Robotic lobectomy with a single robotic stapler from one 12-mm port: a multi-institutional study

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Research Article

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Abstract

Objectives: The introduction of the robotic stapler has made it possible to perform a robotic lobectomy from the console in complete autonomy. The robotic stapler fits a 12-mm port, which is larger than the standard 8-mm port and increases the risk of postoperative neuralgia. However, in many cases, to cover all possible angles of approach, two 12-mm ports are preferably placed. Meanwhile, limiting instruments and simplifying surgical procedures are also required to reduce costs.

Methods: We assessed the feasibility of robotic lobectomy with a single type of robotic stapler inserted through one 12-mm port placed at the anterior tip of the lower intercostal space, and applied a SureForm45 Curved-Tip (Intuitive Surgical Inc., Sunnyvale, CA, USA) in a multicenter setting. We also investigated the potential cost-saving of using an additional 60-mm stapler for interlobar division.

Results: A total of 135 lobectomy cases were enrolled. In all the cases, all stapling procedures were completed using a SureForm45 Curved-Tip inserted from the designated 12-mm port. We found that it was less expensive to use the SureForm60 if more than six SureForm45 Curved-Tips were needed for interlobar division. Nevertheless, in our series, only one case (0.7%) met this requirement.

Conclusion: The use of a single type of stapler from one 12-mm port in a robotic lobectomy is a technically feasible approach, which expected to allow for surgical simplification, minimize the risk of neuralgia, and reduce inventory costs.

Introduction

The da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, California, United States) has several advantages compared with conventional thoracoscopic surgical systems, such as 3-dimensional imaging, a stable camera and operating platform, articulating instruments with 7 degrees of freedom, excellent ergonomics, motion scaling and tremor-free movements [1]. However, although stapler division of the hilar pulmonary structures is the most important and potentially dangerous step of the operation, a robotic stapler has not been available for use with the conventional da Vinci Si system and this task has instead been delegated to and performed by the bedside assistant [2,3].

The introduction of the first robotic stapler, EndoWrist (EW, Intuitive Surgical Inc., Sunnyvale, California, United States), in the da Vinci Xi system made it possible for a Robot-assisted Thoracic Surgery (RATS) lobectomy to be controlled directly by the operating surgeon, who is able to divide the hilar structures from the robotic console, facilitating the introduction of robotic surgery in the field of general thoracic surgery [2,3].

At present, stapling strategies play a significant role in choosing where to place trocars with the da Vinci Xi system. The robotic stapler is a large device, and placing the stapling ports as low as possible (i.e., close to the diaphragm) is thought to be advantageous and to allow the greatest degree of manoeuvrability in the chest cavity. To cover all possible angles, most surgeons have placed one stapling
trocar anteriorly and another posteriorly. Surgeons should also consider that the robotic stapler requires a large 12-mm port, although standard robotic instruments fit through 8-mm ports. Large 12-mm port placement increases the risk of postoperative neuralgia, especially in the narrow posterior intercostal space [4].

Meanwhile, the cost of robotic surgery is high. Obviously, there are many stapling options, including the use of both a robotic stapler and a hand-held endoscopic linear stapler (ELS) by a bedside assistant. Limiting the instruments, including staplers, and simplification of the surgical procedure are required to reduce the inventory cost and operating time for the sustainable development of robotic surgery [5].

The newest robotic stapler, SureForm (SF, Intuitive Surgical Inc., Sunnyvale, California, United States), has a 120-degree cone of articulation, which is much wider than the conventional EW, the articulation of which is elliptical (i.e., 108 degrees left to right and 54 degrees up and down). This improvement may allow surgeons to complete the entire stapling procedure with a single 12-mm stapler port placed in an anterior intercostal space, and since anterior intercostal spaces are larger than posterior intercostal spaces, doing so may reduce the risk of postoperative neuralgia.

Based on the issues described above, we assessed the feasibility of using a single type of stapler (SureForm45 Curved-Tip, SF45C) inserted through one 12-mm port to perform robotic lobectomy in a multicenter setting.

**Materials and methods**

**Institution**

Four institutions participated in this study: Shin-Yurigaoka General Hospital, Saiseikai Yokohama-shi Tobu Hospital, Southern Tohoku General Hospital, and Showa University Hospital. Robotic lobectomies performed at participating institutions between April 2020 and February 2022 were included in the study. During this period, all the participating institutions had introduced robotic lobectomy under the proctoring of the corresponding author (M.O.) and used the same port, instruments and stapler strategy described below.

**Port placement**

We utilized a 4-arm technique and a completely portal approach (RPL-4) with carbon dioxide insufflation using the da Vinci Xi surgical system (Figure 1).

Patients were placed in a lateral decubitus position and were managed with general anaesthesia and double lumen intubation. Three 8-mm ports were placed in the same intercostal space. More specifically, they were placed in the 6th intercostal space for upper lobectomies and in the 7th intercostal space for middle and lower lobectomies. A 12-mm stapling port was placed as far anteriorly as possible, usually one interspace below the other three ports. In this study, in principle, all the stapling procedures were
performed from this 12-mm port using SF45C with a white up to a black reload. A 12-mm AirSeal (ConMed, Utica, New York, United States) assist port was inserted in the anterior 10th intercostal space.

Data collection

Data were collected using a questionnaire. The questionnaires were sent to the coauthors at each institution. The completed questionnaires were then returned to the lead author (Y.I.) by E-mail.

The complete survey included, for each lobectomy:

1. Type of lobectomy,
2. Number of staplers used (excluding staplers used for intraoperative frozen section diagnosis),
3. Number and type of staplers used for division of the pulmonary vessels, bronchus, and fissure,
4. If a stapler other than the designated SF45C was used and why (answers were optional), and
5. Whether a stapler was used from a port other than the designated anterior 12-mm port and if yes, where and why (answers were optional).

Investigation of potential cost saving by the application of an additional 60-mm stapler

The thoracic cavity is much narrower than the abdominal cavity. Thus, from the standpoint of manoeuvrability and safety, the application of a 45-mm stapler, rather than a 60-mm stapler, is appropriate for the division of the hilar structure.

On the other hand, there is a potential cost advantage to the added use of a 60-mm stapler for obliterated interlobar division instead of using a 45-mm stapler alone. Therefore, we estimated and compared the cost of completing the entire procedure using SF45C alone and adding SF60 for interlobar fissure division, and the potential advantages of using SF60 in clinical practice were discussed.

Exclusion criteria

The 28 cases in which staplers other than the SF45C were used for non-technical reasons, that is, because of being out of stock or inventory clearance, were excluded from this study. All stapling procedures in these 28 cases were completed using a robotic stapler inserted through the designated anterior inferior 12-mm port. A hand-held ELS was not used.

Results

A total of 135 consecutive robotic lobectomies were enrolled (Shin-Yurigaoka General Hospital, 35; Saiseikai Yokohama-shi Tobu Hospital, 45; Southern Tohoku General Hospital, 37; Showa University Hospital, 18).
All stapling procedures were completed using a SF45C inserted through the designated anterior inferior 12-mm port. The 135 surgical procedures consisted of 44 right upper lobectomies, 18 right middle lobectomies, 33 right lower lobectomies, 20 left upper lobectomies, and 20 left lower lobectomies. The numbers of staplers required for each surgical step (vessel division, bronchial division and interlobar division) and for the overall operation according to type of lobectomy are listed in Table 1.

The number (median [range]) of stapler reloads required for hilar vessel division was 3 [1-5] per case during a right upper lobectomy, 2.5 [1-5] during a right middle lobectomy, 2 [1-4] during a right lower lobectomy, 4 [2-6] during a left upper lobectomy, 3 [2-4] during a left lower lobectomy, and 3 [1-6] during all lobectomies as a whole.

The number of stapler reloads required for bronchial division was 1 [1-2] during a right upper lobectomy and a left upper lobectomy, 1 [1] during a right middle lobectomy, a right lower lobectomy, and a left lower lobectomy, and 1 [1-2] during all lobectomies as a whole.

The number of stapler reloads required for interlobar division was 3 [0-6] during a right upper lobectomy, 3 [1-5] during a right middle lobectomy, 2 [0-5] during a right lower lobectomy and left lower lobectomy, 1.5 [0-5] during a left upper lobectomy, and 2 [0-6] during all lobectomies as a whole.

Overall, the number of stapler reloads required was 7 [4-11] during a right upper lobectomy and a left upper lobectomy, 6.5 [4-10] during a right middle lobectomy, 5.5 [3-9] during a right lower lobectomy, 6 [3-9] during a left lower lobectomy, and 6 [3-11] during all lobectomies as a whole.

The potential cost savings from the added use of a SF60 were assessed as follows: if X and Y represent the number of SF45C and SF60 stapler reloads required for interlobar division and the catalog cutline lengths of SF45C and SF60 are 40 mm and 55 mm, respectively, when X reloads of the SF45C are required to cut the interlobar tissue, X-1 reloads of the SF45C are insufficient to cut the tissue. This condition can be expressed in the inequality:

40 x (X-1) < Tissue length

When the tissue can be cut with Y reloads of the SF60, the following inequality holds:

Tissue length < 55 x Y

Therefore, the condition for tissue length is:

40 x (X-1) < Tissue length < 55 x Y

If the difference between 40 x (X-1) and 55 x Y is too small, this inequality will almost never be satisfied, making it impractical.

Thus, assuming that the difference in staple length (safety margin) between X-1 reloads of the SF45C and Y reloads of the SF60 is at least 10 mm (Figure 2), the relationship between X and Y is:
\[40 \times (X-1) < 55 \times Y +10 \] (1)

The SF45C and SF60 stapler shafts each cost 35,000 yen. Stapler reloads cost 31,000 yen for SF45C and 34,000 yen for SF60.

If using SF45C and SF60 together is cheaper than using SF45C alone, the following inequality holds:

\[31000 \times X > 35000 + 34000 \times Y \] (2)

Figure 3 shows the range over which the above simultaneous inequalities hold. Based on these inequalities, it can be seen that if the SF45C requires more than six reloads to divide the interlobular fissure, it may be more economical to switch to a SF60. In our series, only one case (0.7%) met this requirement. It was a right upper lobectomy case that required six staples for interlobar division. Replacing the SF45C with a SF60 in such situations would reduce costs by only 15,000 yen per case.

**Discussion**

The development of the first robotic stapler, which was only available on the Xi robotic system, was a major technological leap and facilitated the introduction of robot-assisted technology in thoracic surgery. Before the development of the robotic stapler, inexperienced assistants who had to staple vessels using hand-held ELS were a potential risk factor for intraoperative catastrophic bleeding in major lung resection [2,3]. A considerable number of thoracic surgeons were reluctant to adopt robots in clinical practice. However, the introduction of the robotic stapler made it possible to perform a complete robotic lung resection without entrusting hilar structure division to inexperienced assistants.

Robotic staplers fit 12-mm robotic ports and are larger than standard robotic instruments that fit 8-mm ports; this can potentially increase the risk of postoperative neuralgia. Nevertheless, many surgeons prefer to place two 12-mm ports (one anterior and one posterior) to accommodate virtually all stapler angles for the division of any structure [4]. This may be partially due to the fact that the traditional robotic stapler (EW) has not been sufficiently sophisticated in terms of operability. The latest robotic stapler (SF) has a wider range of motion and improved operability. Therefore, the possibility arose that the use of two 12-mm ports might not always be necessary [5]. On the other hand, among the many stapler options, including hand-held ELS, inventory management could be simplified by limiting the type of staplers used to the SF45C, which has superior manoeuvrability. These issues motivated us to investigate the feasibility of using a single type of stapler (SF45C) from a single 12-mm port for robotic lobectomy. The following results were obtained:

1. In all the lobectomies, it was possible to complete the divisions of all hilar vascular, bronchial, and interlobar fissures using the robotic stapler (SF45C) inserted from the designated single anterior inferior 12-mm stapler port.
2. Adding a 60-mm stapler (SF60) for interlobar division, especially in cases with fused fissures, might be more cost-effective than a 45-mm stapler (SF45C) alone. We also found that it was less expensive to use the SF60 if more than six SF45Cs were needed for interlobar division. Nevertheless, in our series, only 1 of the 135 cases (0.7%) met this requirement, and the expected cost reduction was 15,000 yen, which was not large considering the advantages of the simplified surgical procedure and inventory.

**Conclusion**

Using a single type of stapler (SureForm45 Curved-Tip) inserted through a single 12-mm port is a technically feasible means of performing robotic lobectomies, and it is more cost-effective than using a SF60 in addition for interlobar fissure in most cases. This approach can be expected to allow for surgical simplification, minimize the risk of postoperative neuralgia, and reduce inventory costs.

**Abbreviations**

EW EndoWrist

RATS robot-assisted thoracic surgery

ELS endoscopic linear stapler

SF SureForm

SF45C SureForm45 Curved-Tip

SF60 SureForm60

RPL-4 robotic portal lobectomy with four arms

**Declarations**

**Funding statement:**

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Conflicts of interest statement:**

Makoto Oda has lectured for Intuitive Surgical (Sunnyvale, CA). Yoshimasa Inoue declares that he has no conflict of interest. Koichi Fujiu declares that he has no conflict of interest. Tetsuya Endo declares that he has no conflict of interest. Rurika Hamanaka declares that she has no conflict of interest. Hiroto Tanaka declares that he has no conflict of interest. Hidefumi Takei declares that he has no conflict of interest.
Author contribution statement

Yoshimasa Inoue: Conceptualization; Investigation; Methodology; Data curation; Writing—original draft & editing. Koichi Fujiu: Data curation; Writing—review. Tetsuya Endo: Data curation; Writing—review. Rurika Hamanaka: Data curation; Writing—review. Hiroto Tanaka: Data curation; Writing—review. Hidefumi Takei: Data curation; Writing—review. Makoto Oda: Conceptualization; Supervision; Validation; Data curation; Writing—review.

Ethics statement

All study procedures were conducted in accordance with the Declaration of Helsinki and its later amendments. This study was approved by the Ethics Review Committee of the Saiseikai Yokohama-shi Tobu Hospital, Kanagawa, Japan (referral number: 20210215).

Consent to participate statement

The requirement for informed consent was waived because only anonymized data were included in the customized database used in the present study.

References


Table
Table 1. Number of reloads used per case for each surgical step according to lobectomy type

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Hilar vessel division</th>
<th>Bronchial division</th>
<th>Interlobar division</th>
<th>Overall procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right middle lobectomy (n=18)</td>
<td>2.5 [1-5]</td>
<td>1 [1]</td>
<td>3 [1-5]</td>
<td>6.5 [4-10]</td>
</tr>
</tbody>
</table>

Data are shown as the median [range].

Figures

Figure 1
Our port strategy is illustrated. Three 8-mm ports are placed in the same intercostal space: specifically, in the 6th intercostal space for upper and middle lobectomies and the 7th intercostal space for a lower lobectomy. A 12-mm port for the robotic stapler is placed as far anteriorly as possible on the bottom of the thoracic cavity, usually one intercostal space below the other three ports, in the 7th or 8th intercostal space. In principle, all staple procedures were performed from this 12-mm port using a SureForm45 Curved-Tip (SF45C).

**Figure 2**

The conditions under which a 60-mm stapler (SF60) was used instead of a 45-mm stapler (SF45C) are shown. For example, an SF60 was used for an oblique fissure division during a right lower lobectomy. X and Y represent the number of SF45C and SF60 stapler reloads required for interlobar division and the cutline lengths of SF45C and SF60 are 40 mm and 55 mm, respectively. We set a safety margin of 10 mm for the cutline length between X-1 reloads of the SF45C and Y reloads of the SF60.
The area in which the below inequalities hold is shown, where $X$ and $Y$ are both positive integers. The set of positive integers that satisfying these inequalities is indicated by the highlighted dots.

\[
31000 \times X > 35000 + 34000 \times Y
\]

\[
40 \times (X - 1) < 55 \times Y - 10
\]