Operative Techniques in Thoracic and Cardiovascular Surgery

Robotic Coronary Artery Bypass Grafting

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The long-term benefits of coronary artery bypass grafting (CABG) in treating coronary artery disease are attributed mainly to the use of in situ left internal mammary artery (LIMA) bypass to the left anterior descending artery (LAD). The LIMA graft patency rate remains over 90% after 15 years of bypass. Furthermore, the use of bilateral internal mammary arteries as bypass conduits has been shown to offer better patient survival and fewer reoperation rates when compared with the use of LIMA only as a bypass conduit. Since its approval by FDA for thoracoscopic use in 2001, The DaVinci Robotic system (Intuitive Surgical, Mountain View, CA) has been increasingly used to harvest the left and/or right internal mammary arteries as bypass conduits and perform CABG.

Definition

There are 2 primary methods of performing CABG using the DaVinci Robot. Robotic-assisted CAB (RCAB) denotes a robotic thoracoscopic internal mammary artery (IMA) harvest followed by off-pump IMA to LAD and/or to other left coronary artery anastomoses under direct vision, utilizing a mini-thoracotomy. Totally endoscopic coronary artery bypass (TECAB) denotes a port-only, robotic thoracoscopic approach to the entire procedure, including harvesting of the IMA and performance of the IMA to LAD and/or other left coronary artery anastomoses. TECAB can be performed off-pump or on-pump with a beating heart or an arrested heart. At present, RCAB is more frequently performed than TECAB.

Operating Room Set-Up

The DaVinci system is composed of 2 major components: the surgeon's console and the instrument cart. The surgeon's console houses the 3-dimensional (3D) display system, the surgeon's handles, the surgeon's user interface, and the electronic controller. The surgeon's console is typically parked caudally to the patient's left. The instrument cart consists of a fixed base with 3 or 4 arms mounted on it. The center arm controls the camera and the side arms operate instruments. The instrument cart is located at the patient's right side.

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Patient Positioning

The patient is placed supine on the operating table. A sheet is placed under his left torso to elevate the left chest 15 to 30°. The left arm is slightly flexed at the elbow and supported outside the table below the left posterior axillary line. Such a position opens up the left chest and drops the left shoulder to provide space for maximal robotic instrument range of motion through the ports. The patient is intubated with a double-lumen endotracheal tube for 1-lung ventilation. The alternative is to use a bronchial blocker which, in author's experience, is less reliable to collapse the lung than a double-lumen tube. A central line, a right radial arterial line, and a Foley catheter are placed. The defibrillator pads are placed, one on the right anterior chest and the other pad on the left posterolateral chest. A lower body warming system is applied. Both groins are exposed for establishment of cardiopulmonary bypass if on-pump TECAB is performed or emergency cardiopulmonary bypass support is required in case of circulatory collapse (Fig. 1).

Port Placement

Precise port placement is crucial in ensuring smooth manipulation of robotic instruments in the chest because the rigid ribs limit instrument mobility. The 3rd, 5th, and 7th intercostal spaces are identified and a line along the left anterior axillary line is drawn. Three trocar incisions are made along the line about 1 cm medial and parallel to the anterior axillary line (Fig. 2A). Before the trocar placement, the patient is placed on single-lung ventilation with the left lung deflated. A 12-mm trocar is placed at the 5th intercostal space. In a man, this trocar is placed slightly inferior and lateral to the left nipple. In a woman, the skin incisions for the 5th and 7th intercostal trocars are made more laterally and inferiorly, respectively, to avoid the breast. The breast is then pushed medially and upward so that the trocar chest entry points are similar to that of a man. Through the 5th intercostal trocar, a 30° scope is inserted into the left pleural cavity. A quick inspection of the lung, chest wall, and pericardial sac is performed. Under direct scope vision, two 8-mm trocars are placed separately in the 3rd and 7th intercostal spaces. The left instrument, either a micro-bipolar grasper or a Debakey tissue grasper, is inserted via the 7th intercostal trocar. The right instrument, a monopolar cautery, is inserted via the 3rd intercostal trocar. An Insuflow device (Lexion Medical, St. Paul, MN) is connected to the 5th intercostal trocar to supply

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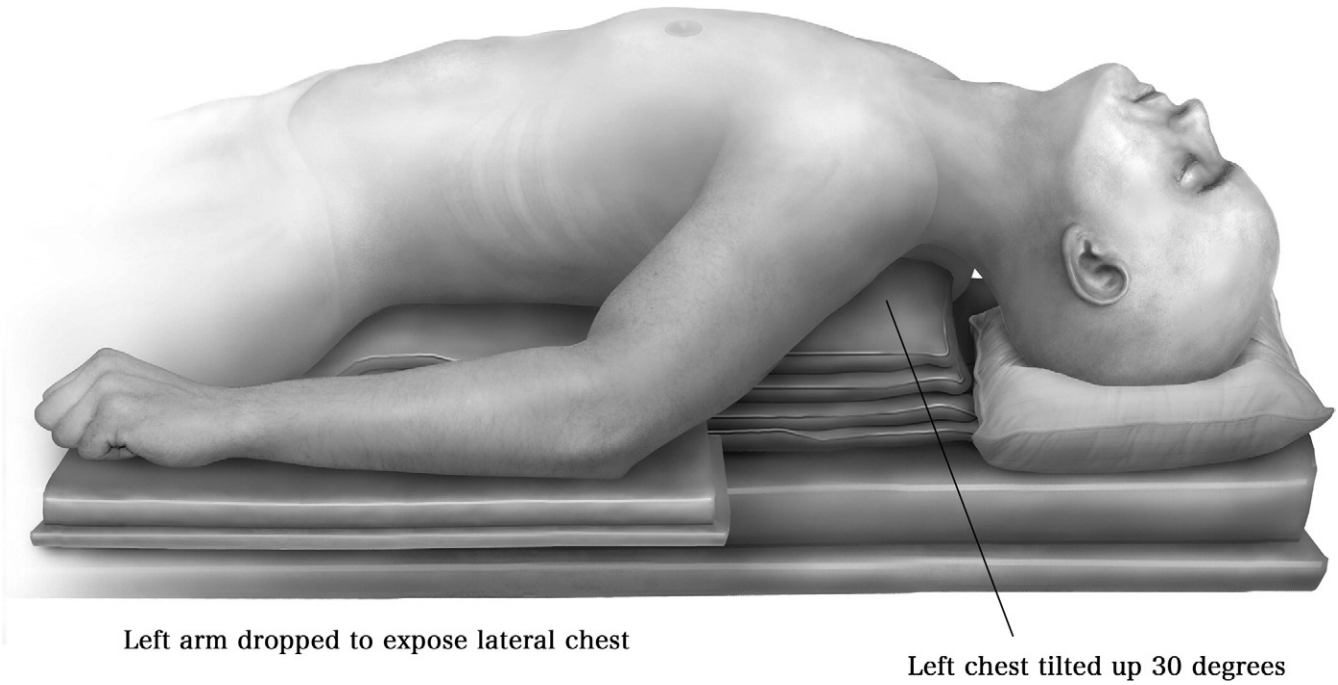

Figure 1 The patient is positioned supine and prepped and draped from the neck to the mid thigh. The left chest is tilted up 30°. The left arm is flexed at the elbow and dropped below the posterior axillary line to lower left shoulder to expose the left anterolateral chest wall.

continuous warm and humidified CO_2 insufflation to the left chest. The CO_2 insufflation pressure is usually kept at 5 mm Hg and can occasionally be increased to 10 to 15 mm Hg depending on the need of exposure of the target vessels (Fig. 2B).

The LIMA and RIMA Harvest

It is important to identify the LIMA, left phrenic nerve, and the first rib before dissecting the LIMA to ensure full-length mobilization of LIMA, while avoiding injury to the left phrenic nerve (Fig. 3). The LIMA is harvested, starting superiorly above the level of the first rib, slightly medial and inferior to the left phrenic nerve, and extending inferiorly to the bifurcation, typically at the 6th intercostal space. The LIMA is dissected either with the skeletonized technique or as a pedicle. For the beginners, the LIMA dissection as a pedicle is the preferred technique. The muscle pedicle and veins along the LIMA are harvested together. All the LIMA and vein branches are clipped medially and divided laterally with cautery. The energy for cautery used in the pedicle dissection is 20 to 25 W. The skeletonized technique requires more meticulous handling of LIMA and should be used after the surgeon has acquired some experience of dissecting the LIMA as a pedicle. A micro-bipolar vascular grasper and a monopolar quatery spatula are used to open the pleura over the LIMA. The cautery spatula is used gently to separate the artery from the accompanying veins and surrounding muscle. The LIMA branches are clipped medially and divided laterally with the cautery, at a lower energy level, 15 to 20 W. The skeletonized technique provides longer graft length and greater blood flow compared with the pedicle technique (Fig. 4).

The RIMA harvest can be achieved through the same left-sided ports that are used for LIMA harvest. When the RIMA is harvested, the CO_2 insufflation pressure is temporarily increased to 10 to 15 mm Hg to improve the right pleural cavity visualization if the patient's cardiopulmonary status allows. The mediastinal pleura are detached from the sternum, starting from the first rib to the 6th intercostal space. The right pleural cavity is entered and the RIMA is identified and fully mobilized, typically with a skeletonized technique to achieve the maximal graft length. The vein accompanying RIMA joins the right subclavian vein at a lower level than its left counterpart. The division of RIMA vein proximally gives an additional 1- to 2-cm length of proximal RIMA.

Once the LIMA and RIMA are mobilized, the heparin is given at a dose of 200 to 250 mg per kilogram to achieve an activated coagulation time between 300 to 400 seconds. The LIMA and RIMA grafts are attached to the pericardial sac with hemoclips before the distal ends are divided to prevent the twist of grafts. The distal ends of LIMA and RIMA are hemoclipped and divided.

Pericardiectomy and Identification of Coronary Artery

Depending on the target coronary arteries, the opening site of the pericardium may vary. If the LAD is the sole target vessel, the pericardium is opened more medially, underneath the medial aspect of the ribs. If the target vessels involve the diagonal and/or obtuse marginal arteries in addition to the LAD, the pericardium is opened more laterally, about 3 to 4 cm anterior to the left phrenic nerve. The pericardium is opened widely from the great vessels down close to the apex. Once the targeted LAD segment and other target vessels are identified, the CO_2 insufflation is temporarily reduced to minimize the shifting of the heart. A long spinal needle is inserted