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Total Endoscopic CABG Using Robotics on Beating Heart

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ABSTRACT

Background: The implementation of a total endoscopic coronary surgery on the beating heart with the aid of the Da Vinci surgical system (Intuitive, Sunnyvale, CA) requires a stepwise learning process. After cadaveric training and clinical start of the program in November 2002, we gained experience with arrested heart procedures starting in May 2003. In November 2003, we moved to beating heart surgery.

Methods: From November 2003 to January 2005, 14 patients with coronary artery disease (mean age of 62 ± 5 years, female to male ratio 2:12) were operated with the intention to perform a beating heart TECAB (totally endoscopic coronary artery bypass grafting) procedure.

Results: Total conversion rate was 35% (5/14), due to pleural adhesions in 2 patients, injury of the lung during port placement, inability to occlude the LAD with saddle loops, atherosclerotic diseased mammary artery in 1 patient each.

Mean operating time was 298 ± 110 minutes with a steady decline throughout the study period (first 5 patients: 342 ± 61 minutes, patients 6 to 9: 337 ± 87 minutes, last 4 patients: 290 ± 53 minutes), resulting in a 60 minute shorter operating time.

Mean ICU stay was 1.3 days and hospital stay lasted on average 8.4 ± 2.8 days.

Conclusion: Total endoscopic bypass surgery on the beating heart with the Da Vinci surgical system can be safely implemented in clinical use. The learning curve results in a constantly decreasing procedure time due to a more effective table team–console surgeon–robotic system interaction and a moderate conversion rate.

INTRODUCTION

Computer-enhanced robotic instrumentation systems have been introduced in 1997, which made total endoscopic cardiac surgery procedures a reality. Since the first use of the Da Vinci surgical system, a variety of successful cardiac surgery procedures have been reported so far [Falk 2000, Jacobs 2001, Kappert 2001, Bonatti 2004].

Herein, we summarize the initial results of a single center with beating heart total endoscopic coronary artery bypass surgery (BH-TECAB).

The implementation of total endoscopic heart surgery procedures with the aid of the Da Vinci surgical system (Intuitive, Sunnyvale, CA) requires a stepwise learning process. After cadaveric training from May 2002, we started the clinical program in November 2002. The clinical implementation process followed the typical path: Beginning with 20 takedowns of the left IMA endoscopically, completing the procedures in an open fashion, we then performed cases with anastomoses between the left IMA and the LAD with the robotic system but through sternotomy under full control.

In May 2003, we started with the first total endoscopic procedure and in November 2003 the first beating heart TECAB was performed.

MATERIAL AND METHODS

Study Cohort

From November 2003 to January 2005, 14 patients with coronary artery disease (mean age of 62 ± 5 years, female to male ratio 2:12) were operated with the intention to perform a BH-TECAB.

A smoking history was present in 8 patients (57%), 4 patients needed medication for chronic obstructive lung disease (28%), and 3 patients (21%) had insulin-dependent diabetes. The majority of patients, 11 out of 14 (78%), had single vessel disease whereas the remainder (3 patients, 21%) had multivessel disease, but were only eligible for single bypass grafting due to anatomical reasons or sufficient stenting of the other coronary vessels. Mean ejection fraction in our study cohort was 62%. Mean cardiac risk score (Euroscore) was 1.3, ranging from 0 to 4.

Besides the standard preoperative workup for cardiac surgery procedures, which include coronary angiography, sonography of the carotid arteries, lung function testing, and echocardiography, all patients underwent a multislice computer tomography with 3D reconstruction to enable the surgeon to have a better visualization for proper identification of the target vessel. Additionally, a postoperative CT scan was performed in all patients to evaluate graft patency and form of the anastomosis.

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Robotic System

In brief, the Da Vinci surgical system (Intuitive Surgical, Mountain view, California, USA) consists of a master console and a slave, which is equipped with 2 instrument arms and 1 camera arm. The surgical arms as well as the instruments have 3 degrees of freedom, so that in summary 6 degrees of freedom are provided. Details of the surgical system are described elsewhere [Falk 2000].

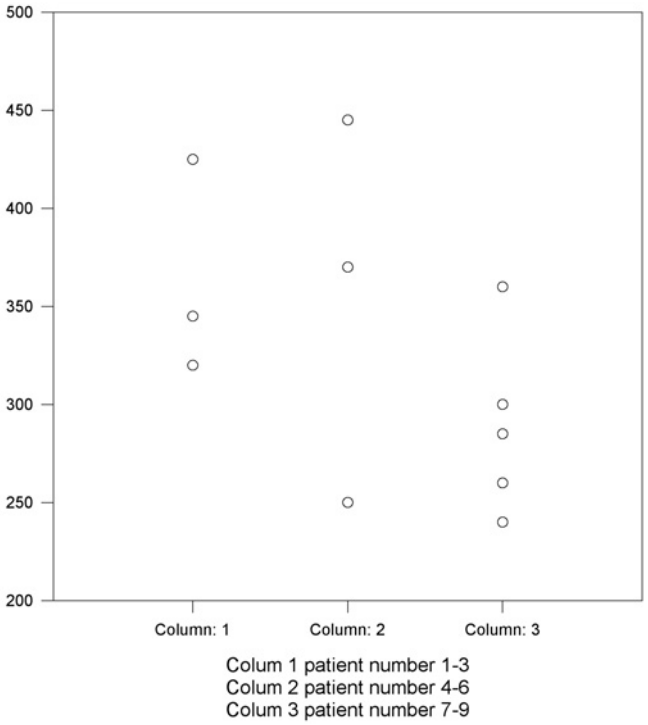
Port placement emerged as a critical part in TECAB procedures, as it ensures or hinders proper instrument arm movement and range of motion [Falk 2000]. We routinely place the right port in the 3rd intercostal space (ICS) lateral to the medioclavicular line, the camera port in the 4th ICS anterior axillary line, and the left port in the 6th ICS anterior axillary line, thus forming a triangle with an obtuse angle of about 120 to 150°. The fourth port for the endostabilizer is placed below the xyphoidal process and directed toward the left side.

Surgical Procedure

After IMA takedown, 5.000 units of heparin are administered, the IMA is occluded by a bulldog clamp (Vascu-Statt IIplus Approximator; Scanlan, St. Paul, Minnesota), and the distal end of the IMA is prepared for the anastomosis. The flow is checked by releasing the bulldog clamp. Then the fatty tissue is removed from the pericardial sack. The pericardium is opened longitudinally to the sternum as medially as possible. On the proximal end, an L-shaped incision is performed toward the phrenic nerve. After identification of the LAD, the endostabilizer is placed and positioned on the anastomotic site. The endostabilizer consists of a straight shaft and two shoes for stabilization. The back of the endostabilizer holds 2 ports for the EndoStabilizer Suction Lines and vacuum hoses (Medtronic, Minneapolis, MN) and 2 ports with Luer fittings. One of these is used for the Multi-link Irrigator (Medtronic, Minneapolis, MN) to provide clear vision on the operative field and anastomotic site respectively. Then, the anterior wall of the LAD is dissected free with a paddle blade snap fit instrument (Intuitive Surgical, Mountain View, CA). Two silastic bands (Quest Medical Inc, Allen, TX) are positioned proximal and distal to the future anastomotic site around the LAD. At first, the LAD is occluded and the hemodynamics is watched carefully. In case of stable condition, which was the case in all patients, the LAD is incised with a blue blade snap fit instrument (Intuitive Surgical, Mountain View, CA) and opened to 4 mm length with Potts scissors (Intuitive Surgical, Mountain View, CA). The anastomosis is performed end-to-side in 7-0 prolene 7 cm (Ethicon, Johnson& Johnson Medical, St. Stevens Woluwe, Belgium) in a running fashion, without the use of any kind of shunts (Video 1). The silastic bands are opened and the bulldog clamp released. After checking the anastomosis for bleeding, the endostabilizer is removed and the pericardial incision closed with 2 stitches of 3-0 vicryl.

RESULTS

Out of the intended consecutive 14 patients, 9 patients underwent total endoscopic bypass grafting off pump with the endostabilizer system. Total conversion rate was 35% (5/14), due to pleural adhesions in 2 patients (patients' number 6 and 11) and injury of the lung during port placement in 1 patient (patient number 13). In 1 patient (patient number 14), the inability to occlude the LAD with silastic bands resulted in severe back bleeding from the target vessel, which made any further endoscopic approach impossible. In 1 patient (patient number 8), the mammary artery was found to be atherosclerotic diseased and had to be rejected. A venous graft was used through sternotomy.



Learning curve mean operating times.

In the remaining 9 patients, mean operating time was 298 ± 110 minutes with a steady decrease from the first 5 patients (342 ± 61 minutes), to patients 6 to 9 (337 ± 87 minutes) to the last 4 patients (290 ± 53 minutes), resulting in a 60 minute shorter operating time. See Figure for details. The corresponding operating times for the patients who had to undergo conversion to the open procedure were 252 ± 78 min, ranging from 180 to 360 minutes. The mean time to complete the Lima ad LAD anastomosis was 27 ± 6 minutes. Patients were extubated after 7.6 ± 5.5 hours, and spent 1.3 days on the ICU.

We routinely placed one chest tube posterolaterally into the left hemithorax. Total chest tube drainage was 340 ± 123 mL and mean duration was 1.5 days (ranging from 1 to 3). One patient developed atrial fibrillation postoperatively, but could be converted into sinus rhythm with amiodarone. One patient had to undergo laparotomy due to a superficial injury of the left hepatic lobe caused by the subxypoid port placement for the stabilizer. Thirty days survival was 100%. All patients could be discharged after a mean of 8.4 ± 2.8 days.

Postoperative CT scans performed during hospital stay showed graft patency in all patients. Follow up is complete

and ranges from 4 to 15 months with all patients being alive and free from recurrence of angina.

DISCUSSION

Total endoscopic bypass surgery on the beating heart with the Da Vinci surgical system can be safely implemented in clinical use. The learning curve results in constantly decreasing procedure times due to a more effective table team–console surgeon–robotic system interaction and a moderate conversion rate.

The causes for conversion to an open procedure were variable and can be divided into complications directly associated with the procedure and those that are not related to the TECAB procedure. Complications directly associated with the procedure were: In 1 patient the camera port, which has a knife blade in the inside, as routinely used for abdominal procedures, was defect and accidentally opened during insertion. The injury mandated thoracotomy to obtain bleeding control. In another patient, we were unable to occlude the left anterior descending artery with the saddle loop, due to a very calcified artery. After several attempts, we converted as the artery had massive back bleeding and no clear vision to the operating field was obtainable. The other causes for conversion were not directly related to the TECAB procedure and not possible to predict preoperatively. In 2 patients severe adhesions of the pleural space were found after insertion of the camera port. This made the preparation of the left internal mammary artery impossible. One patient had a severely atherosclerotic left mammary artery, which precluded its use as a graft. Subsequently, the saphenous vein was harvested and open off-pump surgery performed.

We did not attempt to use the RIMA since that would have increased the operating time and it might have been affected as well. It has to be discussed, however, that it may be beneficial to perform selective angiography of both mammary arteries in all patients scheduled for a TECAB procedure.

One patient had to undergo laparotomy due to a superficial injury of the left hepatic lobe caused by the subxypoid port placement for the stabilizer. Retrospectively, this injury could have been avoided. Adhesions could have been expected in this region, since this patient underwent abdominal surgery previously. Consequently, a subxyphoid approach for port placement should be avoided in such patients.

The relatively long intubation times can be assumed to be the result of the long operating times. In contrast to Bonatti et al [2004], we did not encounter a prolonged ICU stay in these patients. Hospital stay is considerably long for endoscopic procedures, but comparable to the current literature [Kappert 2001, Bonatti 2004], which is mainly due to the reimbursement system in most European countries, where there is no force to discharge patients as soon as possible.

Another issue, which is important in BH-TECAB is the lack of a third hand. Especially during the first stitches of the anastomosis, the movement of the IMA pedicle can be cumbersome. Stay sutures fixed to the thoracic wall can overcome this problem partly. Nevertheless, parts of the anastomosis sometimes have to be performed one handed, while the other hand holds the pedicle. The upgrade of the Da Vinci system to the 4th arm, which is already available on the market, may be extremely helpful in this respect.

CONCLUSION

Total endoscopic bypass surgery off pump with the Da Vinci surgical system can be safely implemented in clinical use. The learning curve results in constantly decreasing procedure times due to a more effective table team–console surgeon–robotic system interaction. It should be possible in the future to reduce the conversion rate with higher proficiency in the handling of the robotic system.

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