Robot-assisted Thoracic Surgery – Initial Experience at National Taiwan University Hospital

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Purpose: We set up a prospective study to evaluate the efficacy of thoracic surgery using the da Vinci system in a single institution.

Methods: We prospectively enrolled patients who underwent robot-assisted thoracic surgery at Nation-al Taiwan University Hospital during the period February 2012 to July 2012. The procedures performed and patient numbers were thymothymectomy [1], lobectomy [10], esophagectomy [1] and excision of esophageal tumor [1].

Results: The median docking time of all procedures was 10.5 minutes (range, 4-21 minutes) and the median console time was 183 minutes (range, 72-327 minutes). No patient was converted to traditional laparoscopy or thoracoscopy, but 1 patient was converted to open surgery due to major bleeding. The postoperative morbidities included 1 prolonged air leak, 1 atrial fibrillation, and 1 worsening of myasthenia gravis. There was no mortality. The median drain tube duration was 3 days (range, 2-11 days), and the median hospital stay was 6 days (range, 4-19 days).

Conclusion: Robot-assisted thoracic surgery proved to be feasible and safe in our initial series in a learning curve setting. A longer follow-up period and randomized controlled trials are necessary to evaluate a potential benefit over open and conventional VATS approaches. ***(Thorac Med 2014; 29: 63-69)***

Key words: thoracic surgery, robot-assisted surgery

Introduction

At the beginning of the 1990s, the introduction of minimally invasive surgery led to revolutionary changes in the field of thoracic surgery. Minimally invasive surgery can be a feasible and safe alterna-tive to open surgery with additional benefits that include shorter hospital stay, decreased acute postop-erative pain, less release of inflammation mediators, better functional results, and enhanced recovery and tolerance of adjuvant therapy [1-3]. Nevertheless, because it is a technically demanding operation whose difficulties are compounded by the inherent disadvantages of video-assisted thoracic surgery (VATS)—rigid instruments re-

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stricting maneuverability, physiological tremor, and only 2-dimensional vision—most anatomic VATS are performed by a small number of highly experienced thoracoscopic surgeons [4]. A robotic surgical system has been developed to overcome some of these limitations. It has several theoretical advantages, including a 3-dimensional field of view, high definition imaging, more dexterous robotic arms with 7 degrees of freedom, filtration of physiological tremor, and greater comfort for the surgeon [5]. Several studies have shown efficacy and equivalent outcomes when com-pared with both VATS and open surgery [6-7].

In January 2012, a da Vinci system was introduced in our hospital, and we began setting up a program to perform thoracic operations for patients. We would like to share our initial experiences in this report.

Patients and Methods

Patients

The study population consisted of 13 elective patients who underwent robot-assisted thoracic sur-gery at National Taiwan University Hospital from February 2012 to July 2012. There were 10 males and 3 females with ages ranging from 30 to 78 years. We performed a variety of thoracoscopic opera-tions using the 4-arm da Vinci Surgical Robotic System (Intuitive Surgical, Sunnyvale, CA, USA). All of these operations have been routinely performed with traditional laparoscopy or thoracoscopy in our department, both before and after the introduction of robotic surgery. Patients were selected on the basis of being candidates for a minimally invasive approach. All of them were thoroughly informed about the novel approach and had given their written consent. Information regarding preoperative characteristics, operative details, hospital course, and postoperative follow-up were recorded at the time. Data specific to robotic surgery were also recorded:

(1) Docking time: time needed for the setup of the robotic system and positioning of the trocars until the surgeon sat at the console to start the robotic part of the procedure
(2) Console time: the overall duration of the operation by the surgeon using the robotic system

Set-up of the Operating Room

Equipment and personnel were positioned similarly to traditional thoracoscopic or laparoscopic surgery. All procedures were performed under general anesthesia. One-lung ventilation was achieved by use of a double-lumen endotracheal tube. A master–slave surgical cart was placed behind the patient's head. The right and left arms of the robot controlled the surgical instruments, and the endoscope was attached (high-resolution 30-degree endoscope) to the center arm. Trocars were positioned in a triangulation pattern at least 8 cm apart to allow adequate range of motion of the external arms. Minor modifications were otherwise necessary depending on the procedures performed. Standard stapling devices were used.

Results

There were 10 males and 3 females in this study population. Median age at surgery was 56 years (range, 30-78 years). The procedures included 1 radical thymothymectomy for myasthenia gravis with thymoma, 1 excision of esophageal leiomyoma, 1 esophagectomy with esophageal reconstruction for esophageal cancer, and 10 lobectomies for lung cancer. There was no mortality in our series. Demo-graphic data, diagnosis, complications, and duration of drain tube use and hospital stay are shown in detail in Table 1. Two (20%) of the 10 lung cancer patients were pathologic N2, and underwent neoad-juvant chemotherapy (No. 5) and neoadjuvant concurrent chemoradiation therapy (No. 13), respectively. The docking time generally decreased as familiarity with the system increased over time. However, the console time was relatively longer than in traditional thoracoscopic surgery because we were still within our learning curve. One intraoperative complication, pulmonary arterial laceration, occurred while using the endoscopic stapler for the bronchus. The lacerations were controlled successfully by endo-clips at first. But the following manipulation dislodged the clips and resulted in significant bleeding. We converted the operation to thoracotomy for pulmonary arterial repair (Table 2). There were 3 postoperative morbidities that were related to underlying diseases rather than the operation itself. Patient follow-up continued regularly on an outpatient basis in our department and no specific robotic surgery-related complication has been detected so far.

Table 1. Patients' Baseline Characteristics and Postoperative Outcome

Patient No.	Gender	Age	Diagnosis	Drain tube duration (d)	Length of hospital stay (d)	Morbidity
1	M	64	Lung cancer	2	4	No
2	M	78	Lung cancer	11	13	Prolonged air leak
3	M	56	Lung cancer	2	4	No
4	M	64	Esophageal leiomyoma	7	8	No
5	M	54	Lung cancer	2	5	No
6	M	41	Myasthenia gravis with thymoma	3	19	Worsening myasthenia gravis
7	F	76	Lung cancer	4	12	Atrial fibrillation
8	M	68	Lung cancer	3	5	No
9	F	51	Lung cancer	3	5	No
10	F	53	Lung cancer	3	6	No
11	M	66	Lung cancer	5	8	No
12	M	41	Esophageal cancer	4	16	No
13	M	30	Lung cancer	4	5	No

Table 2. Patients' Perioperative Outcome

Patient No.	Operative Method	Docking time (min)	Console time (min)	Blood loss (ml)	Transfusion	Intraoperative complication	Conversion
1	RLL lobectomy	20	161	100	No	No	No
2	RUL lobectomy	21	203	200	No	No	No
3	LUL lobectomy	18	169	400	No	No	No
4	Tumor excision	10	72	<50	No	No	No
5	RML lobectomy	5	279	100	No	No	No
6	Radial thymothymectomy	10	176	150	No	No	No
7	LLL lobectomy	11	190	3000	Yes	Pulmonary arterial laceration	Converted to thoracotomy
8	RUL lobectomy	19	171	<50	No	No	No
9	LUL lobectomy	4	162	100	No	No	No
10	LUL proper lobectomy	15	210	100	No	No	No
11	LUL lobectomy	6	327	400	No	No	No
12	Esophagectomy with gastric tube reconstruction	8 (Thoracic part) 10 (Abdominal part)	223 (Thoracic part) 120 (Abdominal part)	300	No	No	No
13	LUL lobectomy	17	327	150	No	No	No

Discussion

Robotic surgery has inaugurated a new era in minimally invasive surgery with major potential changes concerning the concept and performance of surgery itself [5]. With regard to thoracic surgery, there are several reports in the literature demonstrating the safety and feasibility of robot-assisted lo-bectomy, thymectomy, and esophagectomy [6,8-10].

We started the robotic operation with the same indications as for traditional thoracoscopic or lap-aroscopic surgery, and used the 4-arm da Vinci system. So far, we have performed 1 radical thymo-thymectomy for myasthenia gravis with thymoma, 1 excision of esophageal leiomyoma, 1 esoph-agectomy with esophageal reconstruction for esophageal cancer, and

10 lobectomies for lung cancer. There was no mortality in our series. However, 1 of the lobectomies had to be converted to thora-cotomy because of pulmonary arterial laceration. This complication was not directly related to the robotic system. Therefore, we concluded that robotic surgery is both feasible and safe for use in the thoracic field, based on our initial experience.

While robotic operations are comparable to traditional thoracoscopic procedures in terms of duration of operation, overall hospital stay, use of postoperative analgesics, and short-term clinical outcome [11], the system presents its superiority in the physical separation of the surgeon from the patient, the elimination of tremors, articulation for multiple angles of approach, optional motion downscaling, and 3-dimensional stereoscopic imaging [12]. The combination of this processing and filtering provides surgeons an unparallel level of operative precision using an ergonomically com-fortable position with minimum fatigue. The enhanced magnification allows a clear distinction of the anatomic structures, minimizing the risk of damage. And, the motion-scaling system that translates large hand movements into precise surgical maneuvers facilitates safe dissection of these delicate anatomic structures.

The major advantages we experienced were a better degree of freedom of the hand-like articula-tion, with the ability to dissect small delicate structures in confined areas such as the subcarinal space and to perform intracorporeal suturing. During a VATS procedure, lymphadenectomy can be chal-lenging and some authors recommend a combined VATS plus video-assisted mediastinoscopic lym-phadenectomy approach to left-sided tumors to make a pretracheal and paratracheal dissection possible and to facilitate complete dissection of the subcarinal space [13]. The good dexterity of the robotic arms, together with the 3-dimensional vision, facilitates an anatomically precise and radical dissection of the mediastinal and hilar lymph nodes [14], especially for the dense nodes following chemotherapy or radiation therapy. In our series, there was no major bleeding during lymphadenectomy, and no chylothorax or recurrent nerve injury emerged during the postoperative period.

The main problem related to using the current robotic system, as extensively reported in the liter-ature, is the loss of tactile feedback (or haptics). This drawback may result in the breaking of a suture during knot tying or iatrogenic organ injury. Although needle capture and tissue suturing is quite easy with the robotic system compared with traditional thoracoscopic techniques, a high degree of experi-ence is required to avoid tissue damage owing to the exercise of extensive force.

Another disadvantage of the present robotic system is the high costs compared with conventional procedures [15]. This includes the initial capital investment for the main robotic unit, intraoperative robotic supplies plus the cost of all other instruments used, such as staplers and endo-bags, and the maintenance contract. In view of the total utilization and capital costs, there needs to be a high rate of utilization of the system to make this investment cost-effective; however, this unfortunately has not been true for most purchasing institutions. We believe and hope that costs may fall as the tech-nology matures, competing manufacturers enter the field, and more machines become available.

In conclusion, robot-assisted thoracic surgery is safe and feasible, with short-term outcomes comparable to published results using video-assisted or open approaches. Although many lessons are still being learned, our initial experience with robotic surgery is highly encouraging and we believe that the robotic system will serve as a platform for further improvements in minimally invasive surgical technologies.

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機器手臂輔助之胸腔手術－臺大醫院的初步經驗

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前言：在單一醫學機構進行前瞻性研究，以評估達文西機器手臂輔助之胸腔手術的有效可行性。

方法：在臺大醫院胸腔外科，從 2012 年 2 月至 2012 年 7 月的半年期間，利用達文西機器手臂輔助進行胸腔手術，並記錄相關資料進行分析研究。一共完成了一例胸腺瘤切除、10 例肺葉切除、一例食道切除重建、一例食道良性腫瘤切除。

結果：機器手臂接合時間（docking time）之中位數為 10.5 分鐘（範圍 4-21 分鐘），機器手臂操作時間（console time）之中位數為 183 分鐘（範圍 72-327 分鐘）。沒有病患需要轉換成傳統之胸腔鏡或腹腔鏡進行手術，但有一位病患需要轉換成開胸手術來完成出血的控制。術後併發症包括一例延長之肺部漏氣、一例心律不整 一例肌無力症的暫時性惡化;但沒有任何死亡病例發生。胸管留置天數之中位數為 3 天（範圍 2-11 天），住院天數之中位數為 6 天（範圍 4-19 天）。

結論：在我們的初步經驗中，證實機器手臂輔助之胸腔手術是安全可行的。至於它是否有優於傳統開胸或胸腔鏡手術，仍需更長時間追蹤之前瞻性研究來證實。***(胸腔醫學 2014; 29: 63-69)***

關鍵詞：胸腔手術，機器手臂輔助之手術

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