Anesthetic Implications of Chronic Lung Disease in Patients Undergoing Transcatheter Valve Implantation

Mojca Remskar Konia, MD, PhD, MACM*,1, Gregory Helmer, MD†, Ganesh Raveendran, MD†, Ioanna Aposolidou, MD, PhD‡

*Department of Anesthesiology, University of Minnesota, Minneapolis, MN
†Department of Cardiology, University of Minnesota, Minneapolis, MN

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ONE QUARTER OF patients undergoing transcatheter aortic valve implantation (TAVI) have evidence of chronic lung disease (CLD), obstructive or mixed. CLD is recognized as a major risk factor for perioperative morbidity and mortality.1-3 Specifically, the presence of CLD is a risk factor for postoperative pulmonary complications and an independent predictor of 1-year mortality related to cardiovascular deaths.6-8 The impact of restrictive lung disease on perioperative outcomes has not been studied systematically.

Anesthetic choice for the patient with CLD presenting for TAVI procedure can affect patient outcomes. Experiences in patients with chronic obstructive pulmonary disease (COPD) undergoing percutaneous vascular procedures such as endovascular abdominal aortic aneurysm repair indicated that the use of local/regional/neuraxial anesthesia improved outcomes.9 General anesthesia (GA) initially was the preferred anesthetic technique for all TAVI procedures. However, with increasing operator experience and improvement in the devices used, local/regional anesthesia with conscious sedation (LRACS) is being used increasingly in Europe.7,10,11 US practitioners have been slower to accept LRACS as the primary anesthetic choice, but the authors believe that LRACS will become the preferred anesthetic choice in the future.

The perioperative anesthetic management of an elderly patient under LRACS with severe, predominantly restrictive, lung disease and moderate obstructive lung disease is presented here. In addition, the existing literature on the evolving aspects of the anesthetic management of these patients is reviewed, and evidence-based management strategies for patients with CLD is provided.

The patient described in this case report provided informed consent for the deidentified, retrospective use of his data for research purposes.

Case Presentation

An 89-year-old, 175-cm, 69-kg man with a history of congestive heart failure, atrial fibrillation, hypertension, dyslipidemia, severe lung disease, and worsening shortness of breath was diagnosed with severe aortic stenosis (AS). Given his comorbidities and high Society of Thoracic Surgeons mortality risk index score (10.5%), the patient was deemed high risk for surgical aortic valve replacement and was believed to be an appropriate candidate for transfemoral TAVI.

His preprocedural evaluation included transthoracic echocardiography, cardiac catheterization with angiography, and computed tomographic (CT) evaluation of the aortic valve/annulus, aorta, and iliofemoral vessels.

Transthoracic echocardiography revealed severe AS with an aortic valve area of 0.57 cm², mean aortic valve gradient of 37
mmHg, and peak velocity of 3.04 m/s (paradoxic low-flow, low-gradient pattern).\(^{12}\) Other pertinent echocardiographic findings included mild-to-moderate mitral and tricuspid regurgitation, mild pulmonary regurgitation, biaxial enlargement, severe left ventricular hypertrophy, and normal systolic biventricular function. Cardiac catheterization confirmed the hemodynamic echocardiographic findings and did not demonstrate any significant coronary artery disease.

CT angiogram revealed an aortic annulus diameter of 26.8 mm, area of 5.67 cm\(^2\), and perimeter of 86.8 mm. Coronary ostia-to-annulus distance was 11.9 mm for the left and 14.2 mm for the right coronary arteries, respectively. Iliofemoral vessels were significantly tortuous but of suitable size for a transfemoral access. A multidisciplinary team reviewed these studies and a 31-mm CoreValve (Medtronic, Minneapolis, MN) was chosen for the patient.

His medical history included a lifetime history of smoking and severe interstitial lung disease. Preoperative chest x-ray revealed cardiomegaly and pulmonary venous congestion with increased interstitial markings. In addition, pulmonary function tests showed a restrictive pattern with reduced lung volumes (forced vital capacity [FVC] at 44%, forced expiratory volume in 1 second [FEV\(_1\)] at 55%, FEV\(_1\)/FVC\% at 118%, and diffusing capacity of lung for carbon dioxide at 25% [% indicates percent predicted values]), which were consistent with moderate-to-severe restrictive lung disease. His baseline arterial oxygen saturations during his recent clinic visits were between 87% and 95% on room air. The patient refused the use of home oxygen. Pertinent home medications included furosemide, metoprolol succinate extended release, doxazosin mesylate, fluticasone propionate inhalation powder, and warfarin, and his laboratory results were within normal limits. An electrocardiogram showed atrial fibrillation with ventricular response at 80-to-105/minute, left ventricular hypertrophy, and no ST-T abnormalities.

**Procedural Details**

A cutdown was required to obtain vascular access after multiple failed percutaneous attempts that extended the procedure time. The left femoral artery and vein were cannulated with a 5-Fr sheath and the right femoral artery with an 18-Fr sheath. Without valvular predilation, a 31-mm Medtronic CoreValve was introduced and positioned under fluoroscopic guidance with concurrent pacing at 120 beats/minute. Aortography and hemodynamic assessment demonstrated a well-positioned aortic valve. A transthoracic echocardiogram showed that the CoreValve was well-seated and functioning with only a trace paravalvular leak and no evidence of pericardial effusion. The patient developed severe bradycardia after valve deployment that necessitated temporary transvenous pacing; a permanent pacemaker was inserted later, before hospital discharge.

**Anesthetic Management**

Considering the severity of the patient’s lung disease and after discussion with the surgical team and the patient, it was decided to perform the procedure with the patient under LRACS. The regional anesthesia consisted of bilateral transversus abdominis plane (TAP) blocks performed to provide 48-to-72 hour analgesia in the L1 distribution. The TAP blocks were performed under ultrasound guidance in the preoperative area. A total of 20 mL (10 mL each side) of liposomal bupivacaine 0.25% (Exparel, San Diego, CA) was injected into the neurofascial plane between the internal oblique and transversus abdominis muscles to block the lower abdominal wall neural afferent fibers. The patient then was taken to the operating room and placed in the supine position, and supplemental oxygen via nasal cannula was supplied to maintain oxygen saturation above 92%. In addition to standard American Society of Anesthesiologists monitors, a left radial arterial catheter and a right internal jugular central catheter were placed for monitoring. At baseline the patient’s blood pressure was 167/67 mmHg, heart rate was 89 beats per minute, and pulse oximetry was 89% on room air, which improved to 96% with oxygen, 4 L per nasal cannula. Sedation was achieved with dexmedetomidine, 0.4-to-0.7 \(\mu\)g/kg/h, and remifentanil, 0.02-to-0.1 \(\mu\)g/kg/min infusions, which were adjusted to maintain a desired sedation level based on the stage of the procedure. Sedation scores (Ramsey Sedation Scale) were between 3 (light) and 5 (deep).\(^{13}\) The patient remained responsive to loud verbal stimulation throughout the procedure (Ramsey Sedation Scale 2-3), except during valve deployment, at which point sedation was deepened to prevent patient movement (Ramsey Sedation Scale 4). No other sedative or analgesic medications were administered. The authors observed temporal variations of blood pressure and heart rate triggered by cardiology instrumentation during the various stages of the procedure and during the period of valve deployment, when the patient required a total bolus of 0.032 mg of norepinephrine given in 4 doses. After valve deployment, the patient developed complete atroventricular block and required pacing using a right internal jugular vein transvenous temporary pacemaker. During the period of bradycardia, the patient developed dyspnea and oxygen desaturation (oxygen saturation 85%), which was treated effectively with noninvasive positive-pressure ventilation using bilevel positive airway pressure (BiPAP) with the setting 12/6 and 30% oxygen. The BiPAP resulted in improved oxygenation and resolution of his dyspnea, and the patient was weaned from BiPAP within 15 minutes after arrival to the postanesthesia recovery unit. Upon discontinuation of BiPAP, the patient’s arterial oxygen saturation was maintained above 92% with 3 L of oxygen via nasal cannula. The patient received a total of 2.5 L of crystalloid fluids over 7 hours.

**Postoperative Course**

The patient experienced mild postoperative pain (maximum pain score of 3 on a visual analog pain scale [0-10]), and he required a single dose of 2 mg of morphine. He was discharged to an advanced care facility on postoperative day 4. His New York Heart Association classification did not improve in the following months, and he continued to
experience shortness of breath with minimal physical activity and required continuous oxygen therapy for low arterial oxygen saturation (88% on room air). The patient died 8 months after the procedure from complications of a fall resulting in a back injury.

Discussion

The authors present the perioperative anesthetic management of a patient with severe restrictive lung disease and moderate obstructive pulmonary disease who underwent successful transfemoral TAVI under regional anesthesia with bilateral TAP blocks and sedation with remifentanil and dexmedetomidine.

The authors considered the following patient- and procedure-related factors to determine the anesthetic management for the patient described here: (1) severity of the lung disease and its association with perioperative outcome, (2) eligibility for regional anesthesia, (3) availability of the large 31-mm CoreValve, and (4) the patient’s motivation and consent to regional anesthesia with sedation.

Local/Regional Anesthesia Versus General Anesthesia and Patient Outcomes

TAVI procedures can be performed with the use of either GA or LRACS. Initially, GA represented the most popular anesthetic technique due to patient comfort, security of the airway, ability to perform intraoperative transesophageal echocardiography (TEE), and a more expedient management of ventilation and potential complications. However, with increased surgical experience and shorter surgical times, LRACS has become increasingly popular and the main type of anesthesia in several European and American centers. Faster recovery and increased hemodynamic stability are the main advantages of this technique versus GA.

Choice of Anesthesia in Patients With Chronic Lung Disease

Major goals of anesthetic management in patients with chronic lung disease are avoidance of respiratory depressant medications and mechanical ventilation, provision of good analgesia to prevent worsening of respiratory mechanics, and early ambulation. Patients with restrictive lung disease, like the patient described here, have low oxygen reserve and lung compliance arising from the decreased FRC and ventilation/perfusion mismatching that can decrease further after GA with muscle relaxation. Indeed, pulmonary complications are higher after GA than after local or regional anesthesia in patients with COPD. Hausman et al demonstrated that the use of regional anesthesia, as opposed to GA, decreased the risk of pneumonia, ventilator dependence, unplanned postoperative intubation, and overall morbidity in COPD patients undergoing a variety of moderate-risk surgical procedures. Moreover, a study from the American College of Surgeons National Surgical Quality Improvement Program database showed that GA for endovascular abdominal aortic aneurysm repair procedures was associated with higher pulmonary morbidity and postoperative length of stay compared with spinal and local anesthesia/monitored anesthesia care and advised the use of less invasive anesthetic techniques for these procedures, regardless of the presence of COPD. However, the management of intraoperative complications, such as airway obstruction, hypoventilation, and hemodynamic instability, can be more challenging, including the need for rapid conversion to GA. Thus, the presence of an experienced anesthesiology team is essential.

Despite the relative merits of both anesthetic techniques, a recent meta-analysis from Europe of 7 observational studies demonstrated that TAVI procedures performed with the patient under LRACS had shorter duration by a mean difference of 36.3 minutes (95% CI –58 to –15, p < 0.001); shorter hospital stay (mean difference 3 days; 95% CI –5 to –1, p = 0.004); and no difference in mortality rate (relative risk 0.77 [0.38 to 1.56], p = 0.460). Avoiding periods of potential hemodynamic instability, such as during the induction of GA and tracheal intubation and extubation, is an additional benefit of LRACS. The overall conversion rate from LRACS to GA was reported to be 6.3% and was due to complications of the procedure rather than patient intolerance of the anesthetic technique. The main reason for the use of GA was the need for TEE to guide valve deployment and assess the degree of aortic regurgitation after deployment. However, fluoroscopy and transthoracic echocardiography also can be used for this purpose and may reduce the need to use GA as a first option or the need for conversion to GA during the procedure. Guarracino et al reported on the possibility of performing a continuous TEE through a modified face mask with the patient under LRACS. Prolonged TEE may be challenging with the patient under conscious sedation. Intolerance to the TEE probe is one of the main complications, followed by bronchospasm, hypoxia, and aspiration in TEE examinations performed with the patient awake or under moderate sedation.

LRACS Technique

There are no specific protocols reported for the conduct of LRACS for TAVI patients (Table 1). Most centers use a combination of a shorter-acting narcotic (fentanyl or remifentanil) and a sedative/hypnotic infusion (dexmedetomidine or propofol) with rates adjusted to achieve the desired level of sedation. To provide patient comfort for femoral vascular access, different techniques have been tried. Local infiltration, nerve block techniques such as ilioinguinal/iliohypogastric block, and TAP blocks can be used (authors’ experience). There are no studies comparing the different techniques. Neuraxial analgesia and anesthesia mostly are avoided due to the undesirable decrease in systemic vascular resistance induced by neuraxial techniques in patients with severe/critical AS. In addition, the potential need for full heparinization often is worrisome to anesthesiologists, who therefore preferentially choose peripheral nerve block techniques.
Impact of Chronic Lung Disease on Postoperative Outcomes

The available literature related to the impact of CLD on postoperative outcomes in TAVI had several limitations. The majority of studies did not differentiate between the different types of CLD. Little data exist on the impact of restrictive lung disease. Furthermore, even more importantly, studies did not stratify patients by the severity of pulmonary disease.

More data are available on the impact of COPD than restrictive lung disease on patient outcomes. Data from the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapies Registry in the United States demonstrated a 30-day mortality rate of 7.0% (95% CI 6.5%-7.4%) and a 1-year mortality rate of 23.7% in TAVI patients. CLD is present in 21% to 43% of patients undergoing TAVI and has been recognized as a risk factor for postoperative pulmonary complications and worse outcome in surgical patients. When compared with patients without lung disease, TAVI patients with COPD have significantly lower survival rates at 1 year (70.6% vs 84.5%, p = 0.008). Moat et al. (United Kingdom experience) found that COPD was one of the important risk factors for post-procedural mortality (hazard ratio [HR] 1.41, 95% CI 1.02 to 1.93). Similarly, the PARTNER trial data analysis demonstrated significantly higher mortality among TAVI patients with CLD compared with patients without lung disease (23.4% vs 19.6%, p = 0.02). The FRANCE 2 Registry also demonstrated significantly higher mortality in COPD patients (HR 1.19, 95% CI 1.005-1.41, p = 0.03). In contrast, analysis of data from the German TAVI Registry did not identify COPD as a risk factor for patient outcome. The German TAVI Registry researchers did not discuss the type of anesthesia specifically, but considering that only 1% of patients were mechanically ventilated, it can be assumed that a majority of procedures were completed with the patient under LRACS. In other registries the predominant anesthetic choice was GA. Whether the difference in demonstrated outcomes in patients with COPD was related to the choice of anesthesia in different trials is pure speculation, but it may be one of the possible explanations. Studies indicated that similar patient outcomes could be achieved in patients with and without COPD; however, large randomized studies need to clarify the best practice for these patients.

To quantify the clinical significance of the lung disease, a 6-minute walk test (6MWT) can be used. It is a submaximal measurement of aerobic capacity in patients, and in patients with restrictive and obstructive lung disease, it has been shown to be a useful predicting factor for patient mortality. The normal values vary by age and sex. In a 90-year-old male the normal value would be anywhere from 296 to 471 m.

In TAVI patients, a shorter 6MWT (< 170 m) predicted significantly greater cumulative mortality (p = 0.013). Poorer baseline spirometry results (FEV₁ < 60%) predicted a significantly higher rate of periprocedural pulmonary complications (p = 0.04). Other studies have confirmed the importance of poorer mobility on 6MWT (HR 1.67, p = 0.0009) and have identified oxygen dependency (HR 1.44, p = 0.02); high pulmonary artery pressures (HR 1.26, p = 0.0008); renal disease (HR 1.43, p = 0.049); and low body mass index (HR 0.97, p = 0.004) as additional risk factors. A recent analysis demonstrated that in addition to COPD, restrictive ventilatory disease (HR 2.252, p = 0.002); oxygen dependency (HR 3.291, p = 0.004); and noninvasive ventilation (HR 3.799, p = 0.005) were independent predictors of long-term mortality after TAVI. Restrictive lung disease has been reported in up to one-quarter of patients with severe AS. Its impact on postoperative outcomes in TAVI patients has not been investigated in detail. A small study in 94 patients showed similar rates of in-hospital, 30-day, and 1-year mortality in patients with obstructive and restrictive pulmonary disease. In other registries the predominant anesthetic choice was GA. Whether the difference in demonstrated outcomes in patients with COPD was related to the choice of anesthesia in different trials is pure speculation, but it may be one of the possible explanations. Studies indicated that similar patient outcomes could be achieved in patients with and without COPD; however, large randomized studies need to clarify the best practice for these patients.

Table 1

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of Patients</th>
<th>Sedation Technique</th>
<th>Local/Regional Anesthesia Technique</th>
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<tbody>
<tr>
<td>Yamamoto, 2013</td>
<td>174</td>
<td>Propofol (target-controlled infusion)</td>
<td>1% lidocaine subcutaneously, maximum 400 mg</td>
</tr>
<tr>
<td>Bergmann, 2011</td>
<td>151</td>
<td>Midazolam PO 0.05-0.1 mg/kg</td>
<td>Lidocaine (concentration not specified) subcutaneously, maximum 400 mg</td>
</tr>
<tr>
<td>Motloch, 2011</td>
<td>74</td>
<td>Midazolam up to 1 mg IV</td>
<td>1% lidocaine subcutaneously, maximum 400 mg</td>
</tr>
<tr>
<td>Ben-Dor, 2012</td>
<td>142</td>
<td>Propofol/ketamine 10-50 μg/kg/min</td>
<td>1% lidocaine subcutaneously, maximum 400 mg</td>
</tr>
<tr>
<td>Oguri A, 2014</td>
<td>2,326</td>
<td>Sedation (not further defined)</td>
<td>Local infiltration (not further defined)</td>
</tr>
<tr>
<td>Dall’Ara, 2014</td>
<td>4,571</td>
<td>Sedation with target-controlled infusion of an anesthetic and/or opioid</td>
<td>1% lidocaine subcutaneously, maximum 400 mg</td>
</tr>
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However, in patients with AS, restrictive lung disease has been associated with lower left ventricular ejection fraction, higher plasma brain natriuretic peptide levels, and pulmonary edema and should be considered a prognostic marker of mortality after TAVI.47

A component of restriction and obstruction in patients with severe AS may be caused by pulmonary edema from congestive heart failure related to valvular disease. Studies indicated that patients’ pulmonary function tests improved by 1 COPD severity category after TAVI in almost half of patients.49 Improvement only will occur, of course, if the underlying lung disease is caused by reversible causes and not by permanent interstitial pulmonary disease.

Even though the main intent of performing a TAVI procedure is to prevent mortality in patients with severe AS, the secondary outcomes of functional improvement after the procedure also are important.

Several studies have demonstrated a significant improvement in symptoms and quality of life after TAVI.49 Reynolds et al50,51 analyzed data from the PARTNER trial and demonstrated statistically significant improvement of quality of life at 1, 6, and 12 months (p < 0.001). Bagur et al52 also described significant improvements of functional status at 6 months in patients who underwent TAVI. However, about one-third of patients demonstrated no improvement in functional status, in whom the procedure would have been deemed futile.52 One of the predictors of poorer outcomes in the Bagur et al study was pre-existing renal failure (odds ratio 1.7 for each decrease in the estimated glomerular filtration rate of 10-ml/min/1.73 m2, 95% CI 1.3-2.3, p = 0.005). The Mok et al6 analysis of patients with CLD demonstrated a significantly higher rate of either worse or no change in functional status (28.4 v 16.3%, p = 0.036) after TAVI procedures in patients with comorbid pulmonary disease.6 Patients with COPD had a 42.5% rate of futility, defined as death or absence of functional improvement at 6 months’ follow-up.6

The patient described in this case report had no functional improvement after TAVI. Lack of functional status improvement in the patient most likely was attributed to the underlying chronic restrictive lung disease.

Summary

This case highlights the multiple factors that should be taken into consideration for the anesthetic planning of patients with severe restrictive lung disease undergoing TAVI. Assessing whether the clinical benefit of the procedure exceeds its futility can be a big clinical challenge, and multidisciplinary evaluation is mandatory to define the most appropriate therapy for each patient. There is no “cookbook” approach for the anesthetic management, and the final plan should be individualized to the clinical situation, the wishes of the patient, and after taking all relevant factors into account. Prospective, randomized studies are needed to determine whether LRACS offers convincing benefits over GA. Until then, it may be prudent to selectively consider LRACS as an anesthetic option for TAVI patients with CLD.

References