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Anesthetic considerations in supravalvular aortic stenosis: A case series

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ABSTRACT

Supravalvular aortic stenosis (SVAS), characterized by elastin arteriopathy, presents either as a localized narrowing at the sinotubular junction or as a diffuse form with additional involvement of the ascending aorta, aortic arch, and its branches. Associated lesions of the aortic valve, coronary artery narrowing, and pulmonary artery stenosis can further complicate the disease process. These patients are inherently at risk for developing myocardial ischemia, particularly in the setting of anesthesia or sedation. The left ventricular hypertrophy, secondary to the obstruction, results in increased left ventricular wall tension and myocardial oxygen consumption. Associated anatomic factors in the coronary arteries can further impair coronary blood flow. Any anesthetic drug that further increases oxygen consumption or decreases the coronary blood flow will result in an imbalance and increase the risk of cardiac arrest. We present a series of three patients with SVAS who were operated at our institute and subsequently discharged with good outcomes. The hemodynamic goal during the perioperative should aim to balance the myocardial oxygen supply-demand ratio. Extreme vigilance and aggressive resuscitative measures are needed to prevent any adverse myocardial event that can happen immediately after anesthetic induction or during periods of intense sympathetic stimulation such as laryngoscopy, sternotomy, aortic cannulation, or during emergence from anesthesia.

Key words: Supravalvular aortic stenosis; Anesthesia; Sudden death; Myocardial ischemia

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INTRODUCTION

Supravalvular aortic stenosis (SVAS) is a rare congenital cardiac abnormality due to elastin gene degeneration, characterized by an exaggerated narrowing of the aorta at the sino-tubular junction (STJ) (Figure 1). Sometimes, it can present as a diffuse form with additional involvement of the ascending aorta, aortic arch, and its branches.[1] Associated lesions such as valvular aortic stenosis, bicuspid aortic valve, coronary artery narrowing, pulmonary artery stenosis, and coarctation of the aorta can further complicate the disease process. Surgical repair is usually performed at the earliest to prevent the progression of the disease. Management poses a significant challenge to anesthesiologists as sudden cardiac deaths owing to myocardial ischemia have been reported frequently after anesthesia in these patients. We present here an exemplary case series of three children with SVAS who were operated in our institute and subsequently discharged with a good outcome.

CASE 1

A 5-year-old second-born male child presented with a history of breathlessness and palpitations associated with a slight limitation of ordinary activity for 2 months. There was no history of syncope, cyanotic spells, or chest pain. Birth history revealed uncomplicated term pregnancy, spontaneous vaginal delivery with a good Apgar score and no post-natal intensive care unit stay. Immunization and milestones were at par with age. In addition, he had a history of removal of esophageal foreign bodies under GA at 4 years of age, which was uneventful. Family history revealed similar symptoms in the elder brother and paternal aunt.

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On clinical examination, the patient was conscious and oriented, with intact higher mental function, typical facies with a bulging forehead, broad nose, broad lips, increased interdental distance, and no speech problems. Baseline vitals were normal, with no evidence of coarctation. Systemic examination revealed an ejection systolic murmur, grade 3/6, predominantly in the aortic area, radiating to the left sternal border, right and left supraclavicular region, and back. Electrocardiogram (ECG) showed sinus rhythm and left ventricular hypertrophy (LVH). Chest X-ray (CXR) was suggestive of an increased cardiothoracic ratio of 0.7, normal bilateral lung fields with clear costophrenic angles. An echocardiogram (ECHO) revealed severe SVAS (Peak gradient of 90 mmHg), normal valves, and normal biventricular function (Figure 2). Cardiac computer tomogram and angiography confirmed the diagnosis. There was brachiocephalic trunk ostial narrowing of 20% and left common carotid artery (CCA) occlusion of 15% cardiopulmonary bypass (CPB).

CASE 2

The 7-year-old first-born male child came with a history of palpitations and chest pain associated with slight limitation during ordinary activity for 3 months. He did not have any other complaints. Birth and developmental histories were normal. Family history revealed similar symptoms in the younger sibling and paternal aunt.

He had intact higher mental functions, normal facies, and a normal airway. All the baseline vitals were within acceptable range. Systemic examination revealed ejection systolic murmur, grade 3/6 in the right upper sternal border with radiation to the right cervical region. ECG showed a sinus rhythm with LVH and strain pattern in chest leads and CXR showed an increased cardiothoracic ratio of 0.65. ECHO revealed severe SVAS (Gradient of 120 mmHg), severe concentric LVH, asymmetrical septal hypertrophy, left ventricular outflow tract obstruction with the gradient of 60 mmHg, mild MR (Figure 3). Additional findings of ostial stenosis involving the brachiocephalic trunk and left CCA with small left superior vena cava were evident on CECT.

CASE 3

A 7-year-old child presented with a history of exertional dyspnea for 4 years. The only other relevant history was of maternal death soon after delivery due to a brain hemorrhage. No similar complaints were present in the family. Systemic examination revealed ejection systolic murmur, grade 3/6, in his right upper sternal border with radiation to the neck region. ECG showed LVH in chest leads and CXR showed a CT ratio of 0.6. ECHO revealed moderate SVAS (Peak Gradient of 77 mmHg, mean gradient: 30 mm Hg), concentric LVH (Figure 4). Cardiac CT revealed additional findings of left CCA origin narrowing and bilateral segmental pulmonary artery narrowing.

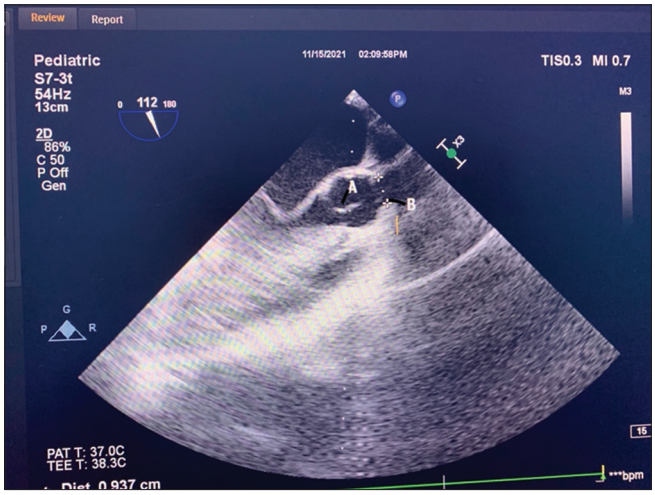

Figure 1: Mid-esophageal aortic long-axis view on transesophageal echocardiography showing A) aortic valve B) supravalvular aortic stenosis

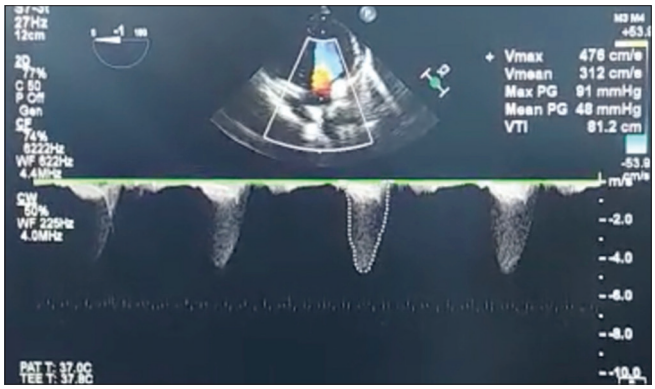

Figure 2: Deep transgastric long-axis view on transesophageal echocardiography showing a peak gradient of 91 and a mean gradient of 48 mm hg (case 1)

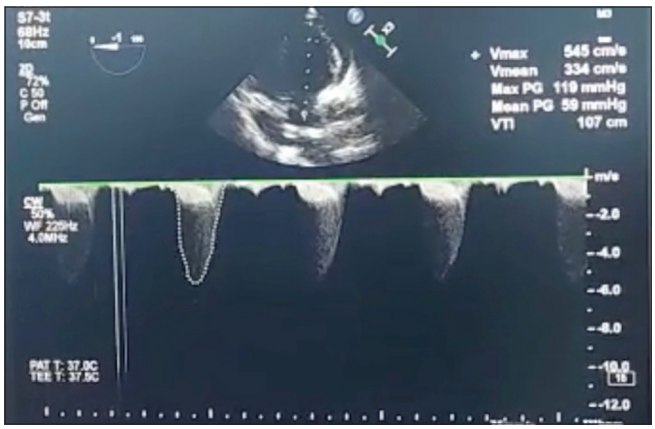

Figure 3: Deep transgastric long-axis view showing a peak gradient of 119 and a mean gradient of 59 mm hg (case 2)

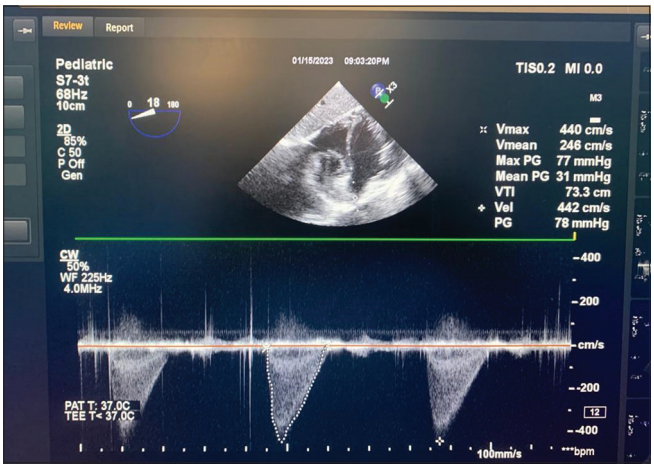

Figure 4: Deep transgastric long-axis view showing a peak gradient of 77 and a mean gradient of 31 mm Hg (case 3)

MONITORING AND ANESTHESIA

All three patients were planned for aortoplasty (Brome's procedure) with aortic branchpasty. The monitoring and anesthetic management was performed in a similar manner in all three cases. In the operating room, ASA standard monitors were attached, intravenous access was secured, and maintenance fluid was initiated. The patient was preoxygenated with 100% oxygen and intravenous induction with 3 mic/kg of fentanyl, 2 mg/kg of etomidate, and 0.1 mg/kg of vecuronium in titrated manner was given, and the airway was secured with appropriately sized ETT. Drug-induced hypotension was immediately treated with fluids and phenylephrine boluses. The right femoral arterial line and central venous line were secured post-induction. Additional monitoring included core temperature with nasopharyngeal and rectal probes, urine output, near-infrared spectroscopy (NIRS), transesophageal echocardiography (TEE), activated clotting time, and arterial blood gas analysis.

SURGERY

Brom's aortoplasty procedure was performed on CPB under moderate hypothermia (28°C) and myocardial protection was done with anterograde cold blood cardioplegia (4°C). In case 2 myomectomy was also performed for the septal hypertrophy. During the repair of the innominate artery and CCA, cerebral protection was done using deep hypothermic circulatory arrest with standard techniques. Patients were cooled to a temperature of 18–20°C and topical cooling of the head was done with ice packs. Injection thiopentone 15 mg/kg and methylprednisolone 30 mg/kg were added on the pump and NIRS monitoring was done. After the completion of the repair, rewarming was initiated, deairing was done and the aorta was unclamped. Weaning from CPB was done after checking all vital and metabolic parameters and with TEE guidance, the inotropic infusion was started before coming off CPB. Decannulation, protamine administration, and hemostasis were done as per the standard approach. Post-repair transesophageal echocardiographic assessment was performed to see the surgical adequacy and cardiac function.

The post-operative echo in all three cases showed a mean gradient of <10 mmHg across the LVOT, and good mobility of valves without any reflux. During 1-month follow-up, all of them were found to be in functional class I, without any cardiovascular symptoms.

DISCUSSION

SVAS was first described in 1930 and has an incidence of 1:20,000 live births.[1,2] It is characterized by systemic elastin (ELN) arteriopathy due to a spontaneous or inherited microdeletion in the elastin gene located on chromosome 7.[3] This leads to an irregular, pathologic deposition of elastin fibers in the aortic wall combined with reduced elastin content leading to abnormal, excessive collagen deposition in the aortic media and hypertrophy of smooth muscle cells, causing obstructive arteriopathy. Most cases show a characteristic hourglass narrowing of the aorta that develops at the STJ, while the remaining cases have a diffuse tubular narrowing of the ascending aorta, which may extend into the aortic arch and the origin of brachiocephalic vessels. The aortic valve may also be pathologically involved, which can become an additional source of obstruction. Partial adhesion of the valve leaflet hinge-points to the hypertrophied STJ can restrict coronary blood flow into the sinus of valsalva, affecting the myocardial perfusion.[4,5]

SVAS can be non-syndromic or syndromic, as in Williams-Beuren syndrome (WS). WS is a complex developmental genetic disorder presenting with neurobehavioral (low intelligence), craniofacial (dysmorphic facies), and cardiovascular and metabolic (hypercalcemia) abnormalities. Non-syndromic patients have normal intelligence and lack dysmorphic features.

Patients usually present with a systolic murmur and become symptomatic before the age of 20 years. Symptoms such as dyspnea, angina, and syncope similar to that of valvular aortic stenosis are seen. If left untreated, they can develop cardiac failure, eventually leading to death. The usual workup consists of echocardiography 2D/3D/Doppler, ECG (signs of LVH with strain pattern, ST-T changes), magnetic resonance imaging, or CT aortography. Angiography

gives information on associated vascular anomalies in the coronaries, aortic arch, arch vessels, or other distal branches and pulmonary arteries. The identification of the genetic defect is essential for a definitive diagnosis and is done by fluorescence *in situ* hybridization, direct sequencing, multiplex ligation probe amplification, and Real-time quantitative polymerase chain reaction.[6]

Surgical correction should ideally be performed in infancy to prevent early aortic valve degeneration, coronary artery pathology, and LVH. The overall perioperative mortality risk is about 3–7%. Surgical techniques for repair are numerous, which include Mc Goon's one-patch, Doty's two-patch, and Brom's three-patch technique.[7-9] No technique is considered the gold standard for SVAS repair, with each having its pros and cons.

The management presents a significant challenge for anesthesiologists due to different grades of severity of obstruction, pediatric age group, possible multi-system involvement, and lack of standard anesthetic management guidelines. A thorough pre-anesthetic assessment, preferably 1–2 weeks before the planned procedure, is recommended, which should focus on the pathophysiological effects of SVAS as well as other clinical manifestations of WS.[10] Screening for active myocardial ischemia, at-risk patients for ischemia and other systemic involvement should be done. WS children can exhibit neurocognitive developmental delays and significant procedural anxiety, which can make even painless procedures difficult without sedation. An airway assessment should screen for mandibular hypoplasia and dental anomalies, which might cause difficulty in airway management.

WS patients can be categorized into low, moderate, and high-risk groups based on the physiological risk factors for myocardial ischemia and the presence of anatomical lesions known to be associated with more severe disease.[11-15] Patients with significant SVAS (gradient >40), biventricular outflow tract disease, documented coronary anomalies, or a combination of any of the three; WS with QT prolongation, recently operated cases are categorized as high risk with increased propensity for myocardial events. The risk of the surgical procedure should also be taken into account. High-risk patients should be anesthetized only in a setting with the availability of extracorporeal membrane oxygenation (ECMO).

Rapid hemodynamic deterioration, unresponsiveness to resuscitation, and sudden deaths have been reported to occur at a high rate while undergoing procedures under sedation or anesthesia. This is of concern, especially because they often have to undergo several of such procedures during their lifetimes.[16,17] Myocardial ischemia is implicated as the cause for the majority of these reported sudden deaths. Sudden death happened mainly with associated coronary arteriopathy/ostial stenosis or when there was biventricular outflow tract obstruction. Burch et al., described a series of nineteen pediatric patients who suffered cardiac arrest during the procedures, and the suspected cause was myocardial ischemia caused by reduced coronary blood flow.[16] Significant left ventricular outflow tract obstruction in SVAS can result in compensatory LVH, increasing the wall tension and thus increasing the propensity for subendocardial ischemia.[18] An associated coronary arteriopathy further impairs the coronary blood flow which aggravates this insult.

Hemodynamic goals aim at maintaining the myocardial oxygen supply-demand balance and are as follows (1) maintain adequate preload, overloading in a non-compliant LV can result in pulmonary venous congestion, whereas underfilling will reduce the LV stroke volume (2) maintain a sinus rhythm and a heart rate around 60–80/min, avoid tachycardia which can increase oxygen consumption and reduce diastolic time (3) maintain contractility (4) maintain afterload as any fall in blood pressure can affect the coronary perfusion (5) avoid increase in pulmonary vascular resistance. In addition to this, any factor that will affect the oxygen content and delivery such as anemia, hypoxemia, and hypothermia should be avoided.

Hemodynamic management is usually done with fluids and alpha agonists, but if LV function is poor, inotropes may be needed. Anesthetic agents used routinely have varied effects on the heart, some are known to cause myocardial suppression, reduce afterload, or increase myocardial oxygen consumption, any of which can cause ischemia in these vulnerable groups. Apart from the drug effects, patients become vulnerable to ischemia during periods of intense sympathetic activity such as laryngoscopy, sternotomy, aortic cannulation, or emergence from anesthesia.

An opioid-based induction technique obviates the vasodilatation and negative inotropy, which can occur with thiopentone, propofol, or inhalational agents. Even in patients at risk for ischemia high-dose opioids have been used safely.[11] There are reports of cardiac arrests with even low to incremental usage of sevoflurane, so its use has been limited to low and moderate-risk cases where intravascular access is not possible preinduction.[16] For obtaining venous access preinduction intramuscular ketamine is a good choice as it maintains contractility and SVR but may produce some amount of tachycardia, increasing myocardial oxygen consumption. Etomidate, due to the cardio-stable nature, can be an alternative to opioids in high-risk cases. Drugs that prolong the QT interval, like 5HT3 inhibitor ondansetron, are best avoided in patients

of WS.[18,19] Regardless of the technique, there is always a risk of myocardial ischemia and arrest in high-risk patients; quick resuscitative measures, including early institution of ECMO, may be lifesaving in such cases.

Post-operative monitoring is recommended in all patients. Moderate-high-risk patients should be admitted for prolonged observation to a location with continuous monitoring. For high-risk cases, ECMO backup should be available. Cardiac arrest has been reported to occur in patients with WS even a day after anesthesia[20] and the possibility of undiagnosed coronary disease may exist in all patients.[20-24] Early post-operative complications of surgical correction are bleeding, tamponade, arrhythmias, and heart block. Resuscitation after sternotomy should follow cardiac intensive care guidelines and, in addition to excluding airway and breathing problems, should focus on early defibrillation or pacing and early reopening.

CONCLUSION

Patients with SVAS continue to challenge anesthesiologists as the risks associated with anesthesia and sedation are high in this population. Optimal management involves a good understanding of the pathophysiology, planning, and patient preparation and a multidisciplinary team approach among anesthesiologists, cardiologists, and surgeons.

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