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ORIGINAL ARTICLE

Impact of robot-assisted laparoscopic prostatectomy on the management of general anesthesia: efficacy of blood withdrawal during a steep Trendelenburg position

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Abstract
Introduction Robot-assisted laparoscopic prostatectomy (RALP) is being increasingly used. However, a steep Trendelenburg position and pneumoperitoneum during RALP has an impact on the respiratory, cardiovascular and cerebrovascular systems. To prevent complications, restrictive fluid management and blood withdrawal have been utilized in our hospital. We examined differences in the anesthetic management between RALP and radical retropubic prostatectomy (RRP), and the efficacy of blood withdrawal.

Methods Medical records of patients who underwent radical prostatectomy in our hospital between January 2012 and October 2013 were retrospectively reviewed. Demographic data, intraoperative blood and fluid administration, perioperative complications and the length of hospital stay were compared among patients receiving RRP, and those receiving RALP with and without blood withdrawal ($n = 78$, 46 and 68, respectively).
Results Patients receiving RALP with and without blood withdrawal received a smaller volume of crystalloid during surgery than those receiving RRP (mean ± SD, 5.8 ± 2.3 and 4.2 ± 1.6 vs 14.3 ± 4.1 ml/kg/h, $p < 0.001$). Median estimated blood loss was 885 g (80–2,800 g) for RRP and 50 g for RALP (3–950 g and 3–550 g, respectively), $p < 0.001$. None of the patients undergoing RALP received red blood cells, but three patients undergoing RRP did so. RALP with blood withdrawal reduced postoperative hospital stay by 45 % (6 vs 11 days). Four patients receiving RALP without blood withdrawal had delayed extubation due to severe laryngeal edema, which did not occur in any of the patients receiving RALP who had blood withdrawal. Renal function did not differ among the groups.
Conclusions RALP was associated with less blood loss, no allogeneic transfusion and shorter postoperative hospital stay. This study indicated that blood withdrawal could prevent severe laryngeal edema.

Keywords Robot-assisted laparoscopic prostatectomy · Steep Trendelenburg position · Blood withdrawal

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Introduction

Minimally invasive surgery has been shown to have some advantages compared with open surgery, and robot-assisted

laparoscopic prostatectomy (RALP) is being increasingly used. A previous study showed that RALP had the potential to improve the surgical outcome and to reduce complications compared with laparotomic radical retropubic prostatectomy (RRP) [1]. However, patients receiving RALP need to be placed in a steep (25°–40°) Trendelenburg position and exposed to CO_2 pneumoperitoneum for several hours in order to ensure adequate visualization and to reduce blood loss, which may induce adverse respiratory, cardiovascular and neurophysiological changes such as severe laryngeal edema, respiratory complications and brachial plexus injury [2, 3]. To prevent these complications, restrictive fluid management is required [4, 5]. In our hospital, to reduce these complications restrictive fluid management and/or blood withdrawal are administered at the start of a steep Trendelenburg position. Retrospectively, we examined differences between RALP and RRP with regard to the anesthetic management and the efficacy of blood withdrawal during a steep Trendelenburg position.

Methods

This study protocol was approved by our university ethics committee (2014-078). Written informed consent from each patient was waived because of its retrospective manner. Profiles and perioperative data were collected from medical records of patients receiving RRP, and those receiving RALP with and without blood withdrawal at Hirosaki University hospital from January 2012 to October 2013 ($n = 78$, 46 and 68, respectively). The decision of whether to undergo RALP or RRP was made by the patients after discussion with the surgeon. The surgeon performed the RALP procedure with the da Vinci Robot Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) using a transperitoneal approach. All RALP procedures were performed on the same table with the same degree of Trendelenburg tilt (25º).

Blood withdrawal procedure

Indication of blood withdrawal was determined by the anesthetic manager on the day of surgery. No particular selection criteria were used. Blood withdrawal was defined as removal of 400–800 g of blood from a central venous line into standard blood collection packs containing citrate phosphate dextrose solution without hemodilution at the start of a steep Trendelenburg position. Patients also continuously received acetate Ringer's solution throughout anesthesia. When vesicourethral anastomosis was completed, collected blood was re-infused to the patients.

Data collection

We collected information concerning patient demographics, intraoperative fluid administration, estimated blood loss, amount of allogeneic blood transfusion, intraoperative use of vasopressors, the highest lactate and blood sugar levels, and duration of surgery and anesthesia from the anesthetic records. Length of postoperative hospital stay, hemoglobin (Hb), serum creatinine (sCre), glomerular filtration rate (GFR), white blood cells (WBC), and C-reactive protein (CRP) were retrieved from each patient's electronic record.

Evaluation of postoperative laryngeal edema and visual function

All data were collected from anesthetic records. To evaluate the upper airway edema, all patients receiving RALP underwent laryngeal fiberscopy. Mild laryngeal edema is defined as edema of the arytenoid region and epiglottis. Severe laryngeal edema is defined when we do not see a space between a tracheal tube and the vocal cord. When there was a space between the tracheal tube and the vocal cord, extubation was performed. When severe laryngeal edema was found, extubation was delayed until the edema subsided in the postanesthesia care unit or intensive care unit. To evaluate the visual function, all patients receiving RALP were required to count their fingers immediately after extubation.

Data analysis

Data analysis was performed using GraphPad Prism V3 (GraphPad Software Inc., CA, USA). Data were summarized using descriptive statistics, including the mean for data with a normal distribution and the median for those without a normal distribution. After examining a normal distribution, mixed models analysis of variance (ANOVA) with Bonferroni test or Kruskal–Wallis analysis with Dunn's test were used to determine whether a statistically significant difference was present across the three groups and to determine the specificity of the difference at each data point compared with all data points. A chi-squared test was applied to determine whether there was a statistically different incidence of laryngeal edema between RALP with and without blood withdrawal. A p value <0.05 was considered significantly different.

Results

There were significant differences in height, body weight and preoperative Hb levels; however, no differences were detected in preoperative sCre or GRF among the 3 groups

Table 1 Patient demographics

	RRP ($n = 78$)	RALP with blood withdrawal ($n = 46$)	RALP without blood withdrawal ($n = 68$)
Age (years)	67 ± 5	66 ± 5	66 ± 6
Height (cm)	163.2 ± 5.6	165.3 ± 6.3	165.9 ± 5.8*
Body weight (kg)	62.2 ± 7.6	66.2 ± 9.8*	67.0 ± 8.0**
ASA-PS I/II/III	1/72/5	0/44/2	1/66/1
Hemoglobin (g/dl)	13.0 ± 1.5	13.6 ± 1.4*	13.9 ± 1.4***
Creatinine (mg/dl)	0.71 ± 0.12	0.78 ± 0.16	0.78 ± 0.17
GFR (ml/min/m^2)	86.0 ± 1.9	78.3 ± 2.5	80.3 ± 2.3

Mean ± SD

RRP radical retropubic prostatectomy, *RALP* robot-assisted laparoscopic prostatectomy, *GFR* glomerular filtration rate

* vs RRP $p < 0.05$, ** vs RRP $p < 0.01$, *** vs RRP $p < 0.001$

Table 2 Intraoperative parameters

	RRP ($n = 78$)	RALP with blood withdrawal ($n = 46$)	RALP without blood withdrawal ($n = 68$)
Anesthesia	PRK 76, PFK2	PRK 45, PFK 1	PRK 68, PFK 0
Surgery time (min)	129 ± 26	201 ± 42*	190 ± 32*
Anesthesia time (min)	189 ± 26	276 ± 57*	255 ± 36*
Estimated blood loss (g)	885 (80, 2,800)	50 (3, 950)*	50 (3, 550)*
Crystalloid (ml)	2,754 ± 729	1,665 ± 602*	1,194 ± 407**
Crystalloid (ml/kg/h)	14.3 ± 4.1	5.8 ± 2.3*	4.2 ± 1.6*
5 % albumin (*n*)	7	0	0
RCC transfusion (*n*)	3	0	0
Ephedrine (mg)	8 (0, 28)*	13 (0, 40)**	4 (0, 34)
Phenylephrine (mg)	0 (0, 0.5)	0 (0, 2.2)*	0 (0, 0.8)
Catecholamine (*n*)	0	6	0
Lactate (mmol/l)	1.5 ± 0.5	1.2 ± 0.3*	1.0 ± 0.3*
Blood glucose (mg/dl)	111 ± 14	112 ± 17	111 ± 19

Mean ± SD, median (range)

PRK propofol remifentanil ketamine, *PFK* propofol fentanyl ketamine, *RCC* red cell concentration, *RRP* radical retropubic prostatectomy, *RALP* robot-assisted laparoscopic prostatectomy

* vs RRP $p < 0.001$,
** vs RALP without blood withdrawal $p < 0.001$

vs RALP blood withdrawal $p < 0.01$

of patients (Table 1). Anesthesia was induced and maintained with propofol, remifentanil, ketamine and rocuronium, except for 3 patients who received fentanyl instead of remifentanil. The duration of anesthesia and surgery was significantly longer, and estimated blood loss and the volume of infusion of crystalloid was significantly smaller in patients receiving RALP with and without blood withdrawal than in those receiving RRP ($p < 0.001$ for all, Table 2). Allogeneic blood transfusion was required in 3 patients receiving RRP; however, no patient receiving RALP required it, irrespective of blood withdrawal. Patients undergoing RALP with blood withdrawal required a larger dose of vasopressors than those receiving RALP without blood withdrawal and those receiving RRP; however, the intraoperative lactate level was lower than in patients receiving RRP.

Postoperative data are shown in Table 3. Hb level was higher for RALP compared with RRP. sCre and GFR did not differ significantly on POD (postoperative day) 1 and discharge. No patients received any allogeneic blood transfusion postoperatively. The median length of postoperative hospital stay for RALP was significantly shorter than for RRP.

Laryngeal fiberscopy revealed that 23 % of patients receiving RALP without blood withdrawal had laryngeal edema, including four (5.8 %) who could not be extubated due to severe laryngeal edema. Furthermore, 28 % of patients receiving RALP with blood withdrawal also had mild edema, but all patients could be extubated immediately after surgery ($p > 0.05$). One patient receiving RALP without blood withdrawal had severe subcutaneous emphysema around the head and neck, found during surgery. His extubation was delayed due to this emphysema and laryngeal edema until $PaCO_2$ and laryngeal edema returned to normal. No patient had visual loss and central or peripheral nervous injury.

Discussion

In this retrospective cohort analysis, we revealed that RALP was associated with longer surgical and anesthesia time, less crystalloid administration, less estimated blood loss, and shorter length of postoperative hospital stay compared with RRP. Furthermore, four patients receiving RALP without blood withdrawal could not be extubated

Table 3 Postoperative parameters and length of postoperative hospital stay

	RRP ($n = 78$)	RALP with blood withdrawal ($n = 46$)	RALP without blood withdrawal ($n = 68$)
POD1			
Hemoglobin (g/dl)	9.8 ± 1.3	11.8 ± 1.4*	12.1 ± 1.4*
Creatinine (mg/dl)	0.70 (0.4, 0.37)	0.76 (0.5, 2.05)	0.74 (0.45, 1.76)
GFR (ml/min/m^2)	86.6 ± 21.0	79.5 ± 20.3	81.1 ± 20.6
WBC (/μl)	11,909 ± 3,518	10,826 ± 3,968	9,925 ± 3,303
CRP (mg/dl)	3.3 (0.9, 8.8)	4.5 (1, 26.4)**,#	3.2 (0.5, 13.5)
Discharge			
Hemoglobin (g/dl)	10.2 ± 1.5	11.9 ± 1.4*	12.1 ± 1.5*
Creatinine (mg/dl)	0.74 (0.48, 1.67)	0.77 (0.53, 1.75)	0.76 (0.45,1.72)
GFR (ml/min/m^2)	82.2 ± 17.7	77.4 ± 16.7	78.4 ± 18.0
WBC (/μl)	6,902 ± 1,873	8,002 ± 2,309	7,551 ± 2,658
CRP (mg/dl)	1.3 (0.1, 10.5)	2.2 (0.4, 14.9)**,#	1.2 (0.1, 6.8)
Postoperative hospital stay	11 (7, 31)	6 (4, 32)*	9 (3, 21)*

Mean ± SD, median (range)

RRP radical retropubic prostatectomy, *RALP* robot-assisted laparoscopic prostatectomy, *POD* postoperative day, *GFR* glomerular filtration rate, *WBC* white blood cell, *CRP* C-reactive protein

* vs RRP $p < 0.001$, ** vs RRP $p < 0.01$, *** vs RRP $p < 0.05$

vs RALP without blood withdrawal $p < 0.05$

due to severe laryngeal edema and subcutaneous emphysema. These results suggested that the primary intraoperative anesthetic consideration during RALP is the management of any sequelae associated with a steep Trendelenburg position and CO_2 pneumoperitoneum, whereas the primary consideration during RRP is fluid management, including decision-making for blood transfusion.

Pharyngeal, laryngeal and facial edema have been associated with a steep Trendelenburg position and CO_2 pneumoperitoneum [3]. Restrictive fluid management has been recommended not only to reduce the severity of upper airway edema but also to decrease excessive urine output that can obstruct the surgical field [6]. However, there is no obvious evidence that the restrictive fluid management is effective in preventing upper airway edema. Indeed, in this study, despite restrictive fluid management during RALP, four patients receiving RALP without blood withdrawal developed severe laryngeal edema. Although no patient receiving RALP with blood withdrawal developed severe laryngeal edema, mild laryngeal edema did occur. Patients with blood withdrawal required more vasopressors to maintain the hemodynamic parameters, compared with those without blood withdrawal; however, there were no differences in blood lactate or glucose levels during surgery between the two groups. These results suggest that blood withdrawal during a steep Trendelenburg position might be an effective and safe way to prevent upper airway edema. However, the incidence of laryngeal edema was not significantly different between the groups in this study. To prevent accidental upper airway obstruction after extubation, a cuff leak test was recommended [3, 6]; however, the sensitivity and specificity of the cuff leak test were relatively low (sensitivity and specificity of 75 and 59 %, respectively) [7]. As this study revealed a high incidence of mild laryngeal edema, a laryngeal fiberscopy as well as a cuff leak test should be performed before extubation. Furthermore, CO_2 pneumoperitoneum can potentially cause gas-related complications, and subcutaneous emphysema is one of the most common complications [4]. Subcutaneous emphysema itself is not a severe complication; however, the possibility of pneumothorax and/or pneumomediastinum should be considered [8]. One patient in this retrospective study developed severe subcutaneous emphysema which extended to the head and neck. Mechanical ventilation was continued until hypercarbia and laryngeal edema were corrected.

Another anesthetic concern in a patient receiving RALP is renal function. Urine output measurement is not available during surgery. One author reported that sCre was significantly higher and GFR was significantly lower on POD 1 after RALP, even though continuous infusion of nicardipine during RALP could offset the deleterious effects of CO_2 pneumoperitoneum and steep Trendelenburg position on renal function [9]. Urine output and GFR could be impaired with insufflation pressures >15 mmHg [10]. Furthermore, restrictive fluid management for RALP could also affect the elevated sCre levels [11]. However, in this study there was no significant change in postoperative sCre levels and GFR in patients receiving either RALP or RRP. Compared with previous studies, a lower insufflation pressure (10–12 mmHg), shorter operative time and smaller blood loss might make a difference to postoperative renal function.

The present study showed that RALP could reduce blood loss as well as the incidence of allogeneic blood transfusion compared with RRP as reported previously [12, 13]. Median estimated blood loss in the patients receiving RALP with or without blood withdrawal was smaller than in RRP, and no patient undergoing RALP received allogeneic blood transfusion during their hospital stay.

Laparoscopic surgery offers potential advantages for reducing blood loss compared with open surgery [12, 13]. Laparoscopy provides better visualization of the prostatic apex and sutures can be passed precisely through the dorsal vein complex. Furthermore, the tamponade effect from CO_2 pneumoperitoneum used during laparoscopy has a significant benefit. This effect could reduce venous bleeding, the most important source of blood loss. Additionally, minimum invasive surgery offers several advantages compared with open surgery. RALP allowed shorter hospital stays in previous studies [11, 14]. Our retrospective study confirms these findings.

There are some limitations to this study. As this is a retrospective study, the results depend upon the accuracy of the patients' anesthetic records and electronic records. A prospective randomized trial is needed to confirm our findings, especially regarding the efficacy of withdrawing blood during surgery. Another limitation is that all surgical procedures, including RRP and RALP, were performed by several surgeons. Therefore, surgical time and/or estimated blood loss might be affected by their technique and carrier; however, as the data did not differ significantly between the patients receiving RALP, the different surgeons did not affect our results.

Conclusions

Although surgical and anesthesia times were longer with RALP, it was also associated with less estimated blood loss, no allogeneic transfusion and shorter postoperative hospital stay. Furthermore, this study suggests that blood withdrawal in RALP could reduce the incidence of severe laryngeal edema without worsening renal function.

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Conflict of interest JS declares no conflict and interest. SN declares no conflict and interest. AS declares no conflict and interest. KJ declares no conflict and interest. TK declares no conflict and interest. TK declares no conflict and interest. MS declares no conflict and interest. FK declares no conflict and interest. TK declares no conflict and interest.

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