

Effect of Robot-assisted Surgery on Anesthetic and Perioperative Management for Minimally Invasive Radical Prostatectomy under Combined General and Epidural Anesthesia

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Background: Robot-assisted surgery and pure laparoscopic surgery are available for minimally invasive radical prostatectomy (MIRP). The differences in anesthetic management between these two MIRPs under combined general and epidural anesthesia (CGEA) remain unknown. This study therefore aimed to determine the effects of robot-assisted surgery on anesthetic and perioperative management for MIRP under CGEA.

Methods: This retrospective observational study analyzed data from patients' electronic medical records. Data on demographics, intraoperative variables, postoperative complications, and hospital stays after MIRPs were compared between patients who underwent robot-assisted laparoscopic radical prostatectomy (RALP) and those treated by pure laparoscopic radical prostatectomy (LRP).

Results: There were no differences in background data between the 102 who underwent RALP and 112 who underwent LRP. Anesthesia and surgical times were shorter in the RALP group than in the LRP group. Doses of anesthetics, including intravenous opioids, and epidural ropivacaine, were lower in the RALP group. Although estimated blood loss and volume of colloid infusion were lower in the RALP group, the volume of crystalloid infusion was larger. Intraoperative allogeneic transfusion was not required in either group. There was no difference between groups in the incidences of postoperative cardiopulmonary complications or postoperative nausea and vomiting. Hospital stays after the procedure were shorter in the RALP group.

Conclusions: Robot-assisted surgery required varied consumption of anesthetics and infusion management during MIRP under CGEA. It also shortened postoperative hospital stays, without increasing rates of postoperative complications. (J Nippon Med Sch 2021; 88: 121–127)

Key words: anesthetic and perioperative management, minimally invasive radical prostatectomy, robot-assisted surgery, pure-laparoscopic surgery, combined general and epidural anesthesia

Introduction

Laparoscopic radical prostatectomy is a minimally invasive approach for treating prostate cancer. Both robot-assisted laparoscopic surgery and pure laparoscopic surgery are available for minimally invasive radical prostatectomy (MIRP)^{1–3}. Robot-assisted radical prostatectomy (RALP) has been widely used, and its use is increasing^{4–6}. Several reports have indicated that RALP is associated

with shorter surgical time, less estimated blood loss, and shorter hospital stays than pure laparoscopic radical prostatectomy (LRP)^{7–9}.

Few reports have compared anesthetic management for RALP with that for LRP. Yonekura et al. reported that, under general anesthesia alone, RALP was associated with greater opioid consumption intraoperatively and a higher incidence of postoperative nausea and vomiting

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(PONV) than was LRP¹⁰. Under combined general and epidural anesthesia (CGEA), differences between robot-assisted surgery and pure laparoscopic surgery with regard to anesthetic and perioperative management are unknown.

We therefore performed a retrospective database study of patients who underwent RALP or LRP at our institution during the period from January 2014 through August 2017. Our goal was to compare perioperative management and outcomes between RALP and LRP and to evaluate the effect of robot-assisted surgery on the anesthetic and perioperative management for MIRP under CGEA.

Materials and Methods

This study was approved by the ethics committee of the Nippon Medical School Hospital (27-03-569). Written informed consent from each patient was waived because the study was retrospective. The perioperative database was searched for patients who underwent RALP or LRP under CGEA from January 2012 through August 2017. Patients who were given desflurane or propofol for anesthetic maintenance were excluded from this study. By December 2013, radical prostatectomies were mainly performed in our hospital by 4 experienced urologic surgeons who had performed more than 500 pure laparoscopic procedures. Since January 2014, for this study, RALP has been performed by 2 surgeons who had previously performed LRP in our hospital. To establish consistent surgical technique, we excluded the first 30 patients who underwent robot-assisted surgery, for each surgeon¹¹.

We collected data from anesthesia records, namely, patients' demographics, intraoperative fluid administration, estimated blood loss, doses of anesthetics used (i.e., sevoflurane, remifentanyl, intravenous fentanyl, epidural fentanyl, and epidural ropivacaine), volume of allogeneic blood transfusion, intraoperative use of vasopressors, and anesthesia and surgical times. Data on the length of postoperative hospital stay, additional analgesic use for postoperative pain before removal of epidural catheters, use of antiemetics for treating PONV, and postoperative airway, respiratory, and cardiovascular complications were retrieved from each patient's electronic record. PONV was diagnosed by a urologist or nurse when a patient reported nausea or had episodes of vomiting during the first 24 hours after either procedure. Urologists prescribed antiemetic drugs for treatment after diagnosing PONV.

An epidural catheter was inserted at the lower thoracic

or upper lumbar level (between Th10 and L1) before induction of general anesthesia. General anesthesia was induced in both groups with propofol (1-2 mg/kg) and fentanyl (1-2 µg/kg), with or without remifentanyl (0.05-0.20 µg/kg/min). Intubation was facilitated with rocuronium bromide (0.6-1.0 mg/kg). Anesthesia was maintained with 1.5% to 2.0% sevoflurane in an oxygen-air mixture and intravenous administration of remifentanyl and fentanyl to maintain blood pressure and heart rate at $\pm 20\%$ of baseline values. Vasoactive drugs were administered to maintain blood pressure and heart rate within those ranges. Rocuronium bromide (0.2 mg/kg) was administered at regular intervals to maintain neuromuscular block; 4-8 mL of a local anesthetic, 0.75% to 0.1% ropivacaine, was also administered into the epidural space, with or without fentanyl (1-2 mg/kg) before the incision. Additional doses of the local anesthetic during the procedures were left to the discretion of the attending anesthesiologist. After completing the vesicourethral anastomosis, we transfused autologous blood (up to a hemoglobin level of 10 g/dL). Epidural analgesia for postoperative pain was continued with a balloon infuser containing 0.1% ropivacaine, fentanyl 1.6 µg/mL, and droperidol 1.4 µg/mL. The infuser was set at 4 mL/h for continuous infusion and at 3 mL for bolus doses, with a 30-min lock-out period. We started continuous epidural infusion by the end of the procedure, and the balloon pump infuser remained in place until the morning of the first postoperative day. When the patient reported pain, additional analgesics were administered, including pentazocine, nonsteroidal anti-inflammatory drugs (e.g., flurbiprofen axetil, diclofenac sodium), and acetaminophen.

RALP and LRP were performed with a transperitoneal approach. The surgeons performed RALP with the da Vinci Robot Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). The patient was placed in the lithotomy position, and the intraperitoneal cavity was insufflated with CO₂ to a pressure of 10-15 mmHg for RALP or 10-12 mmHg for LRP. The patient was then placed in a Trendelenburg tilt position at an angle of 25° to 30° for RALP or 20° for LRP. At the end of the procedure, the table was made horizontal, and the CO₂ pneumoperitoneum was stopped.

All data are presented as medians (range). Statistical analyses were performed using the GraphPad Prism software (GraphPad Software Inc., San Diego, CA, USA). The Mann-Whitney test or the χ^2 test was used to test for differences in median values between the RALP and pure-LRP groups. A value of $p < 0.05$ was considered to

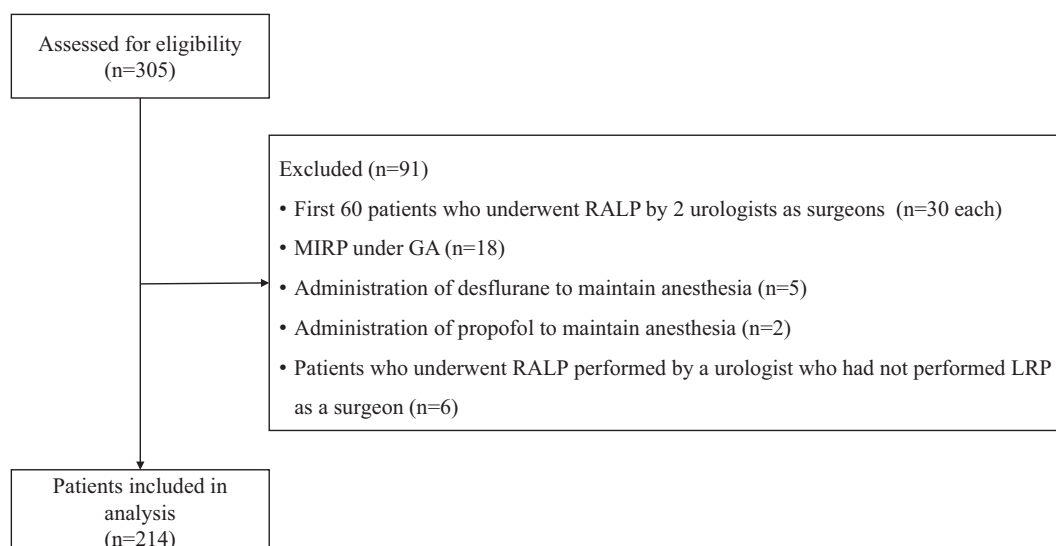


Fig. 1 Flowchart of patient selection

Flowchart of selection. RALP: robot-assisted laparoscopic radical prostatectomy; MIRP: minimally invasive radical prostatectomy; GA: general anesthesia; LRP: pure-laparoscopic radical prostatectomy.

Table 1 Demographic characteristics of patients

	RALP (n = 102)	LRP (n = 112)	P value
Age (y)	68 (46-79)	68 (41-76)	0.71
Height (cm)	165.4 (151-186.5)	167 (151-181)	0.1928
Weight (kg)	66.7 (43.3-103)	65 (25.4-94.2)	0.367
BMI (kg/m ²)	24 (18-31)	23 (17-33)	0.31
ASA-PS, n (%)			0.19
1	7 (6.6)	16 (14)	
2	90 (84)	86 (76)	
3	9 (8.4)	10 (8.9)	

Data are expressed as median (range) or number of patients (%).

RALP: robot-assisted laparoscopic radical prostatectomy

LRP: pure laparoscopic radical prostatectomy

BMI: body mass index

indicate statistical significance.

Results

We extracted the records of 305 patients who underwent MIRP at our institution during the survey period and obtained data from anesthesia records and the electronic database. **Figure 1** shows the process used to select patients for this study. We excluded the first 60 RALP procedures performed by the 2 urologists as surgeons. Eighteen patients were treated by MIRPs under GA alone. Desflurane or propofol was administered to 7 patients, to maintain anesthesia, and 6 patients who underwent RALP performed by urologists who had not performed LRP as surgeons were excluded. After those exclusions, we analyzed data from 214 patients who underwent

MIRP. In no case was it necessary to convert to an open procedure.

Table 1 shows the demographic data for the 102 RALP patients and 112 LRP patients. There were no differences in the background data between the 2 groups.

The intraoperative variables are summarized in **Table 2**. Duration of anesthesia [338 (220-532) vs 376 (264-506) min; $p = 0.0007$] and duration of surgery [267 (169-431) vs 290 (194-423) min; $p = 0.0012$] were significantly shorter in the RALP group than in the LRP group. The doses of intravenous remifentanyl [0.05 (0-0.10) vs 0.06 (0-0.24) $\mu\text{g/kg/min}$; $p = 0.0088$] and fentanyl [100 (0-350) vs 150 (0-450) μg ; $p = 0.0018$] and the dose of epidural ropivacaine were lower in the RALP group than in the LRP group [44 (19-123) vs 67 (16-164) mg; $p < 0.0001$]. There

Table 2 Intraoperative variables

	RALP (n = 102)	LRP (n = 112)	P value
Anesthesia time (min)	338 (220-532)	376 (264-506)	0.0007*
Surgical time (min)	267 (169-431)	290 (194-423)	0.0012*
Sevoflurane (mL/min)	0.51 (0.23-0.71)	0.5 (0.32-0.69)	0.061
Remifentanyl (μ g/kg/min)	0.05 (0-0.10)	0.06 (0-0.24)	0.0088*
Intravenous fentanyl (μ g)	100 (0-350)	150 (0-450)	0.0018*
Epidural fentanyl (μ g)	33.8 (0-175)	36.5 (0-260)	0.6422
Ropivacaine (mg)	44 (19-123)	67 (16-164)	< 0.0001*
Estimated blood loss (mL)	150 (0-660)	400 (200-2,000)	< 0.0001*
Crystalloid infusion (mL/kg/hour)	7.63 (3.31-21.11)	5.57 (2.61-12.65)	< 0.0001*
Colloid infusion (mL)	0 (0-1,500)	500 (0-1,600)	< 0.0001*
Autologous blood transfusion (mL)	400 (0-400)	800 (0-800)	< 0.0001*
Ephedrine (mg)	16 (0-72)	16 (0-55)	0.7858
Phenylephrine (mg)	0 (0-1.05)	0 (0-1.70)	0.3282

Data are expressed as median (range).

*: $p < 0.05$ between groups.

Table 3 Postoperative variables

	RALP (n = 102)	LRP (n = 112)	P value
NSAID or acetaminophen use before removal of epidural catheter, n (%)	11 (10)	18 (16)	0.32
Postoperative airway or respiratory complications, n (%)	1 (1)	0 (0)	0.47
Postoperative cardiovascular complications, n (%)	0 (0)	0 (0)	
PONV treated by antiemetic, n (%)	4 (3.7)	3 (2.6)	0.71
Duration of hospital stay (d)	10 (8-28)	10 (7-32)	0.0045*

Data are expressed as number of patients (%).

*: $p < 0.05$ between groups.

NSAIDs: non-steroidal anti-inflammatory drugs

PONV: postoperative nausea and vomiting

was no difference in sevoflurane dose between the RALP group and LRP group [0.51 (0.23-0.71) vs 0.48 (0.32-0.69) mL/min; $p = 0.061$]. Epidural use of fentanyl was similar in the MIRP groups. Estimated blood loss was lower in the RALP group than in the LRP group [150 (0-660) vs 400 (200-2,000) mL; $p < 0.0001$]. Although the volume of crystalloid infusions was greater in the RALP group than in the LRP group [7.63 (3.31-21.11) vs 5.572 (2.61-12.65) mL/kg/hour; $p < 0.0001$], the volume of colloid infusions was lower in the RALP group than in the LRP group [0 (0-1,500) mL vs 500 (0-1,600) mL; $p < 0.0001$]. The volume of autologous blood transfusion was lower in the RALP group than in the LRP group [400 (0-400) vs 800 (0-800) mL; $p < 0.0001$]. No intraoperative allogeneic transfusions were required in either group. There were no differences in the amounts of vasoactive drugs, ephedrine, or phenylephrine between groups. Although 1 patient with RALP required reintubation because of decreased respiratory drive, no reintubations were needed for airway edema due to the steep Trendelenburg posi-

tion or CO₂ pneumoperitoneum.

Postoperative variables are summarized in **Table 3**. Although 1 patient in the RALP group required intravenous pentazocine after the procedure, none needed an opioid after either MIRP. There was no significant difference between groups in rates of nonsteroidal anti-inflammatory drug or acetaminophen use before epidural catheter removal. The incidence of postoperative cardiopulmonary complications was not significantly different between groups. The frequencies of patients with PONV requiring antiemetic treatment were similar. Although the median duration of postoperative hospital stay was the same, the actual length of stay was significantly shorter for RALP patients than for LRP patients: 10 (8-28) vs 10 (7-32) days ($p = 0.001$).

Discussion

This retrospective study revealed that robot-assisted surgery was associated with shorter anesthesia and surgical durations, less blood loss, and lower doses of anesthetic

agents during MIRP under CGEA. Although the volume of infused crystalloid solution was greater during robot-assisted surgery, the volume of infused colloid solution was lower than that needed for pure laparoscopic surgery. There was no difference between groups in postoperative cardiopulmonary complication rates or need for antiemetic treatment for PONV. Robot-assisted surgery was also associated with shorter hospital stays after MIRP under CGEA.

Several studies reported that patients undergoing RALP had shorter surgical times, less estimated blood loss, and shorter hospital stays than did those who underwent LRP⁷⁻⁹. Our results were consistent with those from past studies. The present patients undergoing RALP had a shorter anesthesia time because surgical time was decreased, and lower estimated blood loss resulted in lower autologous blood transfusion volumes. Thus, our study showed that robot-assisted surgery shortened anesthesia and surgical times and reduced estimated blood loss, thereby requiring less autologous blood transfusion during MIRP under CGEA. Furthermore, robot-assisted surgery decreased the length of hospital stay after MIRP under CGEA.

A previous study reported that intraoperative fentanyl use was higher in patients undergoing RALP than in those undergoing LRP¹⁰. Our results show that fentanyl and remifentanyl doses were lower for RALP patients than for LRP patients. This discrepancy might be attributable to differences in anesthesia time and surgical technique. The dose of epidural ropivacaine was also lower in the RALP group than in the LRP group. In this study, the lower doses of anesthetic drugs required for RALP patients might be attributable to the fact that RALP is less invasive than LRP. In previous studies¹⁰, the data were obtained from both MIRP techniques under GA alone, whereas our data were collected from both MIRP techniques under CGEA. Furthermore, epidural anesthesia itself has a potent analgesic effect, thereby minimizing the need for higher doses of anesthesia¹²⁻¹⁴. Our results indicate that robot-assisted surgery decreases the doses of anesthetic agents required during MIRP under CGEA.

Although anesthesia time was shorter for the RALP group than for the LRP group, the volumes and flow rates of crystalloid infusions were higher in the RALP group than in the LRP group. By contrast, the volumes of infused colloid solutions needed were lower in the RALP patients. Restrictive fluid management seems to be widely accepted as a means to avoid excessive urine output during vesicourethral anastomosis and upper body

edema that can develop when in steep Trendelenburg position^{15,16}. We, however, did not apply restrictive fluid infusion management during either MIRP; nor did the urologists in our institution request it. To maintain stable hemodynamics during RALP, we infuse crystalloid solutions without infusing additional colloid solutions or increasing the vasopressor dose. In addition, lower blood loss might have reduced the amount of colloid solution needed in the RALP group. Our findings suggest that robot-assisted surgery reduces colloid infusion volume and increases the need for crystalloid solution to stabilize hemodynamics during MIRP under CGEA.

There was no difference between the MIRP techniques in postoperative need for additional analgesics. Additional opioids were not administered to our patients for postoperative pain after either MIRP. Pain intensity after RALP and LRP is generally mild to moderate, and less severe than after open radical prostatectomy¹⁷⁻¹⁹. Nevertheless, we use epidural analgesia to avoid postoperative pain after MIRP, because of its strong analgesic effect. Epidural analgesia has also been reported to be more useful than intravenous analgesics for alleviating postoperative pain after LRP²⁰. Patients who underwent RALP and were given postoperative epidural analgesia had lower opioid requirements than did those without epidural analgesia²¹. Thus, epidural analgesia may also be useful for alleviating postoperative pain after RALP.

There was no difference in the rate of postoperative complications between the RALP and the LRP groups. In previous reports, the rate of airway, respiratory, and cardiovascular complications was 0.1% to 1.4% after RALP and LRP^{4,7,22,23}. Our findings were similar. Several studies of RALP patients noted postoperative pulmonary and airway edema that had been induced by the steep Trendelenburg position and CO₂ pneumoperitoneum. Reintubation and postoperative ventilation were required^{15,24,25}. Saito et al. reported that the incidence of upper airway edema was 5.8% in patients who had undergone RALP without blood withdrawal to prevent complications due to the positioning and established pneumoperitoneum. Although we did not perform restrictive fluid therapy during RALP in our patients, none developed upper airway edema. We surmised that edema had been prevented by the effects of epidural anesthesia on blood flow distribution. Thoracic epidural block induces vasodilation of the abdominal vascular bed, thereby increasing abdominal venous capacity and reducing central venous pressure^{26,27}. Hong et al. reported that central venous pressure was lower during RALP under CGEA than dur-

ing RALP under GA, even though the infusion volume was larger in the CGEA group than in the GA group²⁷. Hence, epidural anesthesia induces redistribution of blood flow and pools blood in the abdominal vascular bed, without altering intravascular volume, thereby leading to decreased venous return and lower peripheral venous pressure. In turn, reduced peripheral venous pressures help avoid blood congestion in peripheral tissues, which then helps avoid formation of peripheral edema, including edema of the pharynx, larynx, and face. This mechanism may thus avoid edema. We believe that epidural anesthesia is useful for inhibiting edema formation in peripheral tissues, especially in the upper airway, during robot-assisted MIRP.

We found no difference in the rate of PONV requiring antiemetics between MIRP groups. The Trendelenburg position and prolonged intraperitoneal CO₂ insufflation during laparoscopic surgery induce peritoneal stretching and irritation. Those changes have a role in PONV²⁸. Hence, RALP itself is an important risk factor for PONV²⁹. About 25% of patients needed rescue antiemetics within 6 h after RALP under GA²⁹. In another study, PONV affected 16% to 30% of patients who had undergone 1 or the other MIRP under GA alone, although the incidence of PONV after RALP was higher than that after LRP¹⁰. Our results contradict these earlier findings, perhaps because less opioid was consumed during and after both MIRPs under epidural anesthesia and analgesia^{28,30,31}. Furthermore, several studies reported that postoperative epidural analgesia had more beneficial effects than systemic opioid analgesia on gastrointestinal function^{31–33}, which might reduce the incidence of PONV after MIRP. Our observations support the hypothesis that epidural anesthesia and analgesia reduce PONV incidence and treatment after RALP and LRP.

The study has several limitations. First, it was a retrospective, single-center study, so a prospective, randomized study should be carried to confirm our findings. Second, several surgeons performed both MIRPs, and all anesthetic doses were left to the discretion of the anesthesiologists. However, the surgical techniques were standardized for both MIRPs, and there were no major problems in anesthetic management for either surgery. Thus, our results may not be affected by those limitations. Third, our data were extracted from accurate patients' electronic records, and we were unable to obtain data on some variables, including pain scores after both MIRPs and number of patients with PONV not requiring treatment. Therefore, we could not evaluate differences in

postoperative pain between groups and thus have no information on the total numbers of patients who developed PONV after the 2 MIRPs.

This study revealed that, during MIRP under CGEA, robot-assisted surgery was associated with shorter anesthesia time, less estimated blood loss, and lower doses of anesthetic agents, including opioids, as compared with pure-laparoscopic surgery. Although the volume of crystalloid solution was higher for RALP under CGEA, there were no postoperative airway or respiratory complications related to the steep Trendelenburg position or CO₂ pneumoperitoneum. No patients required opioid administration for postoperative pain after either MIRP under CGEA. Robot-assisted surgery shortened hospital stay after MIRP under GCEA, without increasing the incidences of postoperative cardiopulmonary complications or PONV.

Conflict of Interest: The authors declare no conflicts of interest.

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