Robotic totally endoscopic coronary artery bypass grafting (TECAB) of the left anterior descending and right coronary artery system using an arterial Y-graft technique

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Introduction

A totally endoscopic version of coronary bypass surgery can on a routine basis only be carried out using robotic technology. Since its introduction in 1998, the procedure has evolved from single to multivessel totally endoscopic coronary artery bypass grafting (TECAB) (1). In most instances of multivessel TECAB, the left and right internal mammary artery (RIMA) are used as *in situ* bypasses and the left anterior descending artery (LAD) and higher obtuse marginal branches are grafted (2). These targets are readily accessed robotically and can be tackled even on the fully beating heart. For more distant targets, namely the distal circumflex (Cx) coronary artery and the right coronary artery (RCA) system, no specific techniques have been described yet. These coronary branches lie on the diaphragmatic and posterior surface of the heart and require movement of the heart into extreme positions which may compromise hemodynamics significantly if carried out without unloading. In addition, an *in situ* internal mammary artery bypass may not reach these targets without tension. Y-grafting is an option to achieve better reach. Cardioplegia may facilitate exposure of the RCA and the Cx in the completely endoscopic setting. We describe our technique of completely endoscopic bypass grafting of the posterior descending artery (PDA), a branch of the RCA, using the Y-graft technique. Cardioplegia is achieved by remote access heart lung machine perfusion and endoaortic balloon occlusion. The PDA is exposed on the arrested heart with a special insertion site of the robotic endostabilizer on the left lateral chest wall and lifting up the acute margin of the flaccid, arrested heart.

Clinical vignette

The patient shown in the video is a 56-year-old male who presented with angina New York Heart Association (NYHA) class II. His main cardiovascular risk factor was hypertension. He presented to an outside hospital with NSTEMI. The preoperative coronary angiogram showed an 80% stenosis of the LAD and 95% stenosis of the RCA. On preoperative echocardiography, the left ventricle was normal in size and showed mild concentric left ventricular hypertrophy. The left ventricular ejection fraction was 48%. Right ventricular function was normal. No significant valvular abnormalities were noted. Carotid ultrasound revealed a 50% internal carotid artery stenosis on the left side but the patient was neurologically intact and asymptomatic. The ankle brachial index was 1.2 on the right side and 1.1 on the left side. Preoperative BUN was 4.7 mmol/L and preoperative creatinine was 119 micromol/L. On the preoperative computed tomography (CT) angiogram of chest, abdomen, and pelvis the transverse cardiac diameter was 12.5 cm, the transverse thoracic diameter was 25.9 cm revealing a cardiothoracic ratio of 0.46. The anterior-posterior thoracic diameter was 12 cm. A distance of 3.5 cm between the left heart border and the chest wall was measured indicating adequate intrapleural workspace to carry out the procedure. The ascending aortic diameter was 3.3 cm at the level of the right pulmonary artery indicating suitability for use of the endoballon for cardioplegia. The aortic arch and descending thoracic aorta were disease free and there was mild to moderate atherosclerosis on the abdominal aorta and the iliac arteries. Both common femoral arteries were 8.5 cm in diameter.

Surgical techniques

Preparation

The anesthetist will place a double lumen endotracheal tube or a bronchial blocker for single lung ventilation. Percutaneous defibrillator patches and cerebral near infrared spectroscopy (NIRS) leads are placed for cerebral perfusion and leg perfusion monitoring. A pulmonary artery vent is inserted for support of venous drainage. Transesophageal echocardiography (TEE) is used throughout the procedure for heart lung machine cannulation, proper position of the endoballoon and monitoring of hemodynamics as well as regional wall motion.

Exposition

The patient is placed on the operating table in the supine position with the arms tucked to the body and the left chest elevated to approximately 30 degrees using a towel roll.

Ports are placed on the patient's left chest and should be inserted by the most experienced team member as correct port placement plays a key role in the operation. Insertion requires complete left lung collapse, which should be confirmed by the anesthesiologist before placement. A camera port is placed in the 5th intercostal space along the anterior axillary line and CO_2 is insufflated at a pressure of 8 mmHg. After inspection of the thoracic cavity with the robotic camera, the left and right instrument ports are inserted cranially and caudally four fingerbreadths away from the camera port. For reaching the RCA system, a 12 mm instrument port is used on the left; the EndoWrist stabilizer will be inserted into this port later on to lift up the acute margin of the heart. The surgical robot is then docked to the ports. A da Vinci Si system (Intuitive Surgical, Sunnyvale, CA, USA) is used at our institution and at the time of writing of this article all instruments for performing the described procedure are only available for the Si version of the robot.

Operation

Cannulation

In the case shown, we took the right axillary artery for arterial inflow as the patient had shown moderate aortoiliac atherosclerosis on preoperative CT angiography. This strategy was used to minimise stroke risk that would come with groin retroperfusion. While groin perfusion was not used, left femoral access was still obtained via a 19 F cannula for insertion of the endoballoon. The endoballoon was advanced into the aortic root under TEE guidance. Venous cannulation was performed from the left femoral vein under TEE guidance. We usually also place a distal leg perfusion line into the ipsilateral superficial femoral artery in order to avoid leg ischemia during (often) long cases.

Internal mammary artery harvesting

Using long-tip forceps on the left and electrocautery on the right instrument arm, a retrosternal dissection is carried out and the right pleural space is entered. The RIMA is identified by its visible pulsations. The endothoracic fascia is removed and the RIMA is harvested in a skeletonized fashion. Most side-branches are cauterized and larger ones are clipped. After harvesting and confirming adequate level of heparinization, clips are applied on the RIMA's distal end and the vessel is divided. No vasodilators are used, as the internal mammary arteries nicely autodilate during the following steps. The left internal mammary artery (LIMA) is harvested in exactly the same fashion and harvesting times are similar. Internal mammary artery harvesting is carried out using a "camera up" view, with the 30-degree angled robotic camera.

Assistance port placement

After internal mammary artery harvest, an 8 mm assistance port is inserted opposite the camera port parasternally. This port allows for introduction and removal of suture material, bulldog clamps, and other necessary material. Assisting maneuvers are shown in the video. A 12 mm subcostal port is introduced two fingerbreadths left of the xiphoid angle. The port is directed towards the left shoulder and insertion is guided by the endoscopic camera. This port is docked to the fourth arm of the surgical robot.

Construction of the Y-graft

The RIMA is accessed in its proximal portion, clipped using three clips, and divided. The artery is then moved over to the left side of the chest. The EndoWrist stabilizer is inserted through the subcostal port and the robotic camera is switched to the "camera down" view. A proximal area on the pericardial fat pad is immobilized. The distal end of the LIMA is clipped to the pericardial fat pad, placing the clips on the adventitia of the vessel only—we use four clips. This arrangement stabilizes the distal LIMA enough to allow for comfortable construction of the Y-graft. An endoscopic bulldog is placed on the LIMA and the vessel is opened 3 cm proximal to its distal end—it is best to cut off a side branch before further opening it with a lancet beaver knife and robotic Potts scissors. We open the vessel to 4mm (as indicated by markers on the scissors). The RIMA is then trimmed to a corresponding length and sutured to the distal LIMA using a 7 cm double armed 7/0 polypropylene suture. We use our standard suturing technique which is described in detail at http://www.youtube.com/watch?v=l6DiBz2JUnY. Pulsations in both Y-graft limbs are carefully checked by scope inspection. The Y-graft construct is then dropped into the left chest for further autodilatation.

Resection of the pericardial fat pad and pericardiotomy

The pericardial fat pad is mobilized starting cranially and moving caudally using electrocautery and long-tip forceps. The fat pad is then dropped into the left chest. Subsequently, the pericardium is opened in L-shaped fashion starting above the right ventricular outflow tract, then moving to the caudal pericardial reflection and laterally. Cranially we work towards the phrenic nerve which needs to be respected as much as the left atrial appendage.

Induction of cardioplegia

Cardiopulmonary bypass is started slowly and after achieving full flow, the endoballoon is inflated under guidance of TEE and the two radial artery pressures. Adenosine is given through the balloon catheter into the aortic root which usually induces immediate cardiac arrest. Cardioplegia then follows. During induction of cardioplegia the Y-graft is brought into position so that the RIMA limb passes alongside the right pericardial edge.

Exposure of the PDA and RIMA to PDA anastomosis

The endostabilizer is inserted through the 12 mm left instrument port and a robotic DeBakey forceps is inserted through the subcostal port. With the heart flaccid under cardioplegic arrest, the acute margin of the heart can be lifted up using the endostabilizer and the PDA can be brought into a comfortable position. The vessel is incised using a lancet beaver knife and Pott's scissors. Care has to be taken during insertion of instruments through the right instrument port as the acute margin of the heart is lifted up and space is reduced inside the chest. The distal end of the RIMA limb of the Y-graft is trimmed, free flow is checked and an end to side anastomosis is constructed using 7/0 polypropylene, again using our standard suturing technique. After a careful assessment of hemostasis at the anastomosis, the heart is repositioned.

Construction of the LIMA to LAD anastomosis

The endostabilizer is inserted through the subcostal port again and the LAD is brought into a good position using this instrument. The vessel is incised using the lancet beaver knife and the LIMA to LAD anastomosis is carried out.

Last surgical maneuvers, reperfusion, weaning from cardiopulmonary bypass, and port closure

All foreign material is removed through the parasternal assistance port. A hot shot is then given and the endoballoon is deflated. After achieving sinus rhythm and confirming adequate flow in both graft limbs (using an endoscopic flow probe inserted through the subcostal port), the patient is weaned from cardiopulmonary bypass and is decannulated. During weaning, both lungs are ventilated as there may be a phase of respiratory compromise after single lung ventilation and prolonged cardiopulmonary bypass time. Protamine is given and heart function is properly assessed using TEE. We then deflate the left lung again and several rounds of careful checks of adequate hemostasis follow. Once adequate hemostasis can be stated the robotic instruments are removed and the surgical robot is undocked. A chest tube is inserted through the camera port hole and all port holes are closed in layers.

Comments

Advantages

We regard the described technique as one of the most important steps in robotic TECAB development. Y-grafting allows for reach of very distant targets of the coronary artery tree. For reaching the PDA with a Y-graft from a graft landing on the LAD, a very distal take off of the graft is required. This ensures a tension free course across the acute margin of the heart. We are unaware of techniques to graft the RCA system on the beating and fully loaded heart. Our group has vast experience in both beating and arrested heart TECAB techniques but for reaching the RCA and its branches, we prefer an arrested fully flaccid heart. This allows the right ventricle to be compressed and moved without major difficulties. In a fully loaded beating heart, application of the endostabilizer to the right ventricle may easily cause hemodynamic compromise and may even damage the wall, particularly if it is thin. Insertion of the endostabilizer through the left instrument port allows for easy reach of the RCA system with the same port arrangement as is used for work on the left coronary artery tree. This has major advantages as the alternative would be to move the surgical robot to the contralateral side of the patient which comes with logistical difficulties including extended operative time, requirement for additional port placement and issues of sterility if the machine is undocked and docked again.

Disadvantages

As compared to *in situ* grafts only, adding a Y-graft anastomosis in our experience adds approximately 30 min of operative time. The arrested heart TECAB technique demands careful patient selection, as retroperfusion from the groin and endoaortic manipulation require a reasonably healthy aortoiliac tree. We circumvented the presence of moderate aortoiliac disease in the case presented in the video by antegrade perfusion through the axillary artery and still placed the endoballoon from the groin. Cardiac arrest times in multivessel TECAB often reach two hours and normal baseline left ventricular function is desirable in these cases. Previous data have shown that long cross-clamp times in TECAB increase enzyme release but do not translate into significant clinical consequences (3).

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Caveats

Intense training of the robotic suturing technique in virtual, dry lab, and wet lab models is highly recommended for surgeons who want to apply this technique. Remote access perfusion and endoballoon occlusion for cardioplegia also require specific skills acquired in procedures other than TECAB before application in this complex operation.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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