An Educational Module for Continuous Blood Pressure Monitoring during Shoulder Surgery in the Beach Chair Position

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Abstract

Background: Orthopedic operations of the shoulder joint have been the second most performed surgery in the orthopedic specialty. The advantage for better visualization of intraarticular structures has made the beach chair position the preferred choice for most orthopedic surgeons. However, this position incurred potential complications for the patient if close hemodynamic monitoring was not performed. Significant fluctuations in blood pressure could go undetected during intervals of intermittent blood pressure monitoring which may lead to peri-operative complications. Continuous, non-invasive blood pressure monitoring has offered a beat-to-beat blood pressure reading that could alert the anesthetist of the exact moment when changes in blood pressure occur and how to treat this occurrence diligently. For patients undergoing surgery in the beach chair position, continuous, non-invasive hemodynamic monitoring could provide a more efficient and rapid response to intra-operative hypotension when compared to intermittent blood pressure devices.

Methods: The databases utilized for conducting research included PubMed, CINAHL, and Cochrane Library. Articles were selected based on year of publication, relevance to the researched topic, and evidence supporting the benefits of using continuous, non-invasive hemodynamic monitoring. Surveyors were provided with a pre-test and post-test questionnaire to complete before and after participating in an educational module.

Results: The results yielded ten, high-level research articles that were used to perform a literature review secondary to their relevance and current evidence. The articles used in the review supported the use of continuous, non-invasive hemodynamic monitoring for optimizing peri-operative patient outcomes and minimizing the complications associated with untimely detection of intra-operative hypotension. The results of the pre-test and post-test questionnaire indicated an improvement in knowledge regarding the use of continuous, noninvasive hemodynamic monitoring.

Discussion: The current literature supports the use of continuous non-invasive hemodynamic monitoring for its accuracy in blood pressure readings, ease of use, and ability to detect hypotensive episodes as they occur. This technology has proved to enhance peri-operative outcomes in patients undergoing surgical procedures by allowing clinicians to detect hypotensive episodes in real time and provide timely treatment to decrease morbidity and mortality. The results of the pre-test and post-test questionnaire demonstrated an increase in knowledge regarding use of continuous, noninvasive hemodynamic monitoring and a likelihood for using this technology in practice for patients undergoing surgery in the beach chair position. Limitations included a small sample size of surveyors and insufficient time for significant data collection. In conclusion, the continuous, non-invasive hemodynamic monitor proves to benefit anesthesia practice by improving patient outcomes post-operatively.

Keywords: Continuous, non-invasive hemodynamic monitoring, beach chair position, anesthesia, shoulder surgery, arterial line blood pressure monitor, oscillometric noninvasive blood pressure monitor

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Introduction

Patients undergoing shoulder surgery in the beach chair position have been subjected to a decrease in mean arterial pressure up to 34±10mmHg.[1] Intraoperative hypotension has been associated with an increased risk of postoperative morbidity and mortality.[2] There has been supporting evidence that intraoperative hypotension lead to organ dysfunction affecting the heart, kidneys, brain, and increased risk for mortality in high-risk patients.[2] One study included 66 patients who were placed in the beach chair position for shoulder surgery.[3] Ninety three percent of these patients experienced hemodynamic instability such as hypotension, bradycardia, and subsequently, decreased cerebral oxygenation.[3] Studies have shown that a mean arterial pressure of 50mmHg for just 1 minute increased the risk of mortality by 5%.[4]

The continuous, non-invasive hemodynamic monitor has been used for blood pressure measurement in the intra-operative setting. This device has provided beat-to-beat measurement of hemodynamics for a vast number of surgical procedures. Studies have shown that this method of hemodynamic monitoring reduced the amount of intraoperative hypotension by 50% as it prompted immediate treatment of low blood pressure.[4] The impact of prompt detection and intervention of intraoperative hypotension has been the significant decrease in the risk for postoperative morbidity and mortality.

Purpose

This purpose of this paper was to provide information on the innovative CNIBP monitoring device. This device has been used to provide continuous, non-invasive blood pressure and cerebral oxygenation monitoring in the intra-operative setting. The CNIBP device was described be a portable, easy to use monitor that could offer beat-to-beat blood pressure readings and cerebral oximetry readings throughout the peri-operative phase. For patients undergoing

surgery in the beach chair position, the continuous, non-invasive device could provide a more efficient and rapid response to intra-operative hypotension when compared to conventional, intermittent blood pressure devices.

PICO Question

For patients undergoing shoulder surgery in the beach chair position (P), does the continuous, non-invasive blood pressure device (I) versus use of intermittent oscillometric devices (C) provide earlier detection and treatment of intraoperative hypotension (O)?

Problem Statement

The upright or beach chair position has been a popular and frequently used position by orthopedic surgeons operating on the shoulder joint. This position has allowed for larger flexion angles and subsequently, better visualization of shoulder structures.[1] Other benefits of the beach chair position include less risk for neurovascular and brachial plexus injury.[2] However, while these benefits have been advantageous for surgeons, there have been risks involved secondary to the challenges of maintaining adequate patient hemodynamics and subsequently, adequate cerebral perfusion while in the beach chair position.[2] The upright or beach chair position has resulted in various hemodynamic changes including a reduction in mean arterial pressure, stroke volume, and cardiac output with increases in peripheral vascular resistance.[2] As a result, studies reported a significant decrease in cerebral oxygenation in up to 18% of patients during shoulder surgery in the beach chair position. [2]

Problem Identification

Orthopedic surgeries in the beach chair position have resulted in hemodynamic instability and have presented anesthesia providers with the challenges of maintaining optimal blood pressure parameters for the sake of providing the brain and other organs with adequate perfusion

and oxygenation. The consequences of hypoperfusion could result in secondary organ damage such as acute renal injury. More severe outcomes and high-risk potential for increased morbidity and mortality have included cardiovascular and cerebrovascular events.

Background

Orthopedic operations of the shoulder joint have been the second most performed surgery in the orthopedic specialty.[1] These procedures typically have been performed in 2 positions: the lateral decubitus position and the upright or beach chair position.[1] Approximately two-thirds of patients having shoulder surgery in the United States have undergone the procedure in the beach chair position. The advantage for better visualization of intraarticular structures and ease of positioning has made the beach chair position the preferred choice for most orthopedic surgeons. However, this position incurred certain disadvantages for the anesthesia provider and potential complications for the patient if close hemodynamic monitoring was not performed.

Intermittent blood pressure monitoring for a minimum of every 5 minutes has been the standard of care per the American Society of Anesthesiologists guidelines for basic anesthesia care.[3] However, significant fluctuations in blood pressure could go undetected during intervals of intermittent blood pressure monitoring which may lead to peri-operative complications.[4] The continuous, non-invasive device has offered a beat-to-beat blood pressure reading that could alert the anesthetist of the exact moment when changes in blood pressure occur and how to treat this occurrence diligently.

Scope of the Problem

Hemodynamic monitoring in the operating room consists of recording blood pressure measurements via continuous non-invasive methods, continuous arterial line monitoring, or intermittent blood pressure monitoring with a blood pressure cuff that is placed on an extremity.[4]

Intermittent blood pressure monitoring could be performed every minute and up to every 4 hours on some anesthesia monitors. However, an intermittent measurement has not allowed for immediate detection of intraoperative hypotension.[5] Continuous hemodynamic monitoring would be the preferred method for monitoring blood pressure in high-risk patients undergoing intermediate or high-risk procedures and would warrant invasive blood pressure monitoring via cannulation of an artery.[5] Although invasive arterial blood pressure monitoring has been the most accurate measure for blood pressure, insertion of an arterial catheter has been associated with potential risks for bleeding, embolism, and infection.[5]

Consequences of the Problem

Blood pressure measurement intervals as short as 1 minute could result in dangerously low, undetected levels of hypotension that could pose a threat to certain patient populations such as those classified as ASA 3 or higher, patients on chronic antihypertensive drug therapy, and patients of advanced age.[4] Postural changes such as placing the patient in an upright or beach chair position could further affect hemodynamic stability resulting in decreased organ perfusion, namely the brain.[4]

Knowledge Gaps

The novel continuous, non-invasive blood pressure device was created by leaders in innovative technology targeting cardiovascular disease.[7] Many anesthesia providers may have been unaware of this technology, the prevalence of intraoperative hypotension in the beach chair position, and the severe implications of untimely detection of intraoperative hypotension. According to research conducted by Edwards Lifesciences, intraoperative hypotension continued to occur in 88% of patients with arterial line monitoring.[7] Consequently, prolonged exposure of

mean arterial pressures below 65mmHg could result in acute kidney injury, myocardial ischemia, and cerebral desaturation in the beach chair position.[7]

Proposed Solution

Intermittent blood-pressure devices have not had the capability to detect sudden or significant changes in hemodynamics during induction of anesthesia, postural changes, or accidental injury to vascular structures and organs. The continuous, non-invasive system was designed as a non-invasive device with an inflatable finger cuff which would yield a beat-to-beat blood pressure measurement via the volume clamp method.[6] This device demonstrated a reduction in the incidence of intraoperative hypotension by 57% and subsequently, could decrease the risk for intraoperative and postoperative complications associated with hemodynamic instability.[7]

Summary

The continuous, non-invasive system was a novel device for continuous, non-invasive blood pressure measurement that could be useful in patient's undergoing shoulder surgery in the beach chair position. This device would assist with the early detection and treatment of intraoperative hypotension in the upright position. It would help prevent the incidence and duration of intraoperative hypotension which would improve perfusion to vital organs and decrease the risk for organ damage and subsequent postoperative morbidity and mortality. In summary, the continuous, non-invasive system has aimed to provide a clinically acceptable solution for close hemodynamic monitoring for patients undergoing shoulder surgery in the beach chair position.

Literature Review

Patients having shoulder procedures in the beach chair position have been subjected to a decrease in mean arterial pressure up to 34±10mmHg.[1] Intraoperative hypotension has been associated with an increased risk of postoperative complications.[9] There has been supporting evidence that intraoperative hypotension leads to organ dysfunction affecting the heart, kidneys, brain, and an increased risk for mortality in high-risk patients.[9] One study included 66 patients who were placed in the beach chair position for shoulder surgery.[10] Ninety-three percent of these patients experienced hemodynamic instability such as hypotension, bradycardia, and subsequently, decreased cerebral oxygenation.[10] Studies have shown that a mean arterial pressure of 50mmHg for just 1 minute increased the risk of mortality by 5%.[11]

The continuous, non-invasive monitor was a device created for continuous, non-invasive blood pressure measurement in the intra-operative setting. This device provided a beat-to-beat measurement of hemodynamics for a vast number of surgical procedures. Studies have shown that this method of hemodynamic monitoring reduced the amount of intraoperative hypotension by 50% as it prompted immediate treatment of low blood pressure.[11] The impact of prompt detection and intervention of intraoperative hypotension led to a significant reduction in postoperative morbidity and mortality.

Synthesis of PICO Question

For patients undergoing shoulder surgery in the beach chair position (P), does the continuous, noninvasive blood pressure device (I) versus intermittent oscillometric devices (C) provide earlier detection and treatment of intraoperative hypotension (O)?

The first element in this PICO question involved the population selected for this project. The population included patients undergoing shoulder surgery in the beach chair position. As a

result of this position, patients were subjected to a significant decrease in blood pressure and subsequently, a decrease in perfusion to vital organs. This resulted in an increased risk for post-operative complications such as myocardial ischemia and acute kidney injury.[11] The second component of the PICO question included the selected intervention for the possible prevention of intraoperative hypotension in this patient population. The continuous, non-invasive device provided continuous, non-invasive hemodynamic monitoring for patients in the intraoperative setting. This device provided an advantage over invasive hemodynamic monitoring because it prevented the risk of infection, hematoma, and embolism.[12] Intermittent blood pressure monitoring had the potential to yield inaccurate readings depending on the size of the cuff being used. Also, frequent cycling of blood pressure, such as every minute, may have resulted in pressure injury on the extremity where the blood pressure was being measured. Furthermore, if a patient were to experience drastic decreases in blood pressure on induction, intermittent blood pressure monitors would not be able to quickly detect these significant drops in blood pressure; resulting in inadequate treatment of hypotension. The continuous, non-invasive system would provide a beat-to-beat blood pressure measurement thus, prompting a timely response to significant decreases in blood pressure, especially in patients undergoing surgery in the beach chair position.

Literature Search Process

The search strategy for this project included the selection of various databases to initiate research. The databases utilized included EMBASE, CINAHL, PubMed, and the Cochrane Library. These databases were selected for providing the most up-to-date research on healthcare and medicine. The Cochrane Library provided various level 1 and level 2 evidence studies. Limiters placed on the searches yielded articles published only within the last 5-7 years and only

randomized controlled trials. Other limiters selected were to include studies that only provided full text and were written in English. The search terms used to conduct the research included "Continuous, Non-invasive Blood Pressure Monitor", "Intermittent Blood Pressure Monitoring", "Beach Chair Position", "Shoulder Surgery", "Hemodynamics", "Hypotension", and "Anesthesia".

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were utilized in the literature search process. Inclusion criteria contained articles classified as level 1 or level 2 evidence studies such as Systematic Reviews & Meta-Analysis or Randomized Controlled Trials. Studies that provided a comparison between continuous, non-invasive blood pressure monitoring and intermittent, oscillometric blood pressure monitoring were also included in the literature review. Exclusion criteria removed all studies that were not conducted or published within the last 5-7 years. Some studies did not provide an adequate sample size and therefore, limited data that could support the research findings or sufficient evidence to draw conclusions. These studies were excluded from the literature review. Upon reviewing the abstract and full-text for the articles that were resulted, a total of ten articles were used for inclusion in this review.

Literature Appraisal and Literature Matrix

The literature matrix included a summary of the articles that were selected for the literature review. The content in the literature matrix tables utilized the American nurse association research critique framework. This framework included the name of the article with the corresponding author and publication year, the design and purpose of the study, the sample size used to conduct the study, the setting where the study took place, the major variables of the study that were being compared, how the data was collected and measured, a data or statistical

analysis of the study yielding its results, the findings gathered along with the conclusions drawn, and an appraisal of the study including its worth to practice based on level of evidence.

The translation framework used for the selection of articles was the John Hopkins Nursing Evidence-Based Model.[6] This model provided a rating system for appraisal of evidence in research studies.[13] The determination for the selection of articles used in this literature review was made depending on its level of evidence. The highest level of evidence in the research evidence hierarchy included level 1 and level 2 studies.[13] These included level 1 experimental studies which consisted of randomized controlled trials and systematic reviews of RCTs with or without meta-analysis.

Characteristics of the Included Studies

Appraisal of Evidence #1

The article titled "A randomized trial of continuous noninvasive blood pressure monitoring during noncardiac surgery" compared the effects of intraoperative hypotension when using continuous, noninvasive blood pressure monitors versus intermittent, oscillometric blood pressure monitors during noncardiac surgery under general anesthesia.[11] The introduction to the study provided a background of the problem and it was determined that intraoperative hypotension was associated with an increased risk of postoperative morbidity and mortality. The article emphasized that hypotension was the most significant factor associated with postoperative mortality in the Perioperative Ischemia Evaluation Trail.[11] Other complications related to intraoperative hypotension included renal and myocardial injury secondary to ischemia-reperfusion or a mismatch between oxygen supply and oxygen demand. Another study had reported that a causal relationship existed between systolic blood pressures maintained within 10% of baseline values and a reduction in postoperative organ dysfunction.[11]

The study utilized a patient population that consisted of adults over the age of 45 with the American Society of Anesthesiologists physical status of 3 or 4 and considered to be an increased risk for noncardiac surgery under general anesthesia.[11] A hypothesis for the study was testing the effectiveness of continuous noninvasive blood pressure monitoring in reducing the occurrence of hypotension in the operating room. The design of this study was experimental and quantitative. This study was classified as level 1 in the research evidence hierarchy. The study took place in the Cleveland Clinic in Cleveland, Ohio.[11] The sample size consisted of 320 participants of which 316 were included and divided evenly into 2 groups.[11] Three of the 4 participants who were excluded required invasive arterial monitoring and 1 participant whose surgery was cancelled.[11] The results yielded a significantly lower time-weighted average mean arterial pressure less than 65mmHg with continuous, noninvasive blood pressure monitoring versus intermittent blood pressure monitoring.[11] The probability value significance for this study was at $P<0.48$ with the final outcome yielding a value of $P<0.039$ making this study statistically significant.[11] The conclusion drawn from this study was that continuous, noninvasive blood pressure monitoring significantly decreased the incidence of intraoperative hypotension by nearly half.[11] The strength of this study included its large sample size and level 1 classification in the research evidence hierarchy. The limitations included the lack of a standing protocol for the treatment of intraoperative hypotension. Also, clinicians may have drawn skepticism with the use of the continuous, non-invasive monitor and its level of accuracy for blood pressure measurements despite receiving validation from its manufacturer and users.[11]

Appraisal of Evidence #2

The article titled “Continuous finger-cuff versus intermittent oscillometric arterial pressure monitoring and hypotension during induction of anesthesia and noncardiac surgery: the

DETECT randomized trial" determined whether using a continuous, noninvasive blood pressure monitor would assist clinicians with detecting hypotension within fifteen minutes after the induction of anesthesia when compared to intermittent blood pressure monitors.[14] The purpose of this study was to prove that continuous noninvasive blood pressure monitoring would reduce the area and time of mean arterial pressures under 65mmHg within fifteen minutes of induction. The authors hypothesized that the continuous noninvasive method would assist clinicians with reducing hypotensive episodes by detecting and treating it promptly.

This study consisted of a quasi-experimental, quantitative design and met level 2 evidence criteria with its randomized blinded and unblinded selection of participants.[14] The setting of this research study was at the University Medical Center Hamburg Eppendorf in Hamburg, Germany.[14] The sample size consisted of 242 participants of which 222 were selected for inclusion and divided into 2 groups. The results demonstrated the area under a mean arterial pressure under 65mmHg was 7 out of 109 in patients with continuous, noninvasive blood pressure monitoring versus 19 out of 113 in patients with intermittent oscillometric monitoring.[14] Additionally, the time-weighted average mean arterial pressure under 65mmHg was 0.04mmHg in 112 patients who were monitored using continuous noninvasive devices and 0.40mmHg in 115 patients using intermittent oscillometric monitoring.[14] Therefore, this study concluded that the continuous, finger-cuff monitor would assist clinicians with the detection and treatment of hypotension within 15 minutes after induction of anesthesia versus traditional, intermittent oscillometric pressure monitoring.[14] The strengths in this study were identified by its significant sample size, its level of evidence, and statistical significance with a value of $P=0.004$ (area under mean arterial pressure of 65mmHg) and $P<0.001$(time-weighted average mean arterial pressure

below 65mmHg) which supported the null hypothesis.[14] The limitations of this study were not listed or identified.

Appraisal of Evidence #3

The article "Impact of continuous non-invasive blood pressure monitoring on hemodynamic fluctuation during general anesthesia: a randomized controlled study" assessed whether continuous, noninvasive blood pressure monitoring would reduce the incidence of intraoperative hemodynamic fluctuation when compared to intermittent blood pressure cuff monitoring.[12] The introduction to the study discussed the implications of postoperative cardiac morbidity. The authors explained that perioperative interventions could minimize the risk of cardiovascular complications before, during, and after surgery. Some of the examples provided include intraoperative goal-directed fluid therapy, minimizing blood transfusions, decreasing or avoiding hypothermia, and providing an adequate level of anesthesia.[12] One of the primary goals to minimize cardiovascular complications in the perioperative period, however, was to maintain hemodynamic stability throughout the course of surgery. The article mentioned that fluctuation of hemodynamics in the operating room was a common and expected occurrence under the effects of general anesthesia due to the vasodilating properties of anesthetic drugs, blood loss, and surgical stress.[12] Intermittent blood pressure monitoring in the operating room was typically performed every 5 minutes as recommended by the American Society of Anesthesiologists. However, the occurrence of hypertension or hypotension would be more difficult to detect with intermittent monitoring compared to invasive arterial line monitoring. Although invasive arterial hemodynamic monitoring was more accurate than intermittent monitoring, there were complications associated with the invasive nature of the device. Infection, hematoma, and/or nerve injury were some of the complications linked to invasive line monitoring. The authors'

objectives for the study was to identify the reliability of CNBPM to yield accurate hemodynamic measurements compared to intermittent cuff measurements and the efficacy of CNBPM to reduce the incidence of intraoperative hypotension.

The study design was experimental, quantitative, and met level 1 criteria in the evidence hierarchy due to its blinded selection and randomization of participants. The study took place in a surgery center in Osaka, Japan.[12] The sample size was small, consisting of 40 included participants who were divided evenly into a Control group and a CS (continuous, non-invasive) group. The results of the study determined that patients in the CS group experienced a lower incidence of hypotension during induction and maintenance of anesthesia.[12] In addition, the CS group maintained a longer period of hemodynamic stability when compared to the Control group.[12] Consequently, this study concluded that hemodynamic monitoring with the continuous, noninvasive monitor could reduce the incidence of intraoperative hypotension and result in clinically acceptable hemodynamic stability throughout the intraoperative period.[12] This study did not list any conflict of interests or biases contributing to its potential strengths. Limitations included the lack of blood pressure measurement using the intermittent blood pressure monitor in the Control group's postoperative course. Also, although the continuous, non-invasive system measured hemodynamic parameters such as cardiac output and stroke volume variation, only the blood pressure was the primary focus in the study.[12]

Appraisal of Evidence #4

The article titled "The impact of continuous non-invasive arterial blood pressure monitoring on blood pressure stability during general anesthesia in orthopedic patients; a randomized trial" investigated whether continuous, noninvasive blood pressure monitoring lead to enhanced hemodynamic stability.[5] A brief description of the background listed the adverse

effects of intraoperative hypotension as acute kidney failure, myocardial infarction, and stroke. Additionally, patient's suffering from chronic hypertension were more susceptible to hypotensive events with induction of anesthesia. The article inferred that intermittent blood pressure monitoring would result in a delayed response to detection and treatment of intraoperative hypotension. The author's hypothesized if continuous blood pressure monitoring would improve blood pressure stability by minimizing the incidence of hypotensive events.

The design for this study was experimental, quantitative, and categorized as level 1 on the research evidence hierarchy. The sample size included 160 patients who were divided into 2 groups; 1 group assigned 77 patients to a study group and another group assigned 83 patients to a control group.[5] Patients in the study group received continuous, non-invasive blood pressure monitoring using the continuous, non-invasive system device while patients in the control group were monitored using traditional intermittent, oscillometric blood pressure monitoring.[5] The setting for this study was a German University Hospital in Munich, Germany.[5] The results showed hypotension occurring more frequently in the control group (intermittent blood pressure measurement) than in the study group (continuous, non-invasive device). There were 51 blood pressure recordings with mean arterial pressure below 60mmHg in the control group compared to only 19 occurring in the study group.[5] Additionally, mean arterial pressure below 55mmHg occurred 25 times in the control group compared to 7 times in the study group.[5] In conclusion, the study determined that those patients who received continuous blood pressure monitoring with the continuous, non-invasive system were more hemodynamically stable throughout the intraoperative course compared to those who were monitored using the intermittent device.[5] In this blinded study, the use of continuous, noninvasive blood pressure monitoring prompted the anesthetists to treat hypotension sooner than in patients who received intermittent blood pressure

monitoring.[5] This study provided findings from Walsh et al[15] who suggested that the risk for acute kidney injury was much higher in patients with a mean arterial pressure of 55mmHg or less, even if for just 1 minute.[15] The main strength in this study was the ability to conduct it under normal conditions without having to impose blood pressure control protocols.[5] Because this was a blind study, bias could be ruled out as the anesthetists were unaware of the method or purpose and therefore, did not prompt them to pay special regard to the blood pressure.[5] A limitation that was observed was the inability to conclude whether intermittent blood pressure monitoring intervals less than 3 minutes would yield the same results as continuous, noninvasive blood pressure monitoring.[5]

Appraisal of Evidence #5

The article "Arterial catheters for early detection and treatment of hypotension during major noncardiac surgery: a randomized trial" supported continuous blood pressure monitoring for early detection and treatment of low blood pressure in the operating room.[16] The authors hypothesized that the area under the curve mean arterial pressure below 65mmHg was reduced with continuous invasive monitoring by arterial cannulation.[16] The article listed several complications associated with intraoperative hypotension including myocardial injury, acute kidney injury, cerebral desaturation, and mortality.[16] Additionally, statistical data implied that myocardial injury was consistent with a mean arterial pressure below 65mmHg.[16] Myocardial injury has been linked to a thirty day postoperative mortality.[16] Initially, the authors' primary hypothesis was to assess a decrease in the incidence of serious complications, readmissions, and death with the use of arterial catheter monitoring. Due to the large sample size and slow enrollment, the original trial was stopped and a new one was created. A second hypothesis was created to assess whether the area under the curve mean arterial pressure less than 65mmHg

would be reduced with arterial monitoring versus intermittent oscillometric monitoring.[16] Also, the study would assess if patients with arterial hemodynamic monitoring would receive greater blood pressure support with vasopressor boluses.[16]

The design in this study was a level 1 evidence research study as it was experimental and qualitative.[16] The study was held at the Cleveland Clinic Main Campus in Cleveland, Ohio.[16] One hundred forty three patients were selected for invasive arterial catheter monitoring and 163 patients were subjected to intermittent monitoring after exclusion criteria was applied.[16] The observation was that continuous arterial catheter monitoring resulted blood pressure measurements 5 times greater than intermittent monitors and therefore, increased early detection and treatment of hypotension when compared to intermittent monitoring.[16] The study concluded that continuous, invasive blood pressure monitoring facilitated the early detection of hypotension and consequently, reduced the potential deleterious effects that hypotension could produce if untreated in a timely manner.[16] Additionally, the study provided information gathered by retrospective analyses that emphasized how just a few minutes of hypotension, specifically mean arterial pressures below 55mmHg, strongly correlated with myocardial injury and to a lesser degree, acute kidney injury.[16] The primary strengths in this study were its ample size of selected participants and its randomized design. Limitations included the absence of goal-directed hemodynamic protocols.[16]

Appraisal of Evidence #6

"Continuous intra-arterial versus intermittent oscillometric arterial pressure monitoring and hypotension during induction of anesthesia: the AWAKE randomized trial" hypothesized that continuous, invasive arterial pressure monitoring reduced hypotensive episodes during induction of anesthesia when compared to intermittent, oscillometric blood pressure

monitoring.[17] The author's provided a brief introduction explaining the occurrence of hypotension in the operating room following induction of anesthesia. Although common, reducing the incidence of hypotension was of great importance as it could lead to acute kidney injury secondary to decreased organ perfusion.[17] The author's hypothesized that insertion of an arterial catheter for hemodynamic monitoring would reduce or minimize this occurrence.[17] The benefit of an arterial catheter would be the accuracy of blood pressure measurements and continuous beat-to-beat monitoring, more so during induction of anesthesia. However, the insertion of an arterial catheter before induction of anesthesia proved to be uncomfortable and painful in most patients. The author's aimed to investigate if cannulation of an artery for hemodynamic monitoring prior to induction of anesthesia would reduce hypotension.

This was a single-center randomized trial with blinded and unblinded blood pressure monitoring for patients undergoing noncardiac surgery with general anesthesia.[17] This classified the study as a level 2 evidence research study in the evidence hierarchy. The sample size included 224 patients who were evenly divided in 2 groups and met criteria for arterial catheter cannulation.[17] One hundred twenty-one patients were assigned to continuous intra-arterial monitoring and 121 patients were assigned to intermittent oscillometric monitoring.[17] The study took place at the University Medical Center Hamburg-Eppendorf in Hamburg, Germany.[17] The results yielded a greater incidence of mean arterial pressure below 65mmHg in subjects with intermittent oscillometric monitoring with a median number of 46 when compared to intra-arterial monitoring with a median of 15. The subjects assigned to intra-arterial monitoring also experienced a shorter hypotensive time with median duration lasting 2.6 minutes while patients undergoing intermittent oscillometric monitoring experienced hypotensive episodes averaging 5.4 minutes.[17] Blood pressure treatment in patients with invasive-arterial monitoring was more

aggressive than in subjects with intermittent monitoring.[17] The study concluded that the hypothesis for decreased hypotension with continuous, arterial monitoring was greater when compared to intermittent oscillometric pressure monitoring in noncardiac surgical patients.[17] The primary reason why continuous blood pressure monitoring reduced the incidence of hypotension more frequently than with intermittent monitoring was the ability for the anesthetist to identify hypotension as it occurred and provide immediate treatment.[17] The strengths of this study consisted in its level 2 randomization and adequate sample size. Limitations for this study were undisclosed.

Appraisal of Evidence #7

"Performance of the hypotension prediction index with non-invasive arterial pressure waveforms in non-cardiac surgical patients" studied the ability for continuous, noninvasive blood pressure monitors such the continuous, non-invasive system to assist with predicting intraoperative hypotension a few minutes before it happened so that clinicians could detect and prevent it.[18] The article began with an introduction explaining the background of the problem and the purpose for the study. The author's established that an association between intraoperative hypotension and mortality exists. They emphasized that prompt detection and treatment of hypotension in the operating room reduced the overall occurrence of hypotension and subsequent complications. The study measured the ability of the hypotension prediction index to detect the occurrence of hypotension when used with the continuous noninvasive blood pressure monitor. The study also provided information about the innovative technology that measures blood pressure continuously and noninvasively. The article supported that the continuous noninvasive blood pressure monitor would provide a reliable measurement of arterial blood pressure even during periods where fluctuations in hemodynamics were significantly evident. The examples

provided were during induction of anesthesia and clamping of the carotid artery.[18] This study enrolled patients in a randomized trial of blood pressure monitoring using continuous, noninvasive methods during noncardiac surgery.[18] Subjects were assigned to 2 groups using blinded and unblinded methods for the experiment. This classified the study as a level 2 evidence research study. The study was held at the Cleveland Clinic in Cleveland, Ohio and included the participation of 305 patients for this analysis. The presented results showed that a Hypotension Prediction Index (HPI) of 80-89 provided a 6-minute warning before a decrease in mean arterial pressure below 65mmHg.[18] The study concluded that the Hypotension Prediction Index, which was derived from invasive arterial waveforms, worked well with continuous, noninvasive arterial pressure waveforms too. Additionally, the continuous, non-invasive system used in this experiment provided reliable blood pressure estimates even in situations where high dynamic responses would occur such as induction of anesthesia and clamping of the carotid artery.[18] The difference in mean arterial pressure between invasive radial pressure and noninvasive arterial pressure readings were below the acceptable criteria for pressure measurements instituted by the Association for the Advancement of Medical Instrumentation.[18] Therefore, the use of noninvasive pressure waveforms would provide a wider range of patients who could benefit.[18] The main strength of this study was its randomized design. No limitations were disclosed in this study.

Appraisal of Evidence #8

"Effects of goal-directed hemodynamic therapy using a noninvasive finger-cuff monitoring device on intraoperative cerebral oxygenation and early delayed neurocognitive recovery in patients undergoing beach chair position shoulder surgery: a randomized controlled trial" investigated if reduction of cerebral hypoperfusion in the beach chair position could be

attained with goal-directed hemodynamic therapy using continuous noninvasive blood pressure monitoring.[19] The hypothesis for the study was introduced in the title of the article. It was to be determined whether continuous noninvasive blood pressure monitoring was effective for the purposes of attaining goal-directed hemodynamic therapy for patients in the beach chair position. The author's explained the physiologic effects that occur in the body in the beach chair position. Gravity would result in the pooling of blood in the lower extremities leading to decreased blood pressure and consequently, decreased cerebral perfusion and oxygenation. Decreased cerebral perfusion was linked to delayed neurocognitive recovery and other complications related to hypotension. Thus, the author's aimed to investigate if the continuous noninvasive blood pressure monitor would assist with guiding goal-directed fluid therapy to counter hypotensive events in the beach chair position. The continuous noninvasive device for hemodynamic monitoring was introduced as an alternative to arterial line monitoring and received validation for its accuracy of blood pressure measurements during shoulder surgery in the beach chair position. Therefore, the study supported the use of the noninvasive device to guide GDHT for these procedures.

This was a level 1 evidence study as the design was blinded and randomized. The setting for this study took place at the National Taiwan University Hospital in Taipei City, Taiwan. The sample size was small with only 70 participants who were scheduled to undergo shoulder surgery in the beach chair position. The participants were divided using a GDHT group and a control group at a 1:1 ratio. Cerebral oxygenation was monitored with near-infrared spectroscopy (NIRS) and goal-directed hemodynamic therapy was provided using the continuous, non-invasive system as guidance.[19] The results supported how cerebral desaturation events were shorter and occurred less frequent in the GDHT group.[19] The study drew the conclusion that

implementation of goal directed hemodynamic therapy using the noninvasive finger cuff monitor device would improve cerebral oxygenation intraoperatively and postoperative cognition scores in patients undergoing shoulder surgery in the beach chair position. The main strength in this study was its randomized design which placed it at the top of the pyramid in the level of evidence hierarchy. No limitations were disclosed in the study.

Appraisal of Evidence #9

"Fluid preloading before beach chair positioning for arthroscopic shoulder procedures: a randomized controlled trial" studied whether fluid preloading prior to placing patients in the beach chair position would help decrease hemodynamic instability in the intraoperative setting.[20] The article provided a background of the problem and stated the objectives for the study. Although the beach chair position was advantageous to surgeons due to better visualization of structures and less risk for neurovascular injury, it also created negative effects such as hemodynamic instability. Mean arterial pressure, stroke volume, and cardiac output were reduced in the beach chair position. A significant effect was noted in patients taking antihypertensive medications and presented a challenge for clinicians. Shoulder surgery in the beach chair position led to cerebral desaturation in 18% of patients. As a result, the primary objective for this study aimed to determine if preloading the patient with intravenous fluids prior to placing them in the beach chair position would minimize hemodynamic instability.

This prospective, randomized controlled study met level 2 criteria in the research evidence hierarchy. The study took place in a single center in the Istanbul University, Istanbul Faculty of Medicine. Sixty-two patients were selected for eligibility but after exclusion criteria was applied, 49 patients were eligible for participation and divided into 2 groups.[20] Twenty-three patients were placed in Group C and 26 patients in Group P.[20] The results yielded a greater

cardiac output and mean arterial pressure in the study group who received crystalloids prior to being placed in the beach chair position.[20] Other hemodynamic parameters such as stroke volume were not affected. The study concluded that fluid administration, unless contraindicated, would be an appropriate intervention pre-operatively to improve hemodynamics once the patient is placed in the beach chair position for shoulder surgery. The recommendation was that dynamic preload parameters such as stroke volume variation, cardiac index, and stroke volume be measured to detect intravascular fluid deficiencies.[20] This assisted with gauging the patient's fluid needs prior to the start of surgery and provided adequate hydration before the patient was placed in the beach char position. The continuous, non-invasive device could measure the dynamic preload parameters and would be a helpful tool in determining fluid deficit while monitoring the patient's blood pressure continuously. The main strength in this study was its randomized design. The first limitation in this study was the presented results. These results were solely dependent on the values of the hemodynamic parameters.[20] Another limitation was the lack of organ function testing to monitor the consistency of tissue perfusion. Bispectral Index monitoring was not used in this study. The monitoring could have ensured that hemodynamic data was not affected by inadequate depths of anesthesia.[20] Finally, the lack of cerebral oxygenation monitoring using Near Infrared Spectrometry was another limitation in this study.[20] The continuous, non-invasive system would be appropriate in this patient population as it provides a function for cerebral oxygenation monitoring in addition to hemodynamic parameters and continuous, noninvasive blood pressure monitoring.

Appraisal of Evidence #10:

"Effect of phenylephrine infusion on hypotension induced by the beach chair position" studied the effectiveness of phenylephrine infusions for hemodynamic management in patients

who were undergoing shoulder surgery in the beach chair position. The beach chair position is commonly used by orthopedic surgeons who are operating on the shoulder joint. However, this position has been known to cause hemodynamic instability secondary to decreased venous return from venous blood pooling in the lower extremities. It has also been associated with bradycardia and cerebral hypoperfusion.[10] The purpose of this study was to determine if infusing phenylephrine prior to placing the patient in the beach chair position would help decrease the incidence of hypotension.

This study had a randomized, single blinded design and therefore, was categorized as a level 1 research evidence study in the evidence hierarchy. The study took place in the Inje University Haeundae Paik Hospital in Busan, South Korea.[10] Sixty-six participants were selected and divided into 3 even groups. The groups consisted of group NS (normal saline), group LP, and group HP who received phenylephrine at 0.5 or 1.0mL/kg/min for 5 minutes prior to beach chair positioning.[10] The results in this study indicated that the incidence of hypotension in all 3 groups was 93.65% after having started a phenylephrine infusion before placing the patient in the beach chair position.[10] However, it was noted that a phenylephrine infusion for 5 minutes prior to beach chair positioning reduced the severity of hypotension.[10] In conclusion, it was determined that phenylephrine at 1mcg/kg/min could decrease severe hypotension but could not prevent hypotension related to the beach chair position. Therefore, these patients continued to require careful observation of hemodynamics and strict blood pressure management. The main strength of this study was the single blinded, randomized design. The 3 limitations of this study were the lack of cerebral oxygenation measurement during vasopressor therapy, lack of total systemic vascular resistance index measurement, and the use of remifentanil in this study may have contributed to hemodynamic instability in some of these patients. [10]

A Randomized Control Trial of Continuous Noninvasive Blood Pressure Monitoring During Noncardiac Surgery

First Author (Year)	Conceptual Framework	Design/Method	Sample/Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Maheshwari et al,[11]	None	Design: RCT Purpose: Continuous, non-invasive monitoring versus intermittent blood pressure monitoring effects on decreased blood pressure during non-cardiac surgery under general anesthesia	*N* = 320; 316 were included and randomly divided into 2 groups. 158 patients with intermittent monitor and 158 patients with continuous monitor Attrition = 4 (staff anesthesiologist used arterial catheterization for 3 cases, surgery was cancelled for 1 case) Setting= Cleveland Clinic	IV= Intraoperative Hypotension (Mean Arterial Pressure <65mmHg) DV1= Intermittent Oscillometric Blood Pressure Device DV2= Continuous, Non-Invasive Blood Pressure Device	Level of Measurement= Level 1; Nominal Time-weighted average for mean arterial pressure <65mmHg was compared using 2-sample Wilcoxon rank-sum test and Hodges Lehmann estimation of location shift with corresponding asymptomatic 95% CI.	SAS Software version 9.4 for 64-bit Microsoft Windows was used for retrieval of data and statistical analysis.	Continuous BP monitoring was associated with improved TWA MAP <55 mm Hg threshold in continuous monitoring (unblinded) group 0.00 [0.00,0.02] mm Hg versus blinded group 0.00 [0.00,0.07] mm Hg (*P* = .017, significance criteria *P* < .024).	Strengths: Large sample size Limitations: No protocol for management of hypotension. Clinicians may have had skepticism regarding the accuracy of continuous,non-invasive monitor and ancillary measurements, despite good validation. Level of evidence: L-II RCT

Continuous Finger-Cuff Versus Intermittent Oscillometric Arterial Pressure Monitoring and Hypotension during Induction of Anesthesia and Noncardiac Surgery: The DETECT Randomized Trial

First Author (Year)	Conceptual Framework	Design/Method	Sample/Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Kouz et al,[14]	None	Design: Single Center RCT Purpose: Determine whether continuous, non-invasive monitoring reduced hypotension by early detection and treatment within 15 minutes after starting induction of anesthesia and during noncardiac surgery.	*N* = 242; 121 assigned to 2 groups Attrition:30 (artifactual measurements) Setting: University Medical Center Hamburg-Eppendorf in Hamburg, Germany	IV= Hypotension exposure within 15 min after starting induction of anesthesia and during surgery DV1= continuous, non-invasive system finger cuff DV2= standard or large upper-arm cuffs	Level of Measurement= Level 1; Nominal The first primary endpoint was analyzed using a 2-sample Wilcoxon rank-sum test with a corresponding 95% CI at a 5% significance level. Continuous secondary endpoints were analyzed using a Pearson's chi-square test with Yates's continuity correction.	Categorical data are presented as absolute numbers and percentages. Continuous data are presented as means ± standard deviations, medians with interquartile range, and ranges.	Continuous, non-invasive BP monitoring reduced decreases in blood pressure within a 15 minute window following the induction of anesthesia and in noncardiac procedures compared to intermittent blood pressure monitoring.	Strengths: Large sample size Limitations: Previous studies suggest that oscillometric and invasive pressures are superior than oscillometric and intra-arterial arterial pressures. Level of evidence: L-II RCT

Impact of Continuous Non-Invasive Blood Pressure Monitoring on Hemodynamic Fluctuation During General Anesthesia: A Randomized Controlled Study

First Author (Year)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Juri et al,[12]	None	Design: RCT Purpose: Study the ability of the continuous, non-invasive system to reduce hemodynamic variations compared to intermittent BP cuff measurement.	*N* = 45; 40 were included and divided into 2 groups (Control and CS group) Attrition: 5 (arrythmia, decreased cardia function and valvular heart disease) Setting: Osaka City, Japan	IV= Hemodynamic fluctuation in patients undergoing total knee arthroplasty DV1= continuous, non-invasive system finger cuff DV2= automated digital sphygmomanometer	Level of Measurement= Level 1; Nominal Bland–Altman analysis was performed to compare MBP_{cuff} and MBP_{CS}. Four-quadrant plot and polar-plot analyses were used to evaluate tracking ability. Patient characteristics were compared using the Mann–Whitney U test, the Student's t-test, and the Chi square test.	The data analysis was achieved using StatFlex version 6.0 (Artech Co., Ltd, Osaka, Japan), MedCalc version 14 (MedCalc Software bvba, Ostend, Belgium), and SigmaPlot 13.0 (Systat Software Inc., San Jose, CA, USA)	Hemodynamic monitoring using the continuous, non-invasive device could provide intraoperative hemodynamic stability. The accuracy and reliability of the continuous, non-invasive device for BP measurement was clinically significant and led to decreased hemodynamic instability .	Strengths: No conflict of interest; no bias Limitations: BP measured using intermittent BP cuff in Control group. Did not assess the postoperative course. Although continuous, non-invasive System can provide variable hemodynamic parameters such as CO and SVV, focus was BP. Level of evidence: L-II RCT

The Impact of Continuous Non-Invasive Arterial Blood Pressure Monitoring on Blood Pressure Stability During General Anesthesia in Orthopedic Patients: A Randomized Trial

First Author (Year)	Conceptual Framework	Design/ Method	Sample/Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Meidert et al,[5]	None	Design: Randomized, Controlled and Single-Centre Study Purpose: The current study investigates whether the presence of continuous BP monitoring leads to improved BP stability.	*N* = 198; 160 were included and divided into 2 groups. 77 assigned to a study group and 83 assigned to a control group. Attrition: 38 (missing BP readings, 2 cases had technical issues recording intermittent BP, other cases missing info due to anesthetist stopping BP to allow second IV placement, in 1 patient, continuous, non-invasive failed to provide a waveform) Setting: German University Hospital	IV= BP stability and hypotensive events DV1= continuous, non-invasive Device by volume clamp method DV2= Oscillometric upper arm cuff	BP differences in both groups were tested by using Student's *t* test, corrected for multiple testing by using the Bonferroni–Holm procedure. The Chi-squared test was used to test for differences between the groups with respect to variations in the type of anesthetic used, intraoperative beach chair positioning.	For analysis of the data, Excel 2010 (Microsoft, Redmond, Washington, USA), SPSS version 23 (IBM, Armonk, New York, USA) and R version 3.3.1 (The R foundation, Vienna, Austria) were used.	In patients with chronic hypertension undergoing general anaesthesia under routine conditions, the presence of continuous BP monitoring maintained a stable BP and results in fewer hypotensive episodes when compared to intermittent BP monitoring.	Strengths: Study was performed under nearly normal routine clinical conditions with no BP treatment protocols. The anesthetist not knowing the real purpose of the study ruled out bias that would have been caused by them paying special attention to BP. Limitations: Conclusion could not determine whether intermittent BP less than 3 min has equal effect as continuous BP Level of evidence: L-II RCT

Arterial Catheters for Early Detection and Treatment of Hypotension During Major Noncardiac Surgery: A Randomized Trial

First Author (Year)	Conceptual Framework	Design/ Method	Sample/Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Naylor et al,[16]	None	Design: Randomized Controlled Trial Purpose: To test that MAP <55mmHg is reduced in patients undergoing non-cardiac surgery when monitored with invasive arterial lines versus intermittent BP monitoring.	*N* = 307; 306 were included and divided into 2 groups. 143 patients received an arterial catheter and 163 were monitored with intermittent blood pressure devices. The groups were uneven due to the unsuccessful placement of arterial lines in some patients. Attrition: One participant was removed due to surgery cancellation. Setting:	IV= Intraoperative under the curve – MAP <65mmHg occurrences DV1= Arterial catheter blood pressure monitoring DV2= Intermittent, oscillometric blood pressure monitoring	Individual data was retrieved from each patient including age, sex, BMI, type of surgery, their physical status classification per ASA guidelines, and comorbidities. Blood pressure with intermittent monitoring was recorded every 5 minutes, arterial catheters readings were recorded every minute.	Estimations on arterial catheter effects were analyzed using ordinal-scaled primary and secondary outcomes using proportional odds logistic regression models. Descriptive analyses included means +/- standard deviations and medians. Data analysis was achieved using SAS version 9.4.	Intraoperative blood pressure monitoring with invasive lines was able to detect intraoperative hypotension twice as much than intermittent monitoring. For this reason, hypotension was treated quicker with invasive arterial monitoring. The conclusion drawn from the study indicated that arterial monitoring facilitated detection and treatment of intraoperative hypotension.	Strengths: No conflict of interest or bias. Adequate sample size. Limitations: None were disclosed in this study. Level of Evidence: L-II Randomized Controlled Trial

Continuous Intra-Arterial Versus Intermittent Oscillometric Arterial Pressure Monitoring and Hypotension During Induction of Anesthesia: The AWAKE Randomized Trial

First Author (Year)	Conceptual Framework	Design/ Method	Sample/Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Kouz et al,[17]	None	Design: Single- Centre Randomized Trial Purpose: Hypothesized whether continuous arterial pressure monitoring would reduce the incidence if intraoperative hypotension when compared with intermittent oscillometric monitoring during induction of anesthesia.	*N* = 242; 224 subjects were included and divided evenly into 2 groups. 112 subjects were monitored arterially, and 112 patients were monitored intermittently. Attrition: 18 subjects were excluded due to technical issues with arterial pressure recording, difficulty with arterial cannulation, and acute onset of arrythmias.	IV= Hypotension during induction of anesthesia in noncardiac surgical patients DV1= Intra-arterial monitoring DV2= Intermittent, oscillometric monitoring	Primary endpoint included quantification of hypotension as area under a MAP of 65mmHg within 15 minutes after induction. Secondary endpoint was area under MAP values of 60, 50, 40mmHg, duration of MAP values below 65, 60, 50, 40mmHg, MAP standard deviation.	Two sample, 2-sided Wilcoxon rank-sum test for calculation of the *p*-value. Categorical secondary endpoints were analyzed with Pearson's X^2 test with Yates' continuity correction. Bland-Altman analysis was used to compare oscillometric versus intra-arterial MAP values.	Continuous, non-invasive monitoring reduced the incidence of intraoperative hypotension on induction of anesthesia when compared to intermittent pressure measurements in patients undergoing noncardiac surgery. Clinicians should consider inserting arterial lines prior to the induction of anesthesia for this reason.	Strengths: Adequate sample size. High level of evidence study. Limitations: No limitations were disclosed through the entirety of this study. Level of Evidence: L-II Randomized Controlled Trial.

Performance of the Hypotension Prediction Index with Non-Invasive Arterial Pressure Waveforms in Non-Cardiac Surgical Patients

First Author (Year)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusions	Appraisal: Worth to Practice/Level
Maheshwari et al,[18]	None	Design: RCT Purpose: Evaluate the performance of the Hypotension Prediction Index derived from a non-invasive arterial pressure waveform in non-cardiac surgical patients.	*N* = 320; 305 patients were included in this analysis. Attrition: 15 (4 patients did not receive the allocated intervention and 11 others had incomplete waveform data). Setting: Cleveland Clinic	IV= Hypotension Prediction Index DV1= non-invasive continuous, non-invasive system DV2= Invasive arterial blood pressure monitoring	All statistics were performed with MATLAB. Repeated measurements evaluated by bootstrapping method. This process was repeated 2000 times from which the standard error was calculated. The bootstrap confidence interval was calculated as a 95% asymptotic confidence interval.	A Hypotension Prediction Index of 80–89 provided a median of 6.0 [95% confidence interval 5.3, 6.7] minutes warning before mean arterial pressure decreased to < 65 mmHg. The positive predictive values of the algorithm were similar in the blinded and unblinded groups. We thus present results for the entire population at an HPI threshold of 85.	The continuous non-invasive system gives accurate measures of arterial blood pressure such as during induction of anesthesia; the discrepancy between invasive radial arterial pressure was insignificant which is below the 5 ± 8 mmHg of AAMI acceptable criteria for blood pressure parameters.	Strengths: Large sample size Limitations: Bias and conflict of interest as authors are consultants for Edwards Lifesciences (continuous, non-invasive System). Level of evidence: L-II RCT

Effects of Goal-Directed Hemodynamic Therapy Using a Noninvasive Finger-Cuff Monitoring Device on Intraoperative Cerebral Oxygenation and Early Delayed Neurocognitive Recovery in Patients Undergoing Beach Chair Position Shoulder Surgery: A Randomized Controlled Trial

First Author (Year)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusion	Appraisal: Worth to Practice/ Level
Lee et al,[19]	None	Design: RCT Purpose: Test the hypothesis that the application of goal-directed fluid therapy by non-invasive finger-cuff monitoring would attenuate cerebral hypoperfusion	*N* = 70 patients were included in this study Attrition: Unknown Setting: Unknown	IV= cerebral hypoperfusion in the beach chair position DV1= noninvasive finger cuff monitor DV2= goal directed hemodynamic therapy	Monitoring of cerebral oxygenation using NIRS, and GDHT was given with the continuous, non-invasive system. The primary outcome was CDE duration and the secondary outcomes were CDE incidence, the incidence of delayed neurocognitive recovery, and Taiwanese version of the Quick Mild Cognitive Impairment (Qmci-TW) test score on postoperative day 1 (T_2) adjusted for the baseline score (on the day prior to surgery; T_1).	CDE duration was significantly shorter in the GDHT group (0 [0–0] vs 15 [0–75] min; median difference [95% confidence interval], −8 [−15 to 0] min; *P* = .007). Compared with the control group, fewer patients in the GDHT group experienced CDEs (23% vs 51%; relative risk [95% confidence interval], 0.44 [0.22–0.89]; *P* = .025) and mild delayed neurocognitive recovery (17% vs 40%; relative risk [95% confidence interval], 0.60 [0.39–0.93]; *P* = .034)	Implementing GDHT using a noninvasive finger-cuff monitoring device stabilizes intraoperative cerebral oxygenation and is associated with improved early postoperative cognitive scores in patients undergoing BCP shoulder surgery.	Strengths: No bias or conflict of interest declared by the authors. Limitation: Sample size was limited Level of evidence: L-II RCT

Fluid Preloading Before Beach Chair Positioning for Arthroscopic Shoulder Procedures: A Randomized Controlled Trial

First Author (Year)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusion	Appraisal: Worth to Practice/Level
Gokduman et al,[20]	None	Design: Single Center, Randomized Controlled Study Purpose: To investigate whether preloading would improve hemodynamic stability prior to placing patient in the beach chair position.	*N* = 62; 49 patients were included for the study and allotted into 2 groups. Group C consisted of 23 patients and Group P had 26. Attrition: 11 patients were excluded due to refusal, not meeting inclusion criteria, and changes in the intraoperative period Setting: Istanbul University, Istanbul Faculty of Medicine.	IV= Hemodynamic instability in the beach chair position DV1= Fluid preloading prior to positioning. DV2= No fluid loading prior to positioning	Patients raised to 70 degrees; pressure transducer placed at external auditory canal. MAP, HR, SAP, DAP, CO, and SV were recorded after positioning at specific time intervals. If SVV rised above 13, a fluid challenge was performed. After standard monitoring, SAP, DAP, and HR were recorded.	Performed using the Number Cruncher Statistical System. Distribution of data was evaluated with the Kolmogorov-Smirnof test, Shapiro-Wilk test, and graphical evaluations. Group comparisons were done using Student t-test and Mann-Whitney U test. Post-hoc analyses with Bonferroni correction used for multiple comparisons.	Crystalloid infusion prior to placing patients who were having procedures of the shoulder in the beach chair position resulted in an effective alternative for increasing hemodynamic stability and therefore, reducing post-operative complications.	Strengths: No conflict of interests were declared. High level of evidence study. Limitations: Data and results were dependent on numerical values of hemodynamic parameters. Lack of BIS monitoring to ensure adequate depth of anesthesia so that hemodynamic values are not affected by superficial sedation.

Effect of Phenylephrine Infusion on Hypotension induced by the Beach Chair Position

First Author (Year)	Conceptual Framework	Design/ Method	Sample/ Setting	Major Variables Studied (and Their Definitions)	Measurement	Data Analysis	Findings/ Conclusion	Appraisal: Worth to Practice/Level
Ko et al,[10]	None	Design: Prospective Randomized Trial Purpose: Assess the effectiveness of phenylephrine infusion on hemodynamic measures prior beach chair positioning for shoulder surgery.	*N* = 66 patients were split into 3 groups. Group HP with 22 patients, Group LP with 22 patients, and Group NS with 22 patients. Attrition: 1 patient was excluded from Group LP due to mechanical malfunction and 2 patients were excluded from Group NS due to severe hypotension.	IV= Hypotension after positional change DV1= Phenylephrine infusion before beach chair position DV2= Did not receive phenylephrine prior to positional change	MAP, SVV, and CI were measured with the Flotrac system. Prior to positional change, 1 group received normal saline infusion and the other 2 groups received a phenylephrine drip. Patients were placed in BCP 5 minutes after intervention and MAP, HR, SPO2, CI, SVV, and BIS were measured and recorded for 15 minutes after positional change without surgical stimulation.	Sample size calculated using nQuery Advisor 7.0 program. Chi-squared test or Fisher exact test compared variables among groups. Variance analysis or Kruskal-Wallis test compared continuous variables among groups. Shapiro-Wilk test tested normality assumption. Bonferroni was used in post-hoc analysis. Stats analysis was measured with SPSS version 25.0 statistical software.	Phenylephrine decreased the incidence and severity of hypotension in the beach chair position. However, due to positional change, hypotension still occurred in this position. Vigilance and treatment of blood pressure is still required in all patients having procedures in the beach chair position.	Strengths: No conflict of interests were declared. High level of evidence study. Limitations: Data and results relied on numerical values of blood pressure parameters. BIS monitoring was not used to ensure adequate depth of anesthesia so that hemodynamic measures were not influenced by mild sedation.

Synthesis of the Literature

Methodologies

The research studies that were selected for this literature review were all similar with respect to the methodology used. The approach that was utilized in every study was a quantitative method which relied on data collection, statistical analysis, and conclusions drawn from fact-driven research. The studies also used a randomized design for selection of participants that would be included in the data analysis. Randomized controlled trials, such as the articles used in this literature review, were level 2 research studies in the evidence hierarchy for scientific research and thus, considered valid and reliable. The data analysis for most of the studies included in the literature review were conducted by comparing 2 groups of randomly selected participants. Three of the studies that used continuous noninvasive blood pressure monitoring, such as "A randomized trial of continuous noninvasive blood pressure monitoring during noncardiac surgery", "Continuous finger-cuff versus intermittent oscillometric arterial pressure monitoring and hypotension during induction of anesthesia and noncardiac surgery: the DETECT randomized trial", and "Impact of continuous non-invasive blood pressure monitoring on hemodynamic fluctuation during general anesthesia: a randomized controlled study" used the 2-sample Wilcoxon rank-sum test, also known as the Mann-Whitney U test, to compare the 2 groups of participants in each study.[6,11,14] Two studies that used invasive methods for blood pressure monitoring such as "Continuous intra-arterial versus intermittent oscillometric arterial pressure monitoring and hypotension during induction of anesthesia: the AWAKE randomized trial" and "Arterial catheters for early detection and treatment of hypotension during major noncardiac surgery: A randomized trial" also used the Mann-Whitney U test to compare the 2 separate groups of participants in each individual study.[16,17] Studies that evaluated 2 different

methods for blood pressure monitoring or blood pressure treatment such as “The impact of continuous non-invasive arterial blood pressure monitoring on blood pressure stability during general anesthesia in orthopedic patients: a randomized trial” and “Fluid preloading before beach chair positioning for arthroscopic shoulder procedures: a randomized controlled trial” used similar tests such as the Pearson Chi Square Test and the Student’s *t* test for data analysis between the 2 groups in each study.[5,20]

Outcomes

Several of the articles used in this literature review yielded similar findings and conclusions. The articles that compared the use of CNBPM with the continuous, non-invasive system versus using intermittent oscillometric monitoring concluded that continuous noninvasive monitoring reduced the incidence of intraoperative hypotension. For example, the articles “A Randomized Trial of Continuous Noninvasive Blood Pressure Monitoring During Noncardiac Surgery”, “Impact of continuous noninvasive blood pressure monitoring on hemodynamic fluctuation during general anesthesia: a randomized controlled study”, and “The impact of continuous non-invasive arterial blood pressure monitoring on blood pressure stability during general anesthesia in orthopedic patients: a randomized trial” all concluded that continuous noninvasive blood pressure monitoring significantly impacted the reduction of hypotensive episodes in the intraoperative period. Some of the articles identified the factors that led to decreases in hypotension such as the ability for continuous monitoring to provide early detection of hypotension and consequently, prompt quicker treatment methods to stabilize hemodynamic parameters by the anesthesia provider. Other articles compared continuous, invasive blood pressure monitoring to intermittent monitoring. Articles such as “Continuous intra-arterial versus intermittent oscillometric arterial pressure monitoring and hypotension during induction of

anaesthesia: the AWAKE randomised trial" and "Arterial catheters for early detection and treatment of hypotension during major noncardiac surgery: A randomized trial" also concluded that continuous methods for hemodynamic monitoring resulted in fewer hypotensive events during noncardiac surgery when compared to intermittent oscillometric monitoring. Some articles also presented the potential post-operative complications from undetected or untreated hypotension or untimely treatment of hypotension. The implication was that monitoring hemodynamics with continuous devices would reduce the risk for intraoperative or postoperative events such as myocardial ischemia, acute kidney injury, and cerebral desaturation among other complications.

Synthesis #1: Continuous, Noninvasive Blood Pressure Monitoring

Leaders in innovative technology created a device to monitor hemodynamics using a noninvasive finger cuff device that produced a real-time pressure waveform through what is known as the volume clamp method. The volume clamp method achieved a constant pressure on the arterial walls via a photo-plethysmograph that was installed into the finger cuff.[21] This pressure was achieved through clamping of the artery until a certain volume was reached and adjusting the pressure to 1,000 times per second so that the arterial volume was kept constant.[21] This technological advancement has achieved the ability of providing advanced hemodynamic parameters in addition to blood pressure such as stroke volume, stroke volume variation, cardiac index, systemic vascular resistance, and pulse pressure variation among others.[21] Edwards Lifesciences Corporation provided statistical information regarding the incidence of intraoperative hypotension and its associated complications. The prevalence of intraoperative hypotension that was provided from 1 study indicated that at least 1 hypotensive episode (MAP <65mmHg for greater than 1 minute) occurred in 88% of noncardiac surgeries and that the mean

duration of hypotension in these surgeries was 28.2 minutes.[21] Some of the risks associated with hypotensive events that were mentioned included myocardial injury, acute kidney injury, and mortality.[21] A study conducted by Edwards Lifesciences concluded that the continuous, non-invasive system device reduce intraoperative hypotension by 57%.[21]

Patients at increased risk of morbidity and mortality resulting from intraoperative hypotension included those who were undergoing shoulder surgery in the beach chair position. The beach chair position, however, has resulted in significant decreases in blood pressure due to the hydrostatic gradient that exists between the brain and the site where blood pressure was being measured.[22] The gradient involved an approximate decrease in systolic blood pressure of 2mmHg per inch of height differential.[22] If the blood pressure was being measured on the arm in the beach chair position, this would result in a decrease of at least 25mmHg in systolic blood pressure, subsequently leading to decreased cerebral perfusion.[22]

The use of the continuous, non-invasive system device for continuous, noninvasive blood pressure monitoring in patients undergoing shoulder surgery in the beach chair position would result in less complications related to hemodynamic instability secondary to positioning. The continuous, beat-to-beat monitoring would prompt the anesthesia provider to detect and, subsequently, treat significant hypotension before it occurred. This reduction in hemodynamic instability during surgery would improve patient outcomes postoperatively by preventing complications such as organ injury.

Synthesis #2: Continuous Invasive Blood Pressure Monitoring

Blood pressure monitoring using arterial cannulation for invasive blood pressure measurement has provided continuous monitoring for high-risk procedures and patients.. However, invasive methods have not been without risk and have posed several complications

related to its invasive nature. Arterial cannulation has been considered painful, could lead to symptomatic or asymptomatic thrombosis, nerve damage during insertion especially if multiple attempts are performed, unintentional blood loss from accidental disconnection of assembly or removal of arterial catheter, and the most common risk which has been infection.[23] Serious complications from arterial cannulation, although uncommon, have been reported such as ischemic damage resulting in necrosis and subsequent amputation of digits or the hand.[23] Positional factors may also inhibit an optimal waveform depending on the anatomical location of the arterial line or the positioning of the patient for surgery in relation to the arterial line. For these reasons, patients who are not high-risk and are undergoing shoulder surgery in the beach chair position should be monitored using continuous, noninvasive blood pressure devices. This method would provide constant hemodynamic monitoring to ensure that adequate cerebral perfusion was maintained without the need to use invasive methods.

Discussion

Patients who have undergone shoulder surgery in the beach chair position have been subjected to significant hemodynamic compromise and potential post-operative complications. The continuous noninvasive hemodynamic monitoring device has provided beat-to-beat monitoring of blood pressure and other hemodynamic parameters. It has been simple to use and has allowed anesthesia providers to maintain adequate blood pressure throughout the intraoperative period. It has also allowed providers to detect and treat hypotension as it occurred to minimize decreased perfusion to the brain from the upright patient position and decreased perfusion to other vital organs from decreased blood pressure. The continuous, non-invasive system has been a useful, innovative device that would help decrease the incidence of intraoperative hypotension and consequently, decrease post-operative morbidity and mortality.

Definition of Terms

Beach Chair Position

Surgical position used by Orthopedic surgeons for patients having total shoulder arthroplasty. The position would involve raising the patient approximately 60 degrees from a supine position to an upright position.[1] The head and neck would be maintained in the neutral position with a head strap and a safety foam device to protect the face from surgical instrumentation, the non-operative extremity would be secured onto an arm board, and a safety belt would be placed across the patient's waist to avoid inadvertent shifting of positioning.[1]

CNBPM

Innovative, noninvasive monitor created to provide accurate, continuous blood pressure monitoring with beat-to-beat hemodynamic measurements. The device had proven to significantly reduce intraoperative hypotension by its ability to detect future hypotensive events. The blood pressure measurements would be obtained through the volume clamp method which would produce arterial waveforms through sustained cuff pressure on the finger.[7]

Intraoperative Hypotension

Hypotension occurring in the operating room with criteria defined as a decrease in baseline blood pressure by at least 20%, a mean arterial pressure below 65mmHg, or systolic blood pressure below 90mmHg.[8]

Arterial Line Blood Pressure Monitoring

Continuous invasive hemodynamic monitor that provides accurate beat-to-beat blood pressure measurement via cannulation of a peripheral artery. The device is commonly used in

acute care areas such as the intensive care unit, cardiac catheterization lab, and neuroradiology suites for patients who are considered high-risk or critical.

Oscillometric NIBP

Noninvasive intermittent blood pressure monitoring device used in all healthcare facilities. Blood pressure is obtained via small oscillations in pressure through a deflating cuff around an extremity. Certain factors such as cuff size, patient movement, or patient position may affect blood pressure readings and yield an erroneous result.

Methodology for Proposal

The purpose of this paper was to implement the continuous, non-invasive system for use in patients undergoing shoulder surgery in the beach chair position. The primary goal of this DNP Project was to educate clinicians about the continuous, non-invasive system technology and how it could be used to detect and treat intraoperative hypotension promptly. The SMART objectives would describe specific, measurable, achievable, relevant, and time-bound goals for the organization of interest that would participate in this quality improvement project. An assessment of the organizational needs for the use of the continuous, non-invasive system in the selected institution would be conducted and discussed in a subsection of this paper. Data would be gathered to support the need for this quality improvement project at the targeted facility. An Organizational SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis would be conducted to assess areas of strength, areas that need improvement, opportunities for growth, and threats that would impede the implementation of the continuous, non-invasive system into everyday practice. The theoretical framework used to support this research study, an overview of the theory, the importance of its application in clinical practice, and a theoretical evaluation would be performed and included in this paper.

Primary DNP Project Goal

Intraoperative hypotension, defined as a mean arterial pressure below 65mHg, has been identified as a common occurrence affecting 65% of patients in the operating room.[24] When defined as a 20% decrease from baseline blood pressure readings, intraoperative hypotension occurred in 94% of patients.[24] Depending on the severity, hypotension could significantly reduce perfusion to vital organs resulting from an oxygen supply and demand mismatch.[24] This could lead to complications such as myocardial ischemia, acute kidney injury, and cerebral ischemia which would produce an increased probability of post-operative mortality.[24]

The beach chair position has been commonly used by orthopedic surgeons performing total shoulder replacement procedures. This position has been used in two-thirds of patients undergoing shoulder surgery for its ease of setup including the conversion to an open approach if needed, ease of structure visualization and orientation, and decreased probability of brachial traction injury.[25] However, the risk for intraoperative events related to diminished perfusion of vital organs has been increased in this position due to significant hemodynamic instability when going from the supine position to an upright or beach chair position.[25]

The innovative continuous, non-invasive system used the volume clamp method, a vascular unloading technology, which produced a continuous arterial waveform providing a non-invasive beat-to-beat blood pressure measurement by placing an easy-to-use finger cuff on the patient's digit.[26] This device also provided other hemodynamic measurements including stroke volume variation, cardiac index, and cardiac output. The goal of this project was to implement the use of the continuous, non-invasive system to minimize the incidence of intraoperative hypotension by early detection and treatment of low blood pressure to maintain a constant mean

arterial pressure of 65mmHg or greater in patients subjected to the beach chair position for shoulder surgery.

A level 1 trauma center in Miami, Florida has been a branch of a large network of hospitals across 20 states including Florida and overseas in the United Kingdom. This level 1 trauma hospital has provided anesthesia services through a collaborative team model consisting of 16 anesthesiologists and 22 Certified Registered Nurse Anesthetists (CRNA).[27] The mission, vision, and values at this hospital have been centered around the commitment to improving human life through the provision of high quality, patient-focused care by serving others with compassion and kindness.[28] The anesthesia practice model at this level 1 trauma center created an environment that fostered inclusion and collaboration among all members of the anesthesia team. The full range of surgical cases including specialties, such as Orthopedics, cultivated the ideal domain for the implementation of this quality improvement project.

Orthopedic surgical services, including joint replacement, have been offered at this hospital by board-certified surgeons who are expertly trained in orthopedic medicine. Shoulder surgery at this healthcare facility has been performed in the beach chair position for total joint replacements. Patient hemodynamics have been monitored using standard of care practices for general anesthesia including EKG monitoring, pulse oximetry, CO2 capnography, temperature, and blood pressure. Blood pressure has been measured with intermittent, oscillometric blood pressure devices using standard blood pressure cuffs around the arm or leg. The standard of care for blood pressure monitoring during anesthesia has been determined to be at least every 5 minutes.[29] The standard practice at this level 1 trauma center has been intermittent blood pressure cycling every 3 minutes on average, however, all considerations have been taken into account on a case-by-case basis. For patients undergoing shoulder surgery in the beach chair

position at this facility, intermittent blood pressure monitoring has been used. The continuous, non-invasive device for hemodynamic monitoring of patients in the beach chair position has been observed only on 1 occasion. However, patients who have undergone minor (1-2 level) neurosurgical interventions of the spine at this hospital typically have been monitored using the continuous, non-invasive system to ensure that adequate spinal cord perfusion was maintained throughout the intraoperative course.

The key stakeholders for this project were to include all CRNAs employed at this level 1 trauma center and 1 CRNA who would be assigned to facilitate the quality improvement project intervention. The selected CRNA who would facilitate the project would ensure the participation of all CRNAs (to include approximately 22) throughout the course of this project including surveying and implementation of the intervention. The CRNAs would be the primary population to be included in this project as they would typically be assigned to the case throughout the peri-operative period.

SMART Objectives

For the purposes of this DNP project, the following SMART objectives were identified:

Specific

CRNAs would implement using the continuous, non-invasive system for continuous, non-invasive blood pressure monitoring in patients undergoing shoulder surgery in the beach chair position.

Measurable

CRNAs would participate in a survey before and after implementation of the continuous, non-invasive system for shoulder surgery in the beach chair position. The survey would assess knowledge on the use of the continuous, non-invasive system, risk for organ injury caused by

decreased perfusion, risk for injury with MAP <65mmHg, risk for injury with MAP <55mmHg, time it takes for myocardial ischemia, cerebral ischemia, or kidney injury to begin to occur.

Achievable

CRNAs would incorporate the use of the continuous, non-invasive system for all patients (exception would be high-risk patients who require invasive monitoring) undergoing shoulder surgery in the beach chair position and be aware of the importance of timely treatment of hypotension to prevent risk for organ injury.

Realistic

CRNAs would be knowledgeable and educated on the use of the continuous, non-invasive system and its benefits for detecting and treating blood pressure in a timely manner. The continuous, non-invasive system would be an easy-to-use disposable finger cuff similar to a pulse oximetry monitor.

Timely

The implementation for using the continuous, non-invasive monitor in patients placed in the upright position should be within a week of providing the initial questionnaire for the quality improvement project. The continuous, non-invasive system has already been used at the facility of choice for this DNP project for other surgical procedures and the staff should be familiarized with its use.

Program Structure

The success of this quality improvement project would rely on the cooperation of all members of the anesthesia team to be consistent with the use of the continuous, non-invasive system for blood pressure monitoring in patients in the beach chair position. Closed claims cases surrounding adverse neurological events after shoulder surgery in the beach chair position would

be provided to key stakeholders in this quality improvement project. A questionnaire would be provided to gauge the current knowledge about the potential consequences of positioning patients for shoulder surgery in the upright position. The critical stakeholders would be the CRNAs assigned to orthopedic shoulder surgeries. A presentation would be provided to ensure adequate understanding of the potential risks related to beach chair positioning with respect to hemodynamics and the benefits of using continuous, non-invasive blood pressure monitoring compared to intermittent monitoring to minimize these risks. Identification of the strengths, weaknesses, opportunities, and threats that would propel or impede the development and implementation of this project would be essential in gauging its success.

Organizational SWOT Analysis

An identifiable strength in this project would be the accessibility to the continuous, non-invasive system that has already been purchased and currently used at the selected hospital for this DNP project. The anesthesia team has familiarity with the use of the continuous, non-invasive system for certain surgical procedures such as neurosurgeries of the spine. This would create an advantage as it would further facilitate its use for shoulder surgery in the beach chair position. Another strength would be the reduction of risks associated with intraoperative hypotension. The maintenance of adequate hemodynamic parameters in the operating room would optimize patient outcomes after surgery and reduce the incidence of post-operative morbidity and mortality associated with hypotension. The continuous, non-invasive monitor has also been proved to be accurate with blood pressure measurements when compared to invasive arterial blood pressure monitoring.

A weakness that could potentially inhibit the success of this quality improvement project would be a lack of compliance with the use of continuous, non-invasive hemodynamic

monitoring for every patient (unless identified as high-risk requiring invasive monitoring) having shoulder surgery in the beach chair position. Some clinicians may not be receptive to using the device if it is not readily available, especially with fast turnover rates in between cases. Another weakness would be the facility's limitation on the number of devices available for use secondary to the cost of these monitors.

The continuous, non-invasive system would provide the opportunity for the facility to be one of the first to incorporate its use in orthopedic patients having shoulder surgery in the beach chair position. Many facilities in South Florida have not invested in this innovative technology that could result in better patient outcomes with its use. The facility where this DNP project was conducted could acquire more recognition for having access to this device and using it as part of an implemented protocol for specific procedures.

A potential threat that would impede the successful implementation of this quality improvement project would involve resistance from the staff at the facility of interest to comply with using the continuous, non-invasive monitor. Some clinicians may not feel the need to use continuous blood pressure monitoring for a low-risk procedure such as shoulder surgery. Also, some CRNAs may not participate in the questionnaire used to gauge their knowledge about the continuous, non-invasive system and the detrimental effects of the beach chair position. This would inhibit active participation and decrease the probability of implementing a protocol for using the continuous, non-invasive device during shoulder surgery.

Conceptual Underpinning and Theoretical Framework

Research studies in nursing have been carried out with the incorporation of theories, models, and frameworks which have all been based on the foundation of conceptualization. Middle range theories have typically been more appropriate to apply to nursing research because

they have had the ability to undergo testing.[30] The importance of incorporating theoretical frameworks and theories in nursing practice has been their ability to enhance nursing care through the provision of evidence-based research that has been tested and proven to be effective. Neuman's Systems Model has been based on the concept that multiple factors affect equilibrium.[30] A client's system could be negatively affected by environmental stressors if stability is not maintained. Neuman's model has promoted system stability by identifying stressors, their negative impact on equilibrium, and applying 3 types of prevention – primary, secondary, and tertiary.[30]

Theory Overview

Neuman's Systems Model was provided as a method to promote wellness through the application of 3 interventions.[30] The first of the interventions was known as primary prevention. Primary prevention was based on the reduction of factors that would contribute to an increase in stressors or the identification of stressors before they occurred so that wellness could be retained.[30] The promotion of optimal health conditions was the aim of the primary prevention intervention. The secondary prevention intervention was to enhance a client's ability to resist the effects of a stressor once it has occurred. The goal for secondary prevention was to regain a state of homeostasis after having experienced instability caused by stressors.[30] The tertiary and final prevention intervention focused on the maintenance of wellness by conserving the system's strengths and energy.[30]

Theory/Clinical Fit

Neuman's Systems Model and its pertinence to the implementation of the continuous, non-invasive system for patient's undergoing shoulder surgery in the beach chair position has a clinical fit for the purpose of this project. The application of Neuman's 3 prevention

interventions could affect the outcomes for patient's having surgery in the beach chair position. The primary prevention could involve the use of the continuous, non-invasive blood pressure monitoring system to reduce the risk of post-operative complications related to the untimely detection and treatment of intraoperative hypotension. The primary objective for this intervention has been the promotion of wellness through the identification and reduction of stressors. The secondary prevention intervention would involve the treatment of hypotension once it has occurred and restore adequate hemodynamic parameters throughout the operative course. Finally, the tertiary prevention intervention would include the maintenance of acceptable blood pressure measurements throughout the surgical period by use of a continuous, non-invasive monitor such as the continuous, non-invasive device. This would promote optimal patient recovery after surgery and minimize the complications related to intraoperative hypotension.

Setting and Participants

The project included the selection of CRNAs at a level 1 trauma center to partake in an online survey regarding the current use of the continuous, non-invasive system at their healthcare facility. The selection of participants for this survey to include CRNAs at this level 1 trauma center stemmed from the significant relevance they had to the project as these providers continuously monitored hemodynamics in the perioperative setting and readily have access to the continuous, non-invasive device at their facility. The purpose of the survey was to evaluate the current knowledge about the anesthesia implications related to the beach chair position, the consequences of untimely detection or treatment of intraoperative hypotension, and the significance of the continuous non-invasive device for hemodynamic monitoring.

Description of Approach and Project Procedures

The project proposal was prepared for submission to the Internal Review Board (IRB) for approval prior to submitting the request for participation from the selected participants. This would ensure compliance related to the ethical aspects of the project. The anonymity and safety of the participants was considered, and measures were taken protect their rights.

Upon receiving permission from the IRB to proceed with the project, CRNAs at a level 1 trauma center were invited to participate in the project via email. The purpose of the project was provided in the email along with instructions for participation in a pre-test followed by an educational module, and a post-test via a link. The pre-test questionnaire would assess the participants' current knowledge about the continuous, non-invasive device and its uses. The educational module would follow and provide information regarding the prevalence and consequences of untimely detection and treatment of intraoperative hypotension in the beach chair position, the purpose for using the continuous, non-invasive device for hemodynamic monitoring, and the advantages of using continuous versus intermittent blood pressure monitoring in the beach chair position. The post-test would assess if there was any improvement in the participants' knowledge after completion of the educational module. The scores of each test would be compared to evaluate any gain in knowledge. The objective of the results for this portion of the project was an increased awareness and knowledge about the anesthesia implications for patients in the beach chair position and the use of the continuous, non-invasive system for intraoperative hemodynamic monitoring.

Participant Recruitment

The CRNAs were provided access through an online link via email to facilitate their participation in the survey. A pre-test was created to evaluate their current knowledge about the

continuous, non-invasive monitor followed by a post-test to evaluate improvement in their knowledge about the device after reviewing an educational module provided in the participation link. Participant recruitment was made possible through a facilitator at the level 1 trauma center of choice for this DNP project.

Data Collection

Data collection was facilitated through the Qualtrics surveying system. This web-based software was simple to use and allowed for quick collection of data and storage of results at no cost. The data collection was secure and only accessible through a user identification and password. The results were obtained through a report that included the number of responses including basic percentages, and statistics. The data that was gathered from the pre-test and post-test questionnaire were compared to assess for any new knowledge acquired after participation in the educational module.

Data Analysis

Evaluation of the collected data was carried out using inferential analysis which has been used to make comparisons of data between 2 different groups. The first data analysis was performed after obtaining initial results from the pre-test questionnaire. Based on the initial results, an assumption was inferred regarding the baseline knowledge of practitioners with respect to the continuous, non-invasive monitor. Upon completion of the post-test questionnaire, data results were compared to the pre-test questionnaire and inferential analysis was utilized to draw conclusions from the results of both surveys. The inference drawn from the results would assume an acquisition of new knowledge with respect to the continuous, non-invasive monitor upon successful completion of the online educational model and taking the post-test questionnaire.

Data Management

The storage of data collection was kept under the results section in the Qualtrics web page. The results were accessible through a user identification and password kept by the study's surveyor. Personal computer disposal of the anonymous survey results would take place once all data was accounted for and displayed in the results section of the project.

Protection of Human Subjects

The subjects recruited for participation in this project were the nurse anesthetist group employed at a level 1 trauma center in Miami, Florida. Approval for participation from the subjects in this project was received from the IRB prior to initiating contact with the selected participants. This step was a major aspect in the process for data collection as permission was required to attain access to the participants. This ensured that compliance was maintained with respect subject privacy and confidentiality. Anonymity was maintained in the data collection process and results from the pre-test and post-test questionnaire were stored in Qualtrics for data analysis. Participant benefits included the attainment of new knowledge regarding the use of the continuous, non-invasive monitor and the advantages for using this system in practice. Risks for participation in the study were not included in the email to participants as none were identified.

Results

Pre-Test Demographics

Pre-test demographics can be seen in Table 1 below.

Table 1. Participant Demographics

Demographics	**n (%)**
Total Participants	10 (100.00%)
Age	
20-30	1 (10.00%)
31-40	8 (80.00%)
41-50	1 (10.00%)
51-60	0 (0.00%)
>60	0 (0.00%)
Gender	
Male	7 (70.00%)
Female	3 (30.00%)
Ethnicity	
African American	1 (10.00%)
Caucasian	1 (10.00%)
Hispanic	8 (80.00%)
Asian	0 (0.00%)
Other	0 (0.00%)
Position/Title	
CRNA	10 (100.00%)
Attending Anesthesiologist	0 (0.00%)
Resident Anesthesiologist	0 (0.00%)
Highest Level of Education	
Certificate	0 (0.00%)
Bachelor's degree	0 (0.00%)
Master's degree	0 (0.00%)
Doctoral degree	10 (100.00%)
PhD	0 (0.00%)
Doctor of Medicine	0 (0.00%)
Other	0 (0.00%)
Years of Experience	
< 1 year	0 (0.00%)
1-2 years	3 (30.00%)
2-5 years	4 (40.00%)

5-10 years	3 (30.00%)
>10 years	0 (0.00%)

Pre-Test Demographics

A total of 10 participants completed the pre-test demographics along with the pre-test survey. Seven of the participants were male (*n* = 7, 70.00%), while 3 participants were female (*n* = 3, 30.00%). The ethnicities of the participants varied and included African American (*n* = 1, 10.00%), Caucasian (*n* = 1, 10.00%), and Hispanic (*n* = 8, 80.00%). The position/title of all participants in the survey were Certified Registered Nurse Anesthetists (*n* = 10, 100.00%). A question regarding the participants age range was obtained and 1 participant was between the range of 21-30 years of age (*n* = 1, 10.00%), 1 participant was between the range of 41-50 (*n* = 1, 10,00%), and the rest were between the range of 31-40 (*n* = 8, 80.00%). The participants were asked about their level of highest education and 9 of them obtained their DNP (*n* = 9, 90.00%), while 1 had earned a Master's degree (*n* = 1, 10.00%). The participants were also asked about their years of experience as a peri-operative provider. Three of the participants had 1-2 years of experience (*n* = 3, 30.00%), another 3 participants had between 5-10 years of experience (*n* = 3, 30.00%), and 4 participants had between 2-5 years of experience (*n* = 4, 40.00%).

Pre-Test Knowledge Beach Chair Position

The participants were asked a few questions regarding general facts about the beach chair position. The first question asked about their knowledge regarding the introduction of the beach chair position in the operating room for surgical procedures. None of the participants provided the correct response (*n* = 0, 0.00%). Five participants (*n* = 5, 50.00%) selected 1970s as their answer. Four participants (*n* = 4, 40.00%) selected 1960s and 1 participant (*n* = 1, 10.00%) selected 1950s as their answer. The beach chair position was introduced in the operating room

for surgical procedures in the 1980s. The next question aimed to assess the participants' knowledge about the yearly prevalence of shoulder surgeries in the beach chair position. Three of the participants (*n* = 3, 30.00%) provided the correct response while the remaining 7 (*n* = 7, 70.00%) answered incorrectly. Approximately 400,000 shoulder surgeries occur on a yearly basis with 250,000 (two-thirds) of these occurring in the beach chair position.

Pre-Test Knowledge Hemodynamic Effects in the Beach Chair Position

Prior to completing the educational module for this project, participants were asked to complete a pre-test questionnaire to assess their knowledge about the hemodynamic changes that occur in the beach chair position. The initial question assessed the participants knowledge about the pressure gradient between the brain and the blood pressure taken on the arm. The results indicated that only 2 participants (*n* = 2, 20.00%) were knowledgeable about the 25mmHg gradient that exists between the brain and the blood pressure taken in the arm. Eight (*n* = 8, 80.00%) of the participants selected a different answer that was incorrect. When asked about the average decrease in mean arterial pressure (34mmHg) in the beach chair position, 1 participant (*n* = 1, 10.00%) selected the correct answer. The remaining 9 participants (*n* = 9, 90.00%) answered incorrectly. A question regarding the increased risk of mortality for a mean arterial pressure of less than 60mmHg for just 1 minute yielded mixed responses. The correct answer of 5% was selected by 3 participants (*n* = 3, 30.00%) while the remaining participants demonstrated a lack of knowledge (*n* = 7, 70.00%). When asked about how many mmHg of mean arterial pressure decreased per centimeter elevation above the level of the heart (0.77mmHg per 1cm), 3 participants knew the correct answer (*n* = 3, 30%.00) and the remaining 7 participants (*n* = 7, 70.00%) provided incorrect responses. The last question regarding the hemodynamic effects that occur in the beach chair position assessed the participants' knowledge about the decrease in

mean arterial pressure that occurs after 1 minute in the beach chair position following induction of anesthesia. Five participants (n = 5, 50.00%) demonstrated an understanding of the hemodynamic effects that occur 1 minute after going from the supine position to the beach chair position. The remaining 5 participants (n = 5, 50.00%) demonstrated a lack of knowledge regarding the effects of position changes on hemodynamics.

Pre-Test Knowledge Continuous, Non-Invasive Hemodynamic Monitoring

A pre-test questionnaire assessed the participants current knowledge about the use for continuous, non-invasive hemodynamic monitoring for shoulder surgery in the beach chair position. The participants were asked about the percent reduction of intra-operative hypotensive events when using continuous, non-invasive hemodynamic monitoring. The correct answer was not selected by any of the participants (n = 0, 0.00%). Three of the participants selected a 25% decrease as a response (n = 3, 30.00%) and 7 participants selected 75% percent decrease as a response (n = 7, 70.00%). The correct answer for reduction in hypotensive events when using continuous, non-invasive blood pressure monitoring is 50%. The final question in the survey assessed the participants' familiarity with the technology used in continuous, non-invasive hemodynamic monitoring. One participant (n = 1, 10.00%) selected the volume clamp method which was the correct response while the other 9 (n = 9, 90.00%) participants provided different incorrect answers.

Pre-test Utilization and Attitudes of Continuous, Non-Invasive Hemodynamic Monitoring

The pre-test survey assessed the participants' willingness to utilize the continuous, non-invasive hemodynamic monitor during shoulder surgery in the beach chair position. There were mixed responses, however, the majority of the participants demonstrated an inclination toward utilizing the device in practice. Five participants (n = 5, 50.00%) selected extremely likely to use,

2 participants (n = 2, 20.00%) selected somewhat likely to use, 1 participant (n = 1, 10.00%) was somewhat unlikely to use, and 2 participants (n = 2, 20.00%) were extremely unlikely to use. When combining the participants who selected extremely likely and somewhat likely to use, a total of 70.00% of the participants demonstrated an interest in using the continuous, non-invasive hemodynamic monitor during shoulder surgery in the beach chair position.

Post-test Knowledge Beach Chair Position

The participants were provided with a post-test survey following the completion of an educational module regarding the use of continuous, non-invasive hemodynamic monitoring during shoulder surgery in the beach chair position. A total of 7 participants completed the post-test survey compared to ten participants who completed the pre-test survey. An improvement was noted in the post-test assessment for identifying the introduction of the beach chair position in the operating room for surgical procedures. Six participants (n = 6, 86.00%) identified the correct answer while only 1 participant (n = 1, 14.00%) did not demonstrate an improvement in knowledge. Table 2 shows the overall improvement that occurred pertaining to general knowledge regarding the beach chair position.

Table 2. Pre- and Post-Test Knowledge Beach Chair Position

Question	Correct in Pre-test	Correct in Post-test	Difference
The beach chair position was introduced in:	0.00%	86.00%	86.00%
On average, 400,000 shoulder surgeries are performed in the U.S. annually. Of these surgeries, how many are performed in the beach chair position?	30.00%	71.00%	41.00%

Post-Test Knowledge Hemodynamic Effects in the Beach Chair Position

There was an overall improvement of knowledge among the participants upon completion of the educational module regarding the use of continuous, non-invasive hemodynamic monitoring during shoulder surgery in the beach chair position and the hemodynamic effects that it incurs. Learning occurred when the participants answered the post-test question regarding the gradient that exists between the brain and the systolic blood pressure taken in the arm. The post-test results revealed a 51% increase in knowledge pertaining to this question. The participants showed a significant improvement in knowledge regarding the decrease in mmHg of mean arterial pressure that occurs in the beach chair position. A significant improvement of 71% was noted between the pre-test and post-test with respect to this question. When asked about the percentage of increase in mortality for mean arterial pressure sustained below 60mmHg for just 1 minute, the participants demonstrated a 66.00% improvement in the post-test assessment. A 41% improvement was seen in the post-test survey regarding knowledge about the 0.77mmHg decrease in mean arterial pressure per 1cm increase that occurs when elevating the head with relation to blood pressure taken in the arm. The participants demonstrated adequate knowledge upon completing the educational module when asked about the hemodynamic impact in blood pressure 1 minute after placing the patient in the beach chair position following induction. The participants improved their performance by 36.00% regarding this question. Overall, the participants improved their scores in the post-test assessment when compared to the pre-test assessment. They were able to demonstrate a better understanding of the hemodynamic changes that occur in the beach chair position after completing the educational module.

Table 3. Pre- and Post-Test Knowledge Hemodynamic Effects in the Beach Chair Position

Question	Correct in Pre-test	Correct in Post-test	Difference
The gradient between the brain and the systolic blood pressure taken in the arm could reach a difference of up to:	20.00%	71.00%	51.00%
On average, mean arterial pressure decreases by __mmHg in the beach chair position:	10.00%	86.00%	76.00%
Studies show that a mean arterial pressure of less than 60mmHg for just 1 minute increases mortality by:	20.00%	86.00%	66.00%
Mean arterial pressure falls by __mmHg per __cm elevation above measurement reference point (blood pressure taken in the arm):	30.00%	71.00%	41.00%
On induction, a patient's mean arterial pressure is 90mmHg. After 1 minute in the beach chair position, their average mean arterial pressure would be:	50.00%	86.00%	36.00%

Post-Test Knowledge Continuous, Non-Invasive Hemodynamic Monitoring

The results for post-test knowledge about continuous, non-invasive hemodynamic monitoring displayed an improvement in education regarding the benefit of utilizing the device. There was minimal familiarity with the technology of the continuous, non-invasive device with respect to how it measures hemodynamics in the pre-test. The post-test resulted in a 47.00% improvement following the educational module with 57.00% of the participants answering correctly compared to only 10.00% in the pre-test survey. When asked about the benefit of reduction of intra-operative hypotension with the continuous, non-invasive monitor, the participants did substantially well in the post-test survey. Eighty-six percent of participants answered correctly in the post-survey compared to 0% in the initial survey. This resulted in an

86.00% increase in knowledge about the benefit of using the device to decrease the incidence of hypotension in the operating room.

Table 4. Pre- and Post-Test Knowledge Continuous, Non-invasive Hemodynamic **Monitoring**

Question	Correct in Pre-test	Correct in Post-test	Difference
Continuous, non-invasive blood pressure monitoring devices utilize which method for measuring hemodynamics?	10.00%	57.00%	47.00%
Continuous, non-invasive hemodynamic monitoring reduces the incidence of intra-operative hypotension by nearly:	0.00%	86.00%	86.00%

Post-Test Utilization and Attitudes of Continuous, Non-Invasive Hemodynamic Monitoring

Upon completion of the educational module regarding the use of continuous, non-invasive hemodynamic monitoring, most participants demonstrated an inclination toward using this technology for monitoring hemodynamics in the operating room. Eighty-five percent of participants (n = 6, 85.00%) selected extremely likely to use device while 14.00% (n = 1, 14.00%) selected they were extremely unlikely to use continuous, non-invasive hemodynamic monitoring intra-operatively. Overall, most participants showed a strong, positive response toward the use of continuous, non-invasive hemodynamic monitoring in the operating room. Table 5 displays the results and differences between the pre- and post-test survey.

Table 5. Pre- and Post-test Utilization and Attitudes of Continuous, Non-Invasive **Hemodynamic Monitoring**

Question	Pre-test	Post-test	Difference
How likely are you to utilize continuous, non-invasive blood pressure monitoring for shoulder surgery in the beach chair position?			

Extremely likely	50.00%	85.00%	35.00%
Somewhat Likely	20.00%	0.00%	-20.00%
Neither Likely or Unlikely	0.00%	0.00%	0.00%
Somewhat Unlikely	10.00%	0.00%	-10.00%
Extremely unlikely	20.00%	14.00%	- 6.00%

Timeline

The timeline for the completion of this project was estimated to take place over the course of approximately 6 months. The initial process entailed obtaining the project's proposal approval from the graduate faculty at the Florida International University's College of Nursing & Health Sciences followed by permission from the IRB to proceed with subject participation. Upon obtaining receipt of approval from all parties involved, the participants would have access to the study's survey over several weeks to allot sufficient time for completion of the pre-test questionnaire, online educational module, and post-test questionnaire. Once the results have been populated, data analysis would go underway, and a written summary of the findings would be carried out over several weeks to approximately 1 month.

Summary

The contents of this proposal included the purpose of the project, which was to provide an educational module regarding the use of the continuous, non-invasive device for hemodynamic monitoring in anesthesia practice. A background of the proposed solution and a problem statement identifying the risks and consequences related to surgery in the beach chair position was provided with supporting evidence from the literature. A literature review was conducted, and appraisal of the evidence was summarized with literature that supported the use of continuous noninvasive hemodynamic monitoring devices and its advantages for optimizing patient outcomes after surgery. Finally, the methodology for the proposal included the selection of participants for the study, receipt of approval from the IRB to proceed with the study, data

collection and data analysis, and the implications for advanced nursing practice were summarized with evidence to support the project proposal and the need for its implementation into anesthesia practice.

Discussion

Implications for Advanced Nursing Practice

The anticipated results of this project would demonstrate attainment of new knowledge for using the continuous, non-invasive system over other hemodynamic monitoring devices and how the continuous, non-invasive device could optimize patient outcomes after surgery in the beach chair position. The primary goal would be to acquire receptive participation from the anesthesia providers at a level 1 trauma center in Miami, Florida to incorporate using the continuous, non-invasive device for patients who meet criteria and were scheduled to have shoulder surgery in the beach chair position. Implementation of the continuous, noninvasive monitor for patients having surgery in the beach chair position would promote a safer practice in advanced nursing by enhancing patient hemodynamics in the intraoperative period, to optimize patient outcomes post-operatively, and minimize morbidity and mortality associated with intraoperative hypotension. Limitations to this study would include a small sample size of participants who completed the pre-test and post-test questionnaire. Another limitation that was identified was insufficient time allotted for data collection.

Conclusion

The continuous, noninvasive hemodynamic monitor would increase optimal patient outcomes post-operatively by minimizing the consequences related to intraoperative hypotension during shoulder surgery in the beach chair position. Timely detection of intraoperative hypotension would decrease the risk of organ ischemia and cerebral hypoperfusion. Ischemic

injuries may lead to an increase of mortality by 5% for every minute that mean arterial pressure is maintained below 60mmHg. The continuous, non-invasive hemodynamic monitor reliably measures blood pressure readings and would ensure prompt treatment of hypotensive events. Optimizing patient outcomes after shoulder surgery in the beach chair position would lead to increased patient satisfaction and improve patient management by utilizing current technology to make significant advancements in anesthesia practice.

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Appendix A: IRB Exemption Letter

Project	"An Educational Module for Continuous Non-invasive Blood Pressure Monitoring for Shoulder Surgery in the Beach Chair Position: A Quality Improvement Project"

The Florida International University Office of Research Integrity has reviewed your research study for the use of human subjects and deemed it Exempt via the **Exempt Review** process.

IRB Protocol Exemption #: IRB-24-0058 **IRB Exemption Date:** 02/14/24

TOPAZ Reference #: 113976

As a requirement of IRB Exemption you are required to:

1. 1) Submit an IRB Exempt Amendment Form for all proposed additions or changes in the procedures involving human subjects. All additions and changes must be reviewed and approved prior to implementation.
2. 2) Promptly submit an IRB Exempt Event Report Form for every serious or unusual or unanticipated adverse event, problems with the rights or welfare of the human subjects, and/or deviations from the approved protocol.
3. 3) Submit an IRB Exempt Project Completion Report Form when the study is finished or discontinued.

Special Conditions: N/A
For further information, you may visit the IRB website at http://research.fiu.edu/irb.

KMW

Appendix B : Permission Letter

January 13, 2024

Fernando Alfonso, DNP, CRNA, APRN
Clinical Assistant Professor
Department of Nurse Anesthesiology
Florida International University

Dr. Fernando Alfonso,

Thank you for inviting Envision Physician Services to participate in the Doctor of Nursing Practice (DNP) project conducted by Priscilla Ramos entitled "Continuous Non-invasive Blood Pressure Monitoring for Shoulder Surgery in the Beach Chair Position: A Educational Module" in the Nicole Wertheim College of Nursing and Health Sciences, Department of Nurse Anesthesiology at Florida International University. I have granted the student permission to conduct the project using our providers.

Evidence-based practice's primary aim is to yield the best outcomes for patients by selecting interventions supported by the evidence. This proposed quality improvement project seeks to utilize the latest literature to increase providers awareness on the benefits for using continuous, non-invasive blood pressure monitoring during shoulder surgery in the upright position and its efficacy for prompt detection and treatment of hypotensive events.
We understand that participation in the study is voluntary and carries no overt risk. All Anesthesiology providers are free to participate or withdraw from the study at any time. The educational intervention will be conveyed by a 15-minute virtual PowerPoint presentation, with a pretest and posttest questionnaire delivered by a URL link electronically via Qualtrics, an online survey product. Responses to pretest and posttest surveys are not linked to any participant. The collected information is reported as an aggregate, and there is no monetary compensation for participation. All collected material will be kept confidential, stored in a password encrypted digital cloud, and only be accessible to the investigators of this study: Priscilla Ramos, BSN, RN and Fernando Alfonso, DNP, CRNA, APRN

Once the Institutional Review Board's approval is achieved, this scholarly project's execution will occur over 2 weeks. Priscilla Ramos RN, BSN will behave professionally, follow standards of care, and not impede hospital performance. We support the participation of our Anesthesiology providers in this project and look forward to working with you.

Kendall Regional Medical Center

Dr. Javier Lopez

Envision Physician Services Anesthesiology

Regional Medical Director

Javier.lopez@envisionhealth

Appendix C: Request Letter

Nicole Wertheim College of Nursing & Health Sciences

Continuous Non-invasive Blood Pressure Monitoring for Shoulder Surgery in the Beach Chair Position: A Quality Improvement Project

Dear Envision Physician Services Perioperative Providers:

My name is Priscilla Ramos, and I am a student from the Anesthesiology Nursing Program Department of Nurse Anesthesiology at Florida International University. I am writing to invite you to participate in my quality improvement project. The goal of this project is to increase health care providers' awareness on the benefits for using continuous, non-invasive blood pressure monitoring during shoulder surgery in the upright position and its efficacy for prompt detection and treatment of hypotensive events.

You are eligible to take part in this project because you are a part of the Envision Physician Services perioperative provider.

If you decide to participate in this project, you will be asked to complete and sign a consent form for participation. Next, you will complete a pre-test questionnaire, which is expected to take approximately 5 minutes. You will then be asked to view an approximately 15 minutes long educational presentation online. After going through the educational module, you will be asked to complete the post-test questionnaire, which is expected to take approximately 5 minutes. *No compensation will be provided.*

Remember, this is completely voluntary. You can choose to be in the study or not. If you'd like to participate or have any questions about the study, please email or contact me at 786-897-5797 or pramo049@fiu.edu.

Thank you very much.

Sincerely,

Priscilla Ramos
Cell: 786-897-5797
Email: pramo049@fiu.edu

Appendix D: Proposed Method for Data Collection

Pre-Survey and Post-Survey

I. Demographics

1. Gender
    a. Male
    b. Female
    c. Other _____
    d. Prefer not to say.
2. Age Group
    a. 20-30
    b. 31-40
    c. 41-50
    d. 51-60
    e. >60
3. Ethnicity
    a. Hispanic
    b. Caucasian
    c. African American
    d. Asian
    e. Other _____
4. Position/Title
    a. CRNA
    b. Attending Anesthesiologist

c. Resident Anesthesiologist

5. Highest level of Education

   a. Certificate

   b. Bachelors

   c. Masters

   d. DNP

   e. PhD

   f. Doctor of Medicine

   g. Other _____

6. How many years have you been a peri-operative provider?

   a. <1 year

   b. 1-2 years

   c. 2-5 years

   d. 5-10 years

   e. >10 years

II. Pre-test Questionnaire

1. The gradient between the brain and the systolic blood pressure taken in the arm could reach a difference of up to:

   a. 20mmHg

   b. 25mmHg

   c. 30mmHg

   d. 35mmHg

2. On average, mean arterial pressure decreases by ___mmHg in the beach chair position:
    a. 14mmHg
    b. 24mmHg
    c. 34mmHg
    d. 44mmHg
3. Studies show that a mean arterial pressure of less than 60mmHg for just 1 minute increases mortality by:
    a. 5%
    b. 10%
    c. 15%
    d. 20%
4. Mean arterial pressure falls by ___mmHg per ___cm elevation above measurement reference point (blood pressure cuff on arm):
    a. 0.47mmHg; 0.5cm
    b. 0.57mmHg; 0.5cm
    c. 0.67mmHg; 1cm
    d. 0.77mmHg; 1cm
5. On average, 400,000 shoulder surgeries are performed in the U.S. annually. Of these surgeries, how many are performed in the beach chair position?
    a. ½
    b. 1/3
    c. ¼

d. 2/3

6. The beach chair position was introduced in:
    a. 1950s
    b. 1960s
    c. 1970s
    d. 1980s
7. On induction, a patient's mean arterial pressure is 90mmHg. After 1 minute in the beach chair position, their average mean arterial pressure would be:
    a. 70mmHg
    b. 60mmHg
    c. 50mmHg
    d. 40mmHg
8. Continuous, non-invasive blood pressure monitoring devices utilize which method for measuring hemodynamics?
    a. Volume clamp method
    b. Inflatable Oscillometric Method
    c. Physiocal Method
    d. Photo-plethysmograph Method
9. Continuous, non-invasive hemodynamic monitoring reduces the incidence of intraoperative hypotension by nearly:
    a. 25%
    b. 50%
    c. 75%

d. 90%

III. Attitude Toward Practice Change

10. How likely are you to utilize continuous, non-invasive blood pressure monitoring for shoulder surgery in the beach chair position?

    a. Extremely unlikely

    b. Somewhat likely

    c. Neither likely nor unlikely

    d. Somewhat likely

    e. Extremely likely

Appendix E: Educational Module

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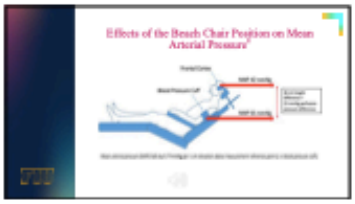

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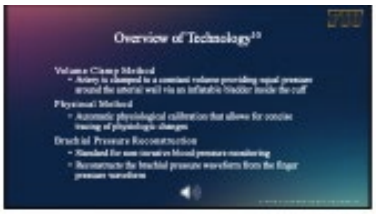
Overview of Technology[13]
Volume Clamp Method
Arteryis clamped to a constant volume providing equal pressure around the arterial wall via an inflatable bladder inside the cuff
Physiocal Method
Automatic physiological calibration that allows for concise tracing of physiologic changes
Brachial Pressure Reconstruction
Standard for non-invasive blood pressure monitoring
Reconstructs the brachial pressure waveform from the finger pressure waveform

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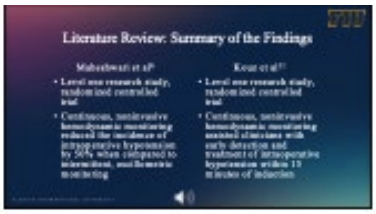
Literature Review: Summary of the Findings
Mahoney et al[9]
Level one research study, random ized controlled trial
Continuous, noninvasive hemodynamic monitoring reduced the incidence of intraoperative hypotension by 50% when compared to intermittent, oscillometric monitoring
Kwan et al[11]
Level one research study, random ized controlled trial
Continuous, noninvasive hemodynamic monitoring assisted clinicians with early detection and treatment of intraoperative hypotension within 13 minutes of induction

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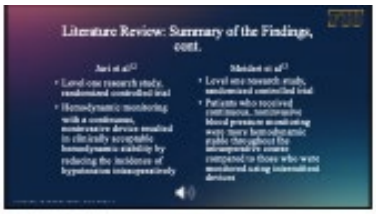
Literature Review: Summary of the Findings, cont.
Jun et al[12]
Level one research study, randomized controlled trial
Hemodynamic monitoring with a continuous, noninvasive device resulted in clinically acceptable hemodynamic stability by reducing the incidence of hypotension intraoperatively
Maslow et al[13]
Level one research study, randomized controlled trial
Patients who received continuous, noninvasive blood pressure monitoring were more hemodynamic stable throughout the intraoperative course compared to those who were monitored using intermittent devices

12


Summary
Beach chair position leads to hemodynamic instability putting patients at risk for multiple organ injury
Anesthesia providers could assist with minimizing morbidity and mortality associated with intraoperative hypotension
Continuous, non-invasive blood pressure monitoring provides a solution to timely detection and treatment of intraoperative hypotension in the beach chair position

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References

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Appendix F: Dissemination PowerPoint

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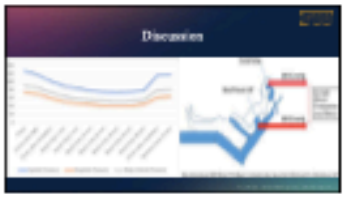

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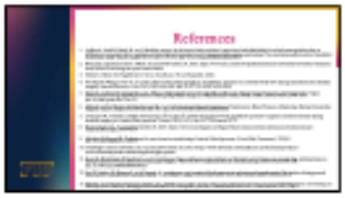

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Appendix G: Poster

Priscilla Ramos, MSN, RN; Natalie Arango, DNP, CRNA, APRN; Fernando Alfonso, DNP, CRNA, APRN

FIU

Introduction

- On average, approximately 400,000 shoulder surgeries are performed in the U.S. annually
  - Two-thirds (>250,000) of these surgeries are performed in the beach chair position
- The beach chair position creates a gradient between the brain and the heart with a perfusion pressure difference of up to 25mmHg.
- Research supports that untimely detection of hypotension while in the beach chair position increases morbidity and mortality.
- Continuous, non-invasive hemodynamic monitoring is an emerging technology with beat-to-beat blood pressure measurement

Project Purpose

- Provide clinicians with an educational module discussing the anesthesia implications of the beach chair position
- Educate anesthesia providers about using continuous, non-invasive hemodynamic monitoring
- Encourage providers to adhere to using continuous, non-invasive blood pressure devices for patients having shoulder surgery in the beach chair position
- Identify the benefits of using continuous, non-invasive devices for hemodynamic monitoring

PICO Question

For patients undergoing shoulder surgery in the beach chair position (P), does the continuous, non-invasive blood pressure device (I) versus use of intermittent oscillometric devices (C) provide earlier detection and treatment of intraoperative hypotension (O)?

Research Objectives & Learning Outcomes

- To promote awareness on the use of the continuous, non-invasive blood pressure monitors
- Provide statistical data that supports using continuous hemodynamic monitoring for patients having surgery in the beach chair position
- Increase provider knowledge about the anesthesia implications of the beach chair position and ways to minimize complications associated with it

Methods

Project Proposal

- A background of the proposed project along with problem identification and supporting research was presented to faculty for approval

Project Objectives

- A large hospital in South Florida was selected for presentation of the project. Anesthesia providers were identified as potential participants in a pre- and post- survey. Upon completion of an educational module, an assessment would measure if knowledge was improved

Project Implementation

- IRB approval was granted, consent to participate was obtained, and participants received an educational module along with a pre- and post-survey. Results were stored in Qualtrics for analysis and comparison of data was made with pre- and post-survey findings

Results