Novel Sternum Lifting Technique for Robotic Internal Thoracic Artery Graft Harvesting

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Abstract: Internal thoracic artery (ITA) harvesting using the robotic system usually requires artificially induced capnothorax to provide visualization and working space, but this procedure has the disadvantage of deteriorating the hemodynamics. We developed an electrical sternum lifting system (ESLS) for robotic ITA harvesting, which is robust and can be finely adjusted, capable of lifting the sternum for a maximum of 5 to 10 cm. Using a mechanical sternum lifting device significantly ($P < 0.01$) shortened the time of ITA harvesting from a mean ± SD of 55.5 ± 24.1 minutes to 33.0 ± 15.7 minutes. No patient using the ESLS required induced capnothorax. Our novel ESLS provides a good operative field of view and allows ITA harvesting without inducing capnothorax.

Key Words: Internal thoracic artery, Sternum lifting, Induced capnothorax.

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Internal thoracic artery (ITA) harvesting using the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA USA) is an extremely useful method in less-invasive coronary artery bypass graft surgery. The two main advantages are that a sufficient long graft can be harvested from the origin of the subclavian artery without cutting the sternum or the ribs and that bilateral ITA can be harvested. The robotic technique also ensures that the IMA is not twisted or kinked, allows accurate intercostal thoracotomy, and permits more accurate determination of the correct target vessel and location for anastomosis. However, with the conventional approach, as we described previously,[1] the heart blocks the view of the operative field, and forceps manipulation may be difficult in some cases. The procedure is more difficult in patients with cardiomegaly because the space between the heart and the anterior chest wall is narrow. Moreover, harvesting of the right ITA in addition to the left ITA is technically difficult in patients with a flat thorax or a small physique because the right ITA is harvested from the left side, crossing the midline of the sternum. Thus, for this procedure, induced capnothorax is used to produce a positive pressure inside the thoracic cavity. The disadvantage of this method is that it can deteriorate the hemodynamics in some patients. There is a need to develop more efficient and safe methods to obtain a sufficient surgical view and working space. We report here a new sternum lifting technique.

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METHODS

Twenty patients who underwent ITA harvesting using the da Vinci Standard Surgical System at our institution between January 2010 and June 2012 were studied. To evaluate the usefulness of the novel sternum lifting technique that we designed, we randomized 10 patients to a lifting group in which the sternum lifting method was used and 10 patients to a nonlifting group in which carbon dioxide insufflation alone was used (Table 1). The two groups were compared with respect to the following parameters: (1) time of ITA harvesting procedure, (2) success rate (ITA harvest accomplishment rate), (3) induced capnothorax pressure (millimeters of mercury), (4) length of harvested ITA with respect to intercostal space accessed, and (5) rate of interruption of the surgical procedure because of hemodynamic deterioration.

Carbon Dioxide Insufflation

Carbon dioxide was insufflated into the thoracic cavity under continuous monitoring of the intrathoracic pressure. The pressure was increased to 4 to 10 mm Hg to maintain a good operative field of view. Internal thoracic artery harvesting was conducted with a maximum insufflation pressure of 10 mm Hg. When the blood pressure decreased by more than 20 mm Hg compared with before carbon dioxide insufflation or when saturation of peripheral oxygen dropped to 95% or lower, insufflation pressure was returned to 0 mm Hg, and the surgery was continued under induced capnothorax after hemodynamics improved.

Sternum Lifting Technique

For the first five cases in the lifting group, a manual lifting device (Kent retractor; Takasago Ika Kogyo, Tokyo, Japan) was used. A support bar was set up by the bedside, and a crane-type traction device was attached to the upper part of the bar. Through a small subxiphoid incision, the blade of the hook was inserted manually under the sternum, and the end of the retraction hook was hooked onto the subxiphoid process, and the sternum was lifted manually (Fig. 1). In the subsequent five cases, the novel electrical sternum lifting system (ESLS; Fig. 2) that we developed was used, as described below.

TABLE 1. Clinical Background and Total Operation Time for CABG of the Lifting and Nonlifting Groups

	Lifting (n = 10)	Nonlifting (n = 10)
Age, mean ± SD, y	66.5 ± 9.4	64.0 ± 9.9
Male/female, n	7/3	8/2
BITA/LITA, n	4/6	2/8
Height, mean ± SD, cm	165.2 ± 7.3	164.6 ± 6.5
Weight, mean ± SD, kg	65.9 ± 7.5	62.5 ± 12.4
BMI, mean ± SD, kg/m^2	24.4 ± 2.2	23.0 ± 3.0
EF, mean ± SD, %	61.3 ± 10.8	57.8 ± 7.4
COLD, n	1	1
Surgery time, mean ± SD, min	263.5 ± 78.3	256.6 ± 48.6

BITA indicates bilateral internal thoracic artery; BMI, body mass index; CABG, coronary artery bypass graft; COLD, chronic obstructive lung disease; EF, ejection fraction; LITA; left internal thoracic artery.

Novel Electrical Lifting Device

We developed the ESLS to provide surgeons a sufficient view when harvesting the ITA. A sternum-lifting hook, a lifting arm, and an actuator are assembled. The sternum-lifting hook and the lifting arm are movable and can be set to the desired angle and length, and their positions can be adjusted to access the sternum of the patient. The ESLS is raised and lowered by a remote control, with a maximum stroke of 150 mm and a maximum load of 60 kg. We set low-speed elevation at 3 mm per second, high-speed elevation at 10 mm per second, and lowering at 15 mm per second. As the actuator mechanically self-locks because it moves along a screw-and-nut mechanism, it will not drop even if the power is cut. Because the fulcrum is at the tip of the open upper side of the hook, the hook does not slip out when the sternum is being lifted. There are hooks of various widths and lengths to choose from for optimal fitting for each patient. Extensive movement tests were conducted followed by safety checks in animal experiments before the ESLS was applied to patients. Through a small subxiphoid incision, the blade of the hook was inserted manually under the sternum, and the end of the hook (Fig. 2) was hooked to the subxiphoid process. The sternum is lifted at a distance depending on the orientation and the degree of exposure of the ITA, and the maximum sternum lifting height is 5 to 10 cm. Carbon dioxide insufflation is used additionally if necessary. The time taken to set up the ESLS including making the incision, inserting the hook, attaching it to the crane, and optimizing its lift was within 10 minutes.

The use of the lifting device does not interfere with the robotic arms. A photograph of the lifting device in position with the robot docked to the patient is shown in Figure 2A. Because the blade of the hook is inserted via a small subxiphoid incision, it does not affect the positions of the ports.

Statistics

All statistical analyses were performed using the Statistical Package for the Social Sciences software (version 19.0.0.2; Statistical Package for the Social Sciences, Chicago, IL USA). Continuous variables are presented as mean ± SD, and categorical variables are given as frequencies. Each parameter of both groups (the lifting method and the nonlifting method) was compared using the two-tailed Mann-Whitney *U* test for the continuous variables and the χ^2 test for categorical data. Statistical significance was defined as a *P* value of less than 0.05.

RESULTS

After the lifting of the sternum by manual method or the ESLS, a sufficient space between the thoracic wall and the heart was secured, and the ITA could be observed and harvested adequately. A sufficient and good operative field of view was obtained by sternum lifting.

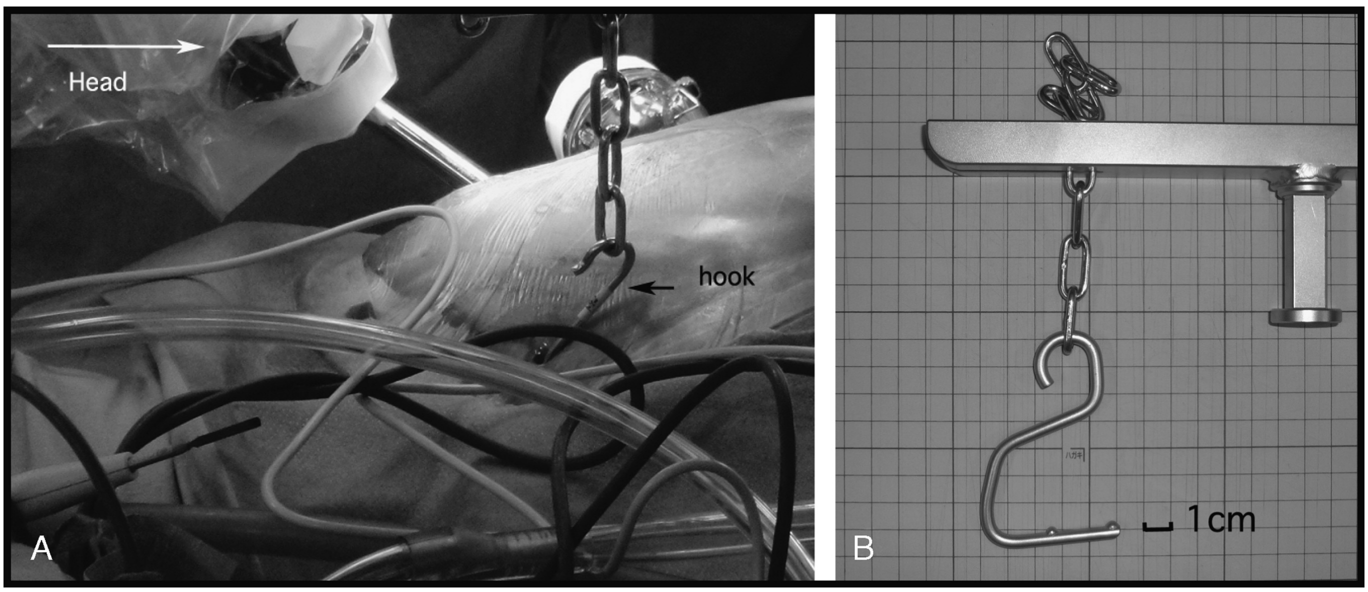

FIGURE 1. Manual sternum lifting technique. A, Photograph showing the use of the manual sternal lifting device. One end of the retraction hook is placed beneath the subxiphoid process. B, Photograph of a retraction hook presented with a scale.

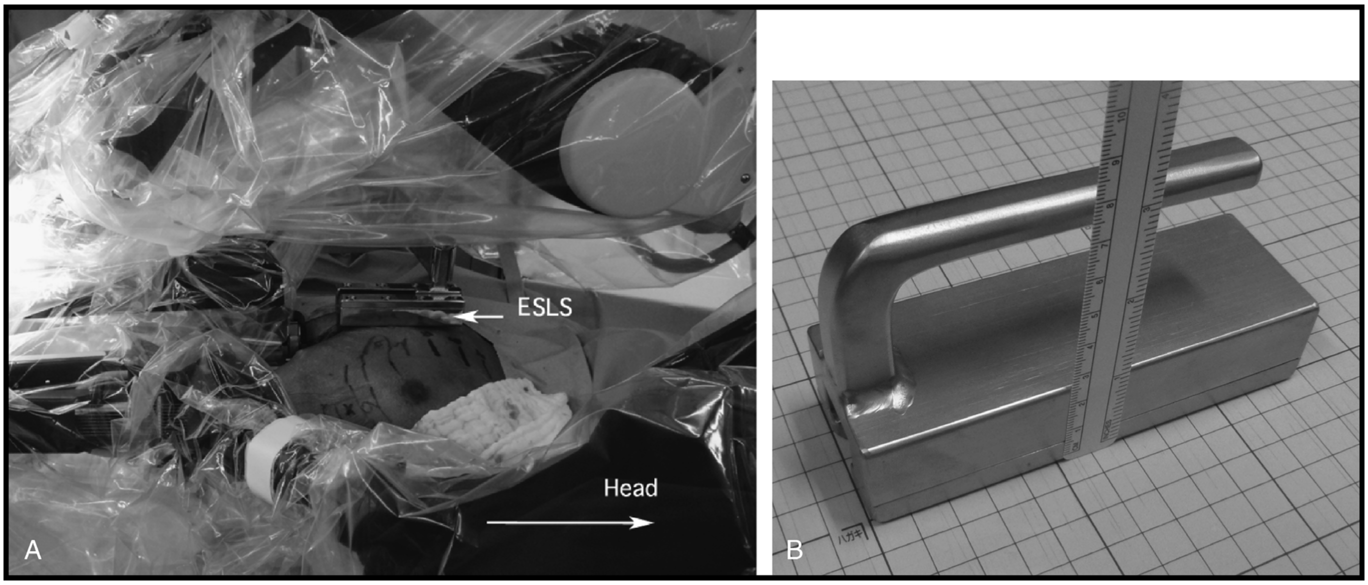

FIGURE 2. The new electrical sternum lifting system. A, Photograph showing the use of the electrical sternum lifting system with the da Vinci system. B, Photograph of a hook presented with a scale. ESLS indicates electrical sternum lifting system.

Comparison of Parameters

The time taken for ITA harvesting was 55.5 ± 24.1 minutes in the nonlifting group and 33.0 ± 15.7 minutes in the lifting group and was significantly shortened in the lifting group ($P < 0.01$). The success rate was 100% in both nonlifting and lifting groups. The pressure of induced capnothorax ranged from 6 to 10 mm Hg (9.5 ± 1.2 mm Hg) in the nonlifting group and 0 to 10 mm Hg (2.4 ± 3.5 mm Hg) in the lifting group and was significantly lower in the lifting group. Internal thoracic artery harvesting was accomplished without inducing capnothorax in 6 of 10 patients in the lifting group. All patients using the ESLS did not require induced capnothorax. The length of ITA harvested with respect to the ribs was five intercostal spaces in both groups. The procedure was interrupted because of lowered blood pressure caused by induced capnothorax in 0 of 10 patients in the lifting group and in 3 of 10 patients in the nonlifting group ($P < 0.05$).

There was no injury to the ITA and no complications related to the use of ESLS.

Comment

Robotic ITA harvesting is a superior method for harvesting the ITA in less-invasive coronary artery bypass graft. However, the conventional approach via the left thoracic cavity is anatomically challenging because the working space between the heart and the anterior thoracic wall is limited. The working space is especially small in patients with cardiomegaly, and harvesting the right ITA is particularly difficult. Therefore, induced capnothorax is conventionally used to enlarge the operative field, although an adequate view cannot be obtained even with this method in many cases. The surgical view becomes narrow when intrathoracic air leaks from the port and results in prolonged operation time. Another shortcoming of this method is that hemodynamics deteriorates when the intrathoracic pressure exceeds 10 mm Hg. These problems limit the use of this method in robotic or totally endoscopic ITA harvesting in some patients. To avoid the previously mentioned problems, we developed the sternum lifting technique.

Using the sternum lifting technique, ITA harvesting was accomplished without the need to induce capnothorax in most patients. In addition, the lifting method shortens the operation time because this method maintains hemodynamics at safe levels, allowing the procedure to proceed without interruption. Our series also shows that the right ITA can be harvested satisfactorily by approaching via the left thorax, consistent with a previous report.[2]

From the technical viewpoint, our study shows that adequate sternum lifting can be achieved easily by a primitive method using a retraction hook. However, when performing robotic surgery using the da Vinci Surgical System, three robotic arms are inserted from the caudal side. When the ITA is harvested using the manual sternum lifting device, the support bar of the Kent retractor may interfere with the robotic arms. In addition, the support bar of the Kent retractor is not sufficiently strong and may bend while lifting the sternum, consequently achieving insufficient lifting. Another disadvantage of this device is that lifting occurs mainly at the subxiphoid process, and the upper sternum is not adequately lifted. To improve sternum lifting techniques, we developed a novel electrical device, the ESLS. This device is robust and electrically operated and can be set up easily. By changing various hooks, the lifting of the subxiphoid process and/or the whole sternum is possible. Because the ESLS is robust enough to lift even a strong rib thoracic cage, sufficient space from the upper to the lower part of the anterior mediastinum can be secured, which facilitates surgical view in the anterior mediastinum.

In other thoracic surgeries, the use of the ESLS provides a good view of the organs located in the anterior mediastinum, such as the thymus. Thus, the ESLS has been used in thymectomy via a subxiphoid approach in our institution.[3]

CONCLUSIONS

The sternum lifting technique is very useful for ITA harvesting. Our novel ESLS provides a good operative field of view and allows robotic ITA harvesting without induced capnothorax.

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