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SCIENTIFIC ARTICLE

Robotic prostatectomy: the anesthetist's view for robotic urological surgeries, a prospective study☆,☆☆

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Abstract
Background and objectives: Although many features of robotic prostatectomy are similar to those of conventional laparoscopic urological procedures (such as laparoscopic prostatectomy), the procedure is associated with some drawbacks, which include limited intravenous access, relatively long operating time, deep Trendelenburg position, and high intra-abdominal pressure. The primary aim was to describe respiratory and hemodynamic challenges and the complications related to high intra-abdominal pressure and the deep Trendelenburg position in robotic prostatectomy patients. The secondary aim was to reveal safe discharge criteria from the operating room.
Methods: Fifty-three patients who underwent robotic prostatectomy 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: Fifty-three robotic prostatectomy patients were included in the study. The main clinical challenge in our study group was the choice of ventilation strategy to manage respiratory acidosis, which is detected through end-tidal carbon dioxide pressure and blood gas analysis. Furthermore, the mean arterial pressure remained unchanged, the heart rate decreased significantly and required intervention. The central venous pressure values were also above the normal limits.
Conclusion: Respiratory acidosis and ''upper airway obstruction-like'' clinical symptoms were the main challenges associated with robotic prostatectomy procedures during this study.

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PALAVRAS-CHAVE
Cirurgia robótica;
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Prostatectomia robótica: análise anestesiológica de cirurgias urológicas robóticas: estudo prospectivo

Resumo
Justificativa e objetivos: Embora muitas características da prostatectomia robótica sejam semelhantes àquelas de laparoscopias urológicas convencionais (como a prostatectomia por laparoscopia), o procedimento está associado a alguns inconvenientes, incluindo acesso intravenoso limitado, tempo cirúrgico relativamente longo, posição de Trendelenburg profunda e pressão intra-abdominal alta. O objetivo principal foi descrever as alterações respiratória e hemodinâmica e as complicações relacionadas à pressão intra-abdominal elevada e à posição de Trendelenburg profunda em pacientes submetidos à prostatectomia robótica. O objetivo secundário foi revelar critérios seguros de alta do centro cirúrgico.
Métodos: Foram inscritos prospectivamente 53 pacientes submetidos à prostatectomia robótica entre dezembro de 2009 e janeiro de 2011. As medidas de desfecho primário foram: monitoramento não invasivo, monitoramento invasivo e gasometria feita em decúbito dorsal (T_0), Trendelenburg (T_1), Trendelenburg + pneumoperitônio (T_2), Trendelenburg pré-desinsuflação (T_3), Trendelenburg pós-desinsuflação (T_4) e posições supinas (T_5).
Resultados: O principal desafio clínico em nosso grupo de estudo foi a escolha da estratégia de ventilação para controlar a acidose respiratória, que é detectada por meio da pressão de dióxido de carbono expirado e da gasometria. Além disso, a pressão arterial média permaneceu inalterada e a frequência cardíaca diminuiu significativamente e precisou de intervenção. Os valores da pressão venosa central também estavam acima dos limites normais.
Conclusão: A acidose respiratória e sintomas clínicos ''semelhantes à obstrução das vias aéreas'' foram os principais desafios associados aos procedimentos de prostatectomia robótica.

Introduction

Laparoscopic prostatectomy was first performed by Bhandari et al. in 1997 using a transperitoneal approach.[1] An extraperitoneal approach was subsequently described by Raboy et al., with the first clinical cases of extraperitoneal laparoscopic radical prostatectomy using a robotic system developed and reported by Pruthi et al. in 2003.[2,3] The introduction of the da Vinci Surgical System has transformed the field of robotic surgery across the country and solved some of the limitations of traditional laparoscopic urology.

Robotic prostatectomy (RP) has enabled urologists to use a more controlled and accurate laparoscopic approach to radical prostatectomy. Compared to the open method, the robotic-assisted approach offers many advantages including better visualization and a more precise manipulation of delicate vessels and nerves.[4] The surgeon can better preserve the integrity of the neurovascular bundles which results in improved postoperative urinary and sexual function.[5] Other benefits include less postoperative pain, diminished scarring, reduced bleeding and shorter hospital stays.

Although many features of RP are similar to those of conventional laparoscopic urological procedures (such as laparoscopic prostatectomy), the procedure is associated with some drawbacks, which include limited intravenous access, relatively long operating time, deep Trendelenburg position, and high intra-abdominal pressure (IAP). Insufflation of the abdomen with CO_2 is not benign. Lung volume decreases, mean arterial pressure increases whereas cardiac index decreases, and absorption of CO_2 causes hypercarbia and a concomitant decrease in blood pH.[6,7] Any of these alterations can lead to sudden cardiopulmonary distress. In addition, unintentional injury to vessels can lead to massive hemorrhage or CO_2 embolism requiring rapid resuscitation.[6–8] Routine capnometry should be used in all laparoscopic cases as it allows the adequacy of mechanical ventilation to be assessed.

Currently, most of the knowledge about robotic urological surgery has been derived from the gynaecologic procedures performed in a less-deep Trendelenburg position and under lower IAP conditions; and studies of laparoscopic cholecystectomy surgeries that were performed under lower IAP, with a relatively short surgical duration, and in the head-up position, which can have different effects on patients' respiratory and hemodynamic parameters as well as their risk of embolism.[9] Herein, we aimed to describe the anesthetic challenges in RP procedures performed under deep Trendelenburg position and high IAP conditions. Additionally, we aimed to describe the criteria for safe discharge from the operating room.

Methods

Study design

Ethical approval from the local institutional committee and written informed consent from each consecutive patient were obtained. Fifty-three consecutive patients admitted to our clinic and who underwent RP between December 2009 and January 2011 were prospectively enrolled in the study.

Non-invasive monitoring (ECG, pulse oximetry, and non-invasive blood pressure, body temperature, and respiratory parameters), invasive monitoring (mean arterial pressure and central venous pressure, and ventilator 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), Trendelenburg (after desufflation) (T_4), and supine (T_5) positions.

After anesthesia induction with pentobarbital 4–7 mg/kg and rocuronium 0.6 mg/kg, endotracheal intubation was performed. Anesthesia was maintained with remifentanil (50 mcg/mL) 1 mcg/kg/min in a 0.1 mcg/kg/min infusion and with 2 MAC 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 in parallel. Fluid management was considered in two intervals, before and after ureteral anastomosis. Fluid was relatively restricted before ureteral anastomosis. 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 mid-axillary line at the 4th intercostal space in the supine position. The peripheral intravenous access and arterial access were lengthened via lines. Ondansetron 4 mg was administered intravenously, and orogastric tubing was inserted with the patient in the supine position. 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 and furosemide 40 mg.

During extubation, the patients were taken into a reverse Trendelenburg position, and diuretic administration was repeated to decrease upper airway edema might 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 edema, 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 as noted in Table 1. Complications from deep Trendelenburg positioning and anesthesia were recorded during and after surgery. The patients were classified according to their arterial pH levels at T_5 as pH < 7.35 (the ones with acidosis at the end of surgery) and pH > 7.35 (the ones with improved acidosis) classes. In these groups, types of acidosis developed intraoperatively and the management of acidosis were documented.

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. Chi-square test was carried out to compare the nominal variables.

Table 1 An integrated checklist for the safe extubation and discharge of robotic prostatectomy 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.

Results

Fifty-three robotic prostatectomy patients (53 males) were included in the study. The mean age was 60.12 ± 7.33, body mass index (BMI) was 27.30 ± 3.97, basal metabolic index was 27.30 ± 3.97, and American Society of Anesthesiologists (ASA) score was 1.72 ± 0.59 for the study group. As for the surgical variables, surgical time was 217.04 ± 80.73 min, Trendelenburg time was 262.45 ± 75.93 min, blood loss was 262.60 ± 50.00 mL, total fluids administered was 1680.00 ± 404.71 mL. $NaHCO_3$ was administered in 20% of the patients, and atropine was administered in 78.6% of the patients. The number of patients who presented pH < 7.35 was 35, while the number of patients who presented pH ≥ 7.35 was 18.

Table 2 shows 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. The heart rates were significantly different between T_0 and T_2 ($p = 0.0001$), with a lower HR at T_2 than at T_0. The mean arterial pressure (MAP) value was significantly higher at T_2 than T_0 ($p = 0.004$). The mean CVP value was significantly higher at T_1, T_2, T_3, and T_4 than at T_0 ($p = 0.0001$ for all time points). The mean PET-CO_2 value at T_3 was significantly higher than T_0 ($p = 0.005$). The mean respiratory rate at T_5 was significantly higher than at T_0 ($p = 0.031$). The mean f values at T_2, T_3, T_4, and T_5 were significantly higher than T_0 ($p = 0.017$, $p = 0.0001$, $p = 0.0001$, $p = 0.0001$, respectively). The mean minute ventilation (MMV) at T_1,

Table 2 Hemodynamic and respiratory data and ventilatory settings in the robotic prostatectomy.

Variables	Robotic prostatectomy				
	T_1	T_2	T_3	T_4	T_5
Mean heart rate	67.29 (71.54)	62.45 (70.91)	69.98 (70.66)	67.13 (71.52)	75.91 (73.29)
(beats/min) (T_0)	$p(T_0-T_1)=0.173$	$p(T_0-T_2)=0.000$[a]	$p(T_0-T_3)=0.762$	$p(T_0-T_4)=0.092$	$p(T_0-T_5)=0.299$
Mean arteriel pressure	91.00 (88.09)	101.56 (89.88)	95.33 (90.18)	91.04 (87.96)	94.41 (91.83)
(mm Hg) (T_0)	$p(T_0-T_1)=0.348$	$p(T_0-T_2)=0.004$[a]	$p(T_0-T_3)=0.101$	$p(T_0-T_4)=0.339$	$p(T_0-T_5)=0.444$
Central venous pressure	17.30 (6.70)	20.61 (7.84)	19.68 (8.39)	17.21 (6.55)	8.15 (7.84)
(mm Hg) (T_0)	$p(T_0-T_1)=0.000$[a]	$p(T_0-T_2)=0.000$[a]	$p(T_0-T_3)=0.000$[a]	$p(T_0-T_4)=0.000$[a]	$p(T_0-T_5)=0.647$
PET-CO_2 (mm Hg) (T_0)	32.40 (33.28)	33.76 (33.00)	35.40 (32.89)	34.27 (32.97)	34.84 (32.88)
	$p(T_0-T_1)=0.116$	$p(T_0-T_2)=0.317$	$p(T_0-T_3)=0.005$[a]	$p(T_0-T_4)=0.144$	$p(T_0-T_5)=0.111$
SpO_2 (%) (T_0)	98.86 (99.14)	98.64 (99.04)	99.20 (99.00)	99.37 (99.20)	99.13 (98.98)
	$p(T_0-T_1)=0.223$	$p(T_0-T_2)=0.079$	$p(T_0-T_3)=0.323$	$p(T_0-T_4)=0.344$	$p(T_0-T_5)=0.464$
Respiration (T_0)	15.68 (14.76)	16.93 (17.45)	15.85 (17.45)	17.04 (15.88)	20.35 (17.33)
	$p(T_0-T_1)=0.446$	$p(T_0-T_2)=0.712$	$p(T_0-T_3)=0.229$	$p(T_0-T_4)=0.467$	$p(T_0-T_5)=0.031$[a]
Set f (breaths/min) (T_0)	12.30 (12.03)	12.65 (12.10)	14.24 (12.07)	15.91 (12.03)	17.21 (12.11)
	$p(T_0-T_1)=0.058$	$p(T_0-T_2)=0.017$[a]	$p(T_0-T_3)=0.000$[a]	$p(T_0-T_4)=0.000$[a]	$p(T_0-T_5)=0.000$[a]
Set VT (mL) (T_0)	577.41 (580.86)	581.33 (581.94)	575.98 (580.76)	579.22 (577.66)	575.80 (582.39)
	$p(T_0-T_1)=0.134$	$p(T_0-T_2)=0.779$	$p(T_0-T_3)=0.260$	$p(T_0-T_4)=0.696$	$p(T_0-T_5)=0.342$
Minute ventilation	6.34 (6.67)	6.60 (6.68)	7.41 (6.64)	8.54 (6.68)	8.97 (6.66)
(mL/min) (T_0)	$p(T_0-T_1)=0.040$[a]	$p(T_0-T_2)=0.493$	$p(T_0-T_3)=0.000$[a]	$p(T_0-T_4)=0.000$[a]	$p(T_0-T_5)=0.000$[a]
Auto-PEEP (mm Hg) (T_0)	1.66 (1.59)	1.60 (1.57)	1.51 (1.60)	1.39 (1.68)	1.74 (1.55)
	$p(T_0-T_1)=0.626$	$p(T_0-T_2)=0.850$	$p(T_0-T_3)=0.352$	$p(T_0-T_4)=0.059$	$p(T_0-T_5)=0.334$
Plateau pressure	21.39 (12.36)	32.21 (12.77)	31.14 (12.98)	24.68 (12.16)	16.65 (13.14)
(mm Hg) (T_0)	$p(T_0-T_1)=0.000$[a]	$p(T_0-T_2)=0.000$[a]	$p(T_0-T_3)=0.000$[a]	$p(T_0-T_4)=0.000$[a]	$p(T_0-T_5)=0.000$[a]
Peak pressure (mm Hg)	24.21 (14.79)	35.38 (15.81)	34.3 (15.81)	27.77 (14.87)	21.47 (16.17)
(T_0)	$p(T_0-T_1)=0.000$[a]	$p(T_0-T_2)=0.000$[a]	$p(T_0-T_3)=0.000$[a]	$p(T_0-T_4)=0.000$[a]	$p(T_0-T_5)=0.000$[a]

PET-CO_2, end tidal carbon dioxide pressure; SPO_2, saturation of peripheral oxygen; set f, set breathing frequency; set VT, set tidal volume.
[a] $p < 0.05$.

T_3, T_4, and T_5 were significantly higher than T_0 ($p = 0.040$, $p = 0.0001$, $p = 0.0001$, $p = 0.0001$, 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 ($p = 0.0001$ for all time points). No significant difference in the SPO_2 values and in the PEEP values at any time point compared with T_0 was observed ($p > 0.05$).

Patients with a pH < 7.35 exhibited significantly higher $PaCO_2$ levels, compared with those with pH > 7.35 at T_5 ($p = 0.034$). Base excess levels in patients with a pH < 7.35 were significantly lower when compared with those with pH > 7.35 at T_5 ($p = 0.024$). Lactate and HCO_3 levels at T_5 did not show significant differences between patients with a pH < 7.35 at T_5 and patients with a pH > 7.35 at T_5 ($p = 0.367$, and $p = 0.073$, 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).

Anesthesia- and position-related complications observed included conjunctival edema (60.4%), regurgitation (15.1%), swollen tongue (15.1%), arrhythmia (bradycardia) (15.1%), head and neck edema (13.2%), loud inspiration (13.2), hyperemia of the head and neck (5.7%), difficulty on inspiration (3.8%), and neuropraxia (1.9%). The need for ICU was observed in 9.3% of the study group postoperatively.

Discussion

In the present study, we aimed to describe the anesthetic challenges related to the high IAP and deep Trendelenburg positioning in RP patients. Although deep Trendelenburg positioning and a prolonged IAP of 18 mm Hg

Table 3 Arterial blood gas reports based acidosis determinants in both pH < 7.35 and pH > 7.35 cases of the robotic prostatectomy at T_5.

Determinants	pH < 7.35 at T_5 ($n = 35$)	pH ≥ 7.35 at T_5 ($n = 18$)	p Value
$PaCO_2$ (mm Hg)	4485 ± 7.55	33.93 ± 3.15	0.034
Base excess (mEq/L)	−5.46 ± 1.57	−3.66 ± 1.53	0.024
Lactate (mg/dL)	13 ± 8.41	12.63 ± 4.17	0.367
HCO_3 (mEq/L)	19.52 ± 2.78	22.02 ± 3.06	0.073

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

	pH < 7.35 at T_5 (n = 35)	pH ≥ 7.35 at T_5 (n = 18)	p Value
Set tidal volume (mL)	553.81 ± 53.75	547.77 ± 78.82	0.446
Set breathing frequency (breaths/min)	16.27 ± 4.02	16.85 ± 4.12	0.342

can produce adverse cardiovascular, respiratory, and neurological effects, Kalmar et al. have reported that the hemodynamic and pulmonary parameters remained within physiological limits in their RP study, which indicates that the Trendelenburg positioning and CO_2 pneumoperitoneum were well tolerated.[7] The results of our study demonstrate that our hemodynamic and respiratory data differ from those reported by Kalmar et al. The difference might have resulted from our relatively larger clinical study of 53 patients who underwent RP procedures in a similar deep Trendelenburg position and a high mean IAP of 18 mm.

Changes in respiratory parameters require intense adjustments. Accordingly, the observed increases in the PET-CO_2 caused by decreases in the VT, which may have been due to the deep Trendelenburg positioning and pneumoperitoneum, were compensated by increases in the f and minute ventilation in order to prevent respiratory acidosis. The plateau pressures and peak pressures, which exceeded the normal limits due to both deep Trendelenburg positioning and pneumoperitoneum, were lowered by increasing the f conservatively, to avoid generating auto-PEEP. Changes in the intrathoracic pressure and the mechanical ventilation settings also could have led to PEEP generation. The high plateau and peak pressures observed in our study group at the end of the operations in the supine position may have been related to the patients' spontaneous breathing efforts and/or possible residual pneumoperitoneum. The main clinical challenge in our study group was the choice of ventilation strategy to manage respiratory acidosis, which is detected through PET-CO_2 and blood gas analysis. First of all, increasing the breathing frequency to increase the MMV, which reduced the PET-CO_2 values, was required during Trendelenburg positioning with pneumoperitoneum. This result demonstrates that the increase in the PET-CO_2 was not due to a higher ASA score or pulmonary complications but rather to an increase in the $PaCO_2$ value caused by CO_2 pneumoperitoneum. Secondly, the plateau pressure (sum of the total PEEP and the driving pressure) was monitored to avoid going beyond a 35 mm Hg limit. In the deep Trendelenburg position, the patients tended to develop auto-PEEP and intrathoracic pressures with high airway pressures, which may have compromised the VT through auto- or excessive PEEP and/or a reduced driving pressure. It is unknown whether a high IAP in a deep Trendelenburg position placed limitations on the driving pressure with or without high airway pressures, which might have compromised the VT. The effects of deep Trendelenburg positioning and a high IAP on lung mechanics are also unknown. 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 made 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.

Peritoneal insufflation induces significant alterations in hemodynamics.[10,11] 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. Maintaining the PET-CO_2 between 32.40 and 35.40 mm Hg resulted in $PaCO_2$ values of 33.23–41.60. These results suggest that the patients' conditions had no negative effects on CO_2 removal. Additionally, as a non-invasive, indirect measurement, PET-CO_2 is an accurate means of monitoring $PaCO_2$, and deep Trendelenburg positioning does not diminish its usefulness.[12,13] In their RP study, Kalmar et al. reported higher PET-CO_2 and $PaCO_2$ values than ours, with PET-CO_2 values between 3.40 and 4.66 kPa, which resulted in a $PaCO_2$ between 4.66 and 6.00 kPa.[7] There were no changes in the PET-CO_2, SpO_2, or respiration as the MMV was increased by increasing breathing frequency to provide the CO_2 removal and the neuromuscular block was reversed properly in this study. Although the plateau and peak pressures were reduced by the use of the supine position at the end of the operations, these pressures remained high during the procedures. However, both pressures reached their highest values during the deep Trendelenburg positioning with pneumoperitoneum.

Although an increase in arterial pressure and slightly increased HR are associated with peritoneal insufflation, a drop in cardiac output has been also reported in the literature, whether the patient is placed in the head-down or head-up position.[12,14–16] In our study, although the MAP remained unchanged, the HR decreased significantly and required intervention. The CVP values were also above the normal limits. These high values might be due to the Trendelenburg positioning as they returned to their initial values by the end of the operation. Although the most obvious effects of the RP procedures on HR, MAP, and CVP 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 supine positioning at the end of the procedures. The most obvious changes were observed in the CVP. The lactate did not increase; therefore, there was no indication that anaerobic metabolism occurred or contributed to the acidosis. In a study of 18 ASA-1 status patients, 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.[14] In the present study, we observed the acute effects of Trendelenburg positioning with pneumoperitoneum as an increase in the MAP and a decrease in the HR, and both parameters had returned to their initial values at the subsequent time points. Kalmar et al. reported similar high-ASA related findings.[7] Kordan et al. demonstrated that Trendelenburg positioning significantly increase MAP.[17] In the present study, the MAP increased significantly at the beginning of the Trendelenburg positioning with no pneumoperitoneum. The increases in the CVP values in both deep Trendelenburg and 5° Trendelenburg positioning, with and without pneumoperitoneum, and the decreases in the CVP values to baseline at the end of the operation indicate a close relationship between CVP values and Trendelenburg positioning alone or with IAP.

Although the blood gas analyses were used to assess both respiratory and metabolic problems at all the time points, the presence of acidosis was determined as ''pH < 7.35'' and normal as ''pH > 7.35'' based on the blood gas reports at the end of the operation (T_5). In this study, at all the time points, the diagnosed acidosis types were respiratory and metabolic acidosis. Increases in the set VT or the set f reflected respiratory acidosis management during the operation. The respiratory problems determined in the present study included the decrease in arterial pH due to the high $PaCO_2$ pressure, and upper-airway and tongue edema due to the deep Trendelenburg position and endotracheal cuff pressure on the tongue base. The management strategy focused on avoiding any additional decrease in the pH, which could have worsened the blood gas parameters toward 7.20 pH and 18 mmol/L HCO_3. Normocarbia and maintenance of an adequate MMV were the main goals in the blood gas monitoring during the surgical procedures and extubation assessment. Because the PaO_2 and SPO_2 did not decrease to critical values, no patients in either group required additional interventions.

Pruthi et al. reported 6.1 h of surgical time for cystoprostatectomy and a mean blood loss of 313 mL.[3] The mean surgical time reported for their RP cases was similar to ours. In a study of the transfusion requirements in open and robotic-assisted laparoscopic radical prostatectomies, Kordan et al. demonstrated that RP was associated with lower blood loss and a smaller change in hematocrit than the open prostatectomy group.[17] In our study, none of the patients required transfusions.

In a study by Bhandari et al., the perioperative complications during robotic RP included one anesthesia-related complication out of a total of 16 complications in 300 patients who underwent RP.[1] 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.[18] In our study, the most frequent anesthesia- and position-related complications were conjunctival edema, regurgitation and ''upper airway obstruction-like'' clinical symptoms that might lead to or worsen respiratory acidosis. Phong et al. reported the clinical signs of upper airway edema via a reduction in the venous outflow from the head caused by pneumoperitoneum during prolonged, deep Trendelenburg positioning.[8] We observed enlarged and dull, edematous tongues, snoring, loud inspiration, inspiratory difficulty, alae nasi retraction and supraclavicular retraction intercostal retractions when the patients awakened and were extubated. Endotracheal cuff pressure on the tongue base can cause and enhance tongue edema by preventing the lymphatic and venous drainage of the tongue. The use of the head-upright position prior to extubation, diuretic use when necessary and extubation itself improved these symptoms. Our criteria for discharge from the operating room, in addition to Alderete scoring, included improvements in these upper airway signs and symptoms. The complications due to deep Trendelenburg positioning and/or pneumoperitoneum were limited to the operating room for most of the patients, the majority of whom did not demonstrate any need for admission to the ICU. In their study of perioperative complications during RP, Bhandari et al. demonstrated an overall complication rate of 5.3% and a major complication rate of less than 2% in their series, using the method of Clavient et al.[1,19] In the present study, neurologic complications were rare and temporary, and they were recorded on the first day postoperatively in the ward. The only neurologic complication observed in the present study was a temporary unilateral sensory and motor neuropraxia in the right arm determined on the 1st postoperative day that lasted for 3 days, similar to a complication observed in the report by Yee et al.[20] Arrhythmia can be induced by several causes in laparoscopic cases. In our study, bradycardia accounted for most of the arrhythmia cases during RP procedures, 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 have 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.

The main purpose of the present study was to describe the anesthetic challenges related to the high IAP and deep Trendelenburg positioning in RP patients. However, the high IAP utilized in the present report could be responsible for several complications adding the deep Trendelenburg positioning. In animal studies, intraperitoneal pressures >20 mm Hg resulted in intraabdominal venous collapse, which occurred at lower levels of intraperitoneal pressure in the presence of hypovolemia.[21] Thus, relative variation in intraperitoneal pressure and peripheral vessels may be the main determinants of vascular wall movements responsible for venous collapse and opening, and there could be situations that facilitate gas embolization. Increasing intraperitoneal pressure might reduce risk of gas embolism, but it could cause hemodynamic and respiratory instability in that position. Therefore, the challenge for clinicians is to obtain an optimal intraperitoneal pressure to balance between the risks of gas embolism and hemodynamic and respiratory instability during laparoscopic radical prostatectomy.

It must be clearly stated that the use of a lower IAP could certainly determine lower anesthetic complications such as respiratory acidosis, metabolic acid-base disorders, fluid management issues, position-related ''upper airway obstruction-like'' clinical symptoms, the maintenance of normocarbia, and the provision of adequate MMV. These respiratory problems may cause decreased arterial blood pH, and require special attention to prevent a worsening in acidosis, which exhibited much greater metabolic deterioration. In the management of these cases, medications and ventilatory settings should be managed carefully. It is critical to monitor fluid infusion regimens (to manage metabolic asidosis), and the PET-CO_2 and blood gases to maintain normocarbia and an adequate MMV.

Conflicts of interest

The authors declare no conflicts of interest.

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