

Original Publication

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Cardiac Tamponade and Complete Heart Block During Transcatheter Aortic Valve Implantation: A Simulation Scenario for Anesthesia Providers

Robert Hitchcock, DO, PhD*, Clark J. Obr, MD, Sudhakar Subramani, MBBS

*Corresponding author: rhitchcock08@gmail.com

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Abstract

Introduction: This simulation on cardiac tamponade and complete heart block in the context of severe aortic stenosis presents the learner with a rare (cardiac tamponade) and a common (complete heart block) complication in the intraoperative setting of transfemoral aortic valve implantation in a high-fidelity, low-risk simulation environment. Based on an amalgam of index cases, the simulation was developed to address a recognized area of need for cardiothoracic anesthesia scenarios in the simulation curriculum of our home institution. **Methods:** The simulation case file covered the case narrative, learning objectives, a summary of critical actions performed, and supplemental figures needed to complete the educational activity. A high-fidelity patient simulator, an anesthesia machine, monitors, and a computer capable of displaying standard computer slide presentation software and movie files provided the optimal environment for simulation. **Results:** Fifteen anesthesia residents experienced the simulation over the 2016-2017 and 2017-2018 academic years. The trainees who experienced this simulation improved their understanding of tamponade hemodynamic pathophysiology and recognition of hemodynamically unstable bradycardia. **Discussion:** This case has been an effective addition to the repertoire of simulation scenarios at the University of Iowa and has been incorporated into the general curriculum of simulation cases for mid-training junior and senior anesthesia residents.

Keywords

Complete Heart Block, Aortic Valve Stenosis, Cardiac Anesthesia, Tamponade, TAVI, Aortic Stenosis, Third-Degree Block

Appendices

- A. Simulation Case File.docx
- B. Supplemental Exhibits.pptx
- C. Critical Actions Checklist .docx
- D. Debriefing Summary.docx
- E. Evaluation Form.docx

All appendices are peer reviewed as integral parts of the Original Publication.

Educational Objectives

By the end of this simulation, the learner will be able to:

1. Develop and implement a plan for the anesthetic management of patients with aortic stenosis.
2. Demonstrate understanding of hemodynamic monitoring with a pulmonary arterial catheter.
3. Diagnose and manage acute cardiac tamponade in the surgical setting.
4. Discuss the common complications associated with transcatheter aortic valve implantation and their management.
5. Diagnose and demonstrate the treatment of hemodynamically unstable bradycardia in the context of complete heart block.
6. Discuss areas of strength and areas for improvement discovered during the simulation.

Introduction

The incidence of degenerative aortic valve disease is increasing along with the aging population in the United States. Therefore, an increasing fraction of these patients will present for definitive procedural or surgical management. Minimally invasive aortic valve procedures, such as transfemoral or transapical transcatheter aortic valve implantation (TAVI), are gaining in popularity and prevalence.¹ Recently, the scope of patients who qualify for TAVI was expanded by the US Food and Drug Administration to include patients at intermediate risk for complications from an open surgery.² As part of the cardiac anesthesiology training at the University of Iowa, learners are often asked to provide care for patients

undergoing these procedures. Though the incidence of tamponade in TAVI is rare, the consequences of delayed diagnosis can lead to significant morbidity.³ Acute rhythm disturbances during TAVI are quite common, with a significant number of patients requiring pacemaker implantation afterwards.^{4,5} The array of critical complications associated with TAVI provided an ideal setting to present symptomatic aortic stenosis, acute cardiac tamponade pathophysiology, and third-degree heart block with symptomatic bradycardia in a low-risk environment while also familiarizing anesthesiology resident learners with the procedure. Within the currently available published simulations, there are scenarios that cover tamponade physiology, anesthesia for aortic stenosis, and symptomatic heart block⁶⁻⁹; however, only one of these is tailored for the intraoperative setting. Our simulation synthesizes much of the core pathophysiology covered in these separate scenarios with a specific focus on intraoperative management and interpretation of advanced invasive monitoring (arterial line, central venous pressure, pulmonary artery catheter), introduces the learner to transesophageal echocardiographic (TEE) diagnosis of cardiac tamponade, and serves as an effective introduction to TAVI. At present, none of the published simulation literature specifically addresses TAVI.

This simulation was designed to provide a valuable, memorable educational experience regarding cardiac tamponade and hemodynamically unstable heart block in a simulation environment. In creating the simulation, our experience was used as a basis for the scenario. Current guidelines for the treatment of cardiac tamponade and complete heart block were referenced for details of the pathophysiology and proposed management.¹⁰⁻¹³

Methods

Development

This simulation was instituted at the University of Iowa for resident physicians within the Department of Anesthesiology. The simulation was based on an amalgam of three cases from our experience and developed to be used in the department's simulation center. Learners from the residency program are required to complete an intern year of training prior to the beginning of anesthesiology specialty training. This intern year includes 2 weeks of inpatient cardiology, 2 months of intensive care, and 1 month of emergency medicine. Prior to their first cardiovascular anesthesia rotation, residents have completed at least 5 months of training in general anesthesiology. As a result, resident physicians currently in anesthesiology training are expected to have a baseline level of knowledge of cardiac physiology, adult cardiac life support, and anesthesiology.

Equipment/Environment

The format of this simulation was designed to be a single 1-hour session using the adult SimMan (Laerdal Medical, Stavanger, Norway) medical simulator connected to standard monitors. A Symbio CS301 3-Lead Heart Rhythm Simulator (Symbio Corporation, Beaverton, OR) was used in conjunction with a Philips HeartStart MRx ALS Defibrillator/EMS Monitor (Phillips Healthcare, Andover, MA) for the heart rhythm portion of the simulation. Access to a SimMan or other similar medical simulator is recommended but not mandatory. Recommended equipment includes simulated real-time vital sign monitoring with cuff and arterial blood pressures, pulmonary artery pressures, capnograph, pulse oximeter, EKG, and temperature probe, as well as a variety of mock syringes and infusions to simulate medication administration such as lidocaine, etomidate, ketamine, propofol, succinylcholine, fentanyl, midazolam, ephedrine, phenylephrine, norepinephrine, and epinephrine. By using the SimMan medical simulator to provide real-time vital signs and procedural guidance, learners were presented with an immersive experience that was more conducive to long-term memory formation than a traditional question-and-answer session would have been.¹⁴

Implementation

The hour-long simulation began with a prescenario briefing including history and physical exam findings, relevant laboratory values, a description of preanesthetic cardiac tests including echocardiography and cardiac catheterization as outlined in Appendix A, and a copy of the patient's 12-lead EKG tracing

(Appendix B, slide 1). At this point, the learner was given some time to formulate a plan. Total time for the prescenario briefing was typically 10 minutes. The scenario then proceeded on the high-fidelity simulator following the case flow. Within this time, the learner was presented with the TEE figures (Appendix B, slides 2-3). When the scenario progressed to the complete heart block phase of the case, the learner was presented with the external defibrillator/pacemaker with the attached heart rhythm simulator. While running the scenario, the learner's progress was monitored in real time with the critical actions checklist (Appendix C). Total time for the scenario was approximately 20 minutes. After the conclusion of the scenario, the learner was debriefed, as described in Appendix D, using the critical actions checklist to help structure learner-specific feedback regarding the experience and to gather feedback from the learner regarding the simulation. Ample time was left in the hour (i.e., 20-30 minutes) for review, debriefing, and feedback. The scenario evaluation form (Appendix E) was given to the learner after the session and collected after completion by a third party, thereby giving the learner anonymity in providing comment.

Personnel

The scenario was designed to run with an instructor leading the case and a medical simulator technician providing real-time changes to the patient status and vital signs. The technician and instructor should meet prior to the presentation to discuss the flow of the case and the cues necessary to transition to different phases of the scenario.

Assessment

Learners during the simulation were assessed on critical actions required to care for patients with severe or critical aortic stenosis, symptomatic bradycardia, and hemodynamic changes related to cardiac tamponade; these items included critical actions that needed to be taken in both diagnosis and treatment. The critical actions checklist was created during evaluation of the step-by-step process of the simulation with the goal of providing a list of the most essential steps in caring for the simulated patient; however, as clinical judgment is more important than any single checklist, this list is meant to be modified based on institutional protocols at the discretion of the instructor.

Debriefing

To allow the learner an opportunity for self-evaluation, the debriefing started with a few open-ended questions, including the following:

- “How do you feel about your performance in the case?”
- “What did you feel you did well?”
- “Where might you want to improve?”

The instructor discussed the critical actions checklist with the learner, which allowed the instructor to review the relevant pathophysiology and to spur discussion about the case. When the debriefing was complete, common complications in TAVI and the pathophysiology and perioperative management of cardiac tamponade and complete heart block were summarized for the learner as a handout.

Results

Fifteen eligible anesthesiology resident physicians were able to experience the content of this simulation with the assistance of the University of Iowa's Department of Anesthesia simulation staff and faculty. The evaluation form consisted of a six-statement survey using a standard 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) for anonymous feedback. Of the six statements in the simulation evaluation survey, all 15 participating learners rated four as strongly agree (5). Of the two remaining statements (“The facilitator helped me to identify areas for improvement discovered during this simulation” and “This activity was appropriate for my level of education and training”), 14 of 15 learners scored them as strongly agree (5), and one rated each as agree (4). During open-ended debriefing, the learners confirmed survey findings of clinical relevance and applicability of the scenario in either preparing for their upcoming cardiac rotation (eight residents) or, for the more senior residents (seven residents), as review and reinforcement of the

concepts. As expected, the senior residents were more adept at finding the correct diagnosis and treatment of cardiac tamponade and complete heart block. For the junior residents, feedback from the cardiac anesthesiology attending physicians was tracked for those learners who were starting their rotations. Those residents who underwent simulation training prior to the rotation were reported to have a better understanding of the TAVI procedure and the associated common and severe complications, were better able to anticipate the anesthetic needs of the patients with critical aortic stenosis regardless of the procedural setting, and had better comprehension of basic TEE cardiac findings.

Discussion

As the number of procedures increased at the home institution, it was felt that developing a simulation around TAVI in a realistic, low-risk environment would be a useful complement to the ongoing training in cardiac anesthesiology. In addition to introducing the procedure itself, simulation provides an opportunity to discuss the cardiovascular changes associated with aortic stenosis, management and diagnosis of cardiac tamponade, arrhythmia interpretation and treatment, and interpretation of advanced hemodynamic monitors. This resource is part of the suite of simulations run by the cardiovascular anesthesiology group for residents on their first month of cardiovascular anesthesia. The index case was selected based on our personal experience.

In the future, this simulation could be expanded to address conversion to emergent open cardiac surgery and the physiology of cardiopulmonary bypass. The scope of the simulation could be expanded to include members of the cardiothoracic surgical team (e.g., scrub technicians, OR nurses, and surgeons) in order to improve communication and teamwork during critical situations (e.g., placement of a pericardial drain, preparation and steps to convert the patient to emergent cardiac surgery). This simulation is also modular: The instructor can adapt the scenario to cover either aortic stenosis or tamponade or complete heart block as a discreet session. A potential alteration to the scenario could place the patient in the ICU during postoperative recovery and run the cardiac tamponade or complete heart block portions of the scenario, which could expand the scope to nonanesthesia trainees.

Specific limitations regarding this simulation are as follows: From an implementation standpoint, the simulation is focused on the intraoperative environment and training anesthesiology residents; therefore, adapting it for other locations and types of trainees would require modification not explicitly covered in the body of the text. In terms of the analysis of efficacy, development and analysis were based on a small sample of trainees (15) and direct feedback from the learners, either in debriefing sessions or through the anonymous survey. However, feedback received from learners and cardiac anesthesia faculty has been overwhelmingly positive. The cardiac anesthesia faculty feedback noted particularly that the junior resident learners had an improved grasp of relevant physiology and the TAVI procedure on rotation; however, formal assessment and comparison of the residents' knowledge presimulation versus postsimulation, which could have captured a more rigorous or quantitative improvement in learner knowledge, were not done. Based on learner feedback, the simulation was extended to include a practical portion where the learner has to prepare the emergency defibrillator/pacemaker. In addition, we expanded the total time for the simulation to include 30 minutes for debriefing. This gave more time than initially planned for the instructors to review the relevant physiology and tailor the debriefing to the individual learner. For the junior trainees, thoroughly reviewing the TAVI procedure during the prescenario briefing and allowing time for planning were felt to be key to maximizing the learning opportunity. Given the positive observations of the cardiac anesthesia faculty and the positive experience of the learners, this simulation was judged to be an effective, valuable learning experience for trainees of intermediate and advanced levels within the Department of Anesthesiology at the University of Iowa and was added to the core simulation curriculum.

Robert Hitchcock, DO, PhD: Clinical Associate Anesthesiologist, Department of Anesthesia, University of Iowa Roy J. and Lucille A. Carver College of Medicine

Clark J. Obr, MD: Clinical Associate Professor, Department of Anesthesia, University of Iowa Roy J. and Lucille A. Carver College of Medicine

Sudhakar Subramani, MBBS: Clinical Assistant Professor, Department of Anesthesia, University of Iowa Roy J. and Lucille A. Carver College of Medicine

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Ethical Approval

Reported as not applicable.

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