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Sandeep Nathan
University of Chicago Medicine, snathan@medicine.bsd.uchicago.edu

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Management of Severe Aortic Stenosis in Cardiogenic Shock: Early Percutaneous Mechanical Circulatory Support or Emergent Transcatheter Aortic Valve Replacement?

Sandeep Nathan, MD, MSc, FACC, FSCAI
University of Chicago Medicine, Chicago, Illinois

Email: snathan@medicine.bsd.uchicago.edu

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Abstract

Aortic stenosis (AS) affects an estimated 1.5 million patients in the United States, with 250,000 patients or more suffering severe, symptomatic aortic stenosis. A subset of these patients also have unrevascularized coronary artery disease and left ventricular dysfunction, representing an extreme risk population of AS patients. Cardiogenic shock (CS) complicates a small minority of AS presentations and/or patients referred for transcatheter aortic valve replacement (TAVR) but is responsible in these cases for a disproportionately high rate of morbidity and mortality. Indeed, CS results in a 4-fold increase in TAVR mortality, proportional to shock severity and largely independent of procedural complications. All patients undergoing TAVR should undergo an assessment of hemodynamics and vascular access as well as an estimation of risk for conduction system abnormalities, coronary occlusion, landing zone rupture, and stroke. In patients with pre-procedural CS or at a high risk of hemodynamic deterioration, preemptive or carefully planned, provisional use of mechanical circulatory support (MCS) helps ensure the best possible outcomes during TAVR.

Keywords: percutaneous mechanical circulatory support, cardiogenic shock, transcatheter aortic valve replacement

Introduction

It is estimated that as many as 1.5 million people in the United States suffer from aortic stenosis (AS).[1-3] While approximately 500,000 Americans are classified as suffering from severe AS, only half of these patients are symptomatic. Patients with severe AS, left ventricle (LV) dysfunction, and unrevascularized coronary artery disease are particularly susceptible to hemodynamic compromise due to limited myocardial reserve, propensity for ischemically-driven arrhythmias, and a further decline in LV systolic performance.[1] The timing and choice of AS treatment in the setting of these coexistent conditions may vary greatly given differences in local practice paradigms and the limited data available to guide therapy.

The interventional management of AS primarily focuses on pressure, volume, flow, and resistance. In reality, however, maladaptive remodeling processes frequently accompany AS, introducing the deleterious effects of pulmonary hypertension, left ventricular hypertrophy, diastolic dysfunction, reduced coronary flow reserve, etc.[1] Thus, what ensues in the patient with severe AS and acute or chronic decompensation, is a complex interplay between numerous recognized and

clinically silent variables. Furthermore, flow parameters in the aorta often vary in patients with severe or critical AS. Variable, asymmetric helical flow patterns have been observed in proximity to the aortic valve (AV) across the spectrum of bicuspid and tricuspid aortic valve disease.[1] While imaging and interventional cardiologists often take note of these flow disturbances, the clinical implications of these and other dynamics are infrequently acknowledged and incompletely understood.

Cardiogenic Shock and Aortic Stenosis

In patients presenting with cardiogenic shock, the incidence of AS is close to 6%.[1,4] While AS is infrequently a coincident finding, the mortality rate in such patients has historically been very high (≥70%) if no durable valve intervention or surgery is performed during the index hospitalization.[4] Medical therapy alone is almost always insufficient, and surgery is often avoided because patients are deemed a prohibitive surgical risk. Thus, the practical decision is to either perform high-risk transcatheter aortic valve replacement (TAVR) or attempt stabilization with mechanical circulatory support (MCS). It should be recognized, however, that in severe AS and worsening cardiogenic shock, it is often impossible to stabilize the shock state without valvular therapy.

A recent study linked data from the Society of Thoracic Surgeons (STS) and American College of Cardiology's (ACC) Transcatheter Valve Therapy (TVT) Registry with claims data sourced from the Centers for Medicare and Medicaid Services (CMS) and identified patients who presented with cardiogenic shock in the setting of severe AS.[4] Approximately 4.1% of patients who underwent TAVR in the United States suffered from cardiogenic shock prior to the procedure. The CS patients (n=2,220, median STS score=9.8%) were compared to the 12,851 high-risk patients without cardiogenic shock (median STS score=10.2%). Patients with cardiogenic shock had significantly higher 30-day mortality rates (19.1% versus 4.9%, $P < .001$) and higher rates of complications than non-CS TAVR patients. Interestingly, the gap between the cardiogenic shock cohorts did not close with time, and the mortality rate remained significantly higher at one year ($P < .001$). A subgroup of patients who met the modified Valve Academic Research Consortium-2 early safety criteria were also analyzed to evaluate the dependence of late adverse outcomes on procedural complications. The absence of 30-day major complications was not associated with a commensurate reduction in 30-day mortality in patients presenting with CS.[4] Simply stated, cardiogenic shock conferred far worse short- and long-term clinical outcomes in TAVR, independent of any procedural complications. Observed 30-day post-TAVR mortality in the cardiogenic shock cohort was nearly 400% of the high-risk matched cohort. The mortality hazard appeared to be proportional to the degree of shock, as evidenced by inotrope usage, percutaneous MCS prior to TAVR, prior cardiac arrest, and use of cardiopulmonary bypass support.[4]

Optimal Technical Planning and Management

In all patients undergoing TAVR, an objective evaluation of preprocedural hemodynamics is a vitally important step in addition to a thorough assessment of vascular access along with an estimation of risk for conduction system abnormalities, coronary occlusion, landing zone rupture, and stroke. Scarsini, et al. compiled a pre-TAVR procedural planning checklist, integrating the aforementioned variables into an easily adaptable format.[5] In patients already manifesting CS or at high risk for rapid hemodynamic compromise during TAVR, additional consideration is mandatory for pre-emptive or bailout mechanical circulatory support. Villablanca, et al. proposed an algorithm using balloon aortic valvuloplasty (BAV) with Impella (Abiomed) support or backup in those patients where TAVR may be safely deferred until clinical stability is restored.[6] Single or bilateral vascular access may be utilized, and in the setting of clinical decompensation or intercurrent oxygenation issues, MCS escalation to extracorporeal membrane oxygenation (ECMO) should be considered. If TAVR cannot safely be deferred in the setting of CS, a number of different options exist to provide left ventricular or biventricular support.[6] One novel solution that has been proposed is a bi-atrial (left atrial (LA)/right atrial) drainage with a vented venous cannula across the interatrial septum returning oxygenated flow via an ECMO circuit through a femoral arterial cannula (LAVA ECMO).[6] Such cannulation strategies, especially when performed under the duress of time and patient acuity, dictate the procedures to be performed at highly experienced TAVR centers.

Challenges to Operationalization: A Case Study

A 61-year-old female with morbid obesity (body mass index=47 kg/m^2), numerous medical comorbidities, and a reduced ejection fraction of 40% was referred for treatment of severe AS. She had a history of multiple percutaneous coronary interventions (PCIs), including recent PCI with multiple drug-eluting stents implanted. Increasing chest pain and shortness of breath were noted prior to admission but were ascribed to her worsening AS, in the absence of any overt ischemic manifestations. Her calculated STS Score was high (12.4%), as was her estimated risk of major morbidity or mortality (46.1%), rendering surgical AVR a high risk. She was deemed suitable for TAVR based on adequate aortic valve complex and peripheral vasculature. The pre-TAVR checklist did not reveal any points of major concern. Based on CT-derived measurements, a 23-mm Sapien S3 (Edwards LifeSciences, Irvine, CA) TAVR implant was chosen. A detailed hemodynamic evaluation was not performed, as she was nominally normotensive, and hemodynamics obtained at the time of recent PCI were unremarkable.

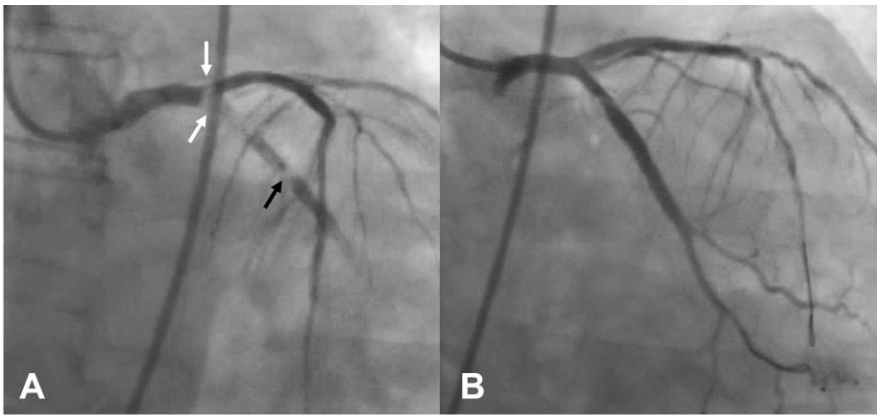

Figure 1. Thrombotic occlusion of the left main coronary artery (LMCA) bifurcation. Angiography was performed after cannulation for extracorporeal membrane oxygenation and stabilization of hemodynamics (Fig. 1A). revealed near-complete thrombotic occlusion of the LMCA bifurcation (white arrows) with resistant thrombus noted within the recently placed left circumflex stent (black arrow). After thrombectomy and PCI of the LMCA bifurcation TIMI III flow was successfully restored (Fig. 1B).

Once in the hybrid operating room, ultrasound-guided, bifemoral arterial access was obtained, and after administration of therapeutic heparin, the patient's activated clotting time was maintained at >300 seconds. A pigtail injection of the aortic root was performed in preparation for crossing the aortic valve. Shortly thereafter, profound hypotension was noted. After ruling out bleeding, vascular complications, and pericardial effusion, coronary angiography was performed, revealing complete thrombotic occlusion of the left main artery. It later became known that the patient had stopped antiplatelet medications one week prior in anticipation of TAVR, presumably leading to acute stent thrombosis. In the context of shock-resistant ventricular fibrillation and ongoing CPR, the patient was emergently cannulated for VA-ECMO via the same femoral vessels intended for the performance of TAVR. Mean arterial pressure increased to 100 mm Hg, organized electrical activity returned, and PCI of the left main, left anterior descending, and left circumflex arteries were performed with adequate technical results (Figure 1). After discussion, TAVR was aborted in favor of hemodynamic stabilization on ECMO.

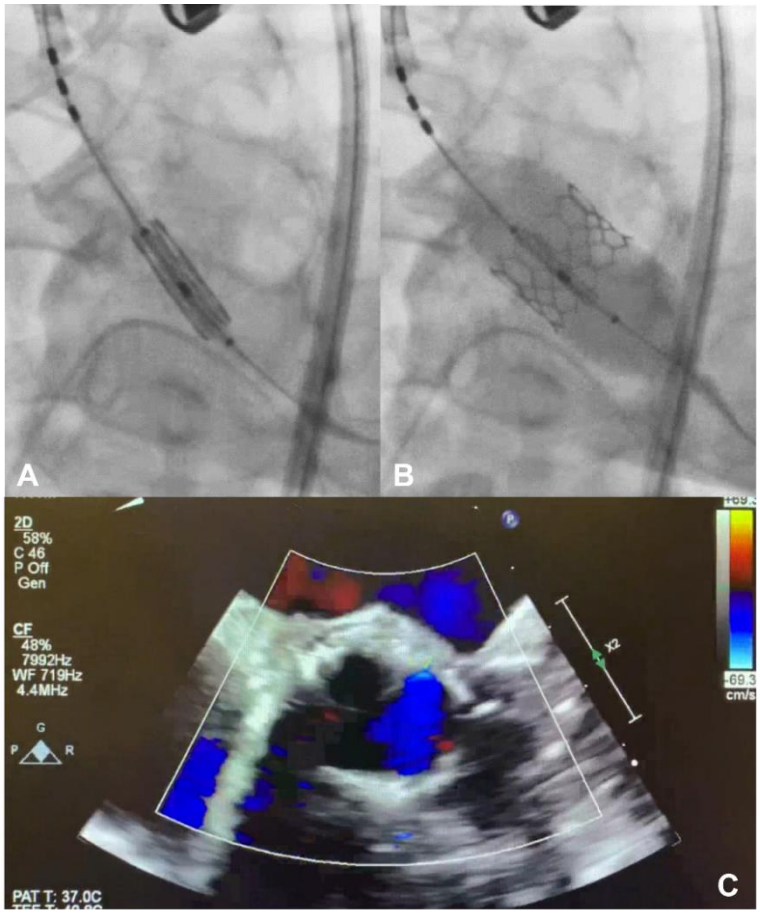

Figure 2. A 23 mm Edwards Sapien S3 transcatheter heart valve was deployed with rapid ventricular pacing at 200 beats per minute, and extracorporeal membrane oxygenation flows decreased to 1 L/min (Figs. 2A, B). Transesophageal echocardiography confirmed a well-seated valve with a trace paravalvular leak (Fig. 2C).

Two days later, the patient was still unable to be weaned off ECMO; thus, the decision was made to proceed with TAVR on VA-ECMO after confirmation of intact neurologic function. A second large-bore femoral arterial sheath was placed contralateral to the ECMO sheath cannulation site. BAV was performed, during which time it was noted that the force of retrograde ECMO flow (4-5 L/min) rapidly moved the BAV balloon into the ventricle during inflation across the aortic valve. We, therefore, elected to deploy the TAVR valve with ECMO flows reduced to 1 L/min and rapid (190-200 bpm) pacing, resulting in a mean arterial pressure of ~20 to 30 mm Hg and zero arterial pulsatility, effectively ensuring that the TAVR valve remained precisely where it was intended to be deployed (Figure 2).

Immediately after valve deployment, pacing was discontinued, and ECMO flow rapidly increased to 4-4.5 L/min. The patient was successfully liberated from ECMO 2 days later, made a complete functional recovery, and she is alive and well over one year later.

Conclusion

In patients with severe AS and cardiogenic shock, management begins with gathering objective data. Other explanations for the shock state should be explored using invasive hemodynamics whenever possible. Immediate valve replacement may potentially be deferred if BAV with MCS is performed. A plan to proceed with TAVR during the index CS admission should mandatorily take primary and provisional hemodynamic support strategies into account.

Disclosures

Dr. Nathan has previously served as a consultant or received honoraria from Abiomed, Biotronik, Cardiovascular Systems, Inc., Getinge, Janssen, Medtronic, Merit Medical, Terumo Interventional Systems and Zoll.

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