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Abstract

Aortic stenosis (AS) is a common valvular disorder that causes left ventricular (LV) outflow obstruction. The prevalence of AS may increase with the aging population and the widespread availability of diagnostic capabilities like echocardiography. With the increasing patient population diagnosed with AS, the chance of encountering these patients during noncardiac surgery (NCS) increases. Performance of anesthesia is challenging in patients with AS due to the pathophysiological consequences of AS and the hemodynamic changes associated with anesthesia. The patient with AS presenting for NCS is at an increased risk of perioperative major adverse cardiac events (MACEs). This project aimed to determine the most up-to-date evidence for the perioperative management of patients with AS undergoing NCS. A literature search was conducted through the EBSCO Discovery Service and Google Scholar to find current evidence. The current evidence was used to create clinical guidelines for the pre and intraoperative management of patients with AS undergoing NCS using the Bayesian approach. The practice question, evidence, translation (PET), part of the Johns Hopkins Evidence-Based Practice Model (JHEBPM), was used as the literature review's framework. An implementation plan to disseminate the guidelines into practice was formed and discussed. The outcome the project team aims to study is the incidence of MACEs in patients with AS undergoing NCS after the implementation of clinical guidelines.

Keywords: aortic stenosis, noncardiac surgery, major adverse cardiac event, preoperative evaluation, intraoperative management

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Introduction

The prevalence of aortic stenosis (AS) may increase with an increasing population of older individuals in modern society (Tashiro et al., 2014). The prevalence of AS ranges from 1.3-1.4% in individuals aged 65-74 but increases to 2.8-4.6% in individuals aged 75 and older (Whitener et al., 2021). With the utilization and increased availability of echocardiography, the recognition of AS in asymptomatic patients has increased (Tashiro et al., 2014). The degree of AS severity (based on echocardiographic parameters) determines if a patient qualifies for aortic valve replacement (AVR) before noncardiac surgery (NCS), and some patients may not receive AVR based on the severity or the circumstance of the need for surgery (Whitener et al., 2021). The pathophysiological consequences of AS place patients at a higher risk for major adverse cardiac events (MACEs; Whitener et al., 2021). Kwok et al. (2017) explained that patients with AS undergoing NCS are at significantly higher risk of a MACE than patients without AS. One observational study showed that 22% of patients with AS undergoing NCS had a MACE (MacIntyre et al., 2018). With the increased prevalence of AS and the availability of echocardiography, more patients will undergo NCS diagnosed with AS.

The 2020 update to the American College of Cardiology and the American Heart Association's guidelines for managing valvular heart disease suggest that it is reasonable to perform NCS on patients with AS, depending on symptoms and severity (Otto et al., 2021). Anesthesia providers will inevitably perform anesthesia on a patient with AS undergoing NCS. Conducting a literature review to gather evidence for clinical guidelines on the risk stratification and perioperative management of patients with AS undergoing NCS is essential to the anesthesia

community. Establishing guidelines for managing AS in NCS allows the CRNA to manage and treat the patient in the perioperative process effectively. In doing so, clinical guidelines will expectantly prevent many perioperative complications. This scholarly project aims to present the evidence found in the data and how that data can be used to formulate clinical guidelines for implementing a plan for the perioperative management of patients with AS undergoing NCS.

Background

AS Pathophysiology

During systole, the aortic valve opens, allowing blood to exit the heart and be delivered to the aorta and the rest of the body (Crawford et al., 2022). The aortic valve closes at the onset of diastole (Crawford et al., 2022). In a typical physiologic environment, the aortic valve opens once the left ventricle (LV) generates a pressure greater than the diastolic blood pressure (DBP) generated from the aorta (DeMers & Wachs, 2022). The average blood flow area through the aortic valve is 2.5-4 cm^2 (Paul, 2017). Changes to the normal physiology occur when AS develops, causing a cascade of consequences.

AS is a narrowing of the aortic valve opening that causes an LV outflow obstruction (Pujari & Agasthi, 2022). With worsening AS, the LV must generate a greater systolic pressure to overcome the narrowing/outflow obstruction (Pujari & Agasthi, 2022). The decreased valvular area causes increased myocardial wall stress on the LV. The increased wall stress leads to chronic pressure overload with the subsequent development of concentric LV hypertrophy (LVH; Paul, 2017). Concentric LVH causes myocardial sarcomeres to build in a parallel fashion (one on top of another), causing a thick, hypertrophied LV leading to diastolic dysfunction (Paul, 2017). Diastolic dysfunction causes decreased compliance of the LV (decreased ability to fill during diastole), which causes a chronic increase in LV diastolic pressure (LVEDP; Paul, 2017). The

decreased ventricular filling causes more reliance on left atrial contraction (kick) and a low normal sinus heart rate to ensure an adequate cardiac output with AS (Paul, 2017). Nearly 40% of cardiac output comes from the atrial kick contribution (Paul, 2017). The previous consequences that ultimately lead to decreased LV filling cause a low fixed cardiac output in patients with AS (Paul, 2017). With a low fixed cardiac output and increased pressure gradient, the aortic DBP relies heavily on systemic vascular resistance (SVR; Paul, 2017).

AS Severity/Staging

Aortic valve area (AVA, measured in cm^2), peak velocity (measured in m/sec), and mean pressure gradient (measured in mm Hg) across the valve are the primary parameters assessed in patients with AS to determine severity (Whitener et al., 2021). The American College of Cardiology (ACC)/American Heart Association (AHA) task force on practice guidelines discusses the various degrees of AS, including mild, moderate, and severe (Nishimura et al., 2014). Mild AS is consistent with an AVA >1.5, peak velocity <3.0, and a mean gradient <20 (Nishimura et al., 2014). Moderate AS is consistent with an AVA of 1.0-1.5, a peak velocity of 3.0-4.0, and a mean gradient of 20-40 (Nishimura et al., 2014). Severe AS is consistent with an AVA <1.0, peak velocity ≥4.0, and a mean gradient ≥40 (Nishimura et al., 2014).

AS is classified into four stages by the AHA/ACC valvular heart disease guidelines (Nishimura et al., 2014). Stage A is defined as “at risk” for developing AS (Nishimura et al., 2014). Stage B is “progressive AS” with mild to moderate severity and no symptoms (Nishimura et al., 2014). Stage C is “asymptomatic severe AS” subdivided into classes C1 and C2. Class C1 is asymptomatic severe AS with normal LV function, while class C2 is asymptomatic severe AS is LV dysfunction (Nishimura et al., 2014). Stage D is “symptomatic severe AS subdivided into class D1, D2, and D3. Class D1 is symptomatic severe high-gradient AS, presenting with LV

diastolic dysfunction, LVH, and possible pulmonary hypertension (Nishimura et al., 2014). Class D2 is symptomatic severe low-flow/low-gradient AS with reduced LV ejection fraction, including LV diastolic dysfunction, LVH, and ejection fraction <50% (Nishimura et al., 2014). Lastly, class D3 is symptomatic severe low-gradient AS with normal LV ejection fraction or paradoxical low-flow severe AS with increased LV wall thickness, low stroke volume, and restrictive diastolic filling (Nishimura et al., 2014). The presenting symptoms in classes D2 and D3 include HF, angina, and syncope (Nishimura et al., 2014). Appendix A shows the complete breakdown of the stages of AS.

MACEs

The pathophysiological background of AS described above places patients at a higher risk for MACEs (Whitener et al., 2021). The risk for MACE originates in the vulnerability of subendocardial tissue in patients with AS. From the literature, MACEs were defined as myocardial infarction (MI), heart failure (HF), stroke, and arrhythmia with hemodynamic compromise (MacIntyre et al., 2018; Tashiro et al., 2014). As the degree of AS worsens (increased symptoms), there is an increased risk of MACE during the perioperative period (MacIntyre et al., 2018).

Significance to Anesthesia

The consequences of AS cause many areas of concern for the anesthesia provider. The pathophysiology behind AS places patients at higher risk for MACEs, including myocardial infarction (MI) (Whitener et al., 2021). First, coronary perfusion pressure (CPP) is the difference between aortic DBP and LVEDP (Heward & Widrich, 2023). In AS, coronary perfusion is highly reliant on aortic DBP/SVR as the LVEDP is chronically elevated (Paul, 2017). In addition to adequate SVR, the heart rate must be kept at a low-normal rate (60-80 beats per minute) to

ensure adequate LV filling and time for coronary perfusion (Paul, 2017). The majority (80-90%) of coronary artery perfusion to the LV occurs during diastole (Heward & Widrich, 2023). Many agents utilized for induction and maintenance of anesthesia decrease SVR, increase heart rate, and are arrhythmogenic, placing patients with AS at a higher risk for a perioperative MACE (Herrera et al., 2023; Whitener et al., 2021).

With AS, the systolic pressure the LV must generate to overcome the stenotic valve increases with the severity of the disease (Whitener et al., 2021). Many agents utilized for anesthesia have direct myocardial depressant effects, preventing the LV from obtaining the needed pressure for forward blood flow. If this happens, the patient immediately goes into cardiovascular collapse (Kim et al., 2022). Chest compressions during cardiopulmonary resuscitation (CPR) cannot produce enough pressure to overcome the stenotic aortic valve if the patient goes into cardiac arrest (Paul, 2017).

The increased risk for a MACE during the induction and maintenance of anesthesia in patients with AS undergoing NCS places high importance on developing evidence-based guidelines for perioperative management. The traditional approach to anesthetic management of AS patients undergoing NCS varies from institution to institution and provider to provider. Developing and implementing evidence-based guidelines with the current literature will expectantly lower the incidence of MACEs during the perioperative period.

PICOT

The PICOT question selected for the literature review involves identifying evidence-based practice guidelines for the perioperative management of patients with AS undergoing NCS. The evidence-based practice guidelines will be compared to the traditional anesthetic approach for the defined patient population. The outcome selected to determine the efficacy of the

guidelines is found in the literature and includes occurrences of MACEs. The MACEs of focus are perioperative MI, HF, stroke, and arrhythmia with hemodynamic compromise. The PICOT question is: In adult patients previously diagnosed with aortic stenosis undergoing noncardiac surgery, how would developing and implementing evidence-based practice guidelines compared to the traditional approach affect the incidence of MACEs during the perioperative period?

Project Objectives

The perioperative management of patients with AS undergoing NCS varies from institution to institution. Evidence shows that the risk for MACEs during NCS increases with AS alone (Kwok et al., 2017). The pathophysiological consequences of AS, with the addition of hemodynamic changes that occur during anesthesia, place patients at an increasingly higher risk of MACEs during the perioperative period (Herrera et al., 2023). The proposed DNP project seeks to create and implement evidence-based guidelines for the perioperative management of patients with AS undergoing NCS.

The objectives outlined for the development of clinical guidelines are as follows:

- Develop evidence-based clinical guidelines for the perioperative management of patients with AS undergoing NCS based on the Bayesian framework.
- Develop a comprehensive plan to implement the guidelines, including distributing education/training related to the perioperative AS clinical guidelines.
- Develop a comprehensive plan to measure and evaluate the perioperative AS guidelines for NCS based on outcomes described in the literature.
- Develop a comprehensive plan to adjust the perioperative AS guidelines for NCS if the outcomes are less than desirable.

Literature Review

The PICOT question directed the literature review for the DNP project. The population researched were patients with diagnosed AS undergoing NCS. The intervention was evidence-based practice guidelines created through the literature review findings and the guideline's effects on patient outcomes compared to the traditional anesthetic approach to the identified patient population. The outcomes included in the research were perioperative MACEs. The evidence outlined can be found in the literature review table, which can be found in Appendix B.

Literature Search

Literature Synthesis

A systematic literature review was conducted through the EBSCO Discovery Service and Google Scholar databases. The databases were searched between June 2022 and July 2023. The following search terms were selected to include all relevant articles: "anesthesia," "aortic stenosis," "noncardiac surgery," "adverse cardiovascular event," "perioperative management," "preoperative evaluation," and "perioperative risk." The Boolean search included "and" to refine the search results. The inclusion criteria for the literature review included articles that were randomized control trials (RCTs), clinical guidelines created through meta-analyses/systematic reviews, meta-analyses/systematic reviews, retrospective studies, observational studies, and case reports that had full-text availability. The articles had to include adult patients with AS. General, regional, and spinal anesthesia were accepted for comparison. The studies had to assess perioperative outcomes that included MACEs.

Exclusion criteria included studies not written in English and those that studied pediatric patients. After including the search criteria, 429 results were found. Many articles were eliminated as they did not focus on the anesthetic impact on the defined population. The goal was

to use the most up-to-date research, but some articles created before 2017 were included as they involved pertinent data deemed credible. Most articles were found in the EBSCO database, and few came from the Google Scholar database. After refinement, 17 articles included the inclusion criteria and were selected for review.

AS Perioperative Risk

The belief used to be that patients with AS had higher mortality rates while undergoing NCS than patients without AS (Tashiro et al., 2014). Newer evidence within the last five years has challenged this belief. Tashiro et al. (2014) conducted a retrospective study comparing 256 patients with AS undergoing major NCS to a control group without AS. The researchers found that AS correlates with a higher incidence of MACE than the control group (Tashiro et al., 2014). MacIntyre et al. (2018) conducted an observational study including 147 patients with AS undergoing NCS in five hospitals in New Zealand. The team aimed to determine the effect of AS on adverse outcomes with NCS (MacIntyre et al., 2018). The researchers found that 22% of patients with AS had a MACE during or after NCS (MacIntyre et al., 2018). However, MacIntyre et al. (2018) found no increased mortality risk. Similar results were found in a systematic review and meta-analysis conducted by Kwok et al. (2017). After literature refinement from the team's initial search, nine articles were selected for review. The authors found that patients with AS are not at an increased mortality risk but have higher rates of MACEs than patients without AS (Kwok et al., 2017).

Herrera et al. (2023) discuss the factors beyond AS that must be considered to determine perioperative risk. One essential factor that must be identified is comorbidities such as coronary artery disease (CAD)(Herrera et al., 2023; Whitener et al., 2021). The concurrence of CAD with AS increases the chance of 30-day mortality and MI (Herrera et al., 2023). The anesthesia

provider must also consider the surgical risk, as the amount of blood loss, surgical stress, and surgical length can all alter the incidence of adverse outcomes (Herrera et al., 2023). There is an increased risk of MACE for patients with AS undergoing NCS. When comorbidities are added in, the risk increases further (Herrera et al., 2023).

Preoperative Evaluation

Preoperative Imaging. The 2014 American Heart Association (AHA)/American College of Cardiology (ACC) guideline for the management of patients with valvular heart disease, written by Nishimura and colleagues, created through research of various levels of evidence, suggests risk stratification strategies for patients with AS. The guidelines were updated in 2017 and again in 2020 with new evidence on various subjects, so all are referenced as indicated. Steps to evaluate patients with AS begin with preoperative transthoracic echocardiography (TTE; Nishimura et al., 2021). TTE is the current standard for preoperative assessment of AS (Herrera et al., 2023). TTE allows for evaluating AS severity and LV systolic function to inform the anesthesia provider for perioperative management (Nishimura et al., 2014). TTE is the first step for evaluation in the 2014 AHA/ACC guideline on the perioperative cardiovascular evaluation and management of patients undergoing NCS (Fleisher et al., 2014). TTE should be performed on patients with diagnosed or clinically suspected AS (symptoms of AS are listed in Appendix A) if there has been no prior echocardiography within one year or a significant change in clinical status since the previous evaluation (Nishimura et al., 2014).

Nanditha et al. (2019) performed a study comparing the accuracy of TTE and transesophageal echocardiography (TEE) in patients with AS. The study included 60 patients with severe AS who received and compared a preoperative TTE and an intraoperative TEE (Nanditha et al., 2019). The results showed that peak aortic jet velocity and pressure gradient

across the aortic valve was underestimated in more than 75% of patients with TEE (Nanditha et al., 2019). The aortic valve area measurement was comparable between TTE and TEE (Nanditha et al., 2019). This study shows evidence of the superiority of TTE over TEE in measuring AS severity before surgery.

Additionally, the non-invasive nature of TTE makes its use in the preoperative setting feasible to adequately evaluate AS severity and LV function. TTE can also be performed before the surgical procedure starts giving the anesthesia provider insight into the patient's cardiovascular status to formulate an anesthetic plan, while TEE would be performed intraoperatively. Disadvantages to using TTE include the inconvenience/unavailability of its use in the preoperative setting in a smaller health system or an outpatient surgery center. Someone with a large body habitus or chest area can make it difficult to accurately measure the aortic valve. Also, patients with asymptomatic AS are unlikely to receive a preoperative TTE, as the AHA/ACC recommends a yearly TTE in patients with asymptomatic AS (Nishimura et al., 2017). Whitener et al. (2021) reported a study that showed that between 30% and 47% of patients with severe echocardiographic AS were asymptomatic. Knowing the pathophysiological consequences of AS, asymptomatic patients can become symptomatic under anesthesia (Whitener et al., 2021).

Stress Testing. Stress testing may be performed to determine the severity of symptoms in patients with severe AS. In cases of symptomatic severe AS or patients who are unable to perform normal stress tests, stress testing with dobutamine is considered "reasonable" to determine clinical hemodynamic changes using echocardiographic or invasive hemodynamic monitoring (Nishimura et al., 2017; Fleisher et al., 2014). The same methodology may be used for asymptomatic patients. The benefits of chemical stress testing with dobutamine include

stopping the infusion if symptoms get clinically severe (Nishimura et al., 2017). The alternative approach for patients with asymptomatic AS may include light exercise stress testing (Whitener et al., 2021). The benefits of exercise stress tests include revealing symptoms that may not be visible during a preoperative assessment (Nishimura et al., 2017). The disadvantage of exercise stress tests is the use in symptomatic AS patients, which places the patient at high risk for complications, including ventricular tachycardia, severe hypotension, and death (Nishimura et al., 2017). Also, the inconvenience of scheduling and performing a stress test before NCS is a drawback.

Medication Therapy. Hypertension is common in patients with AS and adds to pressure overload on the LV (Nishimura et al., 2014). The AHA/ACC guidelines recommend treating patients with asymptomatic AS according to standard guideline-directed medical therapy (GDMT), starting with a low dose and titrating to effect (Nishimura et al., 2014). The guidelines cite the Simvastatin Ezetimibe in Aortic Stenosis (SEAS) study stating that in 1,616 patients with asymptomatic AS, hypertension was associated with a 56% higher rate of ischemic cardiovascular events compared with normotensive asymptomatic AS patients (Nishimura et al., 2014). There are no recommendations for any specific antihypertensive medication for patients with AS (Nishimura et al., 2014). However, angiotensin-converting enzyme inhibitors and beta-blockers could be efficacious (Nishimura et al., 2014). Additionally, diuretics should be avoided as diuretics decrease LV volumes by decreasing preload (Nishimura et al., 2014).

Statin therapy is not indicated to prevent hemodynamic symptom worsening of AS in patients with calcific valve etiology (Nishimura et al., 2014). The AHA/ACC guidelines describe three large “well-designed” RCTs that found no benefit to statin therapy in patients with AS (Nishimura et al., 2014). The studies showed no improvements in hemodynamic severity or

clinical outcomes (Nishimura et al., 2014). The 2020 update to the clinical guidelines reiterates no indication for statin therapy for patients with AS (Otto et al., 2021). However, in the setting of coexisting CAD, statin therapy is indicated per GDMT ((Nishimura et al., 2014). The medication therapy outlined by Nishimura et al. (2014) is primarily for presurgical/preoperative management that would occur before the patient presents for NCS. Intraoperative medication management would vary on a patient-to-patient basis.

Aortic Valve Intervention Before NCS. Aortic valvular intervention is typically based on symptom onset once a patient is diagnosed with severe AS (Whitener et al., 2021). Aortic valve replacement (AVR) is recommended for patients with symptomatic AS before NCS (Nishimura et al., 2017; Fleisher et al., 2014). AVR is only recommended before NCS in patients with asymptomatic severe AS (stage C2), and the LV ejection fraction (LVEF) is less than 50%; the classification for stages can be found in Appendix A (Nishimura et al., 2017). AVR is "reasonable" to perform before NCS if the diagnosis is very severe AS, the patient is at a low or intermediate risk for AVR, and the patient has rapidly progressing AS (Nishimura et al., 2017).

AVR surgery was traditionally performed as an open-heart procedure. The introduction of transcatheter aortic valve replacement (TAVR) has been widespread in recent years as the methodology of choice for valvular repair in patients with AS (Khan et al., 2020). Khan and colleagues (2020) performed a systematic review and meta-analysis to compare 30-day and one-year outcomes of TAVR versus surgical AVR in low-risk patients. The team reviewed seven articles that included 4,859 patients (Khan et al., 2020). The authors found that the TAVR group had lower rates of 30-day mortality and one-year stroke (Khan et al., 2020). TAVR patients also had lower rates of postoperative bleeding and acute kidney injury (Khan et al., 2020). The limitation of the study is that the long-term valve durability with TAVR needs to be studied.

Therefore, the decision to perform surgical AVR versus TAVR varies based on the individual patient's AS severity, age, and surgical risk (Nishimura et al., 2017).

Unlike AVR, balloon aortic valvuloplasty (BAV) is an alternative therapeutic option for patients with AS requiring NCS (Whitener et al., 2021). Debry et al. (2021) performed a retrospective comparing a BAV group with a control group. The researchers aimed to determine the effect of BAV on MACEs and three-month survival. The authors concluded that both groups had similar incidences of MACEs and three-month survival (Debry et al., 2021). Similar to this study, the AHA/ACC guidelines do not recommend preoperative BAV before NCS, with no evidence showing that the benefits outweigh the risks (Nishimura et al., 2017). Improving TAVR devices and techniques makes it a superior procedure to BAV and is indicated before NCS in patients requiring aortic valve intervention (Whitener et al., 2021).

Preoperative Risk Stratification. The AHA/ACC guidelines outline three risk assessment tools before NCS. These include the Revised Cardiac Risk Index (RCRI), National Surgical Quality Improvement Program Surgical Risk Calculator (NSQIP SRC), and the National Surgical Quality Improvement Program Myocardial Ischemia and Cardiac Arrest Calculator (NSQIP MICA; Fleisher et al., 2014). All three use varying assessment criteria. The AHA/ACC guidelines discuss using the Society of Thoracic Surgeons (STS) risk calculator as a risk assessment tool for cardiac surgery patients (Fleisher et al., 2014). The STS risk calculator is a risk prediction model for open cardiac surgery based on data from the National Adult Cardiac Surgery Database (Fleisher et al., 2014).

The AHA/ACC guidelines recommend that risk assessment for a patient with known valvular heart disease can be completed by the STS risk calculator, RCRI, NSQIP SRC, or NSQIP MICA (Nishimura et al., 2017). The RCRI, NSQIP SRC, and NSQIP MICA are

assessment tools for patients undergoing NCS with cardiac risk factors. However, all three do not consider aortic valve function, making risk stratification in patients with asymptomatic AS extremely difficult (Whitener et al., 2021). The STS risk calculator is typically used for patients undergoing cardiac surgery. However, it can be used to determine the risk of an asymptomatic patient with AS for AVR before NCS (Whitener et al., 2021). The benefit of using a known risk assessment tool is that it provides a quantitative value for the level of risk for adverse cardiac events during NCS. The disadvantage to using risk assessment screening tools is that the value may not consider aortic valve function or the risk level of the NCS (Whitener et al., 2021). Alternatively, other cardiac risk assessment tools are available, but the specificity for AS is lacking.

MACE Risk. Many factors contribute to the perioperative risk of MACE in patients with AS undergoing NCS (Kwok et al., 2017). Appropriate preoperative workup, including cardiovascular imaging, medication therapy, stress testing, and potential aortic valve intervention, is essential (Whitener et al., 2021). There are incidences that NCS is performed on a patient with severe AS before valvular intervention, such as when the patient refuses AVR or emergent NCS (Whitener et al., 2021). The AHA/ACC guidelines state that NCS is reasonable for patients with asymptomatic severe AS with appropriate intraoperative hemodynamic monitoring (Nishimura et al., 2017). Nishimura and colleagues (2014) do not disclose what is considered “appropriate intraoperative hemodynamic monitoring,” so that would vary depending on the institutional policy. However, an arterial line, at minimum, should be used in this patient population (Whitener et al., 2021). The decision to proceed with surgery should be a multidisciplinary decision involving cardiology, the surgeon, and the anesthesia provider (Whitener et al., 2021).

Intraoperative Management

Anesthetic Technique. The chosen anesthetic technique should consider patient-specific information such as AS severity, CAD, and other comorbidities (Nishimura et al., 2014). Neuraxial anesthesia has historically been a contraindication in patients with AS due to the nature of the pathophysiology behind AS and the physiological consequence of neuraxial anesthesia (Chaves-Cordona et al., 2022). Neuraxial anesthesia causes sympathetic nervous system blockade, causing systemic vasodilation, placing the patient with AS at risk for major complications (Whitener et al., 2021). Epidural with incremental injections is superior to spinal anesthesia if neuraxial anesthesia is desired (Whitener et al., 2021). On the contrary, a study by Chaves-Cordona et al. (2022) determined negligible differences in adverse outcomes between general and spinal anesthesia. The study was a retrospective chart review and is subject to limitations. With a relatively small sample size of 163 patients and unmeasured intraoperative variables, this study's findings are insufficient to determine the safety profile of performing spinal anesthesia on patients with AS.

Induction/Intraoperative Maintenance. The cardiovascular consequences of AS require stable hemodynamic control during anesthesia induction (Paul, 2017). The decreased LV compliance results in a low fixed cardiac output heavily reliant on preload and atrial contraction (Nishimura et al., 2014). A low normal heart rate (60-80 beats per minute) allows sufficient time for the LV to fill (Paul, 2017). Any arrhythmia also negates atrial contraction, contributing 40% of the cardiac output (Paul, 2017). Afterload must also be maintained to ensure coronary artery perfusion (Paul, 2017). Thus, induction should focus on maintaining stable blood pressure and a low normal sinus rhythm (Nishimura et al., 2014).

Normal sinus rhythm allows the heart to receive the atrial contribution and adequate LV filling in patients with AS (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021). Arrhythmias should be addressed promptly and corrected depending on the pathophysiology of the arrhythmia's origin (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021). Paul (2017) suggests applying external defibrillator pads before induction to correct any shockable arrhythmia. Maintaining a low-normal heart rate allows for sufficient time for LV filling and coronary perfusion (Whitener et al., 2021). Bradycardia causes a low cardiac output, while tachycardia compromises ventricular filling and the myocardial oxygen supply and demand relationship (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021).

Adequate fluid status assists in adequate preload (Whitener et al., 2021). The intravascular volume must be normal to high to ensure sufficient preload but prevent significant increases in left atrial pressure (Nishimura et al., 2014). Maintaining SVR after anesthesia induction is challenging, as many induction agents cause vasodilation and decrease SVR (Whitener et al., 2021). A study by Bendel et al. (2007) compared the incidence/severity of hypotension and other hemodynamic parameters in patients with AS who received propofol or etomidate with anesthesia induction. The researchers found that propofol caused more hypotension than etomidate, with negligible differences in heart rate, stroke volume, cardiac index, and pulmonary capillary wedge pressure (Bendel et al., 2007). Phenylephrine is the ideal vasopressor to maintain SVR without increasing heart rate and should be readily available to administer in the instance of hypotension (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021). Phenylephrine acts on peripheral alpha-1 receptors causing vasoconstriction, meaning adequate contractility is needed to ensure adequate cardiac output (Paul, 2017). Nishimura et al. (2014) also found norepinephrine to be a vasopressor with no adverse LV effects in patients with

AS. The physiologic consequence of anesthetic agents alters the hemodynamic variables listed above. The anesthesia provider must maintain hemodynamic stability by carefully titrating meds and using a multimodal approach of various anesthetic agents (Paul, 2017).

Intraoperative Monitoring. Intraoperative monitoring should, at minimum, align with ASA standards, emphasizing hemodynamic measurements (Nishimura et al., 2014; Whitener et al., 2021; Fleisher et al., 2014). The electrocardiogram (ECG) should be monitored closely to ensure the patient maintains sinus rhythm (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021). Whitener et al. (2021) suggest a five-lead ECG, paying close attention to leads II and V5 to monitor for myocardial ischemia changes. Intraoperative TEE may help assess fluid status and LV/aortic valvular function, guiding intraoperative decision-making (Nishimura et al., 2014; Paul, 2017; Whitener et al., 2021). However, the study by Nanditha et al. (2019) found that intraoperative TEE led to underestimating aortic valvular measurements, which could alter treatment decisions.

The data is conflicting on the importance of different options for invasive hemodynamic monitoring, such as an arterial line, central venous pressure, and pulmonary artery catheter. The AHA/ACC guidelines say NCS is reasonable for patients with AS with appropriate hemodynamic monitoring, but the authors negate including the definition of "hemodynamic monitoring" (Nishimura et al., 2014; Fleisher et al., 2014). Whitener et al. (2021) suggest that the data is weak on the significance of invasive hemodynamic monitoring. Whitener and colleagues (2021) suggest an awake insertion of an arterial line before induction of general anesthesia in patients with AS. Lastly, Paul (2017) suggests hemodynamic monitoring with an arterial line and inserting a pulmonary artery catheter to monitor central venous pressures.

Perioperative Outcomes

The literature describes outcomes associated with anesthesia in patients with AS who undergo NCS. Most articles discuss 30–90-day mortality and MACEs as measurable outcomes. As discussed previously, the evidence shows that patients with AS are at an increased risk of MACEs during NCS but not a higher risk for mortality (Tashiro et al., 2014; MacIntyre et al., 2018; Kwok et al., 2017). As the degree of AS worsens, the risk increases for undergoing NCS without valvular intervention (Nishimura et al., 2014). The anesthetic assessment and plan should aim to prevent a MACE in patients with AS undergoing NCS (Nishimura et al., 2017).

Evidence from studies stating that one strict anesthetic management strategy is superior is lacking. Studies from Bendel et al. (2007) and Chaves-Cordona et al. (2022) that were discussed previously, compare different management strategies in patients with AS. Case reports discuss different anesthetic management strategies and their effect on patient outcomes. However, case reports have many limitations due to low levels of evidence with small sample sizes.

The challenge of comparing anesthetic techniques and effects on outcomes lies in the dangers of cardiovascular collapse in patients with AS, as the pathophysiology of AS is well understood (Whitener et al., 2021). Most literature describes the risk associated with AS patients undergoing NCS or the anesthetic management plan. The perioperative risk evidence looks at the measurable outcomes described above in patients with AS who undergo NCS. The anesthetic management plan described in the literature is based on understanding pharmacology and normal versus pathophysiology. Regardless, choosing an anesthetic management strategy must consider the patient demographics, the severity of AS, surgical risk, and hemodynamic stability to prevent MACEs from occurring.

Model for Project Framework

The known pathophysiological background of AS places patients at risk for adverse events such as cardiovascular collapse and death if adequate hemodynamics are not maintained during anesthesia (Whitener et al., 2021). This fabricates a challenge for clinical trials on patients with AS undergoing NCS. It is unethical to compare interventions that knowingly cause hemodynamic compromise in patients with AS to determine which intervention may be deemed superior. Thus, the evidence-based practice (EBP) guidelines created through the DNP project are created with the Bayesian approach. The Bayesian approach is a theoretical framework and statistical method that uses known information and new data to infer a concept (Introna et al., 2022).

The Bayesian approach expresses the mathematical relationships between two elements (Introna et al., 2022). In clinical research, the two elements are the prior belief about a concept and data from the current evidence (Introna et al., 2022). The relationship is used to calculate the likelihood of a clinical outcome (Introna et al., 2022). In the proposed DNP project, the pathophysiological background of AS and the literature review data regarding anesthetic interventions allow the author to infer clinical outcomes based on those interventions. The Bayesian approach enables clinical guidelines to be created with the most current literature on anesthetic interventions and their effect on hemodynamics in patients with AS.

The Johns Hopkins EBP model (JHEBPM; Appendix C) is best for planning and implementing EBP guidelines and is used in the DNP project with permission (Appendix D). The JHEBPM contains a basic three-step process that involves a practice question, evidence, and translation (Upstate Medical University, 2023). Based on clinical inquiry of the topic, the author

created a practice question, identified the most up-to-date evidence to answer the question, and translated the evidence into practice (Upstate Medical University, 2023). The model provides steps the author must incorporate to translate the EBP guidelines into practice (Johns Hopkins Medicine, 2022). The author must ensure that the most recent evidence is used in the clinical guidelines. If new questions or evidence arise after implementation, the author will re-evaluate the guidelines to ensure that the most current evidence is used for practice improvements. Once implemented, an evaluation must occur to ensure the guidelines improve outcomes in the defined patient population. Measuring the outcomes allows the author to adjust the guidelines if outcomes do not improve. The JHEBPM allows for the planning, implementing, and evaluation of clinical guidelines for patients with AS undergoing NCS.

Design and Methods

The JHEBPM has three components embedded to initiate EBP guidelines (Johns Hopkins Medicine, 2022). The components are as follows: the practice question, evidence, and translation into practice (Johns Hopkins Medicine, 2022). The author uses the guide to complete the process of initiating clinical guidelines. Before a practice question is formed, inquiry drives the desire to create clinical guidelines. The inquiry is described in the "significance to anesthesia" section.

Practice Question

The first step is to recruit an interdisciplinary team within the desired rural health system (Johns Hopkins Medicine, 2022). The interdisciplinary team must include members from the parties involved/affected by the implementation of clinical guidelines. Anesthesia is involved in decision-making as the care provided directly is affected by implementing perioperative management guidelines. In the rural healthcare setting, the anesthesiologist performs pre-operative assessments while nurse anesthetists perform anesthesia intraoperatively, so both

disciplines must have members on the interdisciplinary team. The manager/leader of the operating room and preoperative nursing staff must be included, as some pre/peri-operative interventions could involve the nursing staff. Cardiology and interventional cardiology will be involved, as cardiac clearance/intervention may have to be done before NCS. Pharmacy will be involved as they are responsible for stocking medications that need to be readily available in the OR. Quality improvement (QI) should be involved to assist with measuring outcomes. Lastly, leadership within the health system will be involved as a valuable party to ensure the rest of the steps of the JHEBPM can be performed.

The second step involves selecting a project team leader (PTL) and determining the leader's responsibility (Johns Hopkins Medicine, 2022). The PTL is one of the nurse anesthetists on the interdisciplinary team. The PTL's responsibilities include coordinating project activities, ensuring project objectives meet the timeline, and exhibiting concern for the needs of the project, team members, and stakeholders. The PTL will also schedule team meetings and ensure all parties are active in the project's planning (Johns Hopkins Medicine, 2022). In the project meetings, the PTL describes the problem that is the basis for the need for EBP guidelines (Johns Hopkins Medicine, 2022). In the case of the proposed DNP project, the rate of perioperative MACEs in patients with AS undergoing NCS is the "problem" that needs to be addressed. The interdisciplinary team develops and refines the PICOT question to find appropriate evidence-based research (Johns Hopkins Medicine, 2022).

The stakeholders are identified as the constituents that benefit from clinical guidelines that improve outcomes (Johns Hopkins Medicine, 2022). The primary stakeholder for the proposed DNP project was the patients with AS undergoing NCS, whom are at significant risk for MACEs while undergoing NCS (Kwok et al., 2017). Patients with AS would benefit the most

from improved EBP guidelines. Secondary stakeholders include the anesthesia staff and the health system. The anesthesia staff would benefit from practice guidelines exhibiting EBP strategies for the safe perioperative management of patients with AS. The health system benefits from improved clinical guidelines as perioperative MACEs increase hospital length of stays and costs after surgery.

Evidence

This step describes the literature review or evidence portion of the model. The evidence review can be found in the "Literature Review" section of the DNP project paper. A literature search of the evidence using internal and external sources was conducted (Johns Hopkins Medicine, 2022). The author appraised the level and quality of the evidence, summarized the information, and completed a literature synthesis, which can be found in Appendix B (Johns Hopkins Medicine, 2022). After completion of the literature synthesis, EBP recommendations based on the literature search were exhibited (Johns Hopkins Medicine, 2022). The EBP practice guidelines are created using the Bayesian theory as described previously.

Translation

The translation step involves implementing the EBP guidelines, and the project team identifies setting-specific recommendations based on the literature (Johns Hopkins Medicine, 2022). The rural setting of the health system can present challenges for implementation. Rural setting health systems may lack the staff and resources to accommodate "gold standard" interventions due to the rarity of demand. Many rural setting hospitals do not have the volume of patients that inner-city health systems see. However, the rural setting is ideal for such guidelines to be implemented. Anesthesia staff in a rural hospital most likely do not see patients with AS

presenting for NCS as frequently as inner-city hospitals do. For these possibilities, improved practice guidelines are in greater need in a rural setting.

The project team created an action plan for implementing the EBP guidelines, which is described in the "Implementation Plan" section of the paper (Johns Hopkins Medicine, 2022). The project team must consider many factors to implement the guidelines. The team determines how to disseminate the education for the clinical guidelines and what tools are needed. The anesthesia, nursing (preoperative/operating room), and cardiology must be educated on the new guidelines. The team secures the support and resources needed to distribute information to the pertinent parties (Johns Hopkins Medicine, 2022). Once support, resources, and an implementation plan are secured, the next step is to implement the EBP guidelines (Johns Hopkins Medicine, 2022).

Evaluating outcomes must occur after guideline implementation (Johns Hopkins Medicine, 2022). Quality improvement (QI) involvement is pertinent at this point in the DNP project. The electronic medical record (EMR) is assessed retrospectively for patients with AS who underwent NCS after the implementation date. The QI team evaluates the incidences of MACEs (Appendix E) and compares the findings with pre-implementation values to determine if improvements in patient outcomes have been made (Johns Hopkins Medicine, 2022). Once the data is collected, the results are reported to the stakeholders (Johns Hopkins Medicine, 2022).

Lastly, the project team must determine the next steps for the DNP project. The DNP project team analyzes the evaluation from implementation and determines whether changes to the guidelines need to be made or continue. If outcomes improve, the guidelines will be maintained and monitored. If outcome improvements are not seen, steps must be taken to re-evaluate and make changes. The cause of unimproved outcomes must be identified to determine

what portion of the implementation plan needs to be adjusted. The project team will establish whether the unimproved outcomes originate in the guidelines, the education, or the compliance of practitioners using the guidelines. The team communicates verbally with the anesthesia, nursing, and cardiology staff quarterly to help determine the causes of unimproved outcomes. The team will send QI analyses via email and have in-person meetings on an as-needed basis.

Implementation Plan

To implement this project, the project team must obtain permission from the institutional review board (IRB) and the health system (since the DNP project is a QI project, the IRB process will be completed but not needed). Once permission is obtained, the project team performs education on the clinical guidelines (Appendix F). The team will perform education differently for the various disciplines involved with the guidelines, as the role of each discipline varies.

Anesthesia staff will be educated in a 30-minute morning meeting (coordinating with preset late-start surgeries) before the start of the first case of the day. The education will include an overview of the guidelines, how to apply them, and the charting requirements in the EMR software. The PTL will join the staff meeting to answer any questions regarding implementing the EBP guideline. The information provided in the meeting and the clinical guidelines will be emailed to all the anesthesia staff for reference. The clinical guidelines will be posted in the nurses' station in the pre-operative holding area for staff to view. The guidelines will also be published in every OR for quick intraoperative reference.

The nursing staff will be educated in a 15-minute morning meeting (the same day as the anesthesia staff). The education of the nursing staff will vary significantly from that of the anesthesia staff. The nurses will ask the patient, as part of their pre-operative checklist, to screen for diagnosis of aortic stenosis to notify the anesthesia staff. The nurses' education will be sent

via email for reference. Additionally, the operating room (OR) scheduler must be notified of the need for a late start on the education date. The cardiology department will be educated as well. The cardiology providers will be educated via email. The education includes the guidelines and how referrals for formative evaluations will be made for patients who qualify. The education for the health system leadership is minimal by providing a copy of the guidelines to understand what is being implemented in the operating room.

A TTE machine will be available in the cardiology department to evaluate the identified patients. If a TEE needs to be performed preoperatively, the machine will be available to the necessary personnel. There will be one TEE available for intraoperative monitoring in select patients. The medications needed to manage the defined patient population adequately will be provided. The medications utilized will not require additional supply to be added to the pyxis machines.

Data Collection

The project team will contact the information technology (IT) department for changes to be made to the EMR. The project team will ask the IT department to create a "pop-up" to be added to the intraoperative workflows for patients with AS to remind anesthesia providers of the disease process and to chart the needed information. The intraoperative charting will include a checkbox of the identified outcomes if they occur (perioperative MI, heart failure HF, stroke, and arrhythmia with hemodynamic compromise obtained through vital sign collection). The vital signs, medications, and dosages are part of the regular charting. The project team will contact the QI department to analyze the identified patients' charts to determine what medications/doses were given and the outcomes (occurrences of perioperative MI, HF, stroke, and arrhythmia with hemodynamic compromise) monthly to assess guideline efficacy.

Timeline

The proposed DNP project implementation plan is estimated to take 12 months. Appendix G shows a breakdown of the implementation timeline. The project team's development, research, and guidelines creation take the first three months. Training staff, purchasing needed equipment, and making changes to the EMR take an additional three months. Once resources, technological changes, and training are complete, the guidelines will be disseminated for clinical use in month six. The QI department, with the help of the EMR changes, will monitor outcomes and compliance monthly beginning in month seven. Once monitoring begins, the project team will look at the analytics from the QI department to determine if the guidelines are efficacious, which will take approximately three months beginning in month 10. The project team will adjust the guidelines, if needed, according to the findings at the 12-month mark.

Budget

The cost of implementing clinical guidelines must be accounted for in the implementation plan. Training the staff requires some of the departments to come in for additional training beyond their regular work schedules. The average salary for a nurse anesthetist in Ohio is $121 per hour (ZipRecruiter, 2023a). The health system employs approximately 35 nurse anesthetists, and they would have to be trained on the guidelines for 30 minutes, totaling an estimated $2,120. Additionally, approximately five nurse anesthetists would be trained in performing intraoperative TEE. The cost of the Society of Cardiovascular Anesthesiologists program would cost $2,099 per provider, totaling $10,495 (Society of Cardiovascular Anesthesiologists, 2023). The hospital employs approximately ten anesthesiologists who make, on average, $160 per hour (Indeed,

2023). The additional cost for the anesthesiologists' training is an estimated $800. The average nurse in Ohio makes $38 per hour, and the hospital employs approximately 50 operating room/preoperative nurses (ZipRecruiter, 2023b). The estimated cost of training the nursing staff in a 15-minute meeting would be $475.

Printing the guidelines to post in the ORs and in the nurses' station in the preop area would be minute to the project team's budget. The changes to the EMR would have to be created and added by an IT specialist. The average healthcare IT specialist in Ohio makes $42 per hour (Salary.com, 2023). The creation of the EMR addition would take approximately twelve hours to build, adding an additional estimated $504 to the project budget. Lastly, the need for an echocardiographic ultrasound machine should not be needed as the cardiology department should have a machine available to perform TTEs on patients, so the machine will not be included. However, the health system does not currently have a TEE transducer in the operating room, so a probe would have to be acquired. The average cost of a TEE probe ranges from $30,000 to $60,000, depending on the make and model purchased (McGuire et al., 2022). The total breakdown of the project budget can be found in Appendix H.

Outcome Analysis Plan

The DNP project's primary outcome is decreasing the incidence of perioperative MACEs from implementing EBP guidelines. The project team will contact the QI department for outcome analysis. The QI department will gather the incidences of pre-implementation perioperative MACEs with retrospective information from the EMR. The data the QI department will obtain includes the patients with AS who underwent NCS in the previous year and determine if there were any incidences of perioperative MACEs in the patient population. The QI department will

then gather all the post-implementation data described in the Data Collection section of the paper and compare the results to pre-implementation data.

Guideline Adjustments

Once the outcome comparison is completed with the help of the QI department, the project team decides whether the clinical guidelines are efficacious. The project team will make the guidelines the standard practice in the defined patient population if it is determined the guidelines are indeed improving patient outcomes. Improved outcomes would be decreased incidences of perioperative MI, HF, stroke, and arrhythmia with hemodynamic compromise. If the guidelines are not efficacious and patient outcomes do not improve or worsen, the project team will adjust the guidelines. Worsened outcomes would be increased incidences of perioperative MI, HF, stroke, and arrhythmia with hemodynamic compromise.

The causative factor for unimproved patient outcomes must be determined. The team will assess provider compliance through the EMR and ensure the preoperative evaluation algorithm and intraoperative management strategies are utilized. If anesthesia providers do not follow the guidelines, that could be a causative factor for unimproved outcomes. If the team finds the anesthesia staff disregarding the clinical guidelines, the cause will be determined and improved based on the providers' reasoning. For instance, if the provider is disregarding the guidelines for no clinically appropriate reason, more education would be necessary.

Once the project team determines provider compliance is being met, then, with the help of data collection from the QI department, the team will assess medication administration and determine if the correct drugs/dosages were being administered. When the project team determines that all portions of the clinical guidelines are being followed, the guidelines will be adjusted as there could be an issue with the guideline itself, causing worsened outcomes. To do this, the project

team will re-evaluate the literature and ensure the most current evidence is being used for perioperative management. The team will re-evaluate the research and utilize the evidence to make adjustments to improve patient outcomes.

Limitations

There are limitations to the proposed DNP project. AS is a pathophysiological condition that typically does not stand alone. Most patients with AS have other comorbidities that can affect the incidence of MACEs in NCS (Herrera et al., 2023). These include CAD and other valvular abnormalities, which can be causative factors in the outcomes assessed in this project. Another factor that can impact outcomes is the type and urgency of NCS. Tashiro et al. (2014) determined that emergency surgery was the strongest predictor of 30-day mortality in patients with AS. Surgery type can vary in length, severity, and technique depending on what NCS the patient with AS is undergoing. Unfortunately, the evidence for the specificity of a particular NCS is lacking. Surgery type and patient comorbidities must be considered when the project team reviews outcomes.

Conclusions

AS challenges the performance of anesthesia for the patient undergoing NCS. The pathophysiological consequences of AS and the hemodynamic changes associated with anesthesia induction and maintenance place the patient at a higher risk for MACEs in the perioperative period. The decision to perform NCS on patients with AS should be made on a patient-to-patient basis by the interdisciplinary team of anesthesia, the surgeon, and cardiology. Following the preoperative guideline is an algorithmic approach the interdisciplinary team can use to risk stratify a patient with AS for NCS. Intraoperatively, the EBP recommendations should be followed to assist the anesthesia provider with hemodynamic management for patients with AS undergoing NCS.

Collaboratively, the EBP guidelines can guide the anesthesia provider in perioperative management to decrease the incidences of MACEs in patients with AS undergoing NCS.

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Appendix A

Table 8. Stages of Valvular AS

Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
A	At risk of AS	• Bicuspid aortic valve (or other congenital valve anomaly) • Aortic valve sclerosis	• Aortic V_{max} <2 m/s	• None	• None
B	Progressive AS	• Mild-to-moderate leaflet calcification of a bicuspid or trileaflet valve with some reduction in systolic motion or • Rheumatic valve changes with commissural fusion	• Mild AS: Aortic V_{max} 2.0–2.9 m/s or mean ΔP <20 mm Hg • Moderate AS: Aortic V_{max} 3.0–3.9 m/s or mean ΔP 20–39 mm Hg	• Early LV diastolic dysfunction may be present • Normal LVEF	• None
C: Asymptomatic severe AS					
C1	Asymptomatic severe AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically is ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) • Very severe AS is an aortic V_{max} ≥5 m/s or mean ΔP ≥60 mm Hg	• LV diastolic dysfunction • Mild LV hypertrophy • Normal LVEF	• None: Exercise testing is reasonable to confirm symptom status
C2	Asymptomatic severe AS with LV dysfunction	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2)	• LVEF <50%	• None
D: Symptomatic severe AS					
D1	Symptomatic severe high-gradient AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) but may be larger with mixed AS/AR	• LV diastolic dysfunction • LV hypertrophy • Pulmonary hypertension may be present	• Exertional dyspnea or decreased exercise tolerance • Exertional angina • Exertional syncope or presyncope
D2	Symptomatic severe low-flow/low-gradient AS with reduced LVEF	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1.0 cm^2 with resting aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Dobutamine stress echocardiography shows AVA ≤1.0 cm^2 with V_{max} ≥4 m/s at any flow rate	• LV diastolic dysfunction • LV hypertrophy • LVEF <50%	• HF • Angina • Syncope or presyncope
D3	Symptomatic severe low-gradient AS with normal LVEF or paradoxical low-flow severe AS	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1.0 cm^2 with aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Indexed AVA ≤0.6 cm^2/m^2 and • Stroke volume index <35 mL/m^2 • Measured when patient is normotensive (systolic BP <140 mm Hg)	• Increased LV relative wall thickness • Small LV chamber with low stroke volume • Restrictive diastolic filling • LVEF ≥50%	• HF • Angina • Syncope or presyncope

AR indicates aortic regurgitation; AS, aortic stenosis; AVA, aortic valve area; AVAi, aortic valve area indexed to body surface area; BP, blood pressure; HF, heart failure; LV, left ventricular; LVEF, left ventricular ejection fraction; ΔP, pressure gradient; and V_{max}, maximum aortic velocity.

Note: Adopted from the 2014 AHA/ACC guideline for the management of patients with valvular heart disease

Appendix B

Literature Review Table with Themes

APA Citation: Bendel, S., Ruokonen, E., Pölönen, P., & Uusaro, A. (2007). Propofol causes more hypotension than etomidate in patients with aortic stenosis: a double-blind, randomized study comparing propofol and etomidate. *Acta Anaesthesiologica Scandinavica, 51*(3), 284-289. https://doi.org/10.1111/j.1399-6576.2006.01206.x								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Double-blind randomized study	**N/C:** 66 patients (33 to receive propofol and 33 to receive etomidate, chosen randomly) over the age of 18 scheduled for elective AVR due to AS. Clinicians were unaware of which induction agent was being given. **Exclusion Criteria:** adrenocortical insufficiency, chronic corticoid therapy, porphyria, allergy to any of the induction agents, BMI >35 kg/m2, expected intubation difficulty, GERD, serum creatinine level >160mmol/l, and other types of valvular diseases. **Attrition:** 6 total (3 per group) due to data collection failure. **Setting:** Kuopio University Hospital, Kuopio, Finland	**IV1:** Propofol **IV2:** Etomidate **DV:** Hemodynamic effects (MAP & HR, PCWP, CI, SV) and cortisol levels	**Primary outcome:** Hypotension after drug administration **Secondary outcome:** cortisol levels after administration Collected into database every 10 seconds and medians of 5 consecutive values were used for statistical analysis.	ANOVA for changes in variables between groups. Correlations calculated with Pearson test. Bonferroni correction used to adjust for multiple testing	Propofol caused more hypotension (P=0.006) No difference between the groups in HR changes No difference between the groups in SV, CI, and PCWP Patients receiving propofol were more likely to need intraoperative phenylephrine (P=0.002) Cortisol levels were lower in patients that received etomidate.	Level II	**Strengths:** level of evidence, study design **Weaknesses:** Single site study and attrition number could have slightly varied the outcomes. Age of the study is a potential weakness, but propofol and etomidate are drugs still used on a daily basis in anesthesia. **Feasibility of use:** Despite a different patient population, the information obtained can be applied to induction strategies for induction in patients with AS **Risk or harm:** Either drug, if managed correctly,

								can be given during induction of anesthesia to patients with AS, but etomidate causes less hypotension.

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; AVR= Aortic Valve Replacement; BMI= Body Mass Index; GERD= Gastroesophageal Reflux Disease; IV= Independent Variable; DV= Dependent Variable; MAP= Mean Arterial Pressure; HR= Heart Rate; PCWP; Pulmonary Capillary Wedge Pressure; CI= Cardiac Index; SV= Stroke Volume; ANOVA= Analysis of Variance

Annotated Bibliography statement:
The research article's authors are physicians that work for the Department of Anesthesia and Intensive Care at the Kuopio University Hospital in Finland. The study aimed to determine the hemodynamic effects of propofol versus etomidate as anesthetic induction agents in patients with diagnosed severe aortic stenosis. The sample size included 66 patients, 33 to receive propofol and 33 to receive etomidate, and it was performed as a double-blind, randomized trial. The primary outcome was hypotension after an induction dose of medication, and the second measurement was cortisol levels after the dose. The authors concluded that overall, propofol caused more hemodynamic instability than etomidate. The authors showed no bias in their research and combatted potential bias with the double-blind, randomized design. Although the study is from 2007, the formulations of propofol and etomidate have not changed, making their hemodynamic-altering characteristics the same. In addition, propofol and etomidate are two popular anesthetic induction agents, rendering valuable research for clinical guidelines in 2023.

Thematic Analysis
Key Themes or FSP related significance:

1. Propofol causes more hypotension than etomidate.
2. Patients who were induced with propofol, were more likely to need phenylephrine to combat the hypotension.
3. There was no difference in other hemodynamic parameters, such as heart rate and stroke volume, between the groups.

APA Citation: Chaves-Cardona, H. E., Ross Renew, J., Spaulding, A. C., & Porter, S. B. (2022). Comparison of mortality and serious complications in lower extremity total joint arthroplasty patients with aortic stenosis receiving spinal versus general anesthesia. *Anesthesiology Intensive Therapy, 54*(2), 108-113. https://doi.org/10.5114/ait.2022.117548

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Retrospective chart review	**N/C:** 163 patients (89 who received SA and 74 who received GA) over the age of 18 with AS who underwent lower extremity TJA. **Exclusion Criteria:** Patients <18 years old and >95 years old, patients who signed waiver to	**IV1:** Patients with AS who received GA **IV2:** Patients with AS who received SA **DV:** mortality and serious complications (described in next column)	**Primary outcomes:** 90-day mortality, blood transfusion, hospital LOS, and 90-day incidence of DVT, PE, MI, and stroke **Secondary outcome:** Perioperative incidence of unstable arrhythmias Collected through medical records	Study demographics and outcomes were described as frequency, percentages, or means and standard deviations. Categorial variables assessed with Pearson test. Continuous variables assessed by Kruskal-Wallis test	No significant differences found between groups in the incidence of 90-day mortality, serious complications (DVT, PE, MI, Stroke), or blood transfusion. No incidences of perioperative unstable arrhythmia	Level II	**Strengths:** level of evidence **Weaknesses:** With chart review, there is possible missing data or incorrect data entry into chart. Sample size is relatively small to conclude whether SA is safer than GA or vice versa. The severity of AS varied between groups.

		exclude their medical records from research studies, ASA classifications >4, non-elective lower extremity TJA, prior AVR, and pregnant cases **Attrition:** N/A **Setting:** Three unspecified hospitals within one health system			Propensity score matching models to determine differences in occurrences of complications.	in either group		**Feasibility of use:** Despite different clinical outcomes, the information obtained can be applied to anesthetic techniques for patients with AS undergoing NCS. **Risk or harm:** The hemodynamic requirements of AS typically cause SA to be a contraindication. The information provided is not sufficient to say the risk outweighs the benefit.

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; SA=Spinal Anesthesia; GA= General Anesthesia; TJA; Total Joint Arthroplasty; ASA=American Society of Anesthesiologists; AVR= Aortic Valve Replacement; NCS= Non-Cardiac Surgery; IV= Independent Variable; DV= Dependent Variable; LOS= Length of Stay; DVT= Deep Vein Thrombosis; PE= Pulmonary Embolism; MI= Myocardial Infarction

Annotated Bibliography statement:
The article's authors are members of the Department of Anesthesiology and Perioperative Medicine at the Mayo Clinic in Florida. Their anesthetic backgrounds give the authors credibility. The article compares the outcomes of patients with AS undergoing SA versus GA for TJA. The research design was a chart review of three health hospitals within one health system. The inclusion criteria included patients over the age of 18. The exclusion criteria included patients with ASA class greater than four, pregnant cases, previous AVR, age greater than 95, and patients who wished not to have their medical data used for research. The primary outcomes chosen for the study were 90-day mortality, blood transfusion, hospital LOS, and 90-day incidence of DVT, PE, MI, and stroke. The secondary outcome of perioperative arrhythmias was also included. The authors concluded no critical differences in outcomes between SA and GA. The authors showed no bias in their review. The limitation of the comparative study is that many variables are hard to assess by doing a chart review, limiting the determination of which method of anesthesia is safer.

Thematic Analysis
Key Themes or FSP related significance:

1. The outcomes after SA and GA are relatively the same in the review.
2. Patients who received SA received more phenylephrine intraoperatively (reader can infer that the sympathectomy caused from SA could be the reason why).
3. There are limitations to a chart review that must be considered.

APA Citation: Debry, N., Altes, A., Vincent, F., Delhaye, C., Schurtz, G., Nedjari, F., Legros, G., Porouchani, S., Coisne, A., Richardson, M., Cosenza, A., Verdier, B., Denimal, T., Pamart, T., Spillemaeker, H., Sylla, H., Sudre, A., Janah, D., Aouate, D., … Van Belle, E. (2021). Balloon aortic valvuloplasty for severe aortic stenosis before urgent non-cardiac surgery. *EuroIntervention, 17*(8), e680-e687. https://doi.org/10.4244/EIJ-D-20-01423

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***

N/A	Retrospective study	**N/C:** 133 patients with severe AS undergoing urgent NCS. 93 underwent preoperative BAV, and 40 had a conservative strategy that involved no BAV before urgent NCS. **Exclusion Criteria:** Patients undergoing AVR before NCS. Patients with high gradients or velocities, diseases that would affect doppler indices of AS. **Attrition:** N/A **Setting:** Two separate hospitals	**IV1:** Patients with AS who had BAV before urgent NCS **IV2:** Patients with AS who did not have BAV before urgent NCS. **DV:** MACE that included 1-month mortality, HF, MI, stroke, new onset atrial fibrillation, AKI, and life-threatening bleeding after NCS.	**Primary outcomes:** 1-month MACE **Secondary outcome:** Predictive factors of 1-month MACE, 3-month survival	Quantitative variables are expressed as means. Categorial variables expressed as percentages. Normality of distributions was assessed using histograms and the Shapiro-Wilk test. Primary outcomes analyzed with chi-square test or Fisher's exact test	Patients that do and do not receive BAV before urgent NCS have similar occurrences of 1-month MACE and 3-month survival	Level IV	**Strengths:** Comparison of an intervention and control group **Weaknesses:** Non-randomized design. Many variables can affect the outcome. **Feasibility of use:** The findings can be used to show there is no benefit to BAV. **Risk or harm:** There is no clear benefit to performing BAV before urgent NCS in patients with severe AS.

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; BAV= Balloon Aortic Valvuloplasty; AVR= Aortic Valve Replacement; IV= Independent Variable; DV= Dependent Variable; MACE= Major Adverse Cardiac Event; HF= Heart Failure; MI= Myocardial Infarction; AKI= Acute Kidney Injury

Annotated Bibliography statement:

The article's authors are members of the Department of Interventional Cardiology for Coronary, Valves, and Structural Heart Disease at the Heart Lung Institute in France. Their background in interventional cardiology gives the authors credibility to discuss BAV. The research aimed to determine the benefit of BAV in patients with AS requiring NCS. The researchers compared a control group that did not receive BAV before NCS (40 patients) to a group that underwent BAV before NCS (93 patients). The exclusion criteria included patients with high gradients that contributed to increased cardiac output, patients with AVR before NCS, and patients with disease processes that influenced Doppler indices of AS. The primary outcome evaluated was 1-month MACE. The secondary outcome measured is 3-month survival. The authors concluded that both groups have similar 1-month MACE and 3-month survival. The authors do not appear to have a bias in their research. The study's limitations include factors that were not measured that can affect the occurrence of 1-month MACE and 3-month mortality.

Thematic Analysis

Key Themes or FSP related significance:

1. BAV before NCS does not provide sufficient evidence to produce improved clinical outcomes.
2. Many hemodynamic parameters can affect clinical outcomes in patients with AS.
3. Conservative management of patients with severe AS before urgent NCS are at high risk for events.

APA Citation: Fleisher, L. A., Fleischmann, K. E., Auerbach, A. D., Barnason, S. A., Beckman, J. A., Bozkurt, B., Davilla-Roman, V. G., Gerhard-Herman, M. D., Holly, T. A., Kane, G. C., Marine, J. E., Nelson, M. T., Spencer, C. C., Thompson, A., Ting, H. H., Uretsky, B. F., & Wijeysundera, D. N. (2014). 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: executive summary. *Journal of the American College of Cardiology, 64*(22), 2373-2405. http://dx.doi.org/10.1016/j.jacc.2014.07.945

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Conceptual Framework or Model	*Design or Method*	*Sample & Setting*	*Major Variables Studied & their Definitions*	*Outcome Measurement(s)*	*Data Analysis*	*Findings*	*Level of Evidence*	*Quality of Evidence: Critical Worth to Practice*
N/A	Clinical Guideline created through systematic review	**N/C:** 9 articles were reviewed for valvular heart disease focusing on RCTs but also registries, nonrandomized comparative and descriptive studies, case studies, cohort studies, systematic reviews, and expert opinion **Searched:** MEDLINE, EMBASE, the Cochrane Library, Agency for Healthcare Research and Quality Reports, and others **Exclusion Criteria:** Studies that did not involve human subjects and were not published in English **Attrition:**N/A **Setting:** Varied study to study	**IV1**: AS **DV**: In hospital and 30-day mortality, MI, Ventricular arrhythmias, intraoperative hypotension requiring vasopressor	Rate of in hospital and 30-day mortality, MI, Ventricular arrhythmias, intraoperative hypotension requiring vasopressor were collected in differently in each study.	Varied study to study selected. Research used to create clinical recommendations	**1.** Patients with valvular stenosis should undergo preoperative echocardiography if there has been no prior echocardiography within 1 year or change in clinical status. **2.** Those patients who meet requirements, should have valvular intervention before elective NCS **3.** Elevated risk elective non-cardiac surgery with appropriate hemodynamic monitoring is reasonable to perform in patients with asymptomatic AS.	Level I	**Strengths:** level of evidence, number of studies included **Weaknesses:** Some studies used are not RCTs **Feasibility of use:** The recommendations provided can be implemented to risk stratify and manage patients with AS perioperatively. **Risk or harm:** Risk varies depending on degree of AS, but typically performing NCS with AS is safe with proper management.

Legend

N/C= Number & Characteristics; RCT= Randomized Controlled Trial AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; IV= Independent Variable; DV= Dependent Variable; MI= Myocardial Infarction;

Annotated Bibliography statement:

The authors of the clinical guidelines are physicians that are writing committee members for the ACC and AHA. The purpose was to create evidence-based guidelines for the perioperative cardiovascular management and evaluation of patients undergoing NCS to improve patient-centered quality care. The intended audience is medical professionals needing guidance on evaluating and managing patients undergoing NCS. The authors created guidelines for various cardiac disease processes, but the anesthetic guidelines for patients with valvular heart disease came from nine research articles. The authors searched multiple databases and excluded articles that did not involve human subjects and were not written in English. The articles used to create clinical guidelines determined the effect of AS and its impact on clinical outcomes. The clinical outcomes across the studies were in-hospital and 30-day mortality, MI, ventricular arrhythmias, and hypotension requiring vasopressor use. The guidelines state that patients with valvular heart disease should undergo preoperative echocardiography if there has been no prior echocardiography within one year or a change in clinical status. The patients that meet valvular intervention criteria should have intervention before NCS. The authors also determined that NCS is safe to perform with appropriate hemodynamic monitoring in patients with asymptomatic AS. The 2014 guidelines pose a risk for newer research to discredit the findings. However, the findings correlate with other research within the last five years. The authors show no bias or skewing of results in their study.

Thematic Analysis
Key Themes or FSP related significance:

1. echocardiography if there has been no prior echocardiography within 1 year or change in clinical status.
2. Patients who meet criteria, should have valvular intervention prior to NCS.
3. NCS is safe to perform in patients with asymptomatic AS with appropriate monitoring.

APA Citation: Kwok, C. S., Bagur, R., Rashid, M., Lavi, R., Cibelli, M., de Belder, M. A., Moat, N., Hildick-Smith, D., Ludman, P., & Mamas, M. A. (2017). Aortic stenosis and non-cardiac surgery: A systematic review and meta-analysis. *International Journal of Cardiology, 240*(1), 145-153. https://dx.doi.org/10.1016/j.ijcard.2017.04.037
Funding: North Staffs Heart Committee

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Systematic Review and Meta-Analysis	**N/C:** 9 retrospective observational studies were selected. Sample size ranged from 44-15,433 participants and total number of participants was 29,327 (mean age: 74, 51% male). **Searched:** 2 databases, MEDLINE & EMBASE inclusion criteria: Evaluated mortality and adverse cardiovascular events in patients with AS who underwent NCS. **Exclusion Criteria:** Studies that were case reports, didn't have a control group (free of AS) for comparison **Attrition:** 49 reviewed and 41 excluded for not meeting	**IV1:** AS **IV2:** NCS **DV:** Mortality and adverse cardiovascular events (MI, HF, stroke)	Mortality and composite adverse cardiovascular events and collection strategy varied from study to study.	Data analysis conducted with RevMan 5.3. Meta-analysis conducted with dichotomous analysis method. Statistical heterogeneity assessed with I^2 statistic.	Risk ratio M-H, Random, 95% CI Composite outcome: 2.30 Mortality: 1.49 MI: 1.65 HF: 1.42 Stroke: 0.44	Level I	**Strengths:** Level 1 evidence and study design **Weaknesses:** All studies were retrospective, 6 were case-control design. Studies did not report patients that were lost to follow-up. CAD's effect on clinical outcomes. Grading of AS from different sources across studies. Difference in anesthetic technique among studies. **Feasibility of Use:** The recommendations provided can be implemented to risk stratify and manage patients with AS perioperatively. **Risk or harm:** Benefits outweigh risks

		inclusion criteria **Setting:** Studies derived from USA, Denmark, Netherlands, Ireland, Japan, and Canada						

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; IV= Independent Variable; DV= Dependent Variable; MI= Myocardial Infarction; HF= Heart Failure; CI= Confidence Interval; CAD= Coronary Artery Disease

Annotated Bibliography statement:
The article's authors are from various hospitals in the United Kingdom and Canada with cardiology, anesthesiology, and epidemiology backgrounds. The different locations provide multiple views of the topic, reducing the chance of bias. The article aimed to investigate mortality and adverse cardiovascular events in patients with and without AS undergoing NCS. The authors created a systematic review and meta-analysis, searching two databases. Inclusion criteria included studies with a comparison group that included patients without AS. The exclusion criteria included case reports and studies without a comparison group. The primary outcomes were mortality and adverse cardiovascular events, including MI, HF, and stroke. The authors concluded that patients with AS undergoing NCS are not at higher mortality risk but have higher rates of adverse cardiovascular events. The authors do not show any bias in their literature review. The limitations to the review include the level of evidence of the articles chosen for study and the variables that can affect clinical outcomes that were not measured.

Thematic Analysis
Key Themes or FSP related significance:

1. Patients with AS are at a higher risk for adverse cardiovascular events compared to patients without AS undergoing NCS.
2. Many variables can affect clinical outcomes in patients with AS such as CAD, anesthetic technique, etc.
3. Patients with AS are not at increased risk of mortality compared to patients without AS undergoing NCS.

APA Citation: MacIntrye, P. A., Scott, M., Seigne, R., Clark, A., Deveer, F., & Minchin. I. (2018). An observational study of perioperative risk associated with aortic stenosis in non-cardiac surgery. *Anaesthesia and Intensive Care, 46*(2), 207-214. https://doi.org/10.1177/0310057X1804600211

Funding: Grant from the Medical Research Fund, Nelson Hospital, New Zealand

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Observational study	**N/C:** 5 hospitals selected for an observational study. Study included 147 patients with moderate or severe AS undergoing varying levels of NCS. **Exclusion Criteria:** Patients with mild AS and patients who declined or	**IV1:** AS **IV2:** NCS **DV:** 30-day mortality and MACE not causing death (includes acute MI, acute HF, arrhythmia with hemodynamic compromise, and cardiac arrest with successful resuscitation).	30-day mortality and MACEs collected by daily review of patients during admission If patient left hospital before 30 days post-op, a date of death record was looked for in hospital database	Associations between preoperative factors and outcomes assessed using Pearson chi-square test or ANOVA. Univariate differences with P-value of 0.05 or less underwent multiple logistic regression	13 patients died within 30 days of surgery 33 patients had a MACE: 4 cardiac arrests (1 fatality) 17 arrhythmias 9 acute MIs 13 acute episodes of HF	Level III	**Strengths:** Outcomes strategically measured considering comorbidities. **Weaknesses:** The severity and risk of surgery varied from patient to patient. The contribution of AS to perioperative outcomes can be challenged by multiple comorbidities.

		were refused the planned surgery. **Attrition:** N/A **Setting:** urban hospitals in New Zealand			analyses to identify independent variables associated with adverse outcomes.			Potential selection bias **Feasibility of Use:** Despite the varying levels of severity and comorbidities among the patients, the information provided can be implemented to risk stratify patients with AS preoperatively. **Risk or harm:** Must be assessed on a patient-to-patient basis

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; IV= Independent Variable; DV= Dependent Variable; MACE= Major Adverse Cardiac Event; MI= Myocardial Infarction; HF= Heart Failure;

Annotated Bibliography statement:
The article's authors are members of various anesthesia departments across multiple health systems in New Zealand. Their background in anesthesia gives the authors credibility to discuss perioperative risk. The study aimed to evaluate clinical outcomes in patients with AS undergoing NCS and identify preoperative factors that can affect adverse outcomes. The intended audience is practicing clinicians who will be involved in the perioperative care of patients with AS undergoing NCS. The design was an observational study across five urban hospitals in New Zealand from 2011 to 2015. The population included 147 patients with moderate or severe AS undergoing various levels of NCS. The exclusion criteria included patients without surgery and those with mild AS. The researchers assessed the primary outcomes of 30-day mortality and MACE not causing death. The authors show no bias in their research. The researchers found that 13 patients died within 30 days of surgery, and 33 patients had a MACE. The study's limitations include its observational design, sample size, and other clinical factors/comorbidities that can affect MACE occurrence in patients with AS undergoing NCS. The authors concluded from their study that patients with severe AS are at an increased risk for adverse outcomes than patients with moderate AS undergoing NCS.

Thematic Analysis
Key Themes or FSP related significance:

1. Patients with severe AS are at a higher risk for adverse outcomes compared to patients with moderate AS undergoing NCS.
2. Many preoperative factors can affect the rate of adverse outcomes in patients with AS undergoing NCS.
3. Symptomatic patients with AS had worse clinical outcomes than asymptomatic patients.
4. Aortic valve area correlates with 30-day mortality.

APA Citation: Nanditha, S., Malik, V., Hasija, S., Malhotra, P., Sreenivas, V., & Chauhan, S. (2019). Comparison of grading of aortic stenosis between transthoracic and transesophageal echocardiography in adult patients undergoing elective aortic valve replacement surgeries: A prospective observational study. *Annals of Cardiac Anesthesia, 22*(2), 194-198. https://doi.org/10.4103/aca.ACA_4_18

Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***

N/A	Prospective observational study	**N/C:** 60 patients with severe AS undergoing elective AVR or CABG with AVR **Exclusion Criteria:** Patients <18 and >80. Patients with other valvular abnormalities, paradoxical low flow, low-gradient AS with normal LVEF, hemodynamic instability, patients with contraindication to TEE placement, and patients with a poor TTE window **Attrition:** N/A **Setting:** not specified	**IV1:** TTE **IV2:** TEE **DV:** Accuracy in mean gradient across aortic valve, peak jet velocity, aortic valve area	Pressure gradient, peak jet velocity obtained through continuous-wave doppler tracing. Aortic valve area calculated using a continuity equation Dimensionless index used to grade AS to counter any disparity	Data analysis conducted with STATA/IC 14.2 software and presented as mean (with standard deviation) and frequency percentage. Changes within variable measured by paired t-test	Peak aortic jet velocity and pressure gradient across aortic valve was underestimated in more than 75% of patients with TEE. Aortic valve area measurement through continuity equation and dimensionless index are reliable between TTE and TEE.	Level III	**Strengths:** Comparative study of two interventions. **Weaknesses:** The study was completed on patients with severe AS and results could have varied with other levels of severity. **Feasibility of Use:** TEE can be used intraoperatively for severity assessment of AS but there are limitations to its use such as underestimation of peak jet velocity and pressure gradient and the contraindications to its use. **Risk or harm:** There is benefit that outweighs risk with intraoperative TEE.

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; AVR= Aortic Valve Replacement; CABG= Coronary Artery Bypass Graft; LVEF= Left Ventricular Ejection Fraction; TEE= Transesophageal Echocardiography; TTE= Transthoracic Echocardiography; IV= Independent Variable DV= Dependent Variable

Annotated Bibliography statement:

The article's authors are members of the Departments of Cardiac Anesthesia and Biostatistics at the All India Institute of Medical Science in New Delhi, India. The experience the medical professionals have with biostatistics and the usage of TTE and TEE gives them the credibility to discuss the topic. The study aimed to compare the preoperative grading of AS with the use of TTE and TEE in patients with diagnosed severe AS undergoing elective AVR. The intended audience is medical professionals who interpret results using TTE or TEE to grade AS. The study was prospective in design, and the population was 60 patients with severe AS undergoing elective AVR or CABG with AVR. The exclusion criteria included patients not in the age range of 18-80, patients with other valvular abnormalities, low flow, low gradient AS with normal LVEF, hemodynamic instability, and patients with contraindications to TEE. The researchers compared TTE and TEE by assessing the mean gradient, peak jet velocity, and aortic valve area accuracy. The authors did not show any bias in their study. They concluded that peak jet velocity and mean pressure gradient across the aortic valve were underestimated in more than 75% of patients receiving intraoperative TEE. In contrast, the aortic valve area was comparable between TEE and TTE. The study's limitations include only patients with severe AS being assessed and the effect of left ventricular dysfunction and arrhythmias on parameters.

Thematic Analysis

Key Themes or FSP related significance:

1. Calculating aortic valve area is comparable between TTE and TEE.
2. Intraoperative TEE underestimated peak jet velocity and mean pressure gradient in more than 75% of patients.
3. Left ventricular dysfunction and arrhythmias could affect results and are common in patients with AS.

APA Citation: Otto, C. M., Nishimura, R. A., Bonow, R. O., Carabello, B. A., Erwin III, J. P., Gentile, F., Jneid, H., Krieger, E. V., Mack, M., McLeod, C., O'Gara, P. T., Rigolin, V. H., Sundt III, T. M., Thompson, A., Toly, C. (2021). 2020 AHA/ACC guideline for the management of patients with valvular heart disease: executive summary. *Circulation, 143*(5), e35-e71. https://doi.org/10.1161/CIR.0000000000000923 **Developed in collaboration with and endorsed by the American Association for Thoracic Surgery, American Society of Echocardiography, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons**								
Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement(s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Clinical Guideline created through systematic review	**N/C:** 122 articles were reviewed for valvular heart disease focusing on RCTs but also registries, nonrandomized comparative and descriptive studies, case studies, cohort studies, systematic reviews, and expert opinion **Searched:** MEDLINE, EMBASE, the Cochrane Library, Agency for Healthcare Research and Quality Reports, and others **Exclusion Criteria:** Studies that did not involve human subjects and were not published in English **Attrition:**N/A **Setting:** Varied study to study	**IV1**: AS **DV**: Varied study to study as some articles looked for varying clinical outcomes.	Rate of in hospital and 30-day mortality, MI, Ventricular arrhythmias, intraoperative hypotension requiring vasopressor collected differently in each study.	Varied study to study selected. Research used to create clinical recommendations	**1.** Patients with AS should undergo preoperative echocardiography if there has been no prior echocardiography within 1 year or change in clinical status. **2.** Those patients who meet requirements, should have AVR before elective NCS **3.** Elevated risk elective non-cardiac surgery with appropriate hemodynamic monitoring is reasonable to perform in patients with asymptomatic AS. 4. In patients with AS an anesthetic approach that does not cause hemodynamic compromise should be utilized.	Level I	**Strengths:** level of evidence, number of studies included **Weaknesses:** Some studies used are not RCTs **Feasibility of use:** Despite varying clinical outcomes in the literature, the recommendations provided can be implemented to risk stratify and manage patients with AS perioperatively. **Risk or harm:** Risk varies depending on degree of AS, but typically performing NCS with AS is safe with proper management.

Legend

N/C= Number & Characteristics; RCT= Randomized Controlled Trial; AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; IV= Independent Variable; DV= Dependent Variable; MI= Myocardial Infarction

Annotated Bibliography statement:
The authors of the clinical guidelines are physicians that are writing committee members for the ACC and AHA. The purpose was to provide recommendations for practicing clinicians to diagnose and manage valvular heart diseases and provide evidence to support/encourage using the guidelines. The authors selected 122 articles for review using various databases. The exclusion criteria included articles that did not involve human subjects and were not written in English. The variables studied included AS and its effect on clinical outcomes such as in-hospital and 30-day mortality, MI, ventricular arrhythmias, and hypotension requiring vasopressor use. The guidelines state that patients with valvular heart disease should undergo preoperative echocardiography if there has been no prior echocardiography within one year or a change in clinical status. The patients that meet the criteria should have valvular intervention before NCS. The authors also determined that NCS is safe to perform with appropriate hemodynamic monitoring in patients with asymptomatic AS. Lastly, the anesthetic approach should not cause hemodynamic compromise in patients with AS. The guidelines were created in 2014 and were updated in 2020, making the information current and acceptable. The authors show no bias or skewing of results and clearly label the level of evidence that supports their recommendations.

Thematic Analysis
Key Themes or FSP related significance:

1. echocardiography if there has been no prior echocardiography within 1 year or change in clinical status.
2. Patients who meet criteria, should have valvular intervention prior to NCS.
3. NCS is safe to perform in patients with asymptomatic AS with appropriate monitoring.
4. The anesthetic approach to managing patients with AS should not cause hemodynamic compromise.

APA Citation: Tashiro, T., Pislaru, S. V., Blustin, J. M., Nkomo, V. T., Abel, M. D., Scott, C. G., & Pellikka, P. P. (2014). Perioperative risk of major non-cardiac surgery in patients with severe aortic stenosis: a reappraisal in contemporary practice. *European Heart Journal, 35*(35), 2372-2381. https://doi.org/10.1093/eurheartj/ehu116

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Conceptual Framework or Model	***Design or Method***	***Sample & Setting***	***Major Variables Studied & their Definitions***	***Outcome Measurement (s)***	***Data Analysis***	***Findings***	***Level of Evidence***	***Quality of Evidence: Critical Worth to Practice***
N/A	Retrospective study	**N/C:** 256 patients with echocardiographic evidence of severe AS who underwent major NCS between 2000 and 2010. Control group who did not have AS were selected to match for age, gender, and year. **Exclusion Criteria:** Patients undergoing AVR before NCS. Patients with high gradients or velocities, diseases that would affect doppler indices of AS.	**IV1:** Severe AS **IV2:** major NCS **IV3:** Patients without AS **DV:** Perioperative MACE (death, MI, stroke, ventricular tachycardia or fibrillation, new or worsening heart failure occurring within the first 30 days of surgery	Perioperative MACE and MACEs within 30 days of surgery	Statistical analysis was performed using the JMP software version 9.0 and SAS version 9.3. Baseline characteristics compared between AS and control groups using conditional logistic regression analyses. Symptomatic versus asymptomatic AS groups were compared using Pearson or	Severe AS is associated with increased risk of MACE after NCS Perioperative mortality is lower than previous articles claim. Emergency surgery was the strongest predictor of postoperative death.	Level IV	**Strengths:** Comparative study of group with severe AS and control group **Weaknesses:** Retrospective design, possibility of missing patients with severe AS that did not receive preoperative echocardiography, and intraoperative factors that could affect outcomes. **Feasibility of Use:** The recommendations provided can be implemented to risk stratify and manage

		Attrition: N/A **Setting:** Mayo Clinic Rochester Campus			two sample t-tests. Survival analysis conducted by Kaplan-Meier method.			patients with AS perioperatively. **Risk or harm:** Varies patient to patient

Legend

N/C= Number & Characteristics; AS= Aortic Stenosis; NCS= Non-Cardiac Surgery; AVR= Aortic Valve Replacement; IV= Independent Variable; DV= Dependent Variable; MACE= Major Adverse Cardiac Event; MI= Myocardial Infarction;

Annotated Bibliography statement:

The article's authors are members of the Departments of Cardiovascular Disease, Anesthesiology, and Health Science Research at the Mayo Clinic in Rochester, Minnesota. The study evaluated the risk of major NCS in patients with severe AS in contemporary practice. The intended audience is practicing clinicians who will participate in the perioperative management of patients with AS undergoing major NCS. The researchers identified 256 patients with severe AS undergoing intermediate to high-risk NCS from surgical databases from 2000-2010. They matched control patients without AS with the same age, sex, and year of surgery. The exclusion criteria included patients undergoing AVR before NCS and patients with valvular factors that could affect Doppler indices of AS. The primary outcomes measured were perioperative and 30-day MACE. There was no bias in the design and interpretation of the study. The study's limitations were its retrospective design and intraoperative factors that can affect clinical outcomes. The authors concluded that severe AS correlates with a higher risk of MACE after major NCS, and perioperative mortality was similar to patients without severe AS.

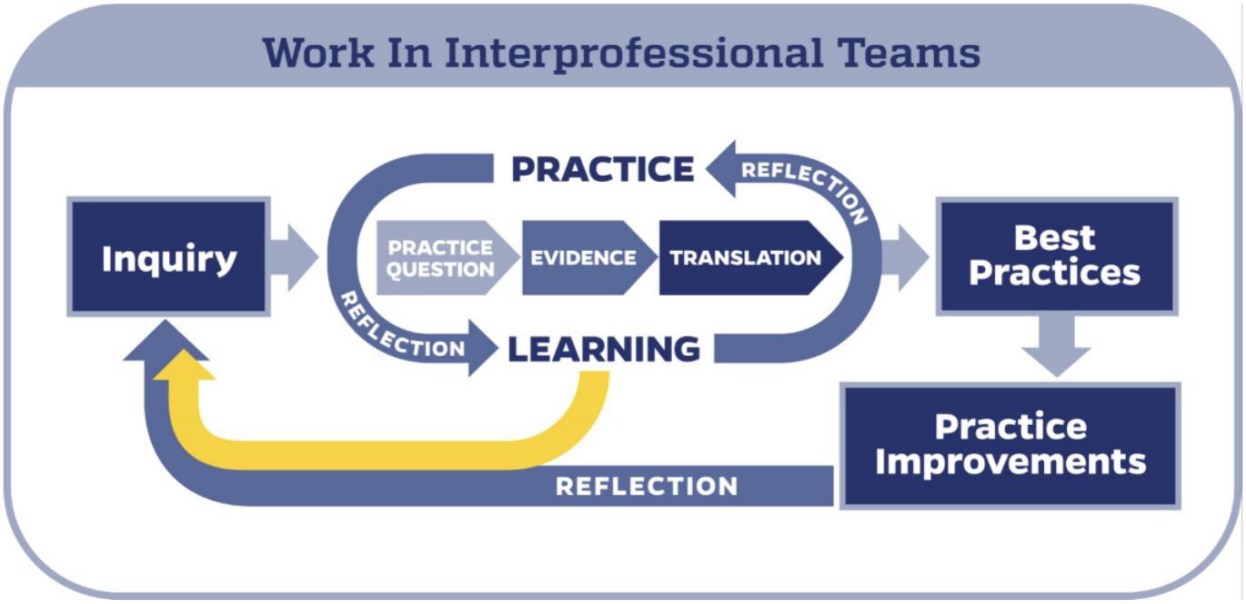
Thematic Analysis

Key Themes or FSP related significance:

1. Patients with severe AS are an increased risk of MACE after NCS.
2. Mortality in patients with and without severe AS is comparable.
3. Emergency NCS was the strongest predictor of postoperative death.
4. New or worsening heart failure is increased in patients with severe AS after NCS.

Appendix C

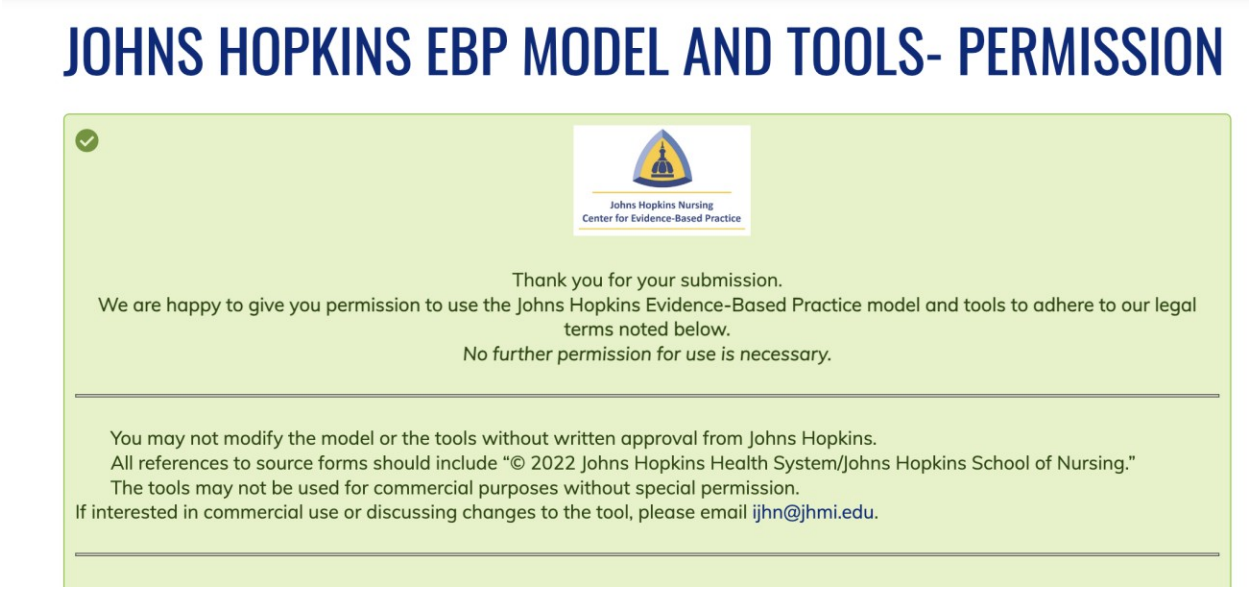
JHEBPM



Note: JHEBPM, PET portion is what is utilized for implementation of this project

Appendix D

JHEBPM Permission



Note: Johns Hopkins Evidence-Based Practice Model permission obtained through Johns Hopkins Medicine

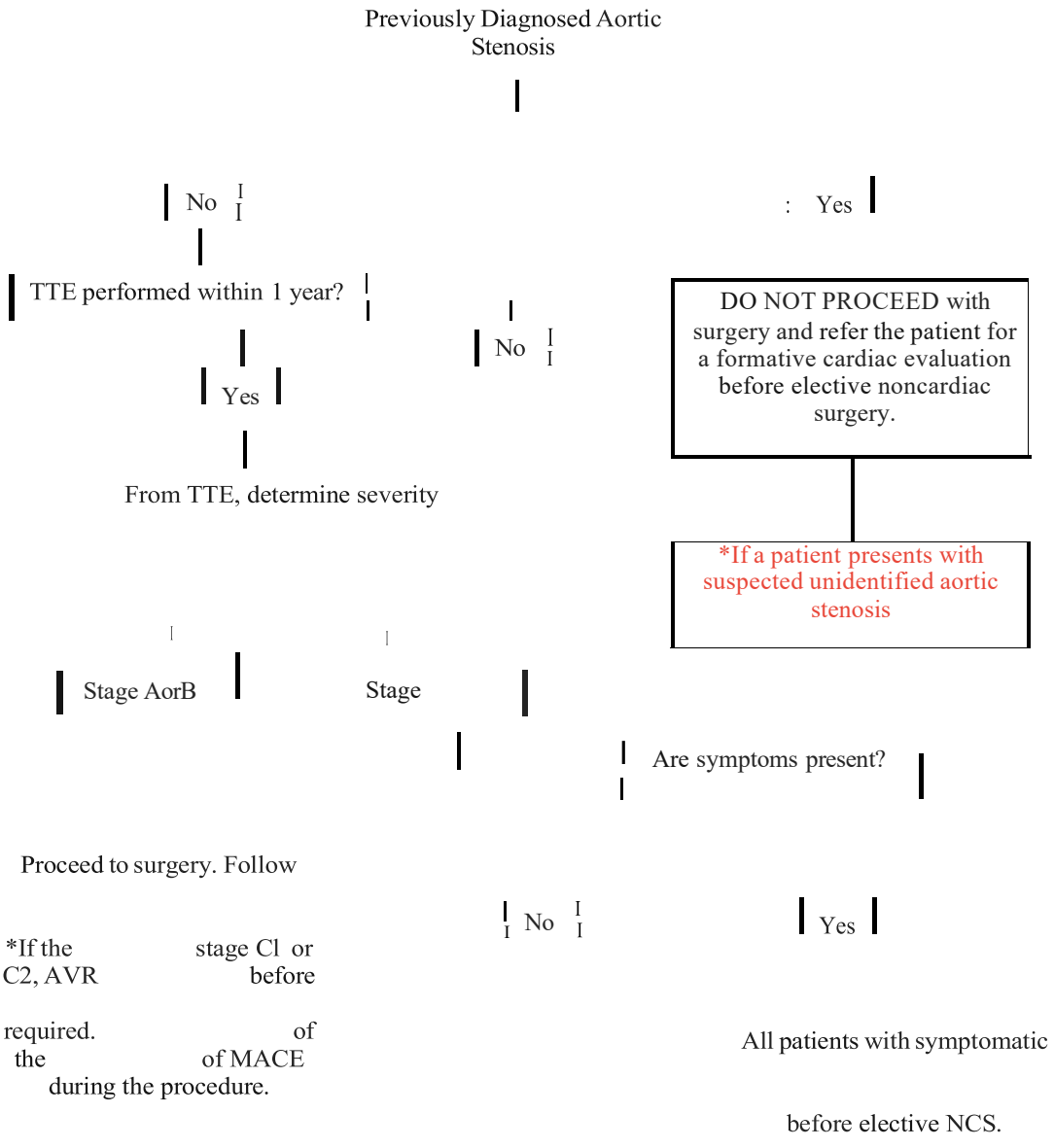
Appendix E

Number of Incidences	MACE
	MI
	HF
	Stroke
	Arrhythmia with hemodynamic compromise

Note: MI=Myocardial Infarction; HF=Heart Failure

Appendix F

Clinical Guideline



*IN THE EVENT OF EMERGENT NONCARDIAC SURGERY, THE

Table 8. Stages of Valvular AS

Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
A	At risk of AS	• Bicuspid aortic valve (or other congenital valve anomaly) • Aortic valve sclerosis	• Aortic V_{max} <2 m/s	• None	• None
B	Progressive AS	• Mild-to-moderate leaflet calcification of a bicuspid or trileaflet valve with some reduction in systolic motion or • Rheumatic valve changes with commissural fusion	• Mild AS: Aortic V_{max} 2.0–2.9 m/s or mean ΔP <20 mm Hg • Moderate AS: Aortic V_{max} 3.0–3.9 m/s or mean ΔP 20–39 mm Hg	• Early LV diastolic dysfunction may be present • Normal LVEF	• None
C: Asymptomatic severe AS					
C1	Asymptomatic severe AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically is ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) • Very severe AS is an aortic V_{max} ≥5 m/s or mean ΔP ≥60 mm Hg	• LV diastolic dysfunction • Mild LV hypertrophy • Normal LVEF	• None: Exercise testing is reasonable to confirm symptom status
C2	Asymptomatic severe AS with LV dysfunction	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2)	• LVEF <50%	• None
D: Symptomatic severe AS					
D1	Symptomatic severe high-gradient AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) but may be larger with mixed AS/AR	• LV diastolic dysfunction • LV hypertrophy • Pulmonary hypertension may be present	• Exertional dyspnea or decreased exercise tolerance • Exertional angina • Exertional syncope or presyncope
D2	Symptomatic severe low-flow/low-gradient AS with reduced LVEF	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1.0 cm^2 with resting aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Dobutamine stress echocardiography shows AVA ≤1.0 cm^2 with V_{max} ≥4 m/s at any flow rate	• LV diastolic dysfunction • LV hypertrophy • LVEF <50%	• HF • Angina • Syncope or presyncope
D3	Symptomatic severe low-gradient AS with normal LVEF or paradoxical low-flow severe AS	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1.0 cm^2 with aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Indexed AVA ≤0.6 cm^2/m^2 and • Stroke volume index <35 mL/m^2 • Measured when patient is normotensive (systolic BP <140 mm Hg)	• Increased LV relative wall thickness • Small LV chamber with low stroke volume • Restrictive diastolic filling • LVEF ≥50%	• HF • Angina • Syncope or presyncope

AR indicates aortic regurgitation; AS, aortic stenosis; AVA, aortic valve area; AVAi, aortic valve area indexed to body surface area; BP, blood pressure; HF, heart failure; LV, left ventricular; LVEF, left ventricular ejection fraction; ΔP, pressure gradient; and V_{max}, maximum aortic velocity.

Note: Adopted from the 2014 AHA/ACC guideline for the management of patients with valvular heart disease

1) Intraoperative Management
   a) Anesthetic Technique
      i) General Anesthesia is safe to perform.
      ii) Peripheral nerve blocks are safe to perform.
      iii) Neuraxial anesthesia should be avoided due to sympathetic nervous system blockade.
   b) Induction/Intraoperative Maintenance
      i) Avoid drops in systemic vascular resistance as it decreases diastolic blood pressure and prevents the driving force of coronary perfusion.
         (1) Propofol is safe to use with low doses titrating to effect maintaining blood pressure.
            (a) Evidence supports moderate opiate dose (fentanyl) with lower dose of propofol.

(2) Evidence shows etomidate causes less hypotension than propofol.
(3) Some evidence supports the use of low-dose benzodiazepine, fentanyl, and etomidate with the addition of low-dose sevoflurane with induction.
(4) Have vasopressor ready for immediate administration with signs of hypotension.
(a) Phenylephrine is shown to be the pressor of choice as it increases systemic vascular resistance while maintaining cardiac output.
(b) Norepinephrine and vasopressin have safe profiles as well.

ii) Goal should be to maintain low-normal sinus rhythm (heart rate 60-80 bpm).
iii) Avoid arrythmias to ensure adequate left ventricular filling from atrial kick.
iv) Maintain intravascular fluid volume status to ensure adequate ventricular filling but careful not to fluid overload the patient.
v) In the event of systemic hypertension, treat with arterial dilators vs. pre-load reducing agents (venous dilators).
(1) Use short-term calcium-channel blockers like nicardipine and hydralazine.
(2) Avoid venous dilators such as nitroglycerine.

c) Intraoperative Monitoring
i) Standard ASA monitors should be applied at minimum with emphasis on the ECG and blood pressure.
ii) The evidence suggests applying a 5-lead ECG and paying close attention to leads II and V5 to monitor for myocardial ischemic changes.
iii) Invasive monitoring
(1) Insertion of an arterial line pre-induction is suggested in the literature.
(2) In the event of caring for a patient with severe aortic stenosis (stages C & D):
(a) Arterial line insertion
(b) Evidence supports the use of intraoperative TEE to monitor left ventricle.
(c) Some evidence supports the insertion of a central venous catheter to monitor central venous pressure.
(i) *Up to the discretion of the provider
(d) Some evidence supports the insertion of a pulmonary artery catheter.
(i) *Up to the discretion of the provider

d) Emergence
i) Maintain normotension and low-normal sinus rhythm.
ii) If reversing paralytic:
(1) Sugammadex if possible.
(2) If using neostigmine and glycopyrrolate, administer both close together to prevent extreme changes in heart rate.

Appendix G

Implementation Timeline

Month	1	2	3	4	5	6	7	8	9	10	11	12
Creation of the Team and Guidelines												
Training and Technology												
Implementation of the Guidelines												
QI analysis of compliance/outcomes												
Adjustment of Guidelines												

Appendix H

Implementation Budget

Requirement	Cost
Nurse Anesthetist training	$2,120
Anesthesiologist training	$800
Operating Room/Preoperative nurse training	$475
Printing Costs	Negligible
EMR changes	$504
TEE Acquisition	$30,000-$60,000
Total Estimated Cost	**$33, 899-$63,899**