science, and Google Scholar were systematically searched for relevant studies. **Population Included:** Only randomized controlled trials including adult women undergoing elective cesarean section who received either crystalloid or colloid fluid therapy as a preload or coload. The comparator was a combination of either a different fluid or time of infusion. **Population Excluded:** studies that did not meet the stated inclusion criteria were excluded. **Size**: 49 trials including 4,317 patients in total met the eligibility criteria and were considered for analysis. **Setting**: studies were conducted in hospital settings worldwide during elective cesarean section
Intervention Procedures	Two types of fluid were studied, crystalloid and colloid, given at one of two possible timepoints: A, as a preload before spinal anesthesia and B, as a coload on injection of the spinal medication.
Primary Outcome and Measures	**Primary outcome:** incidence of maternal hypotension, as defined by the individual authors. Conventional meta-analysis results: Crystalloid preload compared with colloid preload gave a risk ratio for the incidence of hypotension of 1.48 (95% CI 1.29 to 1.69, $P < 0.0001$, I^2 60%. Risk ratio for crystalloid preload compared with crystalloid coload was 1.31 (95% CI 1.04 to 1.65, $P= 0.02$, $I^2 =69\%$) (Fig. 3c). There were no significant differences for the comparison colloid preload vs. colloid coload; risk ratio of 1.01 (95% CI 0.84 to 1.20, $P= 0.92$, $I^2 =12\%$)
Results Conclusions	**Statistical Results:** Network meta-analysis concluded that colloid coload and preload offered the highest chance of success (97 and 67%, respectively). Conventional meta-analysis showed that crystalloid preload is associated with a significantly higher incidence of maternal hypotension than colloid preload: ($P < 0.0001$). However, this result was not supported by Trial Sequential Analysis. There was a significant dose–response effect for crystalloid volume preload, which was not present in the analysis of only double-blind studies. **Conclusion:** The meta-analysis supports the efficacy of colloid pre-or co-loading, and of crystalloid co-loading to a lesser extent or decreasing the incidence of hypotension during elective cesarean sections performed under spinal anesthesia. The overall quality of evidence was given a grade of low quality as there was a moderate risk of selection bias related to inappropriate blinding and moderate indirectness related to differences in direct and indirect comparison.

Citation: Tubog, T. D., Kane, T. D., & Pugh, M. A. (2017). Effects of Ondansetron on Attenuating Spinal Anesthesia–Induced Hypotension and Bradycardia in Obstetric and Nonobstetric Subjects: A Systematic Review and Meta-Analysis. *American Association of Nurse Anesthetists Journal*, 85(3), 113-122.	**Level and Quality** I-A
Purpose or Hypothesis	**Purpose:** The purpose of this systematic review and meta-analysis of randomized controlled trials (RCTs) was to determine the efficacy of intravenous (IV) ondansetron in reducing the incidence of SIH and bradycardia. **Hypothesis:** Ondansetron, administered intravenously 5 minutes before the placement of local anesthetic into the subarachnoid space, helps to attenuate SIH and bradycardia.
Research Design	Systematic review and meta-analysis of randomized controlled trials
Sample - Population, Size, Setting	**Sampling technique:** The electronic databases used for the systematic literature search included MEDLINE (PubMed), Google Scholar, Cumulative Index to Nursing & Allied Health Literature (CINAHL), and The Cochrane Review Database. **Population included:** full English text RCTs assessing the use of ondansetron for attenuation of SIH and bradycardia. **Population Excluded**: duplicate studies, studies not published in the years 2008-2015, not in the English language, not peer-reviewed, not randomized controlled trials **Size**: 13 studies with a combined total of 1,225 patients were analyzed **Setting**: university hospitals around the world during obstetric and non-obstetric procedures
Intervention Procedures	All studies included treatment protocols in which IV ondansetron was administered 5 minutes before induction of spinal anesthesia. Most studies evaluated ondansetron doses of 4 or 8 mg, and some evaluated 2-12 mg doses.
Primary Outcome and Measures	**Primary Outcome:** The 2 primary outcomes of interest were hypotension and bradycardia. Studies defined hypotension as a decrease in systolic blood pressure (SBP) by 75% to 80% of baseline, SBP less than 80 to 90 mm Hg, or both. Bradycardia was defined in beats per minute. Bradycardia definitions varied between >60-40 beats per minuet.
Results Conclusions	**Statistical Results:** Pooled analysis demonstrated that IV ondansetron reduced the incidence of SIH by a relative 36% (RR, 0.64, CI, 0.45-0.90). Meta-analysis of the pooled data showed that treatment with ondansetron reduced the risk of bradycardia by a relative 69% (RR, 0.31; CI, 0.19-0.50). **Conclusion:** Results of this systematic review with meta-analysis support the hypothesis that ondansetron, administered intravenously 5 minutes before the placement of local anesthetic into the subarachnoid space, helps to attenuate SIH and bradycardia. The review and meta-analysis demonstrated high quality evidence with low risk of bias.

Citation: Tubog, T.D, & Bramble, R.S. (2022). Ondansetron reduces the incidence of hypotension after spinal anesthesia in non-caesarean delivery: A systematic review and meta-analysis. *Journal of Perioperative Practice*, *32*(3), 29–40. https://doi.org/10.1177/1750458920964157	**Level and Quality** I-B
Purpose or Hypothesis	**Purpose:** This systematic review and meta-analysis evaluate the efficacy of prophylactic ondansetron in reducing the incidence of spinal anesthesia-induced hypotension in non-cesarean delivery. **Hypothesis:** Ondansetron administered intravenously before the placement of local anesthetic into the subarachnoid space, attenuates spinal-induced hypotension, and bradycardia and reduces the amount of rescue ephedrine during non-caesarean delivery cases.
Research Design	Systematic review and meta-analysis of randomized controlled trials
Sample - Population, Size, Setting	**Sampling technique:** PubMed, MEDLINE, the Cochrane Central Registry for Controlled Trials, EMBASE, and Google Scholar were systematically searched for relevant studies. The following search terms were used alone or in combination with the use of appropriate Boolean modifiers: hypotension, spinal, SIH, prophylaxis, prevention, ondansetron, and spinal anesthesia. **Population Included:** RCTs, non-caesarean surgeries, use of spinal anesthesia as the primary anesthetic, RCT with placebo control, and administration of ondansetron before spinal anesthesia induction. **Population Excluded:** Retrospective studies, cohort studies, case reports, abstract-only articles, editorials and expert opinions. **Size**: 13 RCTs including 1166 participants **Setting**: hospital settings world-wide
Intervention Procedures	**Intervention fidelity:** All of the studies used crystalloid solutions and the fluids were administered before spinal anesthesia induction in varying amounts. All RCTs used hyperbaric bupivacaine 0.5% ranging from 12.5mg to 20mg. The dosages of ondansetron were 4mg, 6mg, 8mg and 16mg.
Primary Outcome and Measures	**Primary outcome:** Incidence of hypotension **Measure:** Since there is variability in the definition of hypotension used in the RCTs a combined eight studies using systolic arterial pressure and four used mean arterial pressure as outcome measures of hypotension at five-minute intervals in the first twenty minutes after spinal anesthesia.
Results Conclusions	**Statistical Results:** Compared to placebo, there is a low quality of evidence that ondansetron was effective in reducing the incidence of spinal anesthesia-induced hypotension (RR 0.62, 95% CI 0.44 to 0.87; p= 0.005) and bradycardia (RR 0.54, 95% CI 0.32 to 0.90; p=0.02). We also found a moderate quality of evidence that ondansetron lowered the number of rescue ephedrine (RR 0.61, 95% CI 0.43 to 0.87; p= 0.007). * The evidence of the incidence of SIH and bradycardia was downgraded to low quality because of potential publication bias, the existence of clinical and methodological heterogeneity, unclear allocation concealment and unclear blinding. However, the quality of evidence for the frequency of rescue ephedrine was moderate because of small effect size. **Conclusion:** The systematic review with meta-analysis supports the hypothesis that ondansetron, administered intravenously before the placement of local anesthetic into the subarachnoid space, attenuates spinal-induced hypotension, bradycardia and reduces the amount of rescue ephedrine during non-cesarean delivery cases.

Citation: Xiao, F., Wei, C., Chang, X., Zhang, Y., Xue, L., Shen, H., Ngan Kee, W. D., & Chen, X. (2020). A Prospective, Randomized, Double-Blinded Study of the Effect of Intravenous Ondansetron on the Effective Dose in 50% of Subjects of Prophylactic Phenylephrine Infusions for Preventing Spinal Anesthesia–Induced Hypotension During Cesarean Delivery. *Anesthesia & Analgesia*, *131*(2), 564–569. https://doi.org/10.1213/ANE.0000000000004534	**Level and Quality** I-A
Purpose or Hypothesis	**Purpose:** To determine the effective dose in 50% of subjects (ED50) of a prophylactic phenylephrine infusion for preventing hypotension in patients who received a single dose of intravenous ondansetron 4 mg or saline control before combined spinal–epidural anesthesia for elective cesarean delivery. **Hypothesis:** not stated
Research Design	parallel-group, randomized, double-blinded study
Sample - Population, Size, Setting	**Sampling technique:** convenience **Population Included:** ASA class I & II with a singleton pregnancy at term (≥37 weeks' gestation) scheduled for elective cesarean delivery under regional anesthesia. **Population Excluded:** allergy to phenylephrine, preexisting or pregnancy-induced hypertension, cardiovascular or cerebrovascular disease, multiple gestation, diabetes mellitus, body weight <50 or >90 kg, height <145 or > 175 cm, significant coexisting maternal disease, ruptured membranes, and placenta previa. **Size**: 60 patients with 30 in each group **Setting**: tertiary care facility in China **Power Analysis:** A sample size of 30 subjects per group was determined based on previous recommendations that 20-40 subjects are needed to provide a stable estimate of the ED50 calculated by the up-and-down method for most realistic scenarios. Six crossovers can be regarded as sufficient based on reports that increasing the number of crossovers from 2 to 6 improved ED50 estimates, whereas an increase in the number of crossovers to 10 affected the ED50 less. This reinforces that the sample size of the study was adequate. **Group Homogeneity:** P values not given; Table 1 demographic characteristics appear to have no significant difference
Intervention Procedures	**Group 1:** Group O received 4mg of IV ondansetron 10 minutes before the spinal anesthetic. **Group 2**: placebo received 2mL of saline before spinal anesthetic. **Intervention fidelity:** Ten minutes before positioning for induction of spinal anesthesia, patients were randomly assigned to receive intravenous ondansetron 4 mg/2mL or saline placebo 2 mL, administered by an investigator who was not involved in subsequent anesthetic management or data collection. This investigator also set the infusion pump rate at the start of each case and was the only individual aware of the assigned infusion rate. The first patient in each group received a phenylephrine infusion at the rate of 0.5 μg/kg/min. The infusion rate for each subsequent patient was varied with increments or decrements of 0.05 μg/kg/min based on the response of the previous patient.
Primary Outcome and Measures	**Primary outcome:** Hypotension, defined as a decrease in SBP to <80% of the baseline value, was treated with an intravenous bolus of 50 μg of phenylephrine. **Measure:** the ED 50 of phenylephrine
Results Conclusions	**Statistical Results:** The ED50 of the rate of intravenous phenylephrine infusion was lower in group O compared with group C ($P < .001$). **Conclusion:** Intravenous ondansetron 4 mg reduced the ED50 of prophylactic phenylephrine infusion by 26% in patients undergoing cesarean delivery under combined spinal-epidural anesthesia.

Table 2

Evidence Synthesis

JHNEBP Model Level	Total Number of Sources	Author and Quality Rating of each study	Synthesis of Findings
Level 1 Experimental study · Randomized Controlled Trial (RCT) · Systematic review of RCTs with or without meta-analysis	3 RCTs 4 Systematic reviews with meta-analysis	Ferre et al., A Mendonca et al., A Xiao et al., A Chooi et al., B Riijs et al., B Tubog, Kane & Pugh, A Tubog & Bramble, B	After reviewing three randomized Controlled Trials (RCT)s and four systematic reviews with meta-analysis all study treatment protocols regardless of intervention, and primary outcome used some combination of a fluid co-load, vasopressor, or ondansetron as a preventative measure along with their intervention to attenuate spinal induced hypotension (SIH). Ferre et al., (2016), Mendonca et al., (2021), and Tubog & Bramble (2022) implemented their respective interventions in the non-obstetric population with strong results, indicating the generalizability of these interventions in different populations receiving a spinal anesthetic. Xiao et al., (2020) and Tubog et al., (2017) were the only two studies that did not indicate a crystalloid co-load in their treatment fidelities or systematic review. Mendonca et al., (2021), Tubog & Bramble (2022), and Xiao et al., (2020) all conclude that prophylactic administration of ondansetron five minutes before the spinal anesthetic had a significant reduction in vasopressor requirements in addition to the primary outcome of hypotension. Chooi et al. (2020), Riijs et al. (2020), and Tubog & Bramble (2022) completed systematic reviews with meta-analyses and reduced the grading and quality of evidence due to a combination of small sample sizes in addition to unclear randomization and bias. Based on these findings, it appears that crystalloid co-loading, ondansetron administration five minutes before the spinal anesthetic, and phenylephrine infusions combined will have a significant reduction in SIH. Chooi et al., (2020) conducted the largest systematic review that suggests that a combination of practices will have a greater impact on the reduction of SIH than just one intervention alone.
Overall Quality Rating w/rational and Recommendation:			
Recommendations Based on Evidence Synthesis: Overall, the evidence can be considered a level 1A representing strong, compelling high-quality randomized controlled trials and systematic review with meta-analysis (Dang et al, 2022). The evidence suggests consistent results with a solid indication to implement a bundled approach of crystalloid co-loading, ondansetron administration five minutes before the spinal anesthetic, and phenylephrine infusions to prevent SIH.			

Table 3
Cultural Assessment Index (CAI) Tool

Collaborative Practice			Evidence-informed Practice			Respect for Persons			Practice Boundaries			Evaluation		
Item #	SA, A, D, SD	Score	Item #	SA, A, D, SD	Score	Item #	SA, A, D, SD	Score	Item #	SA, A, D, SD	Score	Item #	SA, A, D, SD	Score
3	SA	4	4	D	2	2	SA	4	1	SA	4	9	A	3
6	SA	4	7	D	2	5	SA	4	13	SA	4	12	SA	4
10	A	3	11	SA	4	8	A	3	16	SA	4	18	A	3
14	SA	4	17	SA	4	15	SA	4	21	SA	4	24	A	3
19	A	3	23	SA	4	20	SA	4	25	SA	4			
22	SA	4	27	A	3	26	SA	4	30	A	3			
28	A	3	29	SA	4	36	A	3						
31	A	3	32	A	3									
33	SA	4	34	SA	4									
			35	D	2									
			37	D	2									
Total Score:		32	Total Score:		33	Total Score:		26	Total Score:		20	Total Score:		14
# Of Items:		9	# Of Items:		11	# Of Items:		7	# Of Items:		6	# Of Items:		4
Mean:		3.5	Mean:		3.1	Mean:		3.7	Mean:		3.8	Mean:		3.3
Total Mean for all 37 Items = 3.4														

Element: Culture

Statement Numbers	1	3	7	9	12	15	16	18	21	23	24	28	31	33	34	36	**Total scores X 1.5625**
Scores	4	4	2	3	4	4	4	3	4	4	3	3	3	4	4	3	87.5% =88%

Element: Leadership

Statement Numbers	2	6	10	17	22	27	29	**Total Scores X 3.57**
Scores	4	4	3	4	4	3	4	92.8 % =93%

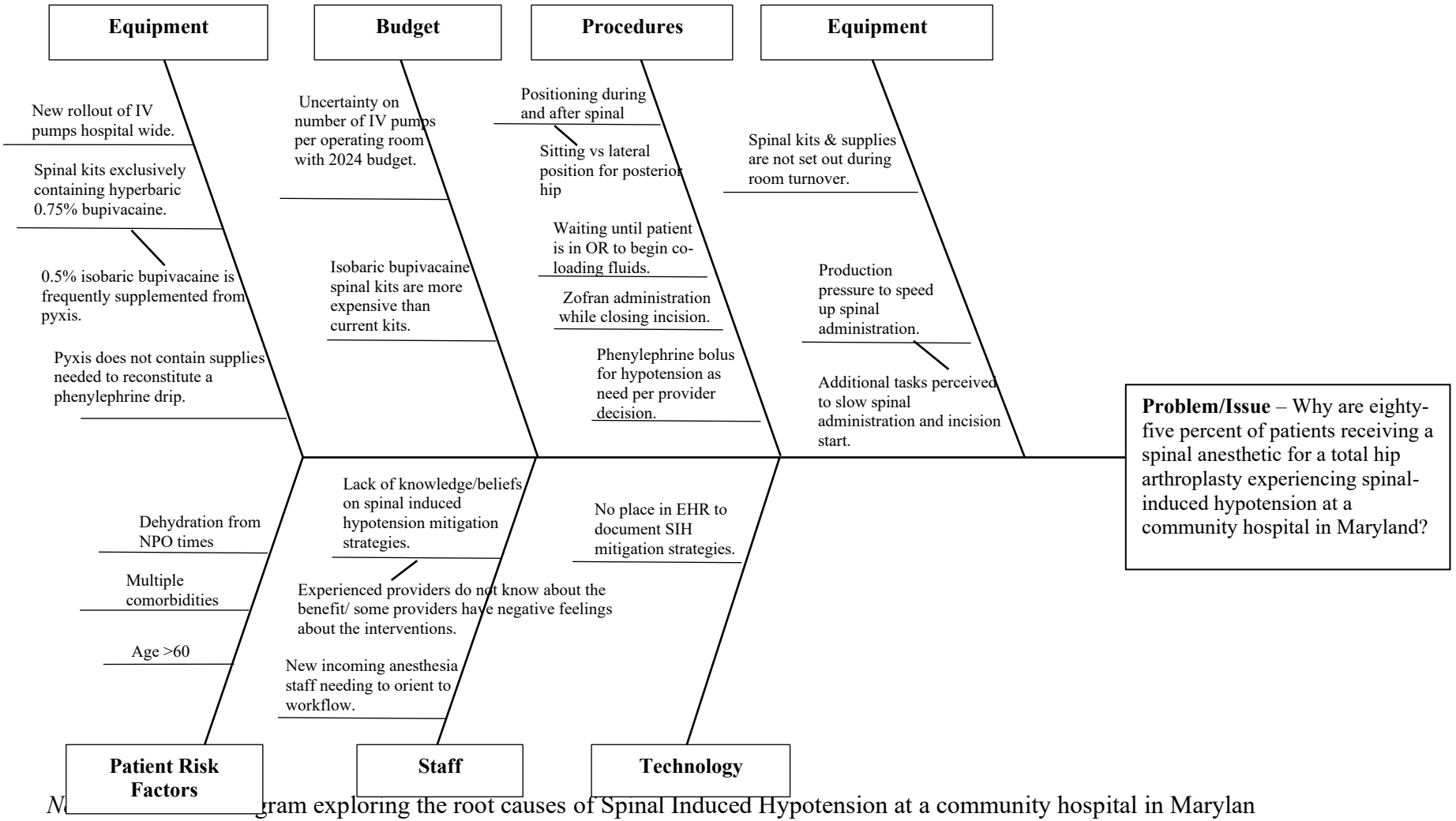
Element: Evaluation

Statement Numbers	4	5	8	11	13	14	19	20	25	26	30	32	35	37	**Total Scores X 1.78**
Scores	2	4	3	4	4	4	3	4	4	4	3	3	2	2	=81.9% =82%

Total % Score: 87.6%= 88

Figure 1

Root Cause Analysis for Spinal Induced Hypotension



N gram exploring the root causes of Spinal Induced Hypotension at a community hospital in Marylan

Figure 2

PubMed Search History

Search number	Query	Sort By	Filters	Search Details	Results	Time
32	spinal anesthesia & hypotension		Meta-Analysis, Randomized Controlled Trial, Systematic Review, Humans, English, from 2016 - 2024	(("spinal anaesthesia"[All Fields] OR "anesthesia, spinal"[MeSH Terms] OR ("anesthesia"[All Fields] AND "spinal"[All Fields]) OR "spinal anesthesia"[All Fields] OR ("spinal"[All Fields] AND "anesthesia"[All Fields])) AND ("antihypertensive agents"[Pharmacological Action] OR "antihypertensive agents"[MeSH Terms] OR ("antihypertensive"[All Fields] AND "agents"[All Fields]) OR "antihypertensive agents"[All Fields] OR "hypotensives"[All Fields] OR "hypotension"[MeSH Terms] OR "hypotension"[All Fields] OR "hypotensions"[All Fields] OR "hypotensive"[All Fields])) AND ((meta-analysis[Filter] OR randomizedcontrolledtrial[Filter] OR systematicreview[Filter]) AND (humans[Filter]) AND (english[Filter]) AND (2016:2024[pdat]))	261	22:20:56
31	spinal anesthesia & hypotension		Randomized Controlled Trial, Systematic Review, Humans, English, from 2016 - 2024	(("spinal anaesthesia"[All Fields] OR "anesthesia, spinal"[MeSH Terms] OR ("anesthesia"[All Fields] AND "spinal"[All Fields]) OR "spinal anesthesia"[All Fields] OR ("spinal"[All Fields] AND "anesthesia"[All Fields])) AND ("antihypertensive agents"[Pharmacological Action] OR "antihypertensive agents"[MeSH Terms] OR ("antihypertensive"[All Fields] AND "agents"[All Fields]) OR "antihypertensive agents"[All Fields] OR "hypotensives"[All Fields] OR "hypotension"[MeSH Terms] OR "hypotension"[All Fields] OR "hypotensions"[All Fields] OR "hypotensive"[All Fields])) AND ((randomizedcontrolledtrial[Filter] OR systematicreview[Filter]) AND (humans[Filter]) AND (english[Filter]) AND (2016:2024[pdat]))	241	22:20:52
30	spinal anesthesia & hypotension		Systematic Review, Humans, English, from 2016 - 2024	(("spinal anaesthesia"[All Fields] OR "anesthesia, spinal"[MeSH Terms] OR ("anesthesia"[All Fields] AND "spinal"[All Fields]) OR "spinal anesthesia"[All Fields] OR ("spinal"[All Fields] AND "anesthesia"[All Fields])) AND ("antihypertensive agents"[Pharmacological Action] OR "antihypertensive agents"[MeSH Terms] OR ("antihypertensive"[All Fields] AND "agents"[All Fields]) OR "antihypertensive agents"[All Fields] OR "hypotensives"[All Fields] OR "hypotension"[MeSH Terms] OR "hypotension"[All Fields] OR "hypotensions"[All Fields] OR "hypotensive"[All Fields])) AND ((systematicreview[Filter]) AND (humans[Filter]) AND (english[Filter]) AND (2016:2024[pdat]))	44	22:20:48
29	spinal anesthesia & hypotension		Humans, English, from 2016 - 2024	(("spinal anaesthesia"[All Fields] OR "anesthesia, spinal"[MeSH Terms] OR ("anesthesia"[All Fields] AND "spinal"[All Fields]) OR "spinal anesthesia"[All Fields] OR ("spinal"[All Fields] AND "anesthesia"[All Fields])) AND ("antihypertensive agents"[Pharmacological Action] OR "antihypertensive agents"[MeSH Terms] OR ("antihypertensive"[All Fields] AND "agents"[All Fields]) OR "antihypertensive agents"[All Fields] OR "hypotensives"[All Fields] OR "hypotension"[MeSH Terms] OR "hypotension"[All Fields] OR "hypotensions"[All Fields] OR "hypotensive"[All Fields]))	608	22:20:42

				AND ((humans[Filter]) AND (english[Filter]) AND (2016:2024[pdat]))		
28	spinal anesthesia & hypotension		Humans, English	(("spinal anaesthesia"[All Fields] OR "anesthesia, spinal"[MeSH Terms] OR ("anesthesia"[All Fields] AND "spinal"[All Fields]) OR "spinal anesthesia"[All Fields] OR ("spinal"[All Fields] AND "anesthesia"[All Fields])) AND ("antihypertensive agents"[Pharmacological Action] OR "antihypertensive agents"[MeSH Terms] OR ("antihypertensive"[All Fields] AND "agents"[All Fields]) OR "antihypertensive agents"[All Fields] OR "hypotensives"[All Fields] OR "hypotension"[MeSH Terms] OR "hypotension"[All Fields] OR "hypotensions"[All Fields] OR "hypotensive"[All Fields])) AND ((humans[Filter]) AND (english[Filter]))	2,089	22:20:28

Figure 3

PRISMA Search Flow Diagram

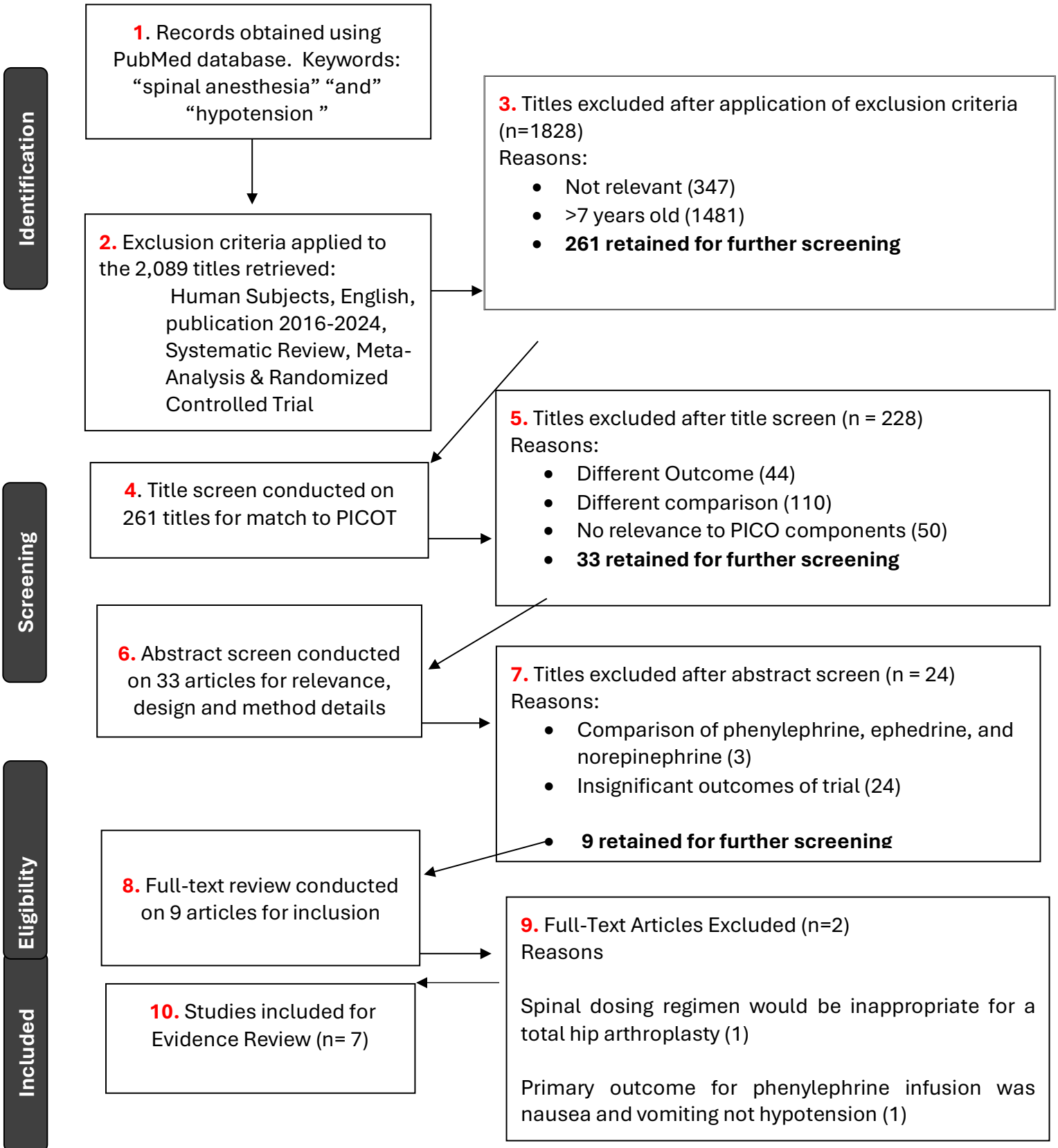
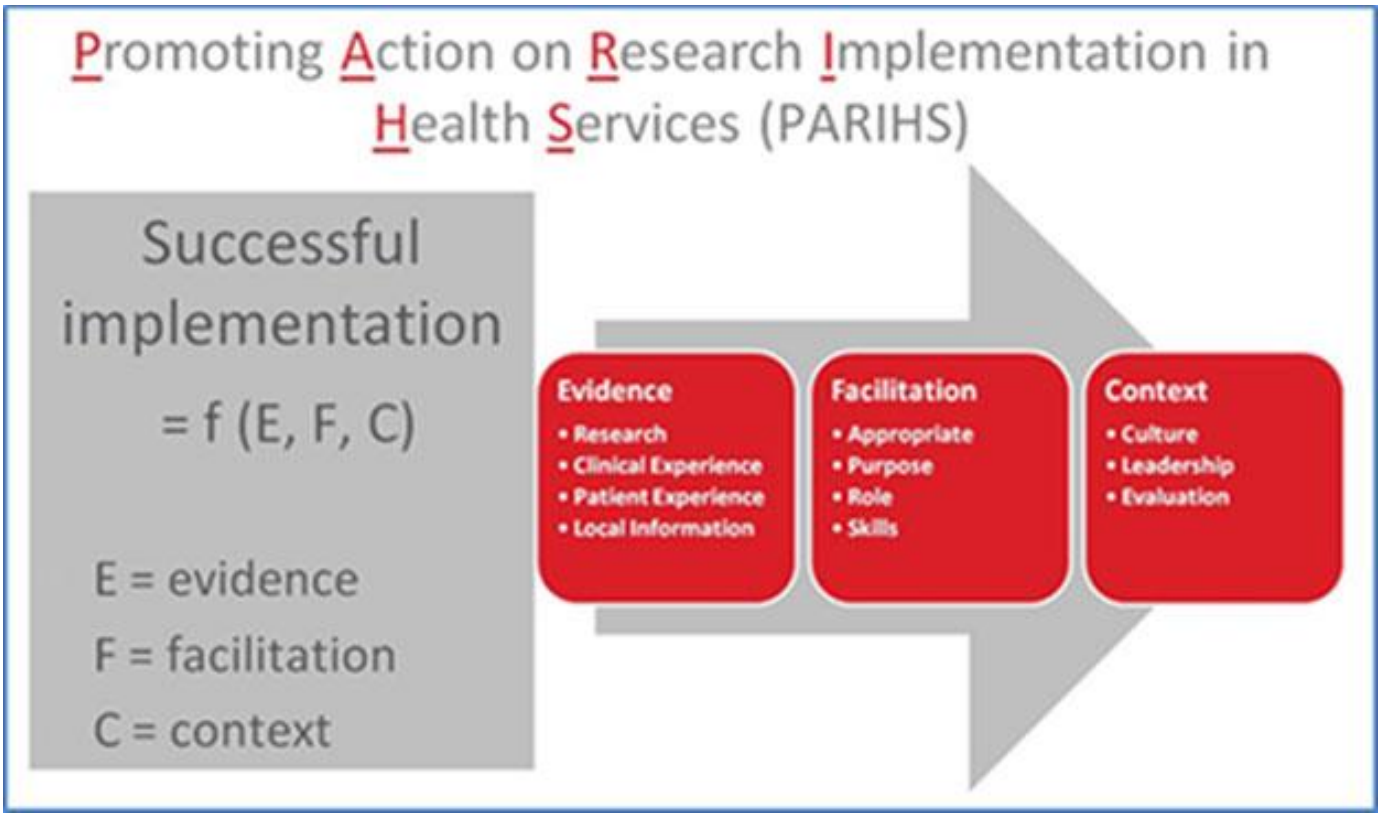


Figure 4

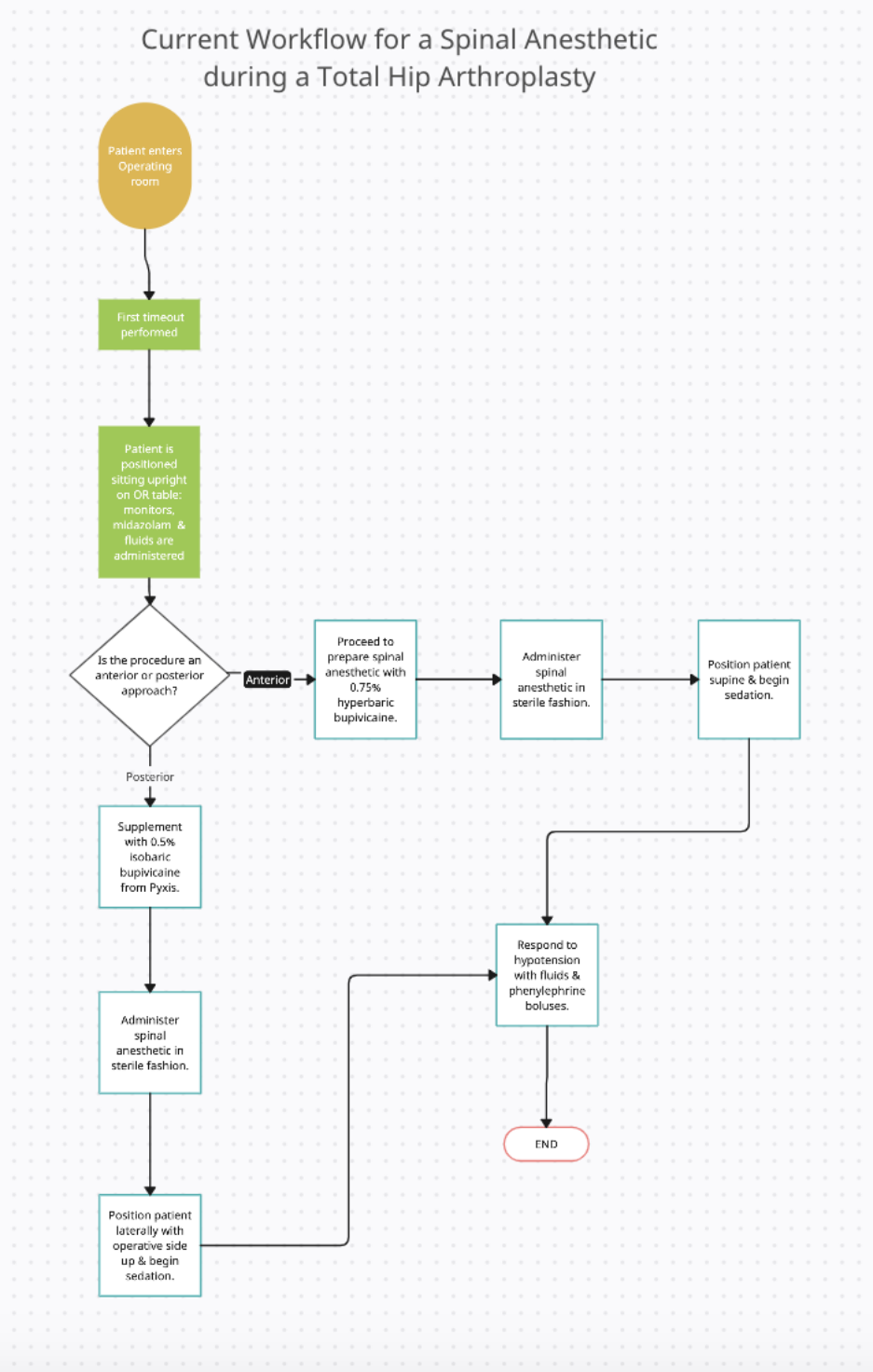
Promoting Action on Research Implementation in Health Services (PARIHS) Framework Diagram



Note. Theoretical framework chosen to assist in designing project implementation.

Figure 5

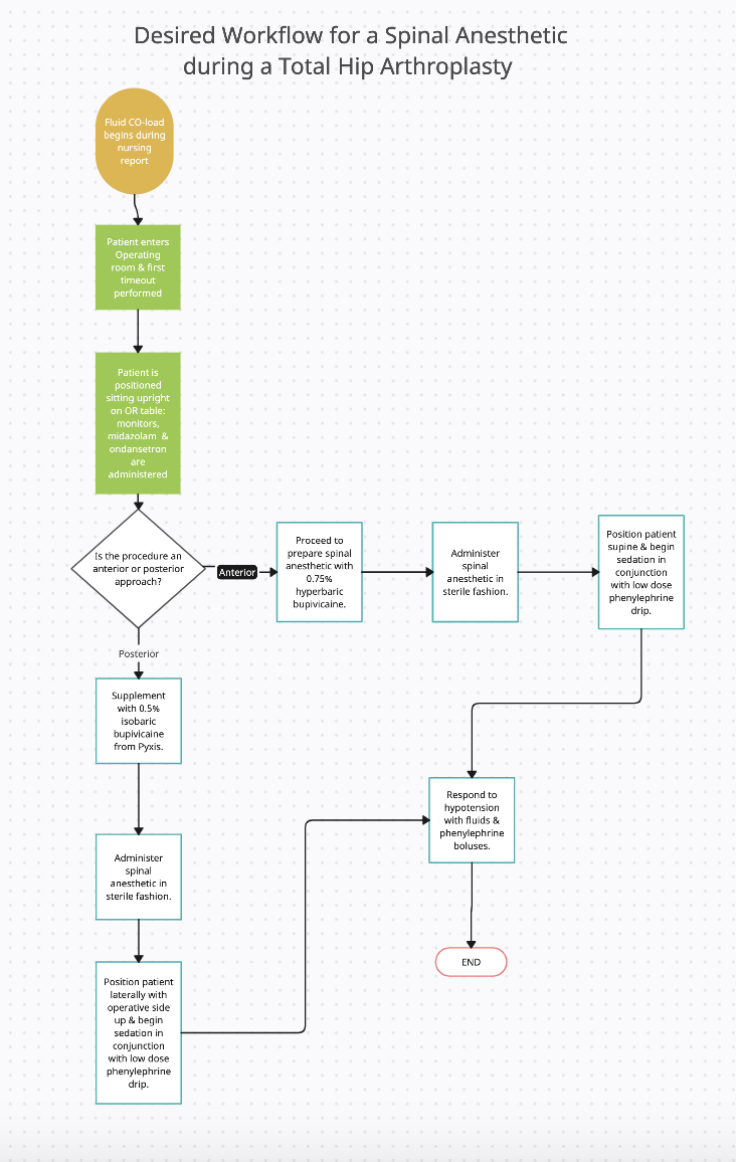
Current Process Map



Note. Process map depicting the current process during THA procedures. Ovals indicate start or end of process, rectangles indicate step in the process, and diamonds indicate a decision point

Figure 6

Desired Process Map



Note. Process map of the desired process during THA procedures. Oval indicates start or end of process, rectangle indicates step in the process, and diamond indicates a decision point.

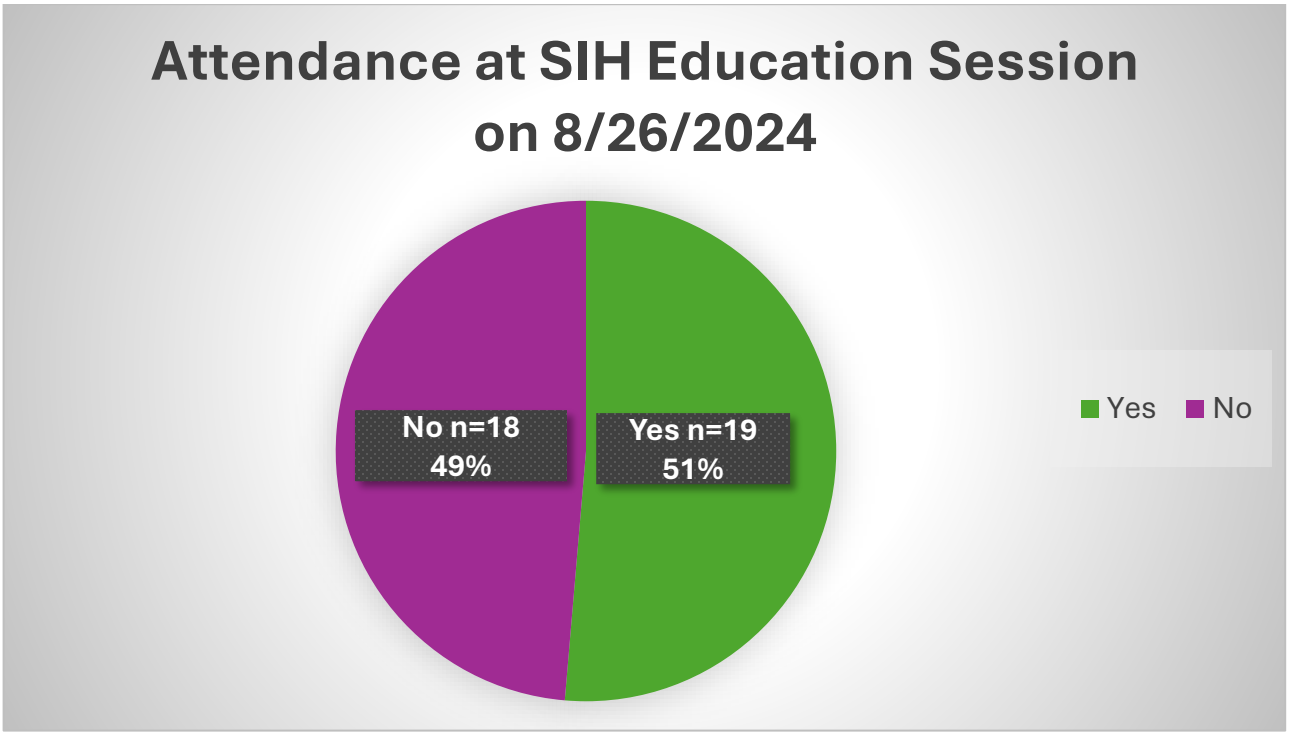
Figure 7

Gannt Chart

Note. Gantt Chart depicting QI project timeline and activities. Some dates are estimated.

Figure 8

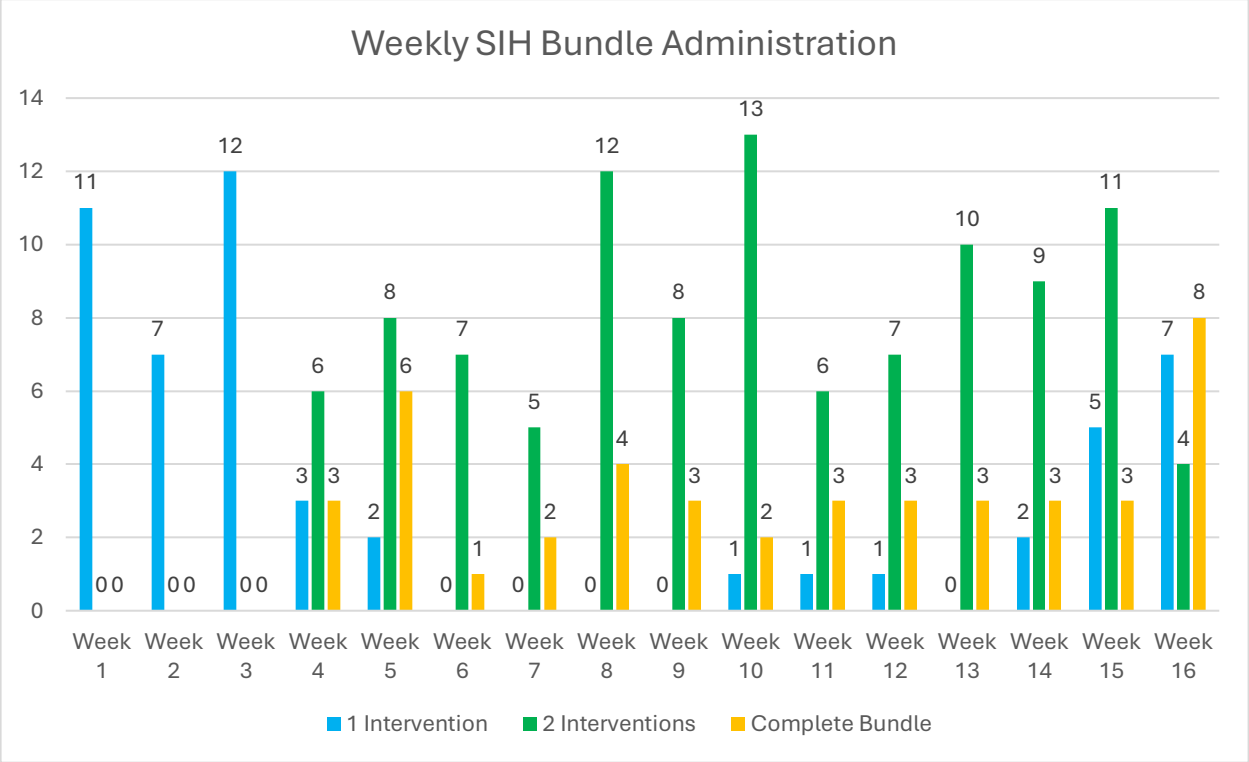
SIH Provider Education Attendance Record



Note: Pie chart depicting the percentage of anesthesia providers who attended to SIH education sessions.

Figure 9

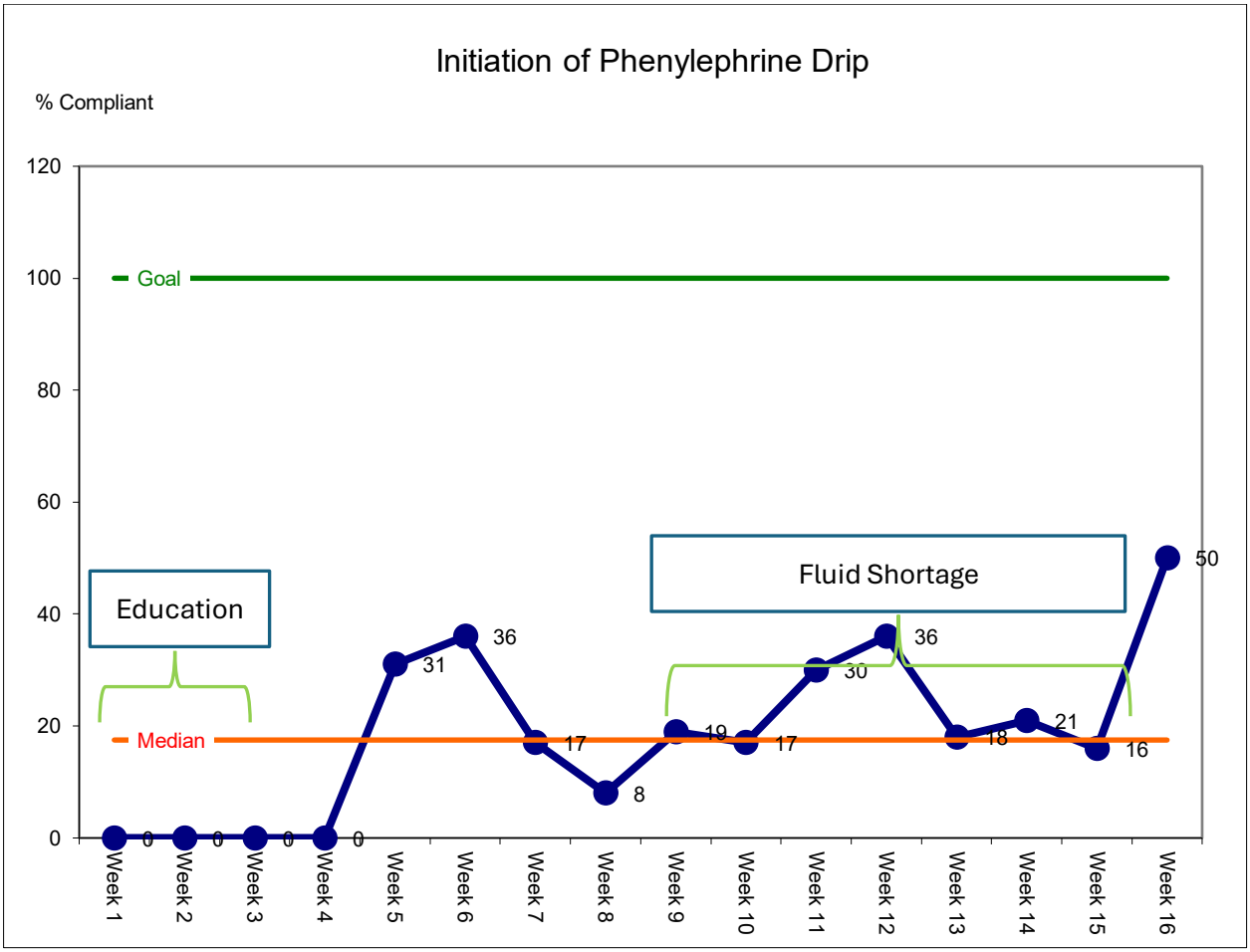
SIH Bundle Interventions Bar Graph



Note. A weekly tally of how many times one or more bundled interventions were performed.

Figure 10

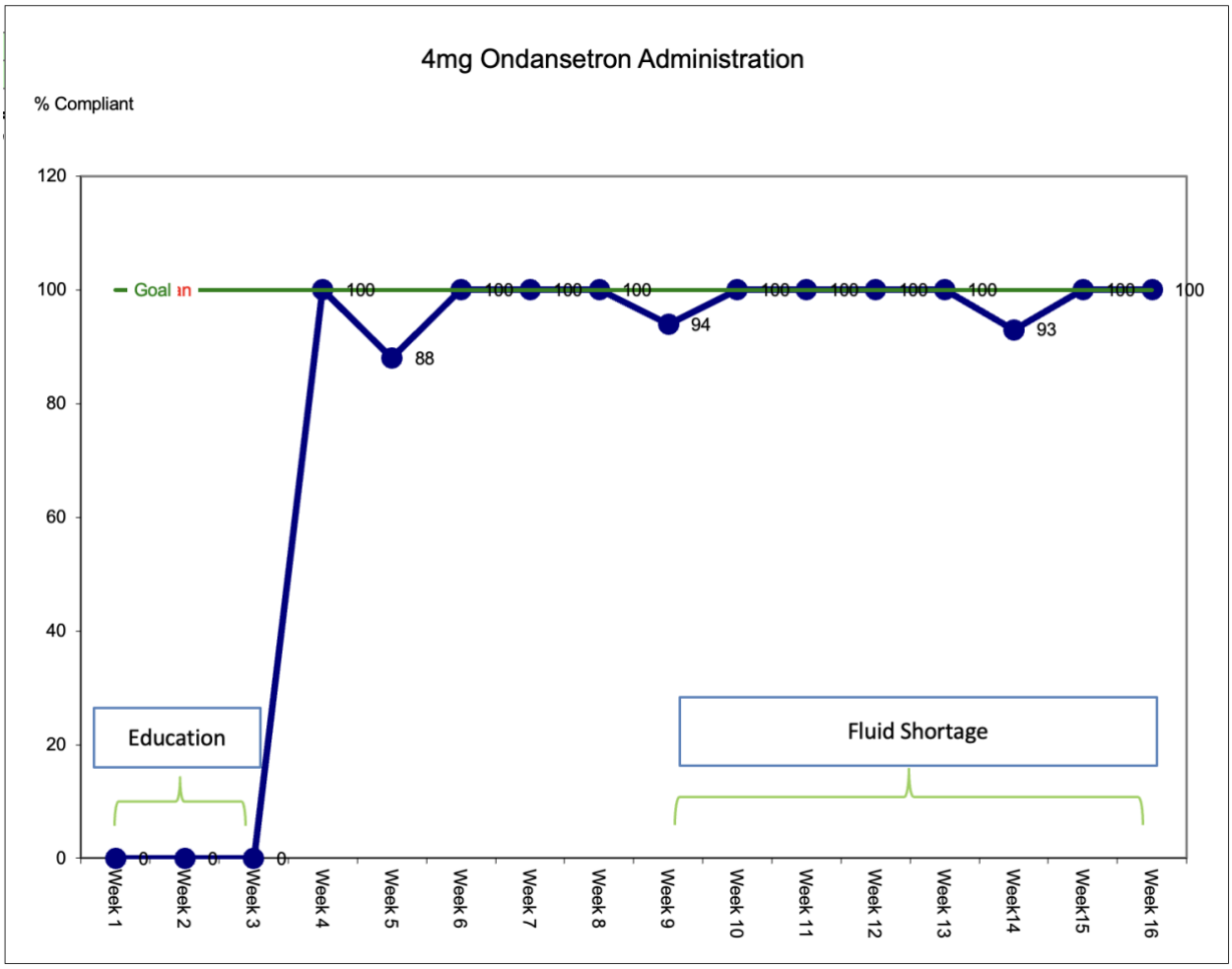
Phenylephrine Drip Run Chart



Note: a run chart depicting weekly administration of a phenylephrine drip on THA patient's

Figure 11

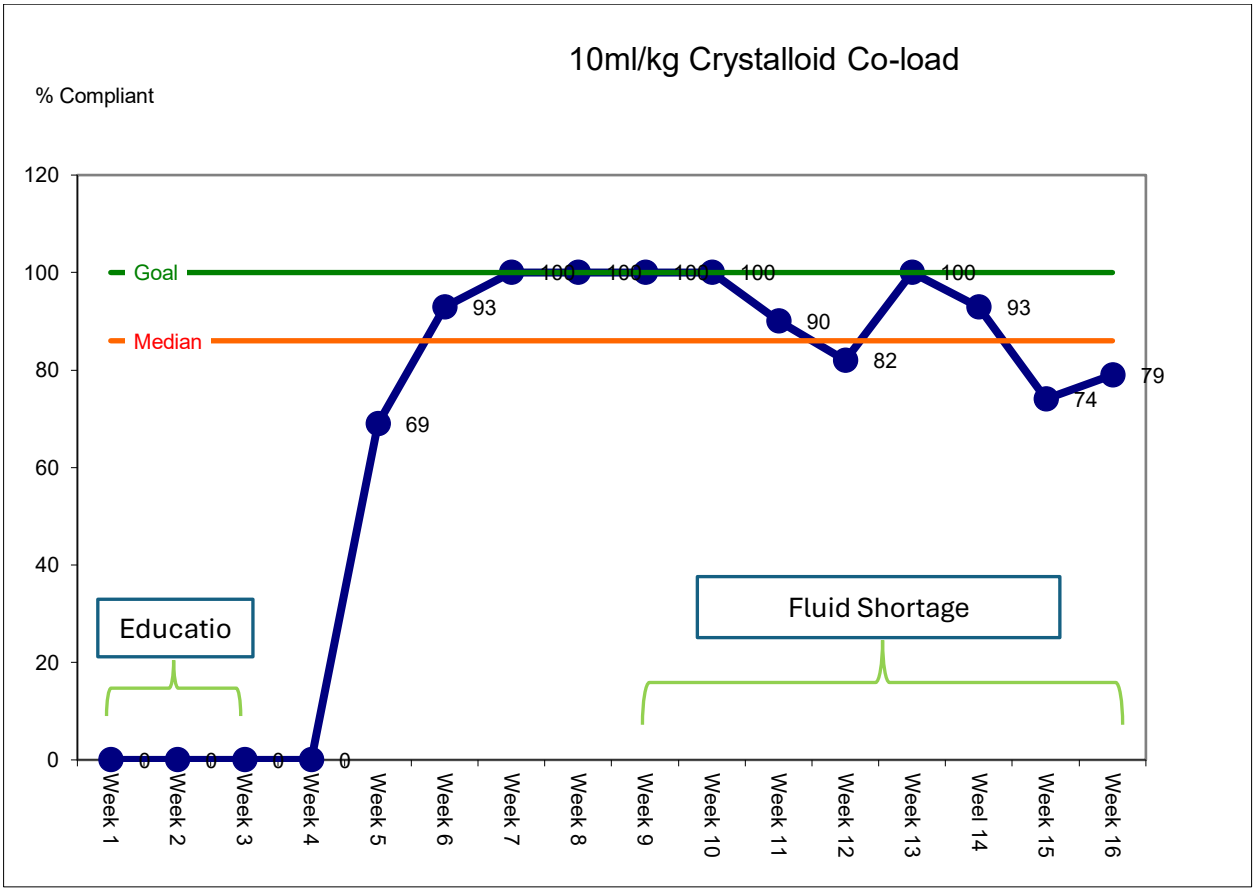
4mg Ondansetron Administration Run Chart



Note: a run chart depicting weekly administration of four milligrams of IV ondansetron five minutes before the spinal on THA patients.

Figure 12

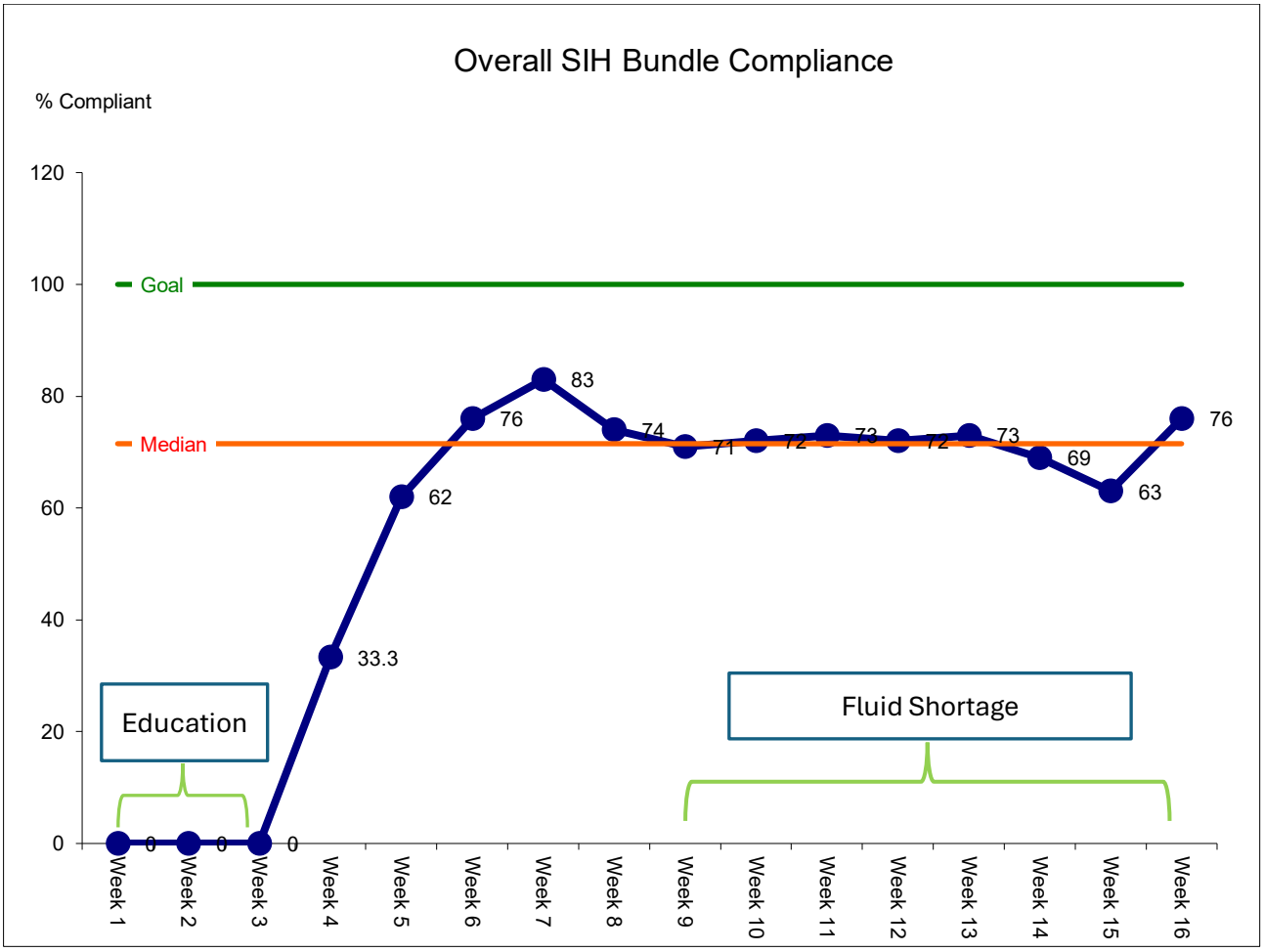
10ml/kg Crystalloid Co-load Run Chart



Note: a run chart depicting weekly administration of a 10ml/kg crystalloid co-load on THA patients.

Figure 13

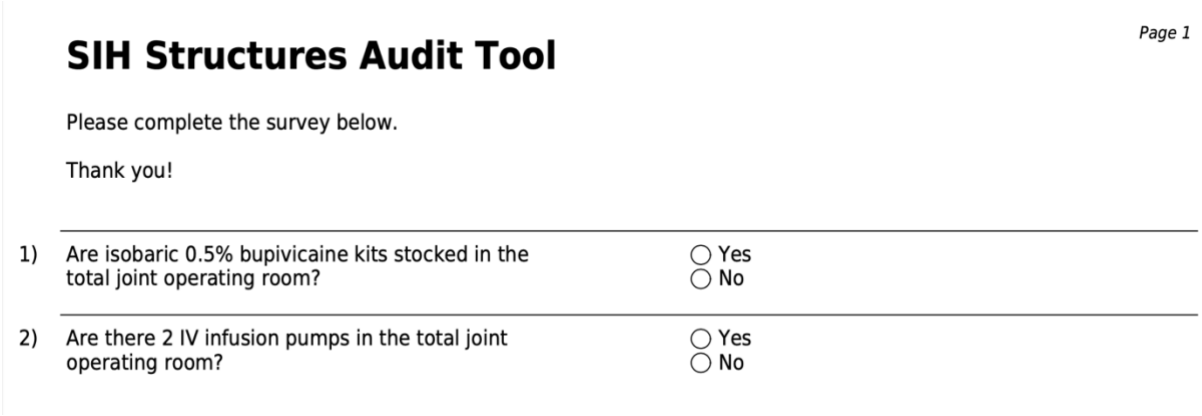
SIH Bundle Compliance Run Chart



Note: a run chart depicting overall weekly SIH Bundle adherence on THA patients.

Appendix A

RedCap SIH Structure Audit Tool



Page 1

SIH Structures Audit Tool

Please complete the survey below.

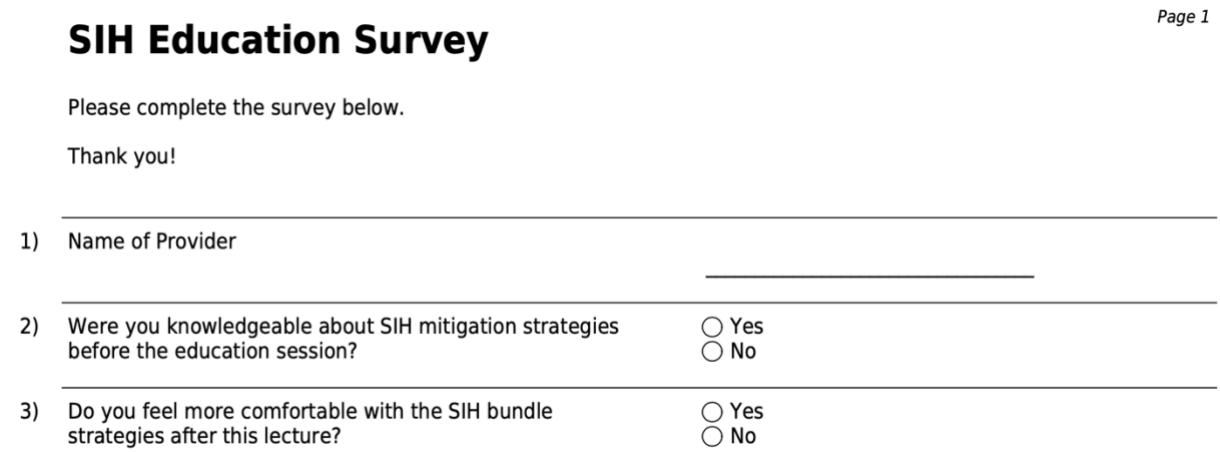
Thank you!

1)	Are isobaric 0.5% bupivicaine kits stocked in the total joint operating room?	◯ Yes ◯ No
2)	Are there 2 IV infusion pumps in the total joint operating room?	◯ Yes ◯ No

Note. Audit tool to be utilized in collecting data concerning project structure goal adherence.

Appendix B

RedCap SIH Education Survey



Page 1

SIH Education Survey

Please complete the survey below.

Thank you!

1) Name of Provider _____

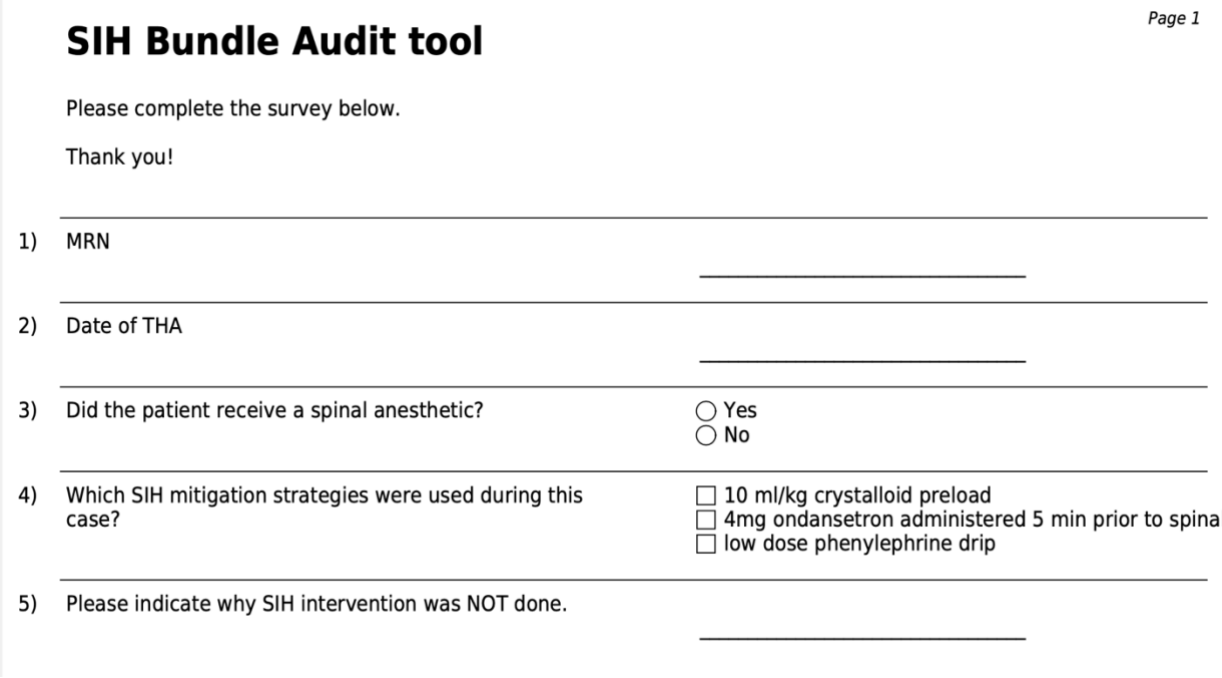
2) Were you knowledgeable about SIH mitigation strategies before the education session? ◯ Yes ◯ No

3) Do you feel more comfortable with the SIH bundle strategies after this lecture? ◯ Yes ◯ No

Note. Survey tool to be utilized in collecting post-education data.

Appendix C

RedCap SIH Process Audit Tool



Page 1

SIH Bundle Audit tool

Please complete the survey below.

Thank you!

1) MRN _____

2) Date of THA _____

3) Did the patient receive a spinal anesthetic?
○ Yes
○ No

4) Which SIH mitigation strategies were used during this case?
☐ 10 ml/kg crystalloid preload
☐ 4mg ondansetron administered 5 min prior to spinal
☐ low dose phenylephrine drip

5) Please indicate why SIH intervention was NOT done. _____

Note. Audit tool to be utilized in collecting data concerning project process goal adherence