Harvesting bilateral internal thoracic arteries using a novel subxiphoid approach versus the conventional lateral thoracic approach—results of an experimental study

Chikako Ikeda, MD, Go Watanabe, MD, PhD, Norihiko Ishikawa, MD, PhD, Hiroshi Ohtake, MD, PhD, and Shigeyuki Tomita, MD, PhD

Objectives: A new method was developed to harvest bilateral internal thoracic artery grafts using a subxiphoid approach and robotic assistance. The present study compared the potential utility of the subxiphoid method with that of the lateral thoracic approach.

Methods: The first part of the study examined the optimal placement of the instrument ports to maximize the robotic arms' range of motion. The second part of the study examined the 2 approaches for harvesting bilateral internal thoracic arteries from pig carcasses. The obtained graft lengths and time needed to conduct each procedure were compared using the Mann-Whitney *U* test.

Results: The preliminary study suggested that optimal positioning of the instrument ports was achieved by placing the right and left instrument ports far apart and linearly arranging all the ports. Using this configuration, the subxiphoid approach yielded a left internal thoracic artery that was 11.7 $\pm$ 1.90 cm long compared with 9.17 $\pm$ 0.74 cm using the conventional approach ($P = .0131$). The right internal thoracic arteries (11.8 $\pm$ 1.69 cm) obtained using the subxiphoid approach were significantly longer than those obtained using the conventional approach (8.88 $\pm$ 0.58 cm). The time needed to harvest the right internal thoracic arteries (34.7 $\pm$ 8.14 minutes) was significantly shorter using the subxiphoid approach than using the conventional approach (52.3 $\pm$ 8.21 minutes).

Conclusions: Because of the maximized lengths of the grafts and the duration of the procedure, the robot-assisted subxiphoid approach could be an effective method for performing minimally invasive myocardial revascularization in patients with multivessel disease. (J Thorac Cardiovasc Surg 2014;148:461-7)

ACD

Video clip is available online.

Coronary artery bypass grafting (CABG) has been associated with low morbidity and mortality and has provided reliable long-term results. However, the invasiveness of this procedure and the requirement for cardiopulmonary bypass result in longer hospital stays.[1] When a pedicled, sequential, or free aortocoronary internal thoracic artery (ITA) is used, the clinical and angiographic outcomes of bilateral ITA (BITA) grafting have been superior to those of single ITA grafting with supplemental vein grafts.[2] BITA grafting has also been identified as an independent predictor of lower rates of angina recurrence, late myocardial infarctions, and lower numbers of composite endpoints for cardiac events.[2] The minimally invasive direct coronary artery bypass technique combines the advantages of limited surgical access with the benefits of off-pump surgery and leads to faster patient recovery; however, it is restricted to the revascularization of a single vessel in 1 area of the heart.[3]

Endoscopic surgery further limits the dexterity and depth perception of the surgeon. In addition, working through trocars limits the freedom of movement and introduces an inverted instrument response and variability in the excursion of the inserted instrument tip from the body cavity.[4] These disadvantages require surgeons to acquire new techniques and practices for performing complex surgical maneuvers during endoscopic procedures, such as challenging dissections and suturing.[4-6] Thus, robotic telemanipulation is a powerful tool, because it further minimizes surgical access, particularly during harvesting of entire lengths of BITAs.[7,8] Moreover, robotic telemanipulation allows additional optimization of minithoracotomy incisions for coronary anastomoses.[1] We introduced a robotic telemanipulation system (the da Vinci Surgical System, Intuitive Surgical Inc, Sunnyvale, Calif) in December 2005. The technological advantages of the system include a true 3-dimensional

From the Department of General and Cardiothoracic Surgery, Kanazawa University Graduate School of Medicine, Kanazawa, Ishikawa, Japan.

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Address for reprints: Chikako Ikeda, MD, Department of General and Cardiothoracic Surgery, Kanazawa University Graduate School of Medicine, 13-1 Takara-machi, Kanazawa, Ishikawa 920-8640, Japan (E-mail: iketti@mac.com).

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Abbreviations and Acronyms

BITA = bilateral internal thoracic artery
CABG = coronary artery bypass grafting
ITA = internal thoracic artery
LITA = left ITA
RITA = right ITA

endoscope that provides a high-resolution binocular view of the surgical field, an instrument system capable of 7° of freedom and 2° of axial rotation to mimic human wrist movements and tremor filtration, and a motion-scaling system to enhance surgical dexterity.

In the present study, we performed a new linear BITA harvesting approach using a subxiphoid approach and robotic manipulation and compared this approach with the conventional lateral thoracic approach in an animal model.

METHODS

Phase I: Simulator Model

The baseline settings were determined by performing a simulated experiment to evaluate the changes in the exfoliation range, depending on the position of the endoscopy port, for specific operational procedures using the standard da Vinci Surgical System (Intuitive Surgical, Inc) and a 30° angle-up camera. The instrument ports were symmetrically placed on the right and left side of the camera port. A movable axis for each port was placed horizontally, 20 cm above the table, and the angle of the instrument arm was adjusted to approximately 45°. The distance between the right and left instrument ports was defined as ‘‘a’’; and the distance between the movable axis of the camera arm (base point) and the marked point on the movable axis of the instrument port was defined as ‘‘b’’ (Figure 1).

To position the ports, group 1 (distance a, 10 cm; distance b, 1 cm) and group 2 (distance a, 6 cm; distance b, 1 cm) formed an isosceles triangle, and group 3 (distance a, 10 cm; distance b, 0 cm) and group 4 (distance a, 6 cm; distance b, 0 cm; Figure 1), a straight line. An inverted triangle pattern was excluded, because it interfered with the instrument arms. Video footage was recorded from the top of the instrument arms during surgery to calculate the range of motion for each pattern (Figure 2), using Hakarundesu PRO software (Kazuyoshi Natsume, Shizuoka, Japan). The range of motion for each pattern, in the horizontal and vertical planes, was calculated to obtain the area described by the range of motion of the instrument arms, and the resultant areas among the different patterns were compared. This procedure optimized the placement of the instrument ports.

Phase II: Animal Experiments

The subjects for the second phase of the study included 12 pig carcasses obtained from our animal facility, with a median weight of 30.8 ± 4.9 kg (range, 28-38). All experimental procedures were performed in accordance with the ‘‘Principles of Laboratory Animal Care,’’ formulated by the National Society for Medical Research, and the ‘‘Guide for the Care and Use of Laboratory Animals,’’ prepared by the Institute of Laboratory Animal Resources of the US National Research Council.

Linear Harvesting Technique Using Subxiphoid Approach

A surgical cart was positioned at the head of the table, with a pig carcass placed in the supine position, in which a 3-cm incision was made under the xiphoid process along the median line. The subxiphoid incision served as the camera port for the robotic system and enabled the insertion of a 30° angle-up camera. A lifting retractor was inserted behind the sternum, through the subxiphoid incision, and lifted horizontally. The instrument ports were symmetrically placed on the right and left side of the subxiphoid incision, under direct vision through the camera (Figure 3). We determined the optimal port positions from the results of the phase I study and used the port position of group 3 for the phase II experiment (see the ‘‘Results’’ section). The BITAs were dissected using a 30° angle-up camera. The skeletonized harvesting technique used was similar to that used for open or endoscopic surgery and involved blunt and sharp dissection with an EndoWrist cautery hook (Intuitive Surgical) on 1 robotic arm and EndoWrist deBakey forceps (Intuitive Surgical) on the other. The ITA was harvested from its adhesion site on the first rib to the first bifurcation on the sixth rib, and the branches were coagulated or clipped endoscopically (Figure 4, Video 1).

Conventional Lateral Thoracic Approach

Given our understanding that the lateral approach method was already widely established and the ideal port position had already been determined, we did not conduct basic experiments to determine the port position in the present study and performed our experiment in accordance with the standard method.[9] Three incisions were made in the second, fourth, and sixth intercostal spaces slightly medial to the anterior axillary line. A port was inserted through the middle incision, and a 30° angle-up camera was inserted. The left and the right instrument ports were inserted under direct vision through the camera. A surgical cart with 3 mechanical arms was attached to the camera and the instrument arm ports.

After finishing both procedures, the BITAs were proximally transected (Figure 4), and the conduit lengths of the free left ITA (LITA) and right ITA (RITA) and the total harvesting times were compared.

Statistical Analysis

The subxiphoid approach and the conventional lateral thoracic procedure were performed on 6 pig carcasses. All data are presented as mean ± standard deviation. Comparative analyses were performed using the Mann-Whitney *U* test and Statistical Package for Social Sciences, version 11.0, software (SPSS, Chicago, Ill).

RESULTS

Phase I: Simulator Model

The vertical range of motion for each group was as follows: group 1, 183.3 cm^2; group 2, 181.9 cm^2; group 3, 182.9 cm^2; and group 4, 178.8 cm^2. The horizontal range of motion for each group was as follows: group 1, 287.3 cm^2; group 2, 276.3 cm^2; group 3, 417.4 cm^2; and group 4, 405.2 cm^2 (Figure 5). In the vertical direction, little difference was found in the range of motion among the 4 patterns. In the horizontal direction, however, the range of motion was greater for groups 3 and 4, with the 3 ports positioned in a straight line affording greater range of motion (Figure 5). These results suggest that the theoretically optimal position was obtained when the right and left instrument ports were placed as far apart as possible, and all the ports were set in a horizontal straight line. These principles were applied to the basic operational procedure in the animal experiments. We determined the ideal port positions from the results of phase I and used the port position for group 3 for the phase II experiments.

Phase II: Animal Experiments

All BIMAs were successfully harvested in a skeletonized fashion. After harvesting the BIMAs, they were