Rev Bras Anestesiol. 2014;64(2):109–115

REVISTA BRASILEIRA DE ANESTESIOLOGIA

Official Publication of the Brazilian Society of Anesthesiology
www.sba.com.br

SCIENTIFIC ARTICLE

Anesthetic considerations for robotic cystectomy: a prospective study☆,☆☆

Menekse Oksar[a,*], Ziya Akbulut[b], Hakan Ocal[a], Mevlana Derya Balbay[b], Orhan Kanbak[a]

[a] *Department of Anesthesiology and Reanimation, Ankara Ataturk Training and Research Hospital, Ankara, Turkey*
[b] *Department of Urology, Ankara Ataturk Training and Research Hospital, Ankara, Turkey*

Received 30 July 2013; accepted 2 September 2013
Available online 11 November 2013

KEYWORDS
Robotic cystectomy;
Anesthesia;
Anesthesiologist

Abstract
Background and objectives: Robotic cystectomy is rapidly becoming a part of the standard surgical repertoire for the treatment of prostate cancer. Our aim was to describe respiratory and hemodynamic challenges and the complications observed in robotic cystectomy patients.
Patients: Sixteen patients who underwent robotic surgery between December 2009 and January 2011 were prospectively enrolled. Main outcome measures were non-invasive monitoring, invasive monitoring and blood gas analysis performed at supine (T_0), Trendelenburg (T_1), Trendelenburg + pneumoperitoneum (T_2), Trendelenburg-before desufflation (T_3), Trendelenburg (after desufflation) (T_4), and supine (T_5) positions.
Results: There were significant differences between $T_0 - T_1$ and $T_0 - T_2$ with lower heart rates. The mean arterial pressure value at T_1 was significantly lower than T_0. The central venous pressure value was significantly higher at T_1, T_2, T_3, and T_4 than at T_0. There was no significant difference in the PET-CO_2 value at any time point compared with T_0. There were no significant differences in respiratory rate at any time point compared with T_0. The mean f values at T_3, T_4, and T_5 were significantly higher than T_0. The mean minute ventilation at T_4 and T_5 were significantly higher than at T_0. The mean plateau pressures and peak pressures at T_1, T_2, T_3, T_4, and T_5 were significantly higher than the mean value at T_0.
Conclusions: Although the majority of patients generally tolerate robotic cystectomy well and appreciate the benefits, anesthesiologists must consider the changes in the cardiopulmonary system that occur when patients are placed in Trendelenburg position, and when pneumoperitoneum is created.

☆ The study was conducted in the Department of Anesthesiology and Reanimation of Ankara Ataturk Training and Research Hospital.
☆☆ Presented in Euroanaesthesia Congress, Paris, France, 9–12 June 2012.
* Corresponding author.
E-mail: menekseoksar@gmail.com (M. Oksar).

http://dx.doi.org/10.1016/j.bjane.2013.09.008

Introduction

Radical cystectomy remains the gold standard for treatment of bladder cancer. Since the introduction of laparoscopy, there has been intense interest in urologic applications. The minimally invasive benefits of laparoscopic approaches have been demonstrated in decreased length of stay, intraoperative blood loss, postoperative pain and recovery. Since Sanchez et al. reported the first case of laparoscopic radical cystectomy for muscle invasive bladder cancer in 1995, several authors have published promising results with this technique.[1,2] The interest in robotics is undoubtedly related to the perceived benefits.

The search for minimally invasive techniques for treating urothelial malignancy has led to the development of robotic cystectomy (RC).[3] RC offers the promise of lower morbidity surgery with potentially equivalent oncological control, optimal imaging and manipulation of the surgical area, and less blood loss compared with open procedures.[4,5] However, these procedures are also associated with some challenges. These drawbacks, which include difficulty of intravenous access due to the covered arms along the side of the body to allow the robotic arms approach the patient during the operation, relatively long operating time, deep Trendelenburg position, and high intra-abdominal pressure (IAP), can lead to specific clinical issues such as respiratory acidosis, and anaesthesia and position related complications to address in the operating room.

RC is rapidly becoming a part of the standard surgical repertoire for the treatment of prostate cancer. In the present study, describing the anaesthetic challenges related to the high IAP caused by CO_2 insufflation and deep Trendelenburg positioning was aimed as well as the management of these challenges, in RC patients. Additionally, describing the criteria for safe discharge from the operating room was the second aim of the study.

Methods

Study design

Ethical approval from the local institutional committee and written informed consent from each consecutive patient were obtained. Sixteen consecutive patients who underwent RC between December 2009 and January 2011 were prospectively enrolled in the study. Sixty-nine patients underwent robotic urological surgeries during this period in our institution (16 RC, 53 robotic prostatectomy).

Non-invasive monitoring (ECG, pulse oximetry, body temperature, and respiratory parameters), invasive monitoring (mean arterial pressure and central venous pressure, and ventilatory parameters) (Infinity Delta patient monitor, Draeger Medical Systems, Inc., Telford, PA 18969, USA) and blood gas analysis were performed at supine (T_0), Trendelenburg (T_1), Trendelenburg + pneumoperitoneum (T_2), Trendelenburg-before desufflation (T_3), a five-degree Trendelenburg + pneumoperitoneum (T_4), and supine (T_5) positions.

After anaesthesia induction with pentobarbital 4–7 mg/kg and rocuronium 0.6 mg/kg, endotracheal intubation was performed. Anaesthesia was maintained with remifentanil (50 mcg/mL) 1 mcg/kg/min in a 0.1 mcg/kg/min infusion and with 2% sevoflurane, with additional boluses of rocuronium as needed. Each patient's lungs were ventilated in volume-controlled ventilation mode using 50% oxygen in air with a set tidal volume (VT) and/or with breathing frequency (f) to achieve an end-tidal carbon dioxide pressure (PET-CO_2) of 25–30%, which was monitored with blood gas reports to check its suitability in parallel. Fluid management was considered in 2 intervals, before and after ureteral anastomosis. Fluid was relatively restricted before ureteral anastomosis in an orthotopic bladder substituted ileal loop cases of the RC group. The second interval included a higher infusion rate to reach 2–3 mL/kg/h of the total fluid amount throughout the operation.

An arterial catheter was inserted in the left radial artery and central venous catheterization was performed through the right internal jugular vein to measure the central venous pressure (CVP). CVP was zeroed and measured on the midaxillary line at the 4th intercostal space in the supine position. The peripheral intravenous access and arterial access were lengthened via lines to be achieved as the upper extremities cannot be reached due to be covered alongside the patients bodies. Ondansetron 4 mg was administered intravenously, and orogastric tubing was inserted with the patient in the supine position to save the airway from gastric contents and drain it properly during a deep Trendelendurg position. Silicon pads were used to support the shoulders to avoid a brachial plexus damage due to the position. In addition to the extremities patients bodies are fixed to the surgical table using chest belts which were allowed chest expansion during ventilation properly. The intraperitoneal pressure was adjusted to 18 mm Hg. Cerebral protection was assured by administering dexamethasone sodium phosphate 8 mg at the beginning of the operation.

During extubation, the patients were taken into a reverse Trendelenburg position, and diuretic was administered to decrease upper airway edema, which might worsen respiratory acidosis after the extubation and be caused by the prolonged use of the deep Trendelenburg position. Extubation was approved after a blood gas analysis confirmed normocapnia during minimally assisted spontaneous breathing and during spontaneous breathing of 10 L/min of ventilation on average, in the absence of or with reduced conjunctival, upper airway and tongue oedema, with reversal of the neuromuscular blockade, and at a body temperature of 35 °C or more.

Safe extubation was performed in the operating room according to our discharge criteria and was properly managed in RC cases as noted in Table 1. Complications from deep Trendelenburg positioning and anaesthesia were recorded during and after surgery. The patients were classified according to their arterial pH levels at T_5 as pH < 7.35 and pH > 7.35 classes to determine the types of acidosis that developed intraoperatively.

Statistical analysis

Data were analyzed using the IBM Statistical Package for Social Sciences 19.0 (SPSS Inc., Chicago, IL). Paired-sample t-tests were used to assess the differences between groups.

Table 1 An integrated checklist for the safe extubation and discharge of robotic cystectomy patients from the operating room/recovery room.

Before extubation
Adequate breathing
Reversal of neuromuscular block
No or improved head and neck hyperemia
No or improved respiratory acidosis
No or improved tongue edema
No or improved swollen and/or white and dull-appearing tongue
No or improved conjunctival edema
Normocapnia in blood gas analysis and 10 L/min MMV on average during spontaneous ventilation
After extubation in the operating room
No snoring during either inspiration or expiration (or when the patient is awake, no sign of being affected by the neuromuscular block)
No loud inspiration (when the patient is awake) and no sign that the patient is affected by the neuromuscular block
No inspiratory difficulty or distress (intercostal retraction, supraclavicular retraction, or retraction of the alae nasi during inspiration)

MMV: mean minute ventilation.

Q Square test was carried out to compare the nominal variables.

Results

In this study trends of circulatory, respiratory and metabolic parameters were recorded during sixteen procedures of robotic cystectomy and analysed the effects of Trendelenburg position and pneumoperitoneum on those parameters.

Sixteen RC patients (1 female, 15 males) were included in the study. The mean age was 66.45 ± 12.73, body mass index (BMI) was 24.20 ± 3.62, basal metabolic index was -24.20 ± 3.62, and American Society of Anesthesiologists (ASA) score was 2.30 ± 0.82 for the study group. As for the surgical variables, surgical time was 475.00 ± 99.50 min., Trendelenburg time was 512.86 ± 105.82 min., blood loss was 240.00 ± 54.77 mL, total fluids administered was 2533.33 ± 864.58 mL. $NaHCO_3$ was administered in 100% patients, and atropine was administrated in 87.5% of the patients.

Table 2 shows the differences between the T_0 value and the T_1, T_2, T_3, T_4, and T_5 values for the hemodynamic and respiratory data, and ventilatory settings. There were significant differences between $T_0 - T_1$ ($p = 0.023$) and $T_0 - T_2$ ($p = 0.018$) with lower heart rates. The mean arterial pressure (MAP) value at T_1 was significantly lower than T_0 ($p = 0.023$). The CVP value was significantly higher at T_1, T_2, T_3, and T_4 than at T_0 ($p = 0.020$, $p = 0.0001$, $p = 0.0001$, $p = 0.012$, respectively). There was no significant difference in the PET-CO_2 value at any time point compared with T_0. There were no significant differences in respiratory rate at any time point compared with T_0. The mean f values at T_3, T_4, and T_5 were significantly higher than T_0 ($p = 0.009$, $p = 0.001$, $p = 0.0001$, respectively). The mean minute ventilation (MMV) at T_4 and T_5 were significantly higher than at T_0 ($p = 0.011$, $p = 0.009$, respectively). The mean plateau pressures and peak pressures at T_1, T_2, T_3, T_4, and T_5 were significantly higher than the mean value at T_0 ($p = 0.018$, $p = 0.0001$, $p = 0.0001$, $p = 0.0001$, $p = 0.025$, respectively). No significant difference was observed in the SPO_2 values and in the pulmonary end-expiratory pressure (PEEP) values at any time point compared with T_0 ($p > 0.05$).

Patients with a pH < 7.35 exhibited significantly higher $PaCO_2$ levels, compared with those with pH > 7.35 at T_5 ($p = 0.003$). Lactate levels in patients with a pH < 7.35 were significantly lower when compared with those with pH > 7.35 at T_5 ($p = 0.002$). BE and HCO_3 levels at T_5 did not show significant differences between patients with a pH < 7.35 at T5 and patients with a pH > 7.35 at T5 ($p = 0.170$, and $p = 0.340$, respectively) (Table 3). There were no significant differences in the set tidal volume (set VT) or the set breathing frequency (set f) at any time point during the operation between the patients with a pH < 7.35 and those with a pH > 7.35 (Table 4).

The surgical complications observed included arthralgia and digit injury (6.3%), regurgitation (6.3%), loud inspiration (6.3%), head and neck edema (12.5%), arrhythmia (bradycardia) (18.8%), need for ICU (31.3%), and conjunctival edema (43.8%).

Discussion

In the past several years, minimally invasive robotic approach has come to the forefront of attention for many urologic malignancies including RC for invasive bladder cancer. The surgical robot has been aggressively marketed during the past decade with the promise of reducing perioperative morbidity and improving oncologic and functional outcomes in many organ sites.[6,7] Although the anaesthesiologists need to be fully aware of, and prepared to handle, the challenges generated by a deep Trendelenburg position and high IAP in that position related to this new technology, and manage the associated complications, data regarding the anaesthetic challenges related with RC are still lacking.

There are two ways to ventilate the patient during RC, either via pressure-controlled or volume-controlled ventilation. Both methods offset the effects of pneumoperitoneum and abnormal positioning to maintain the patient's respiratory mechanics and hemodynamics within a normal range. Balick-Weber et al. investigated the effects of pressure-controlled versus volume-controlled ventilation and showed no hemodynamic benefit of one method over the other during open prostatectomy. However, pressure-controlled ventilation decreased peak airway pressure and increased mean airway pressure during the procedure.[8] This study was replicated by Choi et al.[9] They reported that pressure-controlled ventilation had no advantage over volume-controlled ventilation regarding respiratory mechanics or hemodynamics except for its greater compliance and lower peak airway pressure. In this study, the development of hypoxemia during steep Trendelenburg positioning with pneumoperitoneum was related to the increase of dead space ventilation. Changes in respiratory parameters, which are not well tolerated by patients, require

Table 2 Hemodynamic and respiratory data and ventilatory settings in robotic cystectomy.

Variables	Robotic cystectomy				
	T_1	T_2	T_3	T_4	T_5
Mean heart rate (T_0)	54.43 (68.71)	66.00 (79.80)	75.60 (77.60)	71.31 (77.31)	77.08 (76.31)
	$p(T_0-T_1)=0.023^*$	$p(T_0-T_2)=0.018^*$	$p(T_0-T_3)=0.771$	$p(T_0-T_4)=0.338$	$p(T_0-T_5)=0.903$
Mean arterial pressure (T_0)	71.29 (89.57)	99.47 (95.80)	86.50 (92.70)	89.23 (90.38)	88.46 (88.77)
	$p(T_0-T_1)=0.049^*$	$p(T_0-T_2)=0.612$	$p(T_0-T_3)=0.562$	$p(T_0-T_4)=0.838$	$p(T_0-T_5)=0.956$
Central venous pressure (T_0)	13.33 (3.50)	18.38 (7.62)	17.89 (7.33)	12.50 (7.50)	9.00 (7.82)
	$p(T_0-T_1)=0.020^*$	$p(T_0-T_2)=0.000^*$	$p(T_0-T_3)=0.000^*$	$p(T_0-T_4)=0.012^*$	$p(T_0-T_5)=0.490$
PET CO_2 (T_0)	28.38 (29.63)	32.62 (32.38)	33.22 (32.11)	34.85 (31.69)	35.77 (32.23)
	$p(T_0-T_1)=0.311$	$p(T_0-T_2)=0.929$	$p(T_0-T_3)=0.707$	$p(T_0-T_4)=0.084$	$p(T_0-T_5)=0.251$
SpO_2 (T_0)	99.00 (98.83)	99.36 (99.57)	99.60 (99.60)	99.83 (99.17)	99.85 (99.69)
	$p(T_0-T_1)=0.771$	$p(T_0-T_2)=0.736$	$p(T_0-T_3)=1.000$	$p(T_0-T_4)=0.104$	$p(T_0-T_5)=0.824$
Respiration (T_0)	14.83 (19.83)	16.92 (18.08)	15.63 (18.38)	15.64 (20.82)	17.18 (18.45)
	$p(T_0-T_1)=0.216$	$p(T_0-T_2)=0.655$	$p(T_0-T_3)=0.367$	$p(T_0-T_4)=0.104$	$p(T_0-T_5)=0.672$
Set f (T_0)	12.00 (12.00)	12.60 (12.00)	14.33 (12.00)	15.69 (12.00)	18.45 (12.00)
	$p(T_0-T_1)=1.000$	$p(T_0-T_2)=0.070$	$p(T_0-T_3)=0.009^*$	$p(T_0-T_4)=0.001^*$	$p(T_0-T_5)=0.000^*$
Set VT (T_0)	550.00 (550.00)	550.00 (556.67)	560.00 (570.00)	558.46 (557.69)	561.82 (568.18)
	$p(T_0-T_1)=1.000$	$p(T_0-T_2)=0.106$	$p(T_0-T_3)=0.343$	$p(T_0-T_4)=0.893$	$p(T_0-T_5)=0.586$
Minute ventilation (T_0)	6.15 (6.18)	6.33 (6.14)	6.71 (6.26)	7.78 (6.22)	8.00 (6.09)
	$p(T_0-T_1)=0.865$	$p(T_0-T_2)=0.327$	$p(T_0-T_3)=0.440$	$p(T_0-T_4)=0.011^*$	$p(T_0-T_5)=0.009^*$
Auto-PEEP (T_0)	1.83(1.83)	1.36 (1.43)	1.50 (1.40)	1.46 (1.46)	1.00 (1.20)
	$p(T_0-T_1)=1.000$	$p(T_0-T_2)=0.583$	$p(T_0-T_3)=0.678$	$p(T_0-T_4)=1.000$	$p(T_0-T_5)=0.168$
Plateau pressure (T_0)	23.33 (13.67)	27.86 (12.43)	32.44 (12.67)	25.42 (12.83)	18.36 (12.45)
	$p(T_0-T_1)=0.018^*$	$p(T_0-T_2)=0.000^*$	$p(T_0-T_3)=0.000^*$	$p(T_0-T_4)=0.000^*$	$p(T_0-T_5)=0.025^*$
Peak pressure (T_0)	27.33 (16.33)	30.00 (14.71)	34.56 (14.67)	29.00 (15.25)	23.10 (14.00)
	$p(T_0-T_1)=0.003^*$	$p(T_0-T_2)=0.000^*$	$p(T_0-T_3)=0.000^*$	$p(T_0-T_4)=0.000^*$	$p(T_0-T_5)=0.009^*$

$PETCO_2$: end tidal carbondioxide pressure; SPO_2: saturation of peripheral oxygen; set f: set breathing frequency; set VT: set tidal volume.
* $p<0.05$.

adjustments. Accordingly, the observed increases in the PET-CO_2 were compensated by increases in the f and MMV to decrease or prevent further respiratory acidosis. Also, the plateau pressures and peak pressures were lowered by increasing the f in order to avoid generating auto-PEEP. In the present study, increasing the breathing frequency to increase the MMV was required during Trendelenburg positioning with pneumoperitoneum. Furthermore, the plateau pressure was monitored to avoid going beyond a 35 mmHg limit. In the deep Trendelenburg position, the patients tended to develop auto-PEEP and high intrathoracic pressures, which may have compromised the VT through auto-PEEP and/or a reduced driving pressure. However, it is unknown whether a high IAP in a deep Trendelenburg position placed limitations on the driving pressure, which might have compromised the VT. The effects on lung mechanics of

Table 3 Arterial blood gas reports based acidosis determinants in both pH < 7.35 and pH > 7.35 classes at T_5.

Determinants	pH < 7.35 at T_5	pH > 7.35 at T_5	p-Value
$PaCO_2$	47.91 ± 5.31	29.63 ± 3.78	0.003
Base excess	−5.46 ± 2.81	−6.7 ± 2.88	0.170
Lactate	4 ± 1.41	9 ± 1.41	0.002
HCO_3	18.65 ± 1.55	19.07 ± 2.18	0.340

Table 4 Intraoperative changes in the set tidal volume and set breathing frequency at pH ≥ 7.35 and pH < 7.35 cases at T_5.

	pH < 7.35 at T_5	pH ≥ 7.35 at T_5	p-Value
Set tidal volume	466.14 ± 120.59	543.88 ± 84.17	0.064
Set breathing frequency	17.00 ± 5.19	17.64 ± 2.06	0.246

deep Trendelenburg positioning and a high IAP of 18 mm Hg are also unknown. Therefore, the main clinical challenge in the present study was the choice of ventilation strategy to manage respiratory acidosis. The VT was adjusted to provide adequate ventilation without exceeding a peak airway pressure of 40 cm H_2O. As VT was reduced in the deep Trendelenburg position, an adjustment to MMV was required using *f*. To avoid or minimize auto-PEEP, the breathing frequency was adjusted to allow complete exhalation, with an inspiration-to-expiration ratio (I/E) of 1/2. Respiratory acidosis was further minimized by reducing the alveolar dead space as needed. Kalmar et al. ventilated the lungs in volume control mode with an O_2/air mixture and a PEEP of 5 cm H_2O. The tidal volume was adjusted to achieve a PET-CO_2 gradient between 30 and 35 mmHg. The PET-CO_2 gradient increased from 7.95 mmHg before Trendelenburg positioning to 10.95 mmHg after 120 min of steep Trendelenburg. PET-CO_2 and $PaCO_2$ were highly correlated.[10] In our study, the increased PET-CO_2 may have been due to the use of a large amount of total CO_2 during insufflation prior to extubation and may have been due to inspiration and/or exhalation difficulties. Additionally, as a non-invasive, indirect measurement of $PaCO_2$, PET-CO_2 is an accurate means of monitoring $PaCO_2$, and deep Trendelenburg positioning does not diminish its usefulness.

Pneumoperitoneum is used in laparoscopic cases for proper visualization of the surgical field. Pressures are typically in the 12–15 mmHg range and CO_2 is the most common gas used, although other inert gases have been studied. Pneumoperitoneum has profound effects on the cardiac, renal, pulmonary, and immune systems. The effects of pneumoperitoneum are attributed to two factors: the IAP itself and CO_2 acting as a drug. Peritoneal insufflation to IAPs greater than 10 mm Hg induces significant alterations in hemodynamics.[11,12] Meininger et al. studied cardiopulmonary effects of steep Trendelenburg positioning and pneumoperitoneum specifically related to robotic urologic procedures.[13,14] MMV was adjusted according to repeat arterial blood gas analysis to prevent hypercapnia. A significantly elevated arterial CO_2 pressure even after release of the pneumoperitoneum is attributed to the considerable amounts of CO_2 possibly stored in extravascular compartments of the body that are slowly redistributed and metabolized or exhaled.[15] Although an increase in arterial pressure and an unchanged or slightly increased HR are associated with these conditions, a drop in cardiac output has been reported during peritoneal insufflation, whether the patient is placed in the head-down or head-up position.[16–18] Torrielli et al. reported that increasing the IAP to 10 mm Hg was associated with a decrease in the cardiac index that returned to its initial value after 10 min of 10° Trendelenburg positioning. They also reported that elevated IAP was associated with increases in the MAP and the systemic vascular resistance, and these values did not return to normal after peritoneal exsufflation.[16] Falabella et al. demonstrated that Trendelenburg positioning increased the stroke volume and pneumoperitoneum and steep Trendelenburg position significantly increase MAP.[19] In the present study, whereas the MAP increased significantly at the beginning of the Trendelenburg positioning with pneumoperitoneum, the CVP increased throughout the Trendelenburg positioning. The increases in the CVP values in both deep Trendelenburg and 5° Trendelenburg positioning, with and without pneumoperitoneum, and the decreases to baseline at the end of the operation in the supine position indicate a close relationship between CVP values and Trendelenburg positioning alone or with IAP. Furthermore, the HR decreased significantly and required intervention. Although the most obvious hemodynamic effects of the RC procedures in our study occurred immediately after the patients were moved into the Trendelenburg position with pneumoperitoneum, these measurements continued to be affected to a lesser degree until the end of the procedures.

Although the blood gas analyses were used to assess both respiratory and metabolic problems, the presence of acidosis was determined at the end of the operation (T_5). Increases in the set VT or the set *f* reflected respiratory acidosis management during the operation at both pH levels. Significant increases in the *f* values were interpreted to mean that the MMV had been maintained and that the PET-CO_2 and $PaCO_2$, which had increased due to the reduced VT during Trendelenburg positioning and CO_2 pneumoperitoneum, had decreased. The increases in the VT and/or *f* were the result of our efforts to maintain the MMV and to manage respiratory acidosis. Even though respiratory acidosis was a problem in our study group, metabolic acidosis had significant effect on the pH values and required correction, which included $NaHCO_3$ infusions. Normocarbia and maintenance of an adequate MMV were the main goals in the blood gas monitoring during the surgical procedures and extubation assessment. Our findings suggest that blood gas analysis was necessary for monitoring of the RC patients. As the PaO_2 and SPO_2 did not decrease to critical values, none of the patients required additional intervention to enhance PaO_2. In the present study, the metabolic acidosis alone did not reach a significant level; however, in combination with respiratory acidosis it decreased the pH to a critical level, which necessitated timely and challenging management. In addition, the decreases in the pH values resulted from metabolic events that may have been due to the long surgical durations such as fluid management strategies that included the dilution of the $NaHCO_3$ in large-volume infusions and increases in the hydrogen ion concentrations in the volume restriction period during lengthy surgical procedures. HCO_3 loss could have also resulted from ilial bowel loss due to pouch formation during the surgical procedures. None of the patients in our study group exhibited hypothermia caused by heat loss due to long surgery durations or insufflation with cold CO_2 gas, which might have added to the metabolic acidosis. The greater $NaHCO_3$ use during surgery in the pH > 7.35 cases at T_5 indicates that the metabolic acidosis in our study was well managed.

Pruthi et al. reported 6.1 h of surgical time for cystoprostatectomy and a mean blood loss of 313 mL.[3] The same authors reported a mean operating room time of 4.6 h for all cystectomy cases and a mean surgical blood loss of 271 mL. Prior studies have demonstrated that there is a significant learning curve to the robotic approach, whereas after the first twenty cases a gradual reduction in operative times can be perceived.[20,21] Lowrence et al.[22] reported a mean overall operative time of 287 min. In a prospective comparison of open versus robotic cystectomy, Ng et al reported a mean overall operative time of 5.95 h in the open cohort versus 6.25 h in the RARC group.[23] Several studies have demonstrated a significant increase in operative times associated with the robotic approach, the one previous prospective randomized series showed a difference of 4.2 versus 3.5 h for the robotic versus the open group respectively.[21,24] Our RC cases had longer surgical times. In our current series we have shown that the robotic approach demonstrated a significant increase in operative times.

In a study of the transfusion requirements in open and robotic-assisted laparoscopic radical prostatectomies, Kordan et al. demonstrated that robotic surgery was associated with lower blood loss and a smaller change in hematocrit than the open prostatectomy group.[25] It has been reported that extensive blood loss and blood transfusion requirements predict a higher likelihood of ileus and postoperative complications in open cystectomy series.[26] Boström et al studied risk factors for mortality and morbidity related to open radical cystectomy and concluded that a high ASA score and increasing number of transfusions were predictors of a major complication.[26] Mean blood loss in a study of open radical cystectomies by Lowrance et al. was 750 mL with 38% of patients requiring blood transfusion.[20] In our study, none of the patients required transfusions and our low operative blood loss compares favourably to our open experience and that of other reports in the literature, and is similar to the blood loss seen in other robotic cystectomy reports.

Although complications with the robotic approach are certainly present, those related to anaesthesia have been rare. It has been established that deep Trendelenburg positioning can cause decreases in functional residual capacity, total lung volume, and pulmonary compliance and may facilitate the development of atelectasis.[27] Tongue swelling may have resulted from the Trendelenburg positioning, or the endotracheal cuff pressure on the tongue base. Applying pressure to the tongue base with an endotracheal tube cuff may also enhance tongue oedema. The use of the head-upright position prior to extubation, diuretic use when necessary and extubation itself improved these symptoms. In the present study, the most frequent anaesthesia- and position-related complications were conjunctival oedema, regurgitation and ''upper airway obstruction-like'' clinical symptoms (enlarged and dull, oedematous tongues, snoring, loud inspiration, inspiratory difficulty) that might lead to or worsen respiratory acidosis. Our criteria for discharge from the operating/recovery room included improvements in these upper airway signs and symptoms. Most of the complications documented in our study could be managed with the precautions and medications without any need for admission to the ICU. Yee et al. are reported rare and temporary neurologic complications on the 1st postoperative day that lasted for 3 days. However, in the present study, no serious neurologic complications were observed.[28] Arrhythmia can be induced by several causes in laparoscopic cases. In our study, bradycardia accounted for most of the arrhythmia cases, and these complications occurred immediately after the patients were moved into the Trendelenburg position and/or preceding the surgical procedure. We interpreted this timing as indicating that the arrhythmia resulted from the Trendelenburg position and/or the reflexes induced by the sudden stretching of the pneumoperitoneum, which may have caused an increase in vagal tone. Additionally, the remifentanil infusion may has a role in bradycardia in these cases. However, the bradycardia was not observed during the remifentanil infusions in any other parts of the surgical procedures.

To handle these patients, we recommend that the Trendelenburg position should be given carefully to avoid any neurologic damage, arthralgia or digit injury. Shoulders and feet should be supported properly and chest should be fixed without compromising chest expansion during ventilation. Cerebral edema should be prevented; respiratory acidosis should be managed according to $ETCO_2$ that was checked with $PaCO_2$ in parallel during penumoperitoneum. Metabolic acidosis possibly caused by fluid restriction until the orthotopic bladder substituted ileal loop and the $NaCO_3$ loss due to the losses from and through the bowel should be identified and treated in these debilated surgical patients. Body temperature should be monitored in this relatively long surgical procedures as it may affect the metabolic events. Arteriel catheterisation is helpful but CVP catheter is not essential. During the extubation hyperventilation may be necessary to exchange the increased CO_2 in the lungs due to recovered cardiac output and CO_2 resorbtion from the tissues. Head up right position and diuretic administration can provide relief to the upper airway and head and neck edema, which can help a successful extubation period. During this period, using a checklist as we described in Table 1 can help a safe extubation as considered the most possible problems to this type of surgery.

The majority of patients generally tolerates RC well and appreciates the benefits; however, anesthesiologists must have an intimate knowledge of the physiological changes associated with robotic urological procedures. Specifically, anesthesiologists must consider the changes in the cardiopulmonary system that occur when patients are placed in Trendelenburg position, and when pneumoperitoneum is created. Knowledge of these changes can help guide appropriate interventions and prevent complications and help speed recovery time for patients.

Conclusions

Robotic cystectomy is rapidly becoming a part of the standard surgical repertoire for the treatment of prostate cancer. The aim of the present study was to describe respiratory and hemodynamic challenges and the complications observed in robotic cystectomy patients. Although the majority of patients generally tolerate robotic cystectomy well and appreciate the benefits, anesthesiologists must consider the changes in the cardiopulmonary system that occur when patients are placed in Trendelenburg position, and when pneumoperitoneum is created.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Sánchez de Badajoz E, Gallego Perales JL, Reche Rosado A, et al. Laparoscopic cystectomy and ileal conduit: case report. J Endourol. 1995;9:59–62.

2. Abdel-Hakim AM, Bassiouny F, Abdel Azim MS, et al. Laparoscopic radical cystectomy with orthotopic neobladder. J Endourol. 2002;16:377–81.
3. Pruthi RS, Nielsen ME, Nix J, et al. Robotic radical cystectomy for bladder cancer: surgical and pathological outcomes in 100 consecutive cases. J Urol. 2010;183:510–4.
4. Menon M, Shrivastava A, Tewari A. Laparoscopic radical prostatectomy: conventional and robotic. Urology. 2005;66 Suppl:101–4.
5. Hu JC, Gu X, Lipsitz SR, et al. Comparative effectiveness of minimally invasive vs open radical prostatectomy. JAMA. 2009;302:1557–64.
6. Yates DR, Vaessen C, Roupret M. From Leonardo to da Vinci: the history of robot-assisted surgery in urology. BJU Int. 2011;108:1708–13.
7. Richards KA, Kader K, Hemal AK. Robotic radical cystectomy: where are we today, where will we be tomorrow? Sci World J. 2010;10:2215–27.
8. Balick-Weber CC, Nicolas P, Hedreville-Montout M, et al. Respiratory and haemodynamic effects of volume-controlled vs pressure-controlled ventilation during laparoscopy: a cross-over study with echocardiographic assessment. Br J Anaesth. 2007;99:429–35.
9. Choi EM, Na S, Choi SH, et al. Comparison of volume-controlled and pressure-controlled ventilation in steep Trendelenburg position for robot-assisted laparoscopic radical prostatectomy. J Clin Anesth. 2011;23:183–8.
10. Kalmar AF, Foubert L, Hendrickx JF, et al. Influence of steep Trendelenburg position and CO(2) pneumoperitoneum on cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. Br J Anaesth. 2010;104:433–9.
11. Struthers AD, Cuschieri A. Cardiovascular consequences of laparoscopic surgery. Lancet. 1998;352:568–70.
12. Koivusalo AM, Lindgren L. Effects of carbon dioxide pneumoperitoneum for laparoscopic cholecystectomy. Acta Anaesthesiol Scand. 2000;44:834–41.
13. Meininger D, Westphal K, Bremerich DH, et al. Effects of posture and prolonged pneumoperitoneum on hemodynamic parameters during laparoscopy. World J Surg. 2008;32:1400–5.
14. Meininger D, Byhahn C, Mierdl S, et al. Positive end-expiratory pressure improves arterial oxygenation during prolonged pneumoperitoneum. Acta Anaesthesiol Scand. 2005;49:778–83.
15. Leggett RW. A biokinetic model for carbon dioxide and bicarbonate. Radiat Prot Dosimetry. 2004;108:203–13.
16. Torrielli R, Cesarini M, Winnock S, et al. Hemodynamic changes during celioscopy: a study carried out using thoracic electric bioimpedance. Can J Anaesth. 1990;37:46–51 [in French].
17. Walder AD, Aitkenhead AR. Role of vasopressin in the haemodynamic response to laparoscopic cholecystectomy. Br J Anaesth. 1997;78:264–6.
18. Joris JL, Chiche JD, Canivet JL, et al. Hemodynamic changes induced by laparoscopy and their endocrine correlates: effects of clonidine. J Am Coll Cardiol. 1998;32:1389–96.
19. Falabella A, Moore-Jeffries E, Sullivan MJ, et al. Cardiac function during steep Trendelenburg position and CO_2 pneumoperitoneum for robotic-assisted prostatectomy: a trans-oesophageal Doppler probe study. Int J Med Robot. 2007;3:312–5.
20. Menon M, Hemal AK, Tewari A, et al. Nerve-sparing robot-assisted radical cystoprostatectomy and urinary diversion. BJU Int. 2003;92:232–6.
21. Pruthi RS, Smith A, Wallen EM. Evaluating the learning curve for robot-assisted laparoscopic radical cystectomy. J Endourol. 2008;22:2469–74.
22. Lowrance WT, Rumohr JA, Chang SS, et al. Contemporary open radical cystectomy: analysis of perioperative outcomes. J Urol. 2008;179:1313–8.
23. Ng CK, Kauffman EC, Lee MM, et al. A comparison of postoperative complications in open versus robotic cystectomy. Eur Urol. 2010;57:274–81.
24. Rhee JJ, Lebeau S, Smolkin M, et al. Radical cystectomy with ileal conduit diversion: early prospective evaluation of the impact of robotic assistance. BJU Int. 2006;98:1059–63.
25. Kordan Y, Barocas DA, Altamar HO, et al. Comparison of transfusion requirements between open and robotic-assisted laparoscopic radical prostatectomy. BJU Int. 2010;106: 1036–40.
26. Boström PJ, Kössi J, Laato M, et al. Risk factors for mortality and morbidity related to radical cystectomy. BJU Int. 2009;103:191–6.
27. Hazebroek EJ, Bonjer HJ. Effect of patient position on cardiovascular and pulmonary function. In: Whelan RL, Fleshman JW, Fowler DL, editors. The sages perioperative care in minimally invasive surgery. New York: Springer; 2006. p. 410–7.
28. Yee DS, Katz DJ, Godoy G, et al. Extended pelvic lymph node dissection in robotic-assisted radical prostatectomy: surgical technique and initial experience. Urology. 2010;75: 1199–204.