Anesthetic Implications of Robotic Surgery

2

Pete Roffey

Medical Comorbidities

Oftentimes, patients coming for robotic procedures have medical comorbidities that place them at a higher risk for anesthesia themselves. The appropriate preoperative workup of these issues is discussed in another chapter, but a brief overview of relevant topics follows.

In general, the age of surgical patients is increasing. Elderly patients often have cardiovascular disorders such as coronary artery disease, cardiomyopathies with low ventricular ejection fractions, diastolic dysfunction with or without preserved ejection fraction, peripheral vascular disease such as carotid stenosis, and/or hypertension, which may in turn lead to chronic kidney disease.

Hypertension, seemingly nearly ubiquitous in these patients, is associated with intravascular depletion from chronic vasoconstriction, which tends to cause exaggerated swings in blood pressure until corrected. In addition, though controversial, many anesthesiologists feel that patients who are on angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARB) often show hemodynamic instability intraoperatively due to resistant reduction in afterload [1–3]. ACE inhibitors prevent breakdown of bradykinin, leading to increased levels of nitric oxide (NO) [2]. This in combination with decreased venous return from insufflation can cause severe hypotension that may not be responsive to fluid challenges. Once adequate fluid administration has occurred, if hypotension persists, it may be necessary to institute an infusion of norepinephrine or vasopressin to increase afterload. It is this author's opinion that both ACE inhibitors and ARB agents should be withheld for 24 h prior to surgery, though this does not guarantee this reaction will not still occur.

Smoking results in a significant increase in urologic cancers including transitional cell carcinoma of the bladder, with smokers having approximately three times the risk of bladder cancer relative to nonsmokers [4]. Therefore, a significant number of patients presenting for cystectomy will have this history, whether active or not, often with the associated comorbidities of COPD, productive cough, and coronary artery disease.

Due to the presence of these comorbidities or merely the advanced age of the patient, these patients may have various degrees of chronic kidney disease. It is important to remember that serum creatinine level does not necessarily reflect glomerular filtration rate (GFR), which is also related to age, race, and sex, and may remain normal until significant impairment of GFR exists.

P. Roffey, MD (✉)
USC Keck School of Medicine, Department of Anesthesiology, 1500 San Pablo Street, Los Angeles, CA 90033, USA
e-mail: roffey@med.usc.edu

R. Sotelo et al. (eds.), *Complications in Robotic Urologic Surgery*,
DOI 10.1007/978-3-319-62277-4_2

Patient home medications, such as ACE inhibitors, may also induce renal injury. Additionally, patients with renal cell carcinoma have a 3.1 relative risk of developing disease of the contralateral kidney in the future [5]. Therefore, patients presenting for partial or radical nephrectomy may have already undergone a similar operation on the contralateral side.

Obesity patients are known to have a high incidence of comorbidities such as hypertension and diabetes and present many challenges to the anesthesiologist. These include issues with mask ventilation, intubation, and intravenous and arterial line placement. Their large size may also have a negative impact on intraoperative ventilation, especially in cases of steep Trendelenburg.

Intraoperative Concerns

Pneumoperitoneum

In order to obtain surgical exposure, carbon dioxide is insufflated into the abdomen. This leads to a number of physiologic changes affecting different organ systems that the anesthesiologist must be aware of. These changes tend to be insufflation pressure-dependent, such that the greater the insufflation pressure, the greater the effect on various organ systems. At this time, it is recommended to maintain insufflation pressures below 15 mmHg if possible and below 12 mmHg in cases of steep Trendelenburg [6].

Insufflation has several effects on the cardiovascular system. There can be many reactions to initial insufflation, including tachycardia and hypertension. Response to insufflation includes release of catecholamines and vasopressin with renin-angiotensin activation [7]. Also of great concern is the potential for a vasovagal reaction resulting in severe bradycardia and hypotension, which may be significant enough to lead to asystole and cardiac arrest. This may respond to anticholinergic agents such as glycopyrrolate or in more severe cases atropine or vasopressors such as ephedrine. In cases of hemodynamic instability, the surgeons should be notified to desufflate the abdomen immediately and allow the patient time to recover prior to reinsufflation. Following treatment with anticholinergic agents and adequate recovery time, insufflation can be attempted again slowly; usually subsequent attempts do not lead to such significant hemodynamic consequences. Other complications associated with initial insufflation include hemorrhage due to blood vessel injury during trocar placement and carbon dioxide embolism, resulting in cardiovascular collapse. The latter complication has been shown to occur with a much higher frequency than would be thought, though the incidence of clinically significant embolism is low [8]. The diagnosis can be made by transesophageal echocardiography, along with a high degree of suspicion from the timing of events.

Cardiovascular

Venous return is altered during insufflation. While initially there is an increase in venous return due to compression of the splanchnic circulation, subsequently there is a decrease, due to interference of venous flow from the lower extremities, ultimately leading to a drop in cardiac output and potential hypotension. Patients who are already intravascularly depleted are more at risk for this complication.

Transesophageal echo evaluation during pneumoperitoneum has shown conflicting results with regard to left ventricular ejection fraction (EF). Though some studies have shown no overall effect on EF, a more recent study documented an initial decrease felt to be related to increased afterload followed by a subsequent recovery, often facilitated by positioning in the Trendelenburg position [9]. The author has noted direct distortion of the cardiac profile during pneumoperitoneum, with compression of the right ventricle and rotation of the cardiac axis. Though usually tolerated, this may be of significance in a patient with already compromised cardiac function. The release of catecholamines secondary to the pneumoperitoneum may add stress to patients with preexisting coronary artery disease and, combined with increased afterload and tachycardia in the presence of diastolic dysfunction, may lead to ischemia and cardiac decompensation [9].

Airway/Respiratory System

Many aspects of the respiratory system are affected during robotic procedures. Functional residual capacity, already compromised by anesthesia, undergoes further reduction as a result of the pneumoperitoneum, causing diaphragmatic elevation, lung compression, and decreased pulmonary compliance. This in turn can lead to high peak pressures and an increased risk of barotrauma. Carbon dioxide is used to create the pneumoperitoneum, which is absorbed by patients to a varying degree and leads to a variable rise in $PaCO_2$, necessitating increased minute ventilation. It is estimated that between 14 and 48 mL/min of CO_2 is absorbed during laparoscopic procedures [10]. Just over 5% of the time, $PaCO_2$ rises at a greater rate than can be removed and severe hypercapnia results. This in turn results in a significant respiratory acidosis. The use of bicarb is contraindicated here due to the ultimate rise in CO_2. Though patients often tolerate some degree of respiratory acidosis well, rises in potassium can be seen with this technique and can be significant [11]. One also must bear in mind the effects of hypercarbia on pulmonary artery pressures, especially in those with preexisting pulmonary hypertension. It is important to remember that as $PaCO_2$ rises, $PetCO_2$ can become a less reliable reflection of $PaCO_2$ (difference increases) due to increased dead space or V/Q mismatch, or both.

Various measures can be taken to overcome these issues. Most easily, minute ventilation (tidal volume × respiratory rate) can be increased to assist in blowing off the extra CO_2 present. If peak pressures rise relative to tidal volume (decreased compliance) to what is deemed an unacceptable level, pressure control mode can be utilized, with the caveat that under pressure control, tidal volume is not guaranteed. This means that any sudden change in compliance (increase or decrease) can lead to significant changes in tidal volume. If changing to pressure control mode does not suffice in improving compliance, an alteration in the I:E ratio may be of use: by allowing more time for inspiration each breath, peak pressures may be lowered. Traditionally longer I:E ratios allow for greater removal of CO_2 due to longer expiratory times; however, in these robotic cases, a shorter I:E ratio may allow for improved removal of CO_2 through resulting larger tidal volumes for the same peak pressure. If despite all measures, severe hypercarbia or hypoxemia persists, or if peak pressures remain unacceptably high or blood pressure too low, it is warranted to ask the surgeons to lower the CO_2 insufflation pressure or, in extreme cases, convert to an open procedure.

A major risk factor for development of hypercarbia is the presence of subcutaneous emphysema, which has been shown to occur in 0.4–2.3% of patients [10]. In turn, many factors influence whether or not subcutaneous emphysema develops. These include insufflation pressure, number of ports used, and length of operation, among others. One patient at the author's institution developed such severe subcutaneous emphysema that the patient's EKG voltage diminished significantly. Clearly, patients with preexisting pulmonary disease, who may already have issues with elimination of CO_2, are also at higher risk of hypercarbia.

It is important to be mindful of the degree of hypercarbia present prior to extubation. First, mandatory ventilation should be continued for several minutes following desufflation to allow for adequate expansion of atelectasis and improved removal of carbon dioxide. However, those with higher levels of CO_2 retention intraoperatively may need prolonged ventilation in the postoperative period until their CO_2 levels reach an acceptable range.

In procedures such as prostatectomy and cystectomy, steep Trendelenburg is initiated to optimize surgical access and view. Not only does this position exacerbate the aforementioned issues with pulmonary compliance, but airway edema is often a major concern at the conclusion of these cases. While most patients can be extubated without issue, caution should be exercised in patients who have developed significant facial swelling. A leak test and visual upper airway assessment can be performed, keeping in mind that this edema may make an initially relatively straightforward intubation and/or mask ventilation almost impossible to perform if reintubation is necessary. This edema tends to resolve over the first few hours of surgery.

Renal System

Robotic surgeries affect the renal system via several mechanisms. These include direct effects of the pneumoperitoneum as well as indirect responses such as catecholamine release and activation of the renin-angiotensin-aldosterone system. Though generally transient, with urine output returning to acceptable levels soon after desufflation, patients who are older with less reserve or those with preexisting renal dysfunction are at higher risk of prolonged sequelae in the postoperative period due to these changes. Ultimately, these changes lead to decreased renal blood flow, decreased creatinine clearance, and oliguria [12].

The pneumoperitoneum results in a high intra-abdominal pressure, to the extent that it may mimic abdominal compartment syndrome, leading to compression of renal vasculature and parenchyma, decreasing renal blood flow and urine output intraoperatively. Renal blood flow is additionally reduced due to a decrease in cardiac output secondary to the peritoneum as discussed above [13].

Furthermore, this direct compression mimics hypovolemia to the renal system, resulting in the stimulation of the renin-angiotensin-aldosterone system, as well as antidiuretic hormone release. These substances will further decrease renal blood flow and urine output, respectively.

Other mechanisms of intraoperative renal dysfunction have been examined, and it has recently been demonstrated that both endothelin-1 and nitric oxide systems are involved [13]. In fact, blockade of these systems was shown to result in exacerbation of pneumoperitoneum-induced renal hypoperfusion, whereas the preemptive addition of a nitroglycerin infusion significantly reduced these adverse effects [13]. Additionally, it has been shown that with volume loading, renal blood flow and oliguria can be reversed; however, creatinine clearance remains reduced [12].

There is evidence that renal injury, a serious morbidity on its own, has significant negative effects on many distant organ systems [14]. Thus, it is prudent to take steps to minimize the risk of perioperative acute kidney injury. The author utilizes a multimodal approach to accomplish this.

Given the fact that, as mentioned, many of the negative effects on renal blood flow during pneumoperitoneum appear to involve dysfunction of the nitric oxide system, it can be of benefit to administer a nitric oxide donor intraoperatively in patients who are high risk of perioperative renal dysfunction. For this, we have found nitroglycerin to be of great use. Nitroglycerin is primarily a preload reducer with minimal effects on afterload. It allows for the additional volume loading possibly necessary for improved renal blood flow while minimizing the reflex tachycardia often seen with the use of afterload reducers.

Diuretics are also of use in this setting. Mannitol, an osmotic diuretic, may have renal protective effects, primarily through improvement of renal blood flow and decreased renal vascular resistance [15]. Additionally, furosemide, a loop diuretic, helps to decrease oxidative stress on the kidney. Loop diuretics block the functioning of the Na-K-2Cl pump, an ADP-dependent pump, thereby reducing the kidney's oxygen utilization and increasing oxygen availability [16]. This can be particularly important in cases of partial nephrectomy, which necessitates some element of warm ischemia time during resection.

Central Nervous System

Due to the nature of the position during robotic prostatectomy or cystectomy, there can be concern about any compromise in cerebral blood flow due to elevated intracranial pressure and/or decreased venous return from positioning. Of course, this position does through gravity increase arterial pressure. However, a small study has shown that while zero perfusion pressure (the pressure at which cerebral blood flow ceases) does rise during steep Trendelenburg, the relationship between mean arterial pressure, intracranial pressure, and cerebral perfusion pressure is preserved, and MAP increases adequately to prevent ischemia [17]. There have been anecdotal reports of patients awakening from anesthesia somewhat mentally altered for a brief period after being in this position for some time however.

Optical

Though rare, cases of postoperative blindness following operations requiring steep Trendelenburg have been reported [18]. Intraocular pressure rises from baseline significantly in a time-dependent manner. If mean arterial pressure is low during this time, then blood flow through the optic artery can be compromised, leading to vision loss. Patients with preexisting conditions such as glaucoma who already have elevated intraocular pressure will be at increased risk of this unfortunate occurrence.

Nerve Injury

As with any operative procedure, care must be taken to prevent nerve injury resulting from compression. As both arms are tucked during supine robotic surgeries, proper padding must be placed to prevent ulnar injury. Improper bracing of the shoulders during prolonged steep Trendelenburg or severe stretching while in lateral decubitus can lead to brachial plexus injury. Additionally, though rare, patients in lithotomy and Trendelenburg for extended periods of time can lead to rhabdomyolysis, or even compartment syndrome, reflected in extremely elevated creatine kinase levels and swelling of the affected extremity.

References

1. Nabbi R, Woehlck HJ, Riess ML. Refractory hypotension during general anesthesia despite preoperative discontinuation of an angiotensin receptor blocker. F1000Res. 2013;2:12.
2. Thangathurai D, Roffey P. Intraoperative interaction between angiotensin-converting enzyme inhibitors and nitroglycerin in major surgical cases. J Cardiothorac Vasc Anesth. 2011;25(3):605.
3. Shear T, Greenberg S. Vasoplegic syndrome and renin-angiotensin system antagonists. APSF. 2012; jSpring-summer, p. 18–9.
4. Van Osch FH, Jochems SH, van Schooten FJ, Bryan RT, Zeegers MP. Quantified relations between exposure to tobacco smoking and bladder cancer risk: a meta-analysis of 89 observational studies. Int J Epidemiol. 2016;45:857–70.
5. Wiklund F, Tretli S, Choueiri TK, Signoretti S, Fall K, Adami HO. Risk of bilateral renal cell cancer. J Clin Oncol. 2009;10:3731–3.
6. Neudecker J, Sauerland S, Neugebauer E, Bergamaschi R, Bonjer HJ, Cushieri A, Fuchs KH, Jacobi C, Jansen FW, Koivusalo AM, Lacy A, McMahon MJ, Mlat B, Schwenk W. The European Association for Endoscopic Surgery clinical practice guideline on the pneumoperitoneum for laparoscopic surgery. Surg Endocsc. 2002;16(7):1121.
7. Perrin M, Fletcher A. Laparoscopic abdominal surgery. Congin Educ Anaesth Crit Care Pain. 2004;4(4):107–10.
8. Park EY, Kwon J, Kim KJ. Carbon dioxide embolism during laparoscopic surgery. Yonsei Med J. 2012;53(3):459–66.
9. Dorsay DA, Greene FL, Baysinger CL. Hemodynamic changes during laparoscopic cholecystectomy monitored with transesophageal echocardiography. Surg Endosc. 1995;9(2):126–33.
10. Ott DE. Subcutaneous emphysema – beyond the pneumoperitoneum. JSLS. 2014;18(1):1–7.
11. Demiroluk S, Salihoglu Z, Hayirlioglu M, Yildiz K. Effect of pneumoperitoneum on the level of plasma potassium. Middle East J Anaesthesiol. 2007;19(1):61–70.
12. London ET, Ho HS, Neuhaus AMC, Wolfe BM, Rudich SM, Perez RV. Effect of intravascular volume expansion on renal function during prolonged CO2 pneumoperitoneum. Ann Surg. 2000;231(2):195–201.
13. Sodha S, Nazarian S, Adshead JM, Vasdev N, Mohan-S G. Effect of pneumoperitoneum on renal function and physiology in patients undergoing robotic renal surgery. Curr Urol. 2016;9(1):1–4.
14. Yap SC, Lee HT. Acute kidney injury and extrarenal organ dysfunction: new concepts and experimental evidence. Anesthesiology. 2012;116(5):1139–48.
15. Bragadottir G, Redfors B, Ricksten S. Mannitol increases renal blood flow and maintains filtration fraction and oxygenation in postoperative acute kidney injury: a prospective interventional study. Crit Care. 2012;16:R159.
16. Ricksten S, Bragadottir G, Redfors B. Renal oxygenation in clinical acute kidney injury. Crit Care. 2013;17:221.
17. Kalmar AF, Dewaele F, Foubert L, Hendrickx JF, Heeremans EH, Struys MMRF, Absalom A. Cerebral haemodynamic physiology during steep Trendelenburg position and CO2 pneumoperitoneum. Brit J Anaesth. 2012;108(3):478–84.
18. Molloy BL. Implications for postoperative visual loss: steep Trendelenburg position and effects on intraocular pressure. AANA J. 2011;79(2):115–21.

http://www.springer.com/978-3-319-62276-7

Complications in Robotic Urologic Surgery
Sotelo, R.; Arriaga, J.; Aron, M. (Eds.)
2018, XV, 349 p. 86 illus., 80 illus. in color., Hardcover
ISBN: 978-3-319-62276-7