



REVIEW ARTICLE

The Anesthetic Challenges of Managing Patients with Aortic Stenosis for Non-cardiac Surgery

Cruvinel, MGC¹ and Wells, CM²

¹Clinical Assistant Professor
Department of Anesthesiology &
Perioperative Medicine University of
Pittsburgh School of Medicine

²Clinical Associate Professor
Department of Anesthesiology &
Perioperative Medicine University of
Pittsburgh School of Medicine; Chief
Anesthesiologist UPMC Horizon &
Jameson Hospitals; Director of
Operating Room Management IPMC
Health System

[*mgccruvinel@gmail.com](mailto:mgccruvinel@gmail.com)



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ABSTRACT

Aortic stenosis (AS) is the most common valvular heart disease in adults over 75 years of age. The primary cause is calcification and degeneration of the valve, with the early development of stenosis in congenital bicuspid aortic valves. Obstruction of left ventricular (LV) outflow leads to pressure overload, concentric hypertrophy, and diastolic dysfunction (reduced LV compliance and increased end-diastolic pressures) that all contribute to a decreased stroke volume (SV). These changes increases myocardial oxygen demand and decreases coronary perfusion pressure (CPP). It is not uncommon for patients to present for elective or urgent non-cardiac surgery with unrecognized degrees of AS. These patients are considered to have greater risk of major cardiac complications including hypotension, myocardial ischemia or infarction, arrhythmias, heart failure, stroke, and death. Therefore, anesthesiologists must maintain a high level of suspicion when caring for elderly patients. Proper triaging is required to assess the severity of AS, and provide a safe anesthetic that avoids hemodynamic changes. Maintaining sinus rhythm, CPP, adequate preload, and systemic vascular resistance is important. Appropriate hemodynamic monitoring that allows immediate interventions. Phenylephrine is one of the agents used for treating hypotension in AS patients. The focus of this narrative review is to provide guidance on how to achieve these goals.

Introduction

Aortic stenosis (AS) is a serious and highly prevalent cardiac disease¹⁻⁴. It's the most common cause of left ventricle (LV) outflow obstruction. The increase in population life expectancy over the past decades has resulted in a growing elderly population. When combined with advances in minimally invasive surgical techniques, providers may expect to see greater numbers of surgical candidates that fit into this high-risk category. Of patients over the age of 75, around 3% are affected by severe AS². There is an association between AS and an increased risk of adverse cardiovascular events and mortality after non-cardiac surgery⁵⁻⁹. In addition, patients with AS tend to present with multiple other underlying diseases which further complicate their anesthetic management. AS non rarely is unrecognized before a complication arises.⁵ Preoperative assessment of these patients is essential. Several important hemodynamic changes occurs in these patients that lead to a number of anesthetic considerations. The patient's cardiac rhythm, blood pressure, fluid status, cardiac output, contractility, and systemic vascular resistance should all be monitored and managed during surgery. Anesthesia technique should be carefully selected and conducted in special way. Rapid perioperative interventions are often needed. The goal of this narrative review is to review the pathophysiology of aortic stenosis, discuss the risk and present anesthetic techniques to best manage patients undergoing non-cardiac surgery.

Aortic Stenosis Definition and Diagnosis

The American Heart Association defines aortic stenosis as a narrowing in the opening of the aortic valve which restricts the flow of blood from the left ventricle to the aorta¹⁰. The normal aortic valve area is 3.0-4.0cm⁵. Calcification and degeneration of previously normal tri-leaflet aortic valve is the most common cause of AS over the age of 70. Under 70, the usual cause is bicuspid aortic valve, the commonest congenital malformation⁵⁻⁹. The

diagnosis of AS is based on a combination of physical examination findings, the development of associated symptoms, and various imaging techniques including echocardiography, computed tomography (CT), and ventriculography¹⁰.

The most common physical exam finding is a loud, late-peaking systolic murmur, heard best over the right upper sternal border and radiating to the carotid arteries. The development of symptoms which characterize the progressive nature of aortic stenosis include fatigue, shortness of breath, chest discomfort and dizziness or syncope¹⁰. It is important to highlight that there is a high level of variability in the rate of progression with associated risk factors being a history of tobacco use, chronic hypertension, renal impairment and hyperlipidemia. Early in the disease process, there is a prolonged asymptomatic phase. Once symptoms develop, cardiac remodeling has begun to occur. Diagnosis is most often confirmed using echocardiography which is a widely available, non-invasive imaging modality that can assess the severity of AS as well as provide additional information such as left ventricular function and signs of pressure overload. Echo provides images of the entire valvular apparatus, including the leaflets, as well as calculations of the valve area, velocity, and pressure gradients¹¹. Given the insidious nature of this disease, it is important that anesthesiologists appreciate that the characteristics of a murmur and/or presence of symptoms often do not correlate well with the severity of stenosis. It is not rare that patients can have mild symptoms with moderate to severe valve abnormalities⁵⁻¹¹.

Pathophysiology of Aortic Stenosis

The pathophysiologic changes associated with AS begin with progressive calcification of the valve leaflets, which further triggers inflammation and lipid accumulation. Over time, this leads to decreased leaflet mobility and limited aortic valve opening which restricts the flow oxygenated blood from the left heart⁵⁻¹¹. The chronic elevation in afterload leads to the gradual development of concentric left ventricular hypertrophy. Initially, the

increase in muscle mass of the left heart is able to maintain normal wall stress and stroke volume, despite the increase in afterload. These early changes correlate with the asymptomatic phase which may last for several years⁵⁻¹¹. But as the aortic valve orifice continues to narrow and left heart pressures elevate, myocardial compliance decreases until patients reach a point where symptom onset becomes imminent due to a decrease in cardiac output and elevated left heart pressures, leading to signs of heart failure, angina or arrhythmias. The hypertrophied ventricle gets progressively stiff, ending in diastolic dysfunction. Of particular interest is the risk of these patients developing a compromise in coronary blood flow due to both the severity of hypertrophy and fixed stroke volume causing reductions in coronary blood flow. Coronary perfusion is dependent on the diastolic pressure within the aortic root and left ventricular end diastolic pressure. A decrease in systemic vascular resistance compromises forward flow while elevated intra-ventricular pressure exerts resistance to coronary flow through the myocardium⁵⁻¹¹. These patients are particularly prone to ischemia, even in the absence of obstructive coronary disease. Furthermore, they are highly reliant on

preload to maintain adequate ventricular filling due to reduced left ventricular compliance, therefore, very dependent on atrial contraction⁵⁻¹¹.

Grading of Aortic Stenosis

Echocardiographic evaluation of the aortic valve provides reliable identification of the number of valve leaflets, assessment of their motion, degree of calcification and left ventricular function⁵⁻¹¹. Aortic stenosis is typically graded into three categories: mild, moderate, and severe. Echo assessment of AS severity relies on peak velocity, mean pressure gradients and the aortic valve area (AVA). The normal AVA is 3.0-4.0 cm². Patients typically do not develop symptoms until the valve area is less than 1.0 cm².

Mild AS: aortic valve area > 1.5 cm², peak jet velocity 2.0-2.9m/s, and/or mean pressure gradient <20mmHg.

Moderate AS: aortic valve area >1cm² and > 1.5 cm², and mean pressure gradient >20mmHg but < 40mmHg.

Severe AS: aortic valve area ≤1 cm², peak jet velocity ≥ 4m/s, and/or mean pressure gradient ≥40mmHg.

Measurement	Mild	Moderate	Severe
Peak Velocity (m/s)	<3.0	3.0-4.0	>4
Mean Gradient (mmHg)	<20	20-40	>40
Aortic Valve Area (cm ²)	>1.5	1.0-1.5	<1.0

Of note, there is a subset of patients who present with an aortic valve area that is less than 1cm² but the mean pressure gradient is less than 40mmHg. This is known as low-gradient AS and may be due to cardiomyopathy creating a low flow state with inadequate contractile force to fully open the valve. On the other hand, in high output states such as concomitant aortic regurgitation, the severity will be overestimated. Sometimes additional testing can be performed. Cautions preoperative exercise testing in asymptomatic patients and preserved left ventricular ejection fraction to confirm their status. Dobutamine stress echocardiography may be considered to assess left ventricular contractile

reserve and aortic gradients during peak contractility. In patients with low gradients and preserved left ventricular ejection fraction, aortic valve calcium scores can be used to better define AS severity⁵⁻¹¹.

Aortic Stenosis Treatment

The treatment of aortic stenosis is ultimately based on three main factors: the severity of stenosis, patient symptoms, and left ventricular function. After the onset of AS related symptoms, survival significantly decreases. Therefore, current guidelines recommend aortic valve replacement for patients with symptomatic severe aortic stenosis, patients with asymptomatic severe aortic stenosis and left

ventricular ejection fraction less than 50%, a positive stress test, or if they have another indication for open heart surgery¹²⁻¹⁴. In these situations, consideration to proceed with surgery is given if the risk of mortality outweighs the risk of valve replacement¹²⁻¹⁴. For patients who remain asymptomatic, clinical and echocardiographic follow-up every 6 to 12 months is recommended. More recently, an early transcatheter valve replacement strategy has been proposed for asymptomatic patients with severe stenosis¹⁴.

Perioperative Risk

Aortic stenosis has traditionally been associated with increased perioperative morbidity and mortality. The AHA/ACC predicts a 10% mortality for patients who have uncorrected severe AS undergoing non-cardiac surgery^{8,9}. The leading hemodynamic changes that cause negative intraoperative outcomes are hypotension and tachycardia which acutely decrease coronary blood flow, leading to the rapid onset of myocardial ischemia and potential arrhythmias. An important distinction exists between those patients with symptoms and those without. Whilst asymptomatic patients have a cardiovascular adverse effects relative risk of 1.59, symptomatic patients carry a risk ratio of 3.87 which is indicative of the lack of reserve these patients have once they become symptomatic⁵⁻¹¹. Another retrospective case control study showed that the presence of symptoms are associated with a higher 30-day mortality rate and adverse cardiovascular effects (28.3% vs 8.5%). More recently, careful intraoperative management has been shown to significantly reduced mortality rates of asymptomatic patients, demonstrating a 3.8% 30-day mortality⁷⁻⁹. Other studies that looked exclusively at asymptomatic AS patients did not show a difference in 30-day mortality, but higher rates of adverse cardiac events (myocardial infarct, heart failure, stroke)⁷. Two patient-related risk factors associated with this higher risk are atrial fibrillation and serum creatinine level above 2.0mg/dl¹⁰.

The other highly important risk predictor is the type of surgery. Emergency surgery has a strong

association with an elevated 30-day mortality. This same risk applies to high-risk procedures such as thoracic or major vascular surgeries. The AHA/ACC recommends three risk calculators that can be used to assess perioperative risk: the Revised Cardiac Risk Index (RCRI), National Surgical Quality Improvement Program Surgical Risk Calculation (NSQIP SRC), and the National Surgical Quality Improvement Program Myocardial Ischemia and Cardiac Arrest Calculator (NSQIP MICA)¹⁰.

Indications for Valve Intervention Prior to Non-emergent Non-cardiac Surgery

The decision to proceed with an aortic valve replacement prior to non-emergent, non-cardiac surgery is primarily based on the presence of symptoms and severity of AS. Patients with severe AS and low left ventricular ejection fraction or positive stress test are also candidates¹³. Symptomatic patients with severe AS are a class I indication for valve replacement. Exertional dyspnea, angina, syncope, presyncope, or heart failure are considered the classical symptoms, but these may be indicative of other forms of cardiovascular disease as well which warrants a thorough pre-operative evaluation and risk assessment. Patients who meet criteria should consider valve replacement before elective major non-cardiac surgery with the goal of improving long-term survival¹³⁻¹⁵. The transcatheter aortic valve replacement (TAVR) has provided a less invasive technique that has amplified the number of candidates, especially before major non-cardiac surgery¹⁴. Nevertheless, anesthesia providers will still encounter a significant number of asymptomatic AS patients with moderate-severe disease receiving medical management that remain candidates for non-cardiac surgery prior to undergoing a valve replacement^{13,15}.

Situations where Non-Cardiac Surgery cannot be Delayed

Occasionally, the need to proceed with non-cardiac surgery arises despite the fact that a patient

with severe AS is a candidate for aortic valve replacement. This may be the case for patients with aggressive malignancies or palliative procedures and a limited life expectancy. In a situation where the risk of delaying surgery outweighs the risk of undergoing a procedure, providers must be prepared to manage these cases¹³.

Point of Care Ultrasound (POCUS)

Whenever there is a diagnosis or suspicion of AS and a recent echocardiography is not available, POCUS is a useful tool, especially in urgent cases¹⁶. The goal of bedside ultrasound is to answer simple yes or no questions. Two main aspects need to be addressed: Are there signs of some degree of AS? Are there signs of left ventricle enlargement and/or systolic dysfunction? Although quantification is possible, it is often not necessary when performing a limited exam. Parasternal long axis view is typically used for aortic valve evaluation. The degree of calcification and mobility of the valve are assessed. Ventricular systolic function can be evaluated through all four views used in POCUS protocols. If the cardiac POCUS imaging reveals some degree of AS or systolic left ventricular dysfunction, patients should be managed accordingly. In addition to the evaluation of AS, POCUS can provide additional information on excessive fluid in the lungs or signs of hypovolemia¹⁶.

Intraoperative Management of Patients with Severe Aortic Stenosis

The management of patients with severe aortic stenosis is rather complex. It's important to reemphasize that the natural history of the disease is of long asymptomatic latent period. Between 30% and 47% of patients with echocardiographic severe AS report no symptoms. One explanation for this situation is that patients change their daily level of activity to avoid exertion and experiencing symptoms. Therefore, they initially would not be considered for valve replacement. In addition, there will be those patients for whom non-cardiac surgery cannot be delayed⁵⁻⁹. Either way, it is very

likely that anesthesiologists will face the challenge of taking care of patients with severe AS.

Careful planning to optimize the outcome is necessary. The first point of attention is blood pressure management. The placement of an intra-arterial catheter for continuous monitoring and early detection of blood pressure changes is often indicated prior to induction of anesthesia⁵⁻⁹. There is no specific value considered safe, but a drop in pressure greater than 20% below the patient's baseline should be avoided to minimize the risk of myocardial ischemia⁵⁻⁹. The thickened myocardium is especially sensitive to a decrease in coronary perfusion. The choice of anesthetic agents is important as most cause peripheral vasodilation. As these patients cannot compensate well for a drop in systemic vascular resistance, the co-administration of vasopressors is necessary from the time of induction and titrated intraoperatively to maintain normal values⁵⁻⁹. The first choice to achieve this goal is phenylephrine which acts as a vasoconstrictor to maintain perfusion pressure and does not increase the heart rate. Norepinephrine, metaraminol, and vasopressin are also options. However, norepinephrine has a positive chronotropic effect and the slow rate on onset of vasopressin makes it more difficult to titrate. Having a central venous line for transitory vasopressor infusions is not mandatory, but advisable whenever high-dose or prolonged infusions are necessary^{17,18}.

Patient position during surgery must be considered. Surgeries that require steep reverse Trendelenburg are associated with sudden reduction of pre-load while surgeries that require steep Trendelenburg are associated with rapid increase in venous return. Therefore, changing patient's position slowly is advised¹⁹.

Pneumoperitoneum increases venous return and afterload simultaneously which may challenge ventricular function. Maintain intra-abdominal pressure as low as possible is necessary to avoid excessive cardiac stress. Gradual insufflation allows time for better cardiovascular compensation. The negative effect of pneumoperitoneum on preload

may be counteracted by Trendelenburg position, so careful vigilance and individualization is advised¹⁹.

Hypothermia is highly detrimental once induces sympathetic stimulation causing shivering which raises heart rate and myocardial oxygen consumption. In addition, hypothermia predisposes to cardiac arrhythmias that will be very poorly tolerated by patients with AS. Hypothermia also impairs coagulation increasing surgical bleeding that is more problematic in these patients. Maintaining normothermia through active warming and temperature monitoring is critical²⁰.

The avoidance of hypovolemia is critical for patients with AS due to the risk of hypotension intraoperatively. Ideally, volume status is evaluated preoperatively with a strategy to maintain euolemia. Of note, excessive volume replacement is poorly tolerated due to high filling pressures of the left heart and risk of acute heart failure⁸. The presence of diastolic dysfunction makes cardiac output highly dependent on a delicate balance between volume status, heart rate and rhythm⁵⁻⁹.

The maintenance of normal sinus rhythm is important due to the elevated risk of atrial fibrillation. Atrial contraction provides a greater contribution to left ventricular filling due to higher filling pressures. In addition, the avoidance of tachycardia decreases myocardial oxygen demand, improves coronary perfusion, provides more time for left ventricular filling as well as emptying. For intraoperative heart rate control, the preferred medication is esmolol. Its main advantage over other beta blockers is the short half-life and the ability to titrate the dosing⁵⁻⁹.

Neuraxial Anesthesia

Neuraxial techniques for patients with AS were traditionally considered a poor choice of anesthetic²¹⁻²³. But this was based more on expert opinion than robust evidence. The reasoning for this recommendation was based on the abrupt onset of sympathetic blockade with consequent hypotension that could prove to be very dangerous²¹⁻²³.

More recently, a systematic review of neuraxial anesthesia in patients with AS identified a large volume of successful cases²¹. Therefore, AS should not be considered an absolute contraindication for neuraxial anesthesia²¹⁻²³. In some circumstances, it may be more beneficial for certain patient, but several aspects must be considered with the desired level of the block being the most important²¹⁻²³. The higher the level of the spinal, the more extensive the sympathetic block. While a high thoracic level (T1-T4) is universally related to hypotension in any patient, there is no level considered safe. The rationale would be to try to achieve the lowest level appropriate for the proposed surgery. Strategies have been proposed to minimize the abrupt drop in systemic vascular resistance including adequate preload prior to the performance of a spinal and the timely administration of vasoconstrictors²¹⁻²³. Furthermore, consideration must be given to the puncture level, patient position, and local anesthetic dose, volume, and baricity in single-shot spinals. In contrast, a continuous epidural with slow incremental doses of local anesthetic would help avoid the rapid onset of hypotension. Combined spinal-epidural anesthesia is also proposed as a good method of limiting the initial high level of sympathetic block, but at the same time, providing the ability continue dosing and prolong the duration as needed²¹⁻²³.

Prophylactic or early infusion of vasopressors (phenylephrine, norepinephrine) is a well-established method of avoiding hypotension during C-sections²⁴. It is reasonable to assume that this technique could also prevent or minimize hypotension after neuraxial blocks in patients with AS. Although in one study where AS patients received a low dose spinal, less than 50% needed additional vasopressors²².

Despite all of these considerations, neuraxial anesthesia remains controversial. There is a growing amount of evidence that suggests neuraxial blocks are a safe alternative, large randomized trials are still not available.

Peripheral Nerve Blocks

Regional anesthesia is a very attractive option for patients with AS whether to provide intraoperative anesthesia or postoperative analgesia. By limiting the sympathetic blockage to a more limited area, these techniques lower the risk of hemodynamic changes²⁵⁻²⁷. Depending on the planned procedure, there are many options available to perform central or peripheral nerve blocks.

Conclusion

Severe aortic stenosis is a known risk factor for perioperative cardiac complications during non-cardiac surgery. As life expectancy increases, more patients with this condition are expected to present for such procedures. Importantly, severe AS is often unrecognized preoperatively. The risk of adverse outcome has been decreasing in recent years, so, many of the patients with severe AS can undergo non-cardiac surgery safely. But preoperative identification is crucial, so proper

management can be done. It's imperative to understand the condition's pathophysiology. Avoiding systemic hypotension is essential, and vasoconstrictors such as norepinephrine, phenylephrine or metaraminol play a key role to maintaining vascular tone. Maintaining sinus rhythm and adequate intravascular volume is also critical. While neuroaxial anesthesia was once considered contraindicated, it has been used successfully in selected cases. Peripheral regional techniques alone or in combination with sedation or general anesthesia can also be a valuable tools.

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