The Risk Factors of Postoperative Respiratory Insufficiency after Prolonged Robotic Radical Prostatectomy

Jin Young Lee, M.D., Ph.D., Ji Young Lee, M.D., Ph.D., Sung Jin Hong, M.D., Ph.D.,
Byung Ho Lee, M.D., Ph.D., Ou Kyoung Kwon, M.D., Ph.D. and Young Hee Kim, M.D.

Department of Anesthesiology and Pain Medicine, The Catholic University of Korea, College of Medicine, Seoul, Korea

Background: Robotic radical prostatectomy is performed in elderly patients and requires extreme changes in the patient's position and is often associated with a long surgery time. This study reviewed the pulmonary complications occurring after a robotic radical prostatectomy and analyzed the potential risk factors.

Methods: The medical records of all patients who had undergone robotic radical prostatectomy at our institution were reviewed. Among the 80 total patients, 58 were capable of spontaneous respiration at the end of surgery (Group I), whereas 22 patients required assisted ventilation (Group II). A comparison between the two groups was made in terms of the demographic characteristics, coexisting diseases, anesthesia and operation time, amount of intraoperative blood loss and transfused blood products.

Results: The mean age of the patients was 67.2 ± 7.3 years. The mean operation time was 384.1 ± 203.4 min (range, 195–1,180 min). The anesthesia and operation time, amount of intraoperative blood loss and number of transfused patients were all significantly higher in Group II. Univariate analysis revealed age, body mass index, intraoperative blood loss and transfusion, anesthesia and operation time to be related to postoperative respiratory insufficiency. Multivariate analysis revealed intraoperative transfusion and operation time to be predictive risk factors.

Conclusions: Prolonged laparoscopic surgery in a steep Trendelenburg position has a high likelihood of postoperative respiratory insufficiency, with the intraoperative transfusion and a longer operation time being possible contributing factors.

Key Words: laparoscopic surgery, postoperative respiratory insufficiency, robotic radical prostatectomy.

INTRODUCTION

As laparoscopic procedures have expanded the types of surgery, the procedures are becoming more demanding, requiring longer operation times and are also performed in elderly patients. Elderly patients have a higher incidence of co-morbidity and risk of complications after surgery. The recently introduced procedure for robotic surgery for prostate cancer is commonly performed. Long lasting laparoscopic procedures have the potential hazard of postoperative pulmonary complications, including pulmonary edema, atelectasis, gas embolism, subcutaneous emphysema, pneumothorax, pneumomediastinum

and pneumopericardium.¹⁾ Robotic surgery for prostate cancer is performed in a steep Trendelenburg position, which may aggravate the pulmonary complications. We encountered a high incidence of respiratory insufficiency after robotic radical prostatectomy. This study examined the possible risk factors of postoperative respiratory insufficiency by reviewing the patients' medical records.

MATERIALS AND METHODS

After obtaining approval of the departmental ethics committee, the medical records of all patients who underwent robotic radical prostatectomy at our institution were reviewed. A total of 80 American Society of Anesthesiologist physical status I–III patients, aged 49 to 82 years, were enrolled. All patients had clinically localized prostate cancer for which a radical prostatectomy was indicated. The following data was obtained from the medical records: demographic characteristics, anes-

Received on April 28, 2010, Accepted on July 30, 2010

Correspondence to: Sung Jin Hong, Department of Anesthesiology and Pain Medicine, The Catholic University of Korea, College of Medicine, 62 Yeouido-dong, Yeongdeungpo-gu, Seoul 150-713, Korea

Tel: 82-2-3779-1097, Fax: 82-2-783-0368

E-mail: hongsc@catholic.ac.kr

thetia and operation time, anesthetic agents, amount of intraoperative blood loss and transfused blood products, and postoperative complications as well as co-morbidities. Postoperative hypoxemia and the need for intubation were defined as a respiratory insufficiency.

The standard principles of anesthesia and surgery were the same. The patients were given a preoperative intramuscular injection of glycopyrrolate and midazolam as premedication. Bilateral leg compression stockings were applied. Standard monitoring (IntelliVue MP70 Anesthesia, Philips, USA), including electrocardiography, pulse oximetry, capnography, central venous pressure, noninvasive and invasive blood pressure and body temperature, was performed throughout the procedure. Anesthesia was induced and maintained with a target-controlled propofol infusion with a plasma concentration adjusted to 2.6 to 3 μ g/ml and 0.3 to 0.6 μ g/kg/min remifentanyl. The lungs were ventilated in volume-controlled mode with 50% oxygen in air and a tidal volume of 8–12 ml/kg. The respiratory rate was adjusted to maintain a partial end-tidal carbon dioxide pressure of 32–42 mmHg. Rocuronium was administered as a bolus when needed. The amounts of fluid requirements and blood products transfusion were determined by the anesthesiologist's preference.

The patients were placed in the low dorsal lithotomy position with a boot-support leg holder. Both arms were padded and tucked at the sides. Shoulder braces were placed to prevent cephalad sliding while in the Trendelenburg position. After painting and draping the abdomen, carbon dioxide was insufflated into the peritoneal cavity until the intraabdominal pressure reached 11–15 mmHg, which was maintained throughout the procedure. The patient was placed in the 35° head down Trendelenburg position during surgery. At the end of surgery, the residual neuromuscular block was reversed with intravenous pyridostigmine and glycopyrrolate. Extubation was performed on the table when the patients could obey the commands and spontaneous respiration was deemed adequate. The patients were then transferred to the postanesthesia care unit (PACU). Patients who experienced inadequate respiration, which is composed of hypercarbia or hypoxia, were transferred to the intensive care unit (ICU) for further respiratory support. This decision was based on the clinical judgment considering the hemodynamic parameters and arterial blood gases. At the ICU, under the direction of a critical care physician, ventilation was assisted in pressure support mode with a continuous positive airway pressure, followed by the application of a T-piece and extubation.

The data were analyzed using SPSS 15.0 (Windows Software Package, SPSS, Chicago, IL, USA). Data are expressed as the mean $\pm$ SD. Perioperative data between the two groups were compared using a chi-square test, Fisher's exact test, or Mann-Whitney test where appropriate. The risk factors for postoperative respiratory insufficiency were examined by univariate and multivariate analyses. A p-value of less than 0.05 was considered significant.

RESULTS

A total of 80 patients received robotic radical prostatectomy during the study period. None of the cases needed to be converted to open surgery. The mean age of the patients was 67.2 $\pm$ 7.3 years, all with ASA class below III. Forty three patients (53.8%) had one or more co-morbidities; the most common being hypertension (25 patients, 31.3%). Table 1 lists the demographic characteristics of the patients.

The mean anesthesia and operation times were 445.3 $\pm$ 210.3 min and 384.1 $\pm$ 203.4 min, respectively. The mean intraoperative blood loss was 667.5 $\pm$ 490.7 ml and the volume of intraoperatively transfused packed red blood cells (pRBC) was 2.0 $\pm$ 0.8 units. No patient required a blood transfusion besides pRBC. Upon emergence from anesthesia, 22 patients (27.5%) showed an insufficient respiratory effort requiring intubation maintenance at the PACU. Three of 22 patients (3.8%) required mechanical ventilation for 48 h at the ICU. Table 2 shows the intraoperative data.

To identify the possible risk factors for postoperative respira-

Table 1. Demographic Data

	Data (range)
Patient number	80
Age (yr)	67.2 $\pm$ 7.3 (49–82)
BMI (kg/m ²)	24.1 $\pm$ 2.5 (17.5–30.3)
ASA status: I/II/III	30/47/3
Presence of co-morbid conditions	
Hypertension	25 (31.3%)
Diabetes mellitus	11 (13.8%)
Heart disease (angina, MI)	4 (5.0%)
Cerebrovascular disease	3 (3.8%)
Asthma	1 (1.3%)
Others (dementia, hepatitis, digestive tract disease)	5 (6.3%)

All data are presented as the mean $\pm$ SD or number of patients (%). BMI: body mass index; ASA: American Society of Anesthesiologists; MI: myocardial infarction.

tory insufficiency, the group of patients capable of spontaneous respiration at the end of surgery (Group I, n = 58) was compared with those requiring assisted ventilation at the end of

Table 2. Intraoperative Data

	Data (range)
Anesthesia time (min)	445.3 ± 210.3 (235-1,250)
Operation time (min)	384.1 ± 203.4 (195-1,180)
Intraoperative blood loss (ml)	667.5 ± 490.7 (100-3,000)
No. of transfused patients (%)	16 (20.0%)
Amount of transfused pRBC (units)	2.0 ± 0.8 (0.5-4.0)
No. of patients who required assisted ventilation at the end of surgery (%)	22 (27.5%)

All data are presented as the mean ± SD or number of patients (%). pRBC: packed red blood cells.

surgery (Group II, n = 22). Age, body mass index (BMI), American Society of Anesthesiologist physical status and total dose of muscle relaxant were similar in the two groups, whereas Group II had a longer anesthesia and operation time, larger amounts of intraoperative blood loss and significantly higher number of transfused patients ($p < 0.05$). Although three patients with diffuse subcutaneous emphysema and atelectasis with pulmonary congestion required mechanical ventilation for postoperative 48 h, there were no differences in the number of patients showing atelectasis and subcutaneous emphysema between the two groups. Table 3 lists the perioperative data of the two groups.

Concerning the surgeon's experience and skill during surgery, the first 40 patients was compared with the second 40 patients. The first 40 patients had a longer anesthesia and op-

Table 3. Perioperative Data of the Two Groups

	Group I (n = 58)	Group II (n = 22)	p-value
Age (yr)	67.0 ± 7.3	67.6 ± 7.3	0.134
BMI (kg/m ²)	23.7 ± 2.4	25.0 ± 2.8	0.050
ASA status: I/II/III	20/36/2	10/11/1	0.519
Co-morbidities ≥ 2	5 (8.6%)	2 (9.2%)	0.587
Anesthesia time (min)	360.4 ± 129.1	669.0 ± 221.0*	<0.001
Operation time (min)	301.6 ± 122.7	601.5 ± 215.7*	<0.001
Total dose of rocuronium (mg)	112.9 ± 16.5	121.6 ± 21.3	0.073
Intraoperative blood loss (ml)	524.1 ± 431.1	1,045.5 ± 441.6*	<0.001
No. of transfused patients intraoperatively (%)	3 (5.2%)	13 (59.1%)*	<0.001
Amount of transfused pRBC (unit)	2.2 ± 1.8	2.0 ± 0.5	0.941
Postoperative chest radiograph			0.475
Atelectasis	18 (31.0%)	4 (18.2%)	
Subcutaneous emphysema	5 (8.6%)	3 (13.6%)	
Normal	35 (60.3%)	15 (68.2%)	

All data are presented as the mean ± SD or number of patients (%). BMI: body mass index; ASA: American Society of Anesthesiologists; pRBC: packed red blood cells. Group I: patients who were capable of spontaneous respiration at the end of surgery; Group II: patients who required assisted ventilation at the end of surgery. * $p < 0.05$ compared to Group I.

Table 4. Perioperative Data of the First 40 Patients and the Second 40 Patients

	1 st 40 patients	2 nd 40 patients	p-value
Age (yr)	66.0 ± 7.3	68.3 ± 7.3	0.138
BMI (kg/m ²)	24.1 ± 2.4	24.1 ± 2.7	0.939
ASA status: I/II/III	20/19/1	10/28/2	0.065
Co-morbidities ≥ 2	5 (12.5%)	2 (5.0%)	0.432
Anesthesia time (min)	582.0 ± 221.9*	308.6 ± 45.0	<0.001
Operation time (min)	510.8 ± 221.8*	257.3 ± 40.8	<0.001
Total dose of rocuronium (mg)	117.3 ± 22.0	124.9 ± 15.0	0.757
Intraoperative blood loss (ml)	856.3 ± 537.9*	478.8 ± 353.9	<0.001
No. of transfused patients intraoperatively (%)	13 (59.1%)*	3 (5.2%)	0.005
No. of patients who required assisted ventilation at the end of surgery (%)	21 (52.5%)*	8 (20.0%)	0.002

All data are presented as the mean ± SD or number of patients (%). BMI: body mass index; ASA: American Society of Anesthesiologists. * $p < 0.05$ compared to the second 40 patients.

Table 5. Univariate Analysis of Risk Factors for Postoperative Respiratory Insufficiency

Variables	No. of patients (n = 80)	Group II (n = 22)	p-value
Age (yr)			
< 65	26	5	0.250
≥ 65	54	17	
BMI (kg/m ²)			
< 23	28	3	0.018
≥ 23	52	19	
Intraoperative blood loss (ml)			
< 300	15	1	0.001
300–500	12	0	
500–1,000	32	6	
≥ 1,000	21	15	
Intraoperative transfusion			
Yes	16	13	< 0.001
No	64	9	
Anesthesia time (min)			
< 500	55	2	< 0.001
≥ 500	25	20	
Operation time (min)			
< 400	53	2	< 0.001
≥ 400	27	20	

All data are presented as number of patients. BMI: body mass index. Group II: patients who required assisted ventilation at the end of surgery.

eration time, larger amounts of intraoperative blood loss, significantly higher incidence of transfusion and respiratory insufficiency ($p < 0.05$, Table 4).

Univariate analysis revealed that 6 variables to be related to the occurrence of postoperative respiratory insufficiency (Table 5). Multivariate analysis revealed intraoperative transfusion and operation time to be predictable risk factors for the occurrence of postoperative respiratory insufficiency (Table 6).

DISCUSSION

The main finding of this study was that patients undergoing robotic radical prostatectomy appear to be at higher risk of postoperative respiratory insufficiency. The overall incidence of delayed extubation was approximately 27.5%, which is relatively high. Epstein et al.²⁾ reported that postoperative pulmonary complications related to intubation and mechanical ventilation can occur in 10 to 25% of patients recovering from major abdominal surgery.

Postoperative respiratory failure is one of the most serious postoperative complications that is usually defined as mechanical ventilation for more than 48 h after surgery or the need

Table 6. Multivariate Analysis of Risk Factors for Postoperative Respiratory Insufficiency

Variables	OR	95% CI	p-value
BMI (kg/m ²)			
< 23, ≥ 23	6.8	0.6–80.4	0.128
Intraoperative transfusion			
Yes, No	20.8	1.3–336.6	0.033
Operation time (min)			
< 400, ≥ 400	163.9	9.3–2,887.4	< 0.001

OR: odds ratio; CI: confidential interval; BMI: body mass index.

for reintubation and mechanical ventilation at the immediate postoperative period.³⁾ Regarding the predictors of postoperative respiratory failure, previous studies classified the operation-specific and patient-specific risk factors.³⁾ Operation-specific risk factors include the location of the incision in relation to the diaphragm, emergent operation, and the type of anesthesia used. The patient-specific risk factors included the patient's general health status (age, functional status, diabetes mellitus, cancer or alcohol use), pulmonary status (smoking, chronic obstructive pulmonary disease, or increased BMI), neurological status, cardiac status (myocardial infarction), renal, and fluid status (blood transfusion).³⁾

In this study, intraoperative transfusion and a long operation time were possible risk factors. Transfused blood would have some adverse effect on the respiratory function. The mechanism of blood transfusion related acute lung injury is well known. An immune reaction induced by allogenic blood, fine disturbance of the electrolytes, and the effect of preservatives and anticoagulants should be considered. In a steep Trendelenburg position, shed blood will collect in the subphrenic area, irritate the diaphragm and induce tissue reactions, and ultimately interfere with diaphragmatic movement. In addition, a pulmonary gas embolism through the disrupted intraperitoneal vessels during surgery may have an effect. Therefore, a longer operation with a steep head down position would be associated with the collection of a larger amount of fluid in the lung and diaphragmatic area, which interferes with spontaneous respiratory movement at the early postoperative period.

For a laparoscopic procedure, a pneumoperitoneum is fundamental because it causes hemostatic tamponade, allowing better visualization of the surgical field.⁴⁾ However, carbon dioxide pneumoperitoneum induces a marked decrease in functional residual capacity (FRC) and diaphragmatic movement, which causes ventilation perfusion mismatch and intrapulmonary shunting.⁵⁾ Hypercapnia, atelectasis, pneumomediastinum, subcutaneous emphysema and delayed spontaneous respiration are

common complications.^{6,7)} In particular, the retroperitoneal approach for urologic surgery is associated with greater carbon dioxide absorption than an intraperitoneal operation due to the greater vascularity and profuse areolar connective tissue.⁸⁾ Retroperitoneal carbon dioxide inflation should be considered risk factor for postoperative respiratory insufficiency. Prolonged hypercapnia and pharyngeal and facial swelling can cause delayed tracheal extubation.⁹⁾ Respiratory acidosis and increased carbon dioxide output last for up to 1 h postoperatively, and this output is even delayed when the cardiopulmonary function is compromised.^{10,11)} In some instances, prolonged postoperative mechanical ventilation should be provided until all the extra carbon dioxide has been eliminated.¹²⁾ Wolf et al.¹³⁾ reported a 34% rate of subcutaneous emphysema in laparoscopic cases confined to urologic procedures. In the present study, three patients who required mechanical ventilation for 48 h postoperatively showed diffuse subcutaneous emphysema of the chest and abdomen as well as atelectasis with pulmonary congestion. Therefore, respiration must be carefully monitored when extensive subcutaneous emphysema is present.

Considering the positioning, the 20° Trendelenburg position was reported to increase the physiological dead space, increasing the possibility of hypoxemia.¹⁴⁾ The Trendelenburg position, particularly the long lasting extreme head down position, is associated with decreased pulmonary compliance and increased pulmonary venous pressure.¹⁵⁾ In this study, the anesthesia and operation times were significantly longer in Group II. Theoretically, longer anesthesia would be accompanied by a higher risk of respiratory insufficiency. The long duration of mechanical ventilation, inhalation of dry gas, pneumoperitoneum inducing atelectasis and overstretching of the abdominal wall muscle should increase the likelihood of postoperative respiratory insufficiency.

Typically, prostate cancer patients are generally older and at risk of other significant medical conditions, such as emphysema, chronic bronchitis or chronic obstructive pulmonary disease (COPD). Increasing age is associated with physiological emphysematous changes and a decrease in FRC, which may result in worsening pulmonary gas exchange during laparoscopy.¹⁶⁾ In this study, univariate analysis revealed age over 65 years to be significantly associated with the occurrence of postoperative respiratory insufficiency. However, this model was not enough to generalize to all populations. Therefore, a large randomized controlled trial will be needed to confirm this finding.

Recently, the use of robotic technology has increased for

many operations. The robotic system translates the surgeon's hand movements from a remote console to manipulate "wrist-like" instruments in the surgical field. Such robotic assistance provides excellent visualization of the surgical field, intuitive movement of the instruments, ergonomic comfort and a short learning curve for the surgeon.⁴⁾ Although robotic laparoscopic surgery has improved the clinical results significantly, the long operation time during the learning curve is associated with many potential hazards of perioperative complications. In this study, the mean operative time (384.1 min) was longer than those reported in the published data (141–210 min).^{17,18)} Additionally, first 40 cases showed significantly longer operative time. So, it is hard to completely deny the impact of surgeon's experience and skill on the postoperative pulmonary complication. It should be noted that the present study encompasses our initial experience with robot. Surgeons should be aware that a shortening of the operative time is an important factor for reducing the patient's exposure to the pneumoperitoneum and related adverse consequences.

This study had some limitations. The number of patients was low. Further studies on a larger scale will be needed to evaluate the risk factors related to morbidity after robotic radical prostatectomy. However, the prediction of postoperative respiratory insufficiency is critical enough to draw attention to patient management. As novel, minimally invasive techniques become increasingly popular, the patients and health providers are confronted with some of the complications described above. Postoperative pulmonary complications are associated with increased morbidity, unexpected intubation and mechanical ventilation as well as longer hospital stays. Therefore, intensive care providers should understand the physiological changes related to pneumoperitoneum and Trendelenburg position, assess the risk factors for expected complications, and make the appropriate decisions to prevent further deteriorations in the patients' condition.

REFERENCES

- 1) Henny CP, Hofland J: Laparoscopic surgery: pitfalls due to anesthesia, positioning, and pneumoperitoneum. *Surg Endosc* 2005; 19: 1163-71.
- 2) Epstein SK, Ciubotaru RL, Wong JB: Effect of failed extubation on the outcome of mechanical ventilation. *Chest* 1997; 112: 186-92.
- 3) Arozullah AM, Daley J, Henderson WG, Khuri SF: Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. *The National Veterans*

- Administration Surgical Quality Improvement Program. *Ann Surg* 2000; 232: 242-53.
- 4) Costello AJ: Beyond marketing: the real value of robotic radical prostatectomy. *BJU Int* 2005; 96: 1-2.
  - 5) Bready LL: Anesthetic issues in laparoscopy and thoracoscopy. In: American Society of Anesthesiologists Refresher Courses in Anesthesiology. 27th ed. Edited by Schwartz AJ: Philadelphia, Lippincott Williams & Wilkins Publishers. 1999, pp 43-54.
  - 6) Santana A, Crausman RS, Dubin HG: Late onset of subcutaneous emphysema and hypercarbia following laparoscopic cholecystectomy. *Chest* 1999; 115: 1468-71.
  - 7) Gottlieb A, Sprung J, Zheng XM, Gagner M: Massive subcutaneous emphysema and severe hypercarbia in a patient during endoscopic transcervical parathyroidectomy using carbon dioxide insufflation. *Anesth Analg* 1997; 84: 1154-6.
  - 8) Streich B, Decailliot F, Perney C, Duvaldestin P: Increased carbon dioxide absorption during retroperitoneal laparoscopy. *Br J Anaesth* 2003; 91: 793-6.
  - 9) Fitzgerald SD, Andrus CH, Baudendistel LJ, Dahms TE, Kaminski DL: Hypercarbia during carbon dioxide pneumoperitoneum. *Am J Surg* 1992; 163: 186-90.
  - 10) Kazama T, Ikeda K, Kato T, Kikura M: Carbon dioxide output in laparoscopic cholecystectomy. *Br J Anaesth* 1996; 76: 530-5.
  - 11) Hsieh CH: Laparoscopic cholecystectomy for patients with chronic obstructive pulmonary disease. *J Laparoendosc Adv Surg Tech A* 2003; 13: 5-9.
  - 12) Schulte-Steinberg H, Meyer G, Forst H: Are high risk patients candidates for minimally invasive surgery with CO2 pneumoperitoneum? Viewpoint from anesthesiology. *Chirurg* 1996; 67: 72-6.
  - 13) Wolf JS Jr, Clayman RV, Monk TG, McClellan BL, McDougall EM: Carbon dioxide absorption during laparoscopic pelvic operation. *J Am Coll Surg* 1995; 180: 555-60.
  - 14) Wilcox S, Vandam LD: Alas, poor Trendelenburg and his position! A critique of its uses and effectiveness. *Anesth Analg* 1988; 67: 574-8.
  - 15) Costello TG, Webb P: Anaesthesia for robot-assisted anatomic prostatectomy. Experience at a single institution. *Anaesth Intensive Care* 2006; 34: 787-92.
  - 16) Takahata O, Kunisawa T, Nagashima M, Mamiya K, Sakurai K, Fujita S, et al: Effect of age on pulmonary gas exchange during laparoscopy in the Trendelenburg lithotomy position. *Acta Anaesthesiol Scand* 2007; 51: 687-92.
  - 17) Tewari A, Srivasatava A, Menon M; Members of the VIP Team: A prospective comparison of radical retropubic and robot-assisted prostatectomy: experience in one institution. *BJU Int* 2003; 92: 205-10.
  - 18) Patel VR, Tully AS, Holmes R, Lindsay J: Robotic radical prostatectomy in the community setting--the learning curve and beyond: initial 200 cases. *J Urol* 2005; 174: 269-72.