Institutional report - Coronary

Computer-assisted coronary surgery: lessons from an initial experience

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Abstract

Robotic-enhanced coronary surgery has been performed on sixty consecutive unselected patients (60.8 ± 12 years) requiring CABG only. Nine had single-vessel (LAD), 13 double-vessel, and 38 triple-vessel disease. Since the endostabilizer was made available in the autumn of 2002 only, the first 47 patients were proposed to have closed chest LIMA dissection only. This was achieved successfully in all but one patient. In addition, 12 distal anastomosis have been performed after full sternotomy with the robot. Every other anastomosis has been hand sewn. The last 13 patients were TECAB candidates. After successful LIMA harvesting, LIMA to LAD suture has been attempted in totally closed chest on the beating heart: it has been successful in two only, the remaining lesions (a total of three) being dilated and stented the day after surgery. In the other 11 patients, the coronary anastomosis was hand sewn after full sternotomy. This suggests that the difficulties in anastomosing small vessels with a standard suture technique jeopardizes the reproducibility of the technique and that further technological developments are needed, to make robotic surgery safe and attractive for the patients.

Keywords: Coronary surgery; Robotically assisted surgery; Minimal invasive surgery

1. Introduction

Surgical robots have recently been introduced in surgical practice to improve less invasive techniques. The great enthusiasm expressed by some pioneers in robotically-enhanced surgery, both for coronary [1] and mitral [2,3] surgery, prompted us to acquire the da Vinci™ system in April 2000. Following prolonged and intensive training on human cadavers and in vitro models using preserved saphenous, mammary artery grafts and pig hearts, unselected coronary patients referred for surgical revascularization alone were offered the following protocol: a LIMA computer assisted LIMA take down and, when the endostabilizer was available, a totally closed chest beating heart LIMA to LAD graft (TECAB), the remaining lesions being treated percutaneously by balloon angioplasty and stenting.

2. Method

After routine general anesthesia, the camera port (usually in the 5th intercostal space) and the two arm ports (usually in the 4th and 6th space) of the Intuitive Surgical robot are selected to facilitate dissection of the proximal segment of the LIMA. A CO2 pneumothorax (pressure of 6–10 mmHg) is performed. The single-lung ventilation is used during LIMA mobilization, and the coronary anastomosis.

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According to the availability of the EndoOctopus stabilizer, the surgery is then performed according to two different protocols.

(a) The Medtronic stabilizer EndoOctopus introduced via a sub-xiphoid port, is positioned along the LAD artery. The LIMA is skeletonized over a 1–2 cm length, at its distal segment using Pott’s scissors. At 5–6 cm from the distal end, the LIMA is also skeletonized over a 1 cm length, in order to place the bulldog clamp (Scanlan™) with a suture retrieval tail. The LIMA is then transected using Endowrist™ Pott’s scissors. The LAD artery is controlled upstream and downstream using GoreTex vessel loops. The midline 6 mm arteriotomy of the LIMA is then performed using the 15ª scalpel blade. The anastomosis is performed by a continuous running suture, using an 8-0 Gore-Tex double needle. A continuous running suture was used. The time spent to complete the anastomosis on the arrested heart was 22 ± 9 min. Post-operative angiographic studies did not show any anomaly.

(b) When the Medtronic stabilizer EndoOctopus is not available, the robot arms and the camera are withdrawn and a full sternotomy performed. Coronary surgery is performed either on-pump or off-pump, according to the number of grafts to be performed. In 12 instances, the distal anastomosis is made with the assistance of the robot.

3. Clinical experience

From April 2000 to April 2003, 60 coronary patients were offered robotically-enhanced coronary surgery and signed a patient consent form. As the endostabilizer in its final configuration was only available from late September 2002 only the last 13 patients were systematically offered a TECAB operation.

There were 57 males and 3 females aged 60.8 ± 12 years (34–80). Every patient had stable angina. Nine patients had single-vessel disease (LAD artery), 13 had double-vessel disease (LAD + right or LAD + left), and 38 had triple-vessel disease. Five had associated left main stenosis. Mean left ventricular ejection fraction was 59 ± 14%. The risk factors did not differ from those in the general population.

4. Results

4.1. Mammary take-down

The left mammary artery was successfully harvested in every patient but one. In the 5th patient of the series, the mobilization of the left arm at the end of a successful dissection led to an unacceptable stretch on the vessel. The dissection was almost totally bloodless, and by the end of the procedure the mammary artery was free of any subadventitial ecchymosis.

The time required for the dissection has been rapidly reduced from 56 ± 12 min in the first 10 patients to 37 ± 9 min in the last 10. Unexpected events occurred in one patient selected for a TECAB operation: a mechanical failure of one forceps, the reason for the conversion.

4.2. Open robot-assisted anastomosis

As the stabilizer was not available, the coronary anastomosis was nevertheless performed using the system, after a full sternotomy, in 12 cases: LIMA to LAD artery in 10 patients, saphenous vein to the diagonal branch in two. The suture material was an 8-0 Prolene, 10 cm, double-armed suture. A continuous running suture was used. The time spent to complete the anastomosis on the arrested heart was 22 ± 9 min. Post-operative angiographic studies did not show any anomaly.

4.3. TECAB procedures

The TECAB could be attempted in the last 13 patients. The operation was totally successful in 2 patients only. Time required for the suture was 41 min. Post-operative coronaryography showed a normal patency in both cases and permitted dilatation of three associated lesions. In every other patient, conversion and full sternotomy was required for an unexpected ventricular fibrillation (in 2), difficulties either in LAD identification (in 3), or in an adequate stabilization of the anastomotic site (in 5), or unfavorable anatomical conditions with a small calcified LAD (in 1). In those circumstances, every graft was handsewn, following a full sternotomy.

4.4. Coronary revascularization

In the entire group of 60 patients, the coronary revascularization included 9 single grafts (performed in 2 patients according to the complete TECAB protocol, and in 7 open-chest procedures), thirteen double grafts, 17 triple grafts, 12 four grafts, and 2 five grafts were performed on the remaining patients. Mean bypass time was 134 ± 45 min (43–219), and mean aortic cross clamping time was 82 ± 14 min (21–148).

4.5. Results

The post-operative outcome was uneventful in all patients except for one who died at day 4 of a persistant cardiogenic shock. Extubation time (mean 6 h, Z–28) did not differ from the general population. No septic complication was observed. Early coronary angiography showed patency of all grafts.

5. Discussion

This initial experience permits comments. First, the lack of a stabilizer for almost 2 years has been a quite unpleasant surprise. In other words, the instruments required to complete a new operation, the TECAB, aggressively marketed, were not available! This has had an extremely negative impact on referring cardiologists who initially had expressed a huge enthusiasm for the whole non-invasive approach.

The most positive observation is the possibility of a very precise surgery on stable structures such as during LIMA harvesting. The learning curve is quite short because of the high performances of the 3D imaging system. Instrument conflicts during the mobilization of the dissecting
arm, both intracorporeally (with the camera arm) and extracorporeally (the left shoulder), are minimized by experience, precise evaluation of the anatomy on the standard chest X-ray and an adequate selection of the port sites. Further improvements should be achieved by pre-operative planning [4].

The most crucial limitations today remain related to the stabilization procedure, and the suture technique itself. The presently available stabilizer is not fully satisfactory. The area of correct stabilization is not very large, making difficult upstream and downstream control of the vessel and the arteriomy on an optimal length. In addition, the excessive size of the instruments does not allow very fine surgery. The issue of the suture itself is a major problem which has led most of the groups to discontinue their robotic programs or restrict the use of the robot to LIMA and RIMA harvesting only. The use of our standard anastomosis technique [5] is actually too challenging. Further technological developments in suture technique are much needed: a computerized stabilization platform, innovative sutureless anastomosis techniques, based either on magnetic devices such as the Ventricair system [6] or on expandable stents such as those of Saint Jude Medical [7]. New suture material, such as Nitinol made needles [8] might be a solution.

Our initial experience shows that only very few patients can actually benefit from a TECAB. The number of patients referred for a single LAD artery anastomosis has been dramatically decreased. The enthusiasm of the cardiologists in drug-covered stents is further reducing referrals.

The hybrid approach which combines fully endoscopic LIMA and RIMA harvesting only. The use of our standard anastomosis technique [5] is actually too challenging. Further technological developments in suture technique are much needed: a computerized stabilization platform, innovative sutureless anastomosis techniques, based either on magnetic devices such as the Ventricair system [6] or on expandable stents such as those of Saint Jude Medical [7]. New suture material, such as Nitinol made needles [8] might be a solution.

The issue of the cost of the program has to be addressed. Following a major initial investment, charges due to the limited use of instruments has to be covered. A drastic reduction in the time spent in the operating theater and in the hospital has to be observed to economically justify the specific charges related to the robot. Such an observation has not been made in our initial experience.

To conclude, robotic techniques in coronary surgery may constitute a step towards a less aggressive treatment [13, 14]. Nevertheless, progress in surgical instrumentation and suture techniques is mandatory if good anastomoses are to be achieved totally endoscopically, without cardiopulmonary bypass on a repeated and safe basis. In the meantime, it should not be forgotten that continuous progress by interventional cardiologists will further reduce the number of referrals. Coronary surgery is therefore probably not, as it was speculated years ago, the ideal field for routine application of the presently available robots.

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References


Appendix A. ICVTS on-line discussion: Invited Editorial eComment

Author: Gerhard Wimmer-Greinecker (JW-Goethe University, Frankfurt, Germany)

eComment: Although endoscopic surgical procedures are routine in many operating disciplines, comparable procedures in cardiac surgery have only become possible since the introduction of telesurgical systems. These computer enhanced, so called ‘robotic systems’, facilitate totally endoscopic cardiac procedures, which have not yet become standard of care. Since the first report of a totally endoscopic coronary artery bypass grafting (TECAB) by D. Loulit et al. several cardiac centers throughout the world have established successful ‘robotic’ programs. Initially these procedures have been performed on the arrested heart, using endoclamp technology [A1]. Because of initial reports on deleterious complications and the fact,
that it is rather complex to use, this technology has never gained wide acceptance among the cardio-surgical community. Though excellent technology can be achieved by routine use [A2], quite some resistance in using endoclamp technology remains. However, mastery of this technology is a prerequisite for TECAB on the arrested heart, and TECAB on the arrested heart again is a prerequisite for a successful beating heart TECAB program [A3]. Only on the arrested heart, experiences in several little details of these complex procedures can be gained in a safe and ethical way.

Of course, the ultimate goal of minimally invasive cardiac revascularization is to synthesize the principles of surgery performed on the beating heart with a totally endoscopic approach. To be successful in this type of surgery you first of all need a dedicated team. Intense communication between all the members (anesthesiologist, perfusionist, scrub nurse, table side surgeon, and console surgeon) is necessary, who ideally should not be exchanged in robotic programs. Only if the console surgeon can completely rely on all the other team members and can solely focus on his surgical tasks, success is possible. It is not advised, that the console surgeon e.g. performs the port placement himself. A further critical issue is patient selection. At this stage of evolution, these procedures are not applicable for an unselected patient cohort.

There are several difficulties, that robotic surgeons still have to face to date, which have to be addressed [A4]. If they cannot be solved in the future TECAB on the beating heart will never be applicable to a large group of patients neither a wide range of cardiac surgeons. The most difficult part is definitely performing the anastomosis. One obstacle is the stable presentation of the internal thoracic artery pedicle close to the anastomotic site. This problem can be overcome by using a fourth arm for endoanastomosis [A5]. Suturing is very demanding, particularly because even the slightest movements of the anastomotic site can impair surgical manipulation due to the 10× magnification. Unfortunately anastomotic devices, which are warranted and have been experimentally used [A6], are not capable yet of reaching comparable patency rates to hand-sewn anastomoses. Due to strict FDA regulations, none of the distal devices have been approved yet, resulting in lack of development for totally endoscopic application. Furthermore, adjunct technology is still suboptimal. Requirements for totally endoscopic stabilization are different compared to conventional sternotomy procedures. These are not completely fulfilled in the endoscopic stabilizer available to date. Space rarely is an issue, if intrathoracic pressures can be elevated up to 12-14 mmHg. This needs an anesthesiologist though, who is familiar with these kind of procedures. A further issue remains the target site of the coronary vessel. Endoscopically, some coronary arteries are more difficult to find, they can even be exchanged by mistake, and due to lack of tactile feedback, quality often is difficult to determine. Parts of these issues can be overcome by preoperative multi-slice CT scanning [A7], whereas this field as well needs further technological development. As consequence of all these difficulties, even in experienced centers, conversion rates of beating heart TECAB are rather high (around 30%) [A4]. Almost all of these cases may be converted to a MIDCAB procedure though, which still is a minimally invasive off-pump procedure with excellent results [A8]. Therefore, conversions should not be considered as failure, but as safe and still attractive bail out. Certainly costs for robotically assisted cardiac procedures remain high. However, as long as this kind of surgery remains in development and under evaluation, this issue should not be stressed too much.

The experience by Loisance et al. is a unique one. In contrast, many centers have shown comparable good results performing on-pump respectively off-pump TECAB procedures [A4]. In performing experimental surgery, published guidelines and suggestions of the pioneers in this field should be respected. As stated by different authors, TECAB on the arrested heart is still a prerequisite for totally endoscopic beating heart revascularization. Furthermore, patient selection is absolutely necessary. Not having followed these crucial rules and having attempted a totally endoscopic procedure in only 13 patients, the strong statements of Loisance et al. are not justified at all.

In conclusion, totally endoscopic robotically assisted coronary revascularization is still a demanding procedure. It is absolutely technology dependent and needs further development. It has been proven by several centers, that excellent results can be achieved. If suggested guidelines are strictly followed, conversion rates are acceptable and converting to a MIDCAB procedure is still an attractive solution. Finally, the ultimate role of these procedures in cardiac surgery cannot be determined yet, the future is depending on a close partnership between industry and dedicated centers, and their developmental achievements.

References


