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Anesthetic Implications of Robotically Assisted Surgery with the Da Vinci Xi Surgical Robot

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Abstract

Surgeries performed with traditionally available robotic systems have many well-documented anesthetic implications. In this observational report, new and unique anesthetic considerations encountered with the introduction of the da Vinci Xi robot related to positioning operating room equipment, patient access and chance for unintended patient contact are described.

Keywords

Anesthetic Implications, Robotic Surgery, Da Vinci Xi

1. Introduction

The annual number of robotic-assisted surgeries performed worldwide has increased from approximately 1000 in the year 2000 to over 450,000 in 2013 [1]. Currently, a wide variety of surgical procedures—urologic, gynecologic, hepatobiliary, colorectal, otolaryngologic, thoracic and cardiothoracic—are performed robotically.

As has been described [2]-[4], robotic-assisted surgery has many implications for the anesthesiologist. Patient hemodynamics and ventilation are affected by the pneumoperitoneum and degree of trendelenburg (or reverse trendelenburg) position needed for the use of a robotic surgical system. Also, docking of the robot may require that the head of the patient be rotated away from the proximity to the anesthesiologist, which affects the position of equipment in the operating room, may reduce airway access and affect the use of arterial, central and intravenous lines. In addition, there may be a need to turn the orientation of the operating room table when converting from a robotic to an open procedure in order to use of fixed lighting designed for open surgery or to admi-

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nister emergency therapy such as electronic pacing or defibrillation.

The FDA approved the Da Vinci Xi robotic surgical system manufactured by Intutive Surgical, Inc. in April 2014. Prior to acquiring the da Vinci Xi system, the da Vinci S and Si robotic surgery systems were used at our institution since 2003 to perform over 9000 robotic-assisted procedures in urology, gynecology, hepatobiliary surgery, general surgery, otolaryngology and thoracic surgery. Since October 2014, the da Vinci Xi surgical system has been used in over 250 procedures at our hospital. Several important and unique issues relating to anesthetic care have been observed with the use of the da Vinci Xi versus the da Vinci S and Si surgical robots. The purpose of this observational report is to describe new and unique anesthetic implications encountered with the introduction of the da Vinci Xi robotic surgical system at our institution.

2. Anesthetic Implications

2.1. Robot and Operating Room Table Position

Robotic systems are made up of multiple components—the patient-side unit containing the robotic arms, the imaging tower and the surgeon's operating console. With the da Vinci S and Si surgical systems, the patient-side unit is typically brought in at a 45 degree angle relative to the initial position of the operating room table. To accommodate this position of the robot, the operating room table and the patient's head are routinely turned away from their initial position near the anesthesiologist (**Figure 1**).

By contrast, the patient-side unit of the da Vinci Xi robot is brought in perpendicular to the standard patient position, and the operating room table is less frequently turned relative to the anesthesiologist (**Figure 2**). This is due to the fact that the robotic arms on the patient-side unit of the da Vinci Xi robot are able to rotate and assume different orientations relative to the base of the unit. The result is that in the head of the bed is near the anesthesiologist for the majority of surgical procedures. The exception to this at our institution is the robotically assisted nephrectomy for which the configuration of operating room equipment is as listed in **Figure 1** for both the Xi and the Si and S systems.

Not turning the patient relative to the anesthesiologist reduces the need for extensions to intravenous, arterial and central line tubing and the need to move the anesthesia machine to accommodate connection to the anesthesia circuit and monitors. It also may reduce the chance for displacement or disconnection of lines, the anesthesia circuit and the endotracheal tube. In addition, the setup time needed to disconnect the anesthesia circuit and monitor cables, to unlock and to turn the operating room table and to reconnect equipment is eliminated at both

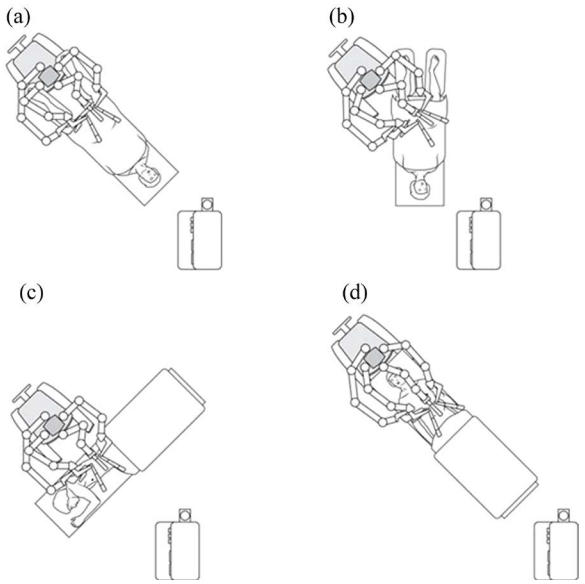

Figure 1. Typical position of operating room equipment for da Vinci S and Si surgical systems. (a) Prostatectomy; (b) Gyenocological surgery; (c) Nephrectomy; (d) Thoracic/hepatobiliary surgery.

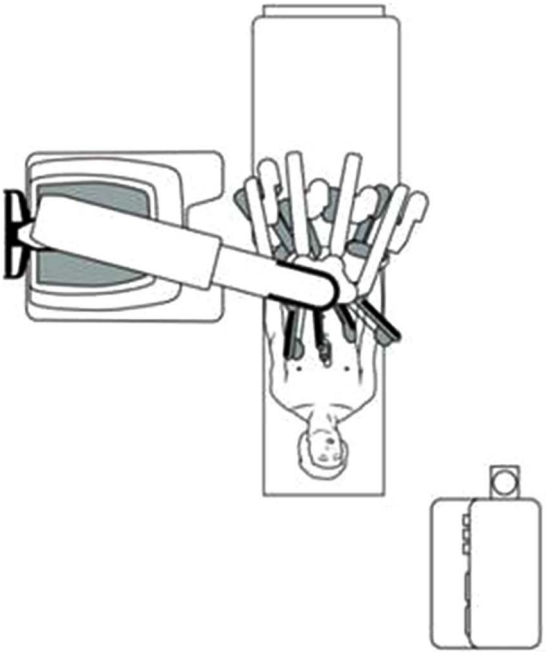

Figure 2. Typical position of operating room equipment for da Vinci Xi surgical system.

the start and end of surgery. Also, there is no need to turn the patient when converting from a laparoscopic to open procedure (in order to utilize fixed lighting designed for open surgery) and when administering emergency therapy such as electronic defibrillation. The ability to convert to an open procedure and to administer emergency therapy quickly without the need to turn the patient may improve patient safety.

2.2. Patient Access

Because the majority of surgeries performed with the Xi robot do not require turning of the operating room table, the anesthesiologist has continuous airway access and ability to monitor the patient's head and eyes routinely during a surgery. Conversely, due of the larger footprint size of the patient-side unit of the Xi robot (1.46 m^2) compared to the S and Si robots (1.15 m^2) and due to the physical position of the Xi robot relative to the patient, access to the patient's arm and any line or monitor (intravenous line, arterial line, blood pressure cuff or pulse oximeter) placed on the arm ipsilateral to the patient-side unit of the Xi robot is reduced relative to such access with da Vinci S and Si systems.

2.3. Unintended Patient Contact with Robotic Arms

The robotic arms on the da Vinci Xi robot patient side cart are supported from above as opposed to from the side on the S and Si robots. Docking with the Xi robot is laser and voice guided and distance from the robotic arm to the patient is greater during surgery on the Xi robot relative to the S and Si robots. As a result, the chance for unintended patient contact and trauma appears to be reduced. This is especially true for the third arm on the S and Si robots.

3. Discussion

After completing over 250 cases using the new da Vinci Xi surgical system and comparing it to our experience with the da Vinci S and Si systems, several new anesthetic considerations unique to the Xi system have been observed. Because of the larger size of the Xi system, reduced access to the patient's arm ipsilateral to the patient-side unit has been noted. On the other hand, more standardized positioning of operating room equipment for different types of surgeries, the elimination of the need to turn the patient when docking or undocking the patient-side robotic unit and when converting to open surgery or administering emergency therapy, less need for extensions to line tubing and for movement of the anesthesia machine to accommodate connection of the anes-

thesia circuit and monitors, improved airway access and improved ability to monitor and check the patient's head and eyes, and reduced chance for unintended patient contact and trauma have all been observed with the new Xi system.

4. Conclusion

After completing over 250 procedures with the da Vinci Xi surgical system and noting the anesthetic implications, we believe that use of the da Vinci Xi may lead to decreases in operating room times and to increased patient safety. Further studies are needed to validate these initial observations.

Disclosures

This study was funded institutionally by the City of Hope.

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Perioperative Landiolol Infusion Reduces the Incidence of Atrial Fibrillation after Pulmonary Lobectomy: Postoperative Randomized Controlled Study

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Abstract

Background and Objective: Atrial fibrillation is a common complication after lung resection. We sought to determine the relationship between low-dose landiolol only intraoperatively administration and the incidence of atrial fibrillation development in patients who did not have atrial fibrillation before undergoing lung resection. Methods: Forty-five patients undergoing lung resection (lobectomy or bilobectomy), as indicated for lung cancer at Nippon Medical Hospital, between August 2012 and September 2013. Two patients were excluded from the final analysis. Patients were given either intravenous landiolol (n = 22) or placebo (n = 21) during lobectomy or bilobectomy only intraoperatively. This is prospective, randomized, placebo-controlled study. Main Outcome Measures: The primary end point was the incidence of sustained atrial fibrillation (≥30 min). Results: Postoperative atrial fibrillation occurred in 1 (4.5%) of the 22 patients in the landiolol group and 6 (28.6%) of the 21 patients in the placebo group. No serious adverse effects such as bradycardia and hypotention secondary to landiolol were observed. Conclusion: Low-dose landiolol infusion intraoperatively reduced the incidence of clinically significant atrial fibrillation in patients undergoing pulmonary lobectomy.

Keywords

Atrial Fibrillation, Lung Resection, Lobectomy, Bilobectomy, Landiolol

1. Introduction

Atrial Fibrillation (AF) is one of the most common complications after thoracic surgery. In addition to reducing

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quality of life and causing palpitations and cardiac hypofunction, AF also increases the risk of cardiogenic embolus. Therefore, it is necessary to prevent the development of AF in patients undergoing thoracic surgery.

AF often occurs after cardiac surgery. For this reason, various studies have investigated means of inhibiting AF after cardiac surgery. One such study used landiolol. This study, the JL-NIGHT study, demonstrated that intraoperative administration of landiolol hydrochloride reduces the incidence of AF after open-heart surgery [1]. On the other hand, it has also been noted that there is an elevated risk of AF after lung resection, with incidences of approximately 4% - 30% in patients undergoing lobectomy and 10% - 40% in patients undergoing pneumonectomy [2]-[4]. Although the efficacy of landiolol administration has been investigated in for lung surgeries, more studies have examined its use for heart surgeries. Further, while several studies have reported the efficacy of landiolol [5], no prospective study has investigated the effects of only intraoperative low-dose landiolol infusion in patients undergoing lung resection. Therefore, we undertook a prospective study to determine whether administration of low-dose landiolol could reduce the incidence of AF after lobectomy.

2. Methods

2.1. Patients

The study protocol was registered with the University Hospital Medical Information Network (UMIN) Clinical Trials Registry (UMIN000007561). Ethical approval for this study (Protocol number 223009) was provided by the Institutional Review Board of Nippon Medical School Hospital, Tokyo, Japan, (Chairperson: Hospital director Sakamoto) on August 8, 2011. We obtained written informed consent from all patients on the day before surgery. This study included 45 patients undergoing lung resection at Nippon Medical School Hospital between August 2012 and September 2013. The indication for lung resection in all subjects was lung cancer, which required treatment with lobectomy or bilobectomy. The patients were randomized to receive landiolol (2.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$) (Ono Pharmaceutical Co., Osaka, Japan), or an identical amount of saline as a placebo. Both landiolol and the placebo were administered, intravenously during anesthesia. All patients had an American Society of Anesthesiologists (ASA) physical status of I/II. The exclusion criteria were acute myocardial infarction within 3 days prior to surgery, a history of supraventricular arrhythmia requiring treatment, sinus node disease, presence of a permanent pacemaker, severe heart failure (New York Heart Association III/IV or ejection fraction <35%), atrioventricular block (AV block ≥ second degree), contraindications to β-blocker therapy, secondary AF with a known primary cause (e.g., electrolyte imbalance, Wolff-Parkinson-White syndrome or hyperthyroidism), hypotension (<90/60 mmHg), and the perioperative use of an anti-arrhythmic agent other than digitalis.

2.2. Study Protocol

At enrolment in the study, the patients were randomized using the sealed envelope method to receive either the placebo or the study drug. Patients were continuously monitored from immediately after surgery for up to 72 hours thereafter. Landiolol or saline was administered from the start of anesthesia as a continuous infusion at an initial rate of 2.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$, which was titrated to a maximum rate of 20 $\mu g \cdot kg^{-1} \cdot min^{-1}$ (reassessed every 10 min) based on the hemodynamic or electrocardiographic response. The maintenance infusion of landiolol was titrated upward to maintain the ventricular rate at <90 beats/min. If hypotension (systolic blood pressure < 90 beats/min) or bradycardia (heart rate < 50 beats/min) occurred, the dose was reduced or infusion of the drug was discontinued until symptoms resolved.

The Holter electrocardiogram (ECG) was recorded on a secure digital (SD) card-type recorder (Fukuda Denshi 600; Fukuda Denshi Co., Tokyo, Japan). Postoperative recording was initiated after the surgery and continued for 72 hours.

The occurrence of episodes of AF lasting more than 30 minutes was considered as the study endpoint. More specifically, the primary endpoint was the frequency of AF occurrence from the end of the surgery to 72 hours thereafter.

Age, height, and weight were recorded for each patient. Information was also collected on preoperative pulmonary status, which was expressed as the percentage of the predicted value of forced vital capacity.

2.3. Statistical Analysis

Continuous variables are expressed as mean ± standard deviation (SD). Clinical characteristics of the two groups

were compared using the independent t-test for continuous variables and the chi-square test for categorical variables. Adverse events were analyzed by the chi-square test, as appropriate. In all analyses, $P < 0.05$ was considered statistically significant.

3. Results

One patient was excluded because the surgery type was changed intraoperatively, and another was excluded because of undergoing reoperation; hence, 43 patients completed the study. There were no statistically significant differences between the two groups in terms of sex, age, height, weight, and other preoperative data or the measured lung function parameters (**Table 1**). Further, no statistically significant differences were found in terms of operation time, anesthesia time, or the type of operation. However, no bilobectomy was performed in the landiolol group.

The numbers of patients with arrhythmias are provided (**Table 2**). AF developed in 17% of the patients overall, including 5% of patients in the landiolol group and 28% of patients in the control group ($P = 0.03$, chi-square test). No differences were found between the two groups in terms of the incidences of other types of arrhythmias. AF developed postoperatively on day 2 in 2 patients and on day 3 in 4 patients. Episodes of AF occurred only once in the patients in whom it was observed. Patients in whom AF occurred were not treated for it immediately because the Holter ECG was not analyzed instantly and they had no subjective symptoms. There was no difference between the landiolol and control groups with regard to heart rate. Indeed, there were no significant differences in heart rate between the two groups throughout the Holter monitoring period (**Table 3**). AF was not observed intraoperatively in any patient.

With respect to side effects, hypotension, bradycardiaand other serious eventswere not observed in either group.

Table 1. Epidemiological data on the study cohort.

	Landiolol	Placebo	P
No. of patients	22	21	
Perioperative data			
Gender (male)	9	12	0.12
Age (years)	70.9 ± 7.54	69.1 ± 7.10	0.34
Height (cm)	156 ± 8.3	158 ± 9.8	0.29
Weight (kg)	51.9 ± 7.3	55 ± 10.4	0.21
FEV1%	70.6 ± 4.96	73.3 ± 9.30	0.30
VC	119 ± 25.5	110 ± 18.9	0.24
Perioperative data			
Bilobectomy	2	0	0.16
Anesthesia time (min)	212 ± 86.8	228 ± 78.5	0.80
Operation time (min)	323 ± 110	331 ± 101	0.52

FEV1%: forced expiratory volume in 1 s; VC: vital capacity; Values are mean ± SD numbers.

Table 2. Results of heart rhythm (Holter) monitoring.

	Landiolol	**Placebo**	P
No. of patients	22	21	
Partial block	6	2	0.10
Negative T wave	0	1	0.32
Sinus arrhythmia	8	5	0.27
Atrial fibrillation	1	6	*0.03

*$P < 0.05$.

Table 3. Heart rate (Holter) monitoring (beats/min).

	Landiolol	Placebo	P
Preoperative	70.2 ± 14.6	73.3 ± 12.2	0.23
Postoperative-24 hour	78.9 ± 11.3	76.6 ± 9.9	0.52
24 - 48 hour	80.0 ± 12.6	82.8 ± 10.7	0.48
48 - 72 hour	82.6 ± 11.3	83.3 ± 7.7	0.87

4. Discussion

This study has two main findings. First, landiolol decreases the incidence of AF for up to 72 hours after surgery. In this study, AF onset occurred an average of 2.7 days after surgery. This result is, therefore, similar to the findings of previous studies, which have stated that AF is prone to occur from 2 or 3 days after surgery [6] [7]. The second key finding of this study is that low doses of landiolol, such as those used in this study, rarely result in adverse reactions, such as excessive reductions in heart rate and blood pressure.

The present study demonstrated that landiolol decreases the incidence of intraoperative AF with only a small dose. Studies of a similar-blocker, metoprolol, have also shown a significant reduction in the incidence of AF [8]. However, metoprolol was orally administered from preoperatively to 4 days postoperatively, which is less convenient than the administration of landiolol in the present study. Specifically, landiolol was administered only intraoperatively in the present study, offering both a shorter duration and the ability to lower the incidence of AF through management by the anesthesiologist alone. Moreover, since only a small dose of landiolol was given, obvious side effects did not develop. Even if an adverse reaction had occurred, landiolol has a short half-life (4 minutes) as compared with metoprolol (2.8 hours), is well-regulated, and is easy to use.

The mechanism of AF onset after thoracic surgery remains unclear, although the origin of AF and its association with the pulmonary vein have both been demonstrated. In AF, frequent local excitation (premature atrial contraction) is the trigger for the initial formation and onset of reentry arrhythmia. Haissaguerre *et al.* reported that the aberrant excitation that triggers AF mostly originates in the atrial muscle in the pulmonary veins [9]. Meanwhile, based on the results of electrophysiological testing, Jaiss *et al.* found that premature atrial contraction typically originates at the entrance to the pulmonary veins [10]. The complex network of cardiac muscles at the junction of the pulmonary vein and left atrium means that delayed conduction and reentry is prone to occur at this site [11]. Further, stretch stimulation accompanying increased pulmonary venous pressure may enhance motility via stretch-activated channels [12]. During lung resection, pulmonary vein dissection is believed to induce AF.

Although it is not entirely clear why handling of the pulmonary vein triggers AF, our findings show a strong correlation between AF and thoracic surgery. Indeed, AF occurred in 17% of our patients, including 28% of those in the control group and 5% of those in the landiolol group ($P = 0.03$). These findings indicate that the incidence of AF was significantly inhibited in the group of patients who received landiolol.

Our findings demonstrate that administration of landiolol during surgery decreased the incidence of AF following lung resection. Although-blockers, such as landiolol, are known to reduce perioperative increases in sympathetic nervous system (SNS) activity and reduce AF onset, the underlying mechanisms of these changes remain unclear. Further research is needed to determine the optimal dose of landiolol required to reduce AF onset.

Our study has the following limitations. First, the incidence of AF was greater than those in many previous reports. This was attributed to the high percentage of elderly patients in the present study, and in fact, the mean age of the seven patients who developed AF was 82 years. It is known that aging causes degenerative changes in atrial anatomy that are accompanied by a shorter atrial effective refractory period, longer sinoatrial and atrioventricular nodal conduction times, atrial stiffening, and splitting of the atrial excitation waveform by the pectinate trabeculae [13] [14]. The second limitation of our study was the small patient cohort. Further study is therefore necessary, and should include the assessment of landiolol administration in a large cohort of patients.

5. Conclusion

In conclusion, perioperative landiolol administration was found to be an effective means of reducing the incidence of atrial fibrillation after pulmonary lobectomy.

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