Intraoperative Goal-Directed Anesthetic Management of the Patient with Severe Pulmonary Hypertension

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Patient:	**Female, 76**
Final Diagnosis:	**Right upper lung tumor with severe pulmonary hypertension**
Symptoms:	**Shortness of breath**
Medication:	**—**
Clinical Procedure:	**Ecective bronxhoscopy • robotic right upper lobectomy • thoracic lymphadenectomy**
Specialty:	**Anesthesiology**

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Objective:	**Rare co-existance of disease or pathology**
Background:	It is very challenging for anesthesiologists to manage patients with pulmonary hypertension undergoing general anesthesia for elective or emergent surgeries.
Case Report:	We present a patient with severe pulmonary hypertension going through a major robotic thoracic surgery.
Conclusions:	A goal-directed anesthesia management algorithm based on serial stroke volume (SV) values obtained from FloTrac (Edwards Lifesciences, LLC.) minimally invasive arterial pressure sensor was utilized in an attempt to reduce the anesthetic and surgical risk associated with severe pulmonary hypertension.

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Background

Pulmonary hypertension (PHT) is one of the most challenging pathophysiologic conditions for an anesthesiologist to manage. The morbidity and mortality of such patients undergoing surgical procedures is much higher due to more intense hypoxia, hypercarbia, arrhythmias, ischemia, and right ventricular failure. The complexity of these conditions associated with PHT can lead to intra- and post-operative hemodynamic instability which can be extremely difficult to manage. Until recently, severe PHT was a contraindication to administering anesthesia. However, with the advance of innovative treatments, the life expectancy and functional capacity of patients with PHT has significantly improved. Today, anesthesiologists are more likely to encounter patients with PHT presenting for elective surgeries [1,2]. The anesthetic management of patients with severe PHT undergoing major thoracic surgery demands an especially focused approach guided by the etiology of the disease and the nature of the surgical procedure. Understanding the cause, type, and severity of PHT allows anesthesiologists to formulate a detailed anesthesia management plan to decrease overall risk to the patient.

The patient described in this case report had severe PHT and underwent a pulmonary lobectomy, a major thoracic surgical procedure, which is prone to an elevated risk of peri-operative morbidity and mortality. The required one lung ventilation (OLV) represented a functional form of extracardiac right to left shunt with simultaneously increased dead space ventilation, which was expected to worsen the patient's already existing hypoxia and hypercarbia.

With the assistance of advanced technology, intra-operatively minimally invasive cardiopulmonary monitoring allowed for prompt recognition of cardiac and pulmonary dysfunction and goal-directed optimal anesthetic management to minimize the patient's risk of peri-operative complications [3,4]. Stroke volume variation (SVV) and pulse pressure variation (PPV) are used as indicators of fluid responsiveness, but these values have proven to not be useful for video-assisted thoracoscopic surgery or open thoracic surgery [5]. In fact, in patients with severe PHT, PPV and SVV values would not accurately predict preload due to right heart strain in other surgical procedures as well such as major abdominal operations.

The main purpose of peri-operative goal-directed therapy is to maintain oxygen delivery by providing adequate vital organ perfusion. Both under- and over-resuscitation may lead to adverse outcomes [6]. A reliable systematic review validated the usefulness of peri-operative goal-directed therapy [7]. Conversely, a randomized controlled trial showed that goal directed therapy including SV and dobutamine and norepinephrine infusions during transthoracic esophageal resection
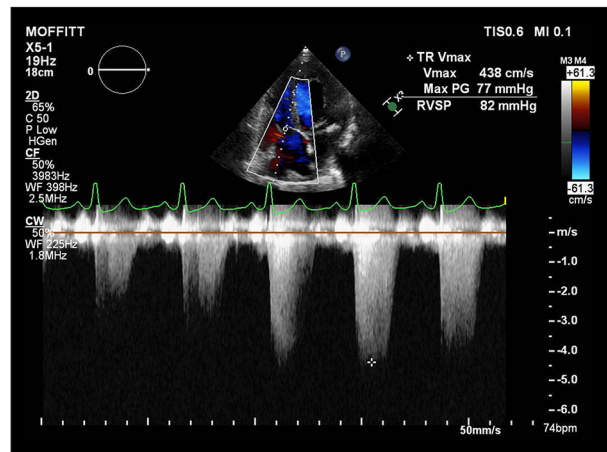
Figure 1. Echocardiogram with pulsed-wave Doppler demonstrating a RVSP of 82 mmHg.

did not improve outcomes [8]. Thus, we used serial SV values in conjunction with standard anesthesia monitors as our optimal goals to direct this patient's anesthesia management.

Case Report

The patient was a 76-year-old Native American female with an enlarging right upper lobe lung nodule who presented for elective bronchoscopy, robotic right upper lobectomy, thoracic lymphadenectomy, and possible thoracotomy. The patient weighed 77.2 kg, was 167 cm tall, and had an American Society of Anesthesiologists (ASA) classification IV due to multiple severe medical conditions including severe pulmonary hypertension, history of severe aortic stenosis with percutaneous trans femoral aortic valve replacement 7 months prior, cardiomyopathy and associated congestive heart failure, a small ventricular septal defect, severe chronic obstructive pulmonary disease, and left breast cancer. Her ongoing severe PHT was documented by several 2D-Doppler studies and right cardiac catheterization. Her pulmonary artery systolic pressure was measured at 72 to 82 mmHg (Figure 1) on multiple occasions at different institutions. A dose of sildenafil 20 mg was given to her by mouth 1 hour pre-operatively in an attempt to relieve her intra-operative pulmonary artery pressure. The risks of anesthesia, including possible serious cardiac and pulmonary complications, were discussed in detail with the patient and her husband. Both agreed to proceed with the planned operation. The peri-operative anesthesia management plan was communicated to the surgical team in detail to avoid all potential factors which could worsen her PHT by restricting fluid administration, and avoiding hypercarbia, hypoxia, and hypothermia.

A left radial arterial line was inserted under local anesthesia and linked to a FloTrac (Edwards Lifesciences, LLC.) minimally invasive monitoring system before anesthetizing the patient.

After calibrating the FloTrac monitor, the patient's baseline SV was recorded as 51 mL (normal range 60–100 mL) as was expected due to a known left ventricular ejection fraction of 45–50% from prior echocardiograms. Her blood pressure (BP) was 122/75 mmHg, heart rate was 74–82 beats per minute, and oxygen saturation was 98%. After the smooth induction of general anesthesia with 10 mg of etomidate, 100 ug of fentanyl, and 50 mg of rocuronium, direct laryngoscopy was performed, and a 35 French double-lumen endotracheal tube was positioned into the left mainstem bronchus and verified by fiberoptic bronchoscopy. Her baseline oxygen saturation on OLV was 94–96% with a 40% fraction of inspired oxygen (FiO_2). After Foley catheter insertion, a prophylactic antibiotic, and subcutaneous heparin administration, the patient was placed in the left lateral decubitus position. Shortly after surgical incision and carbon dioxide insufflation to a pressure of 8 mmHg to the patient's right thoracic cavity, her SV dropped to 40–45 mL and her oxygen saturation decreased to 86–88%. In an attempt to improve the patient's SV without aggressive intravenous fluid administration, 0.5 mcg/kg/minute of intravenous milrinone (4 mg total) along with 3 units/hour of vasopressin (5.4 units total) were initiated as continuous infusions. Her SV gradually improved to 64–67 mL with only 150 mL/hour of intravenous Plasma-Lyte injection as a maintenance fluid. Both infusions were titrated carefully, and were eventually weaned off at the end of surgery. Additionally, a 0.1–0.2 mg bolus of phenylephrine was injected intravenously when the patient's BP dropped below 90/50 mmHg (2.3 mg total). Her oxygen saturation improved and was consistently above 95% with this management strategy as well as by utilizing a higher FiO_2 and adding 8 cm H_2O of positive end-expiratory pressure so as not to have a deleterious effect on the patient's preload. At the conclusion of her procedure, a multi-level intercostal block from T2 to T11 using 25 mL of 0.5% bupivacaine with 1: 200 000 epinephrine was performed under thoracoscopic guidance in order to minimize post-operative opioids and the potential for hypoventilation with resulting hypercarbia which could further exacerbate her PHT. The technical portion of the robotic lobectomy and lymphadenectomy was uneventful with an estimated blood loss of 50 mL and a "skin-to-skin" operative time of 155 minutes. Her core body temperature was kept normal with a lower body Bair Hugger warmer system and warm intravenous fluids. Overall, the patient tolerated the procedure well and was brought to the recovery room in stable condition. The patient did well post-operatively, was discharged home on post-operative day #2, and reported no significant concerns at a follow-up outpatient clinic visit on post-operative day #10.

Discussion

It is well known that PHT is associated with increased morbidity and mortality in the peri-operative period, particularly in major thoracic surgical procedures, such as a pulmonary lobectomy. OLV is required for optimizing surgical conditions for robotic thoracic surgery, and can cause many significant physiological derangements. These derangements are typically well-tolerated and ultimately reversible without prolonged adverse consequences in healthy patients. This patient with severe PHT undergoing major thoracic lobectomy and lymphadenectomy required OLV and extremely careful fluid management to maintain cardiopulmonary stability, and especially avoid right heart failure, which proved very difficult to manage.

In the wake of mounting evidence suggesting a lack of benefit to the routine use of pulmonary artery catheters [9–14], minimally invasive monitoring techniques can alert anesthesiologists of changes in hemodynamics, and have become a part in routine assessment of critically ill patients. In this patient, we attempted to choose the most relevant and reliable monitoring values considering the nature of robotic surgery. Multiple studies have shown that stroke volume variation and pulse pressure variation are not useful for predicting fluid responsiveness in video-assisted thoracoscopic or open thoracic surgery. Research on peri-operative fluid therapy has recently focused on either fixed high- versus low-volume regimens and individualized optimization strategies, often referred to as goal-directed therapy [15,16]. Therefore, instead of using stroke volume variation, we chose to use serial SV values as our goal-directed targets adjunctively with other standard vital signs to guide our overall anesthesia management. It is known that maintaining sufficient cardiac output in the anesthetized patient allows adequate oxygen delivery to and tissue perfusion of critical organs. Therefore, anesthetic management guided by serial SV values in conjunction with heart rate ensured adequate cardiac output in this patient with severe PHT, potentially decreasing peri-operative complications.

The patient did well clinically throughout the peri-operative period, despite consistently high pulmonary arterial pressures (82 mmHg) as evidenced by post-operative day #1 echocardiography. One of the patient's medical conditions that may have contributed favorably to her outcome was her congenital ventricular septal defect (VSD). This small VSD may have offset her PHT by allowing a partial decompression of the right ventricle by having a small portion of blood bypass the lungs in a right to left intracardiac shunt, thus leading to improved left ventricular blood flow and cardiac output without significantly diminishing systemic arterial oxygen saturation. Additionally, maintaining a restrictive fluid strategy in this patient (less than 2 mL/kg/hour total intravenous fluids) may have reduced the chances of exacerbating her PHT, and therefore been a major contributing factor to the patient's favorable outcome.

Conclusions

Guided by minimally invasive goal-directed serial SV values as an additional monitoring target in conjunction with standard anesthesia monitors, we were able to provide safe anesthesia for this ASA classification IV patient with severe PHT undergoing robotic pulmonary lobectomy.

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Conflict of interest

None.