Minimally-Invasive Video-assisted Coronary-Artery Bypass Grafting

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Abstract

Background: **In general, surgeries currently tend to be less invasive and cardiac surgery has started to follow this trend.**

Objective: **To evaluate the evolution of one hundred patients undergoing minimally-invasive coronary artery bypass grafting.**

Methods: **Access to the heart was attained through a small; 6-cm thoracotomy, located in the 4th left intercostal space, starting at the nipple. Through the same intercostal space, 3 cm after the primary incision, a 6.5-mm optical device was inserted at 30°. Where the saphenous vein was used, the pericardium was opened above the aorta and the latter was partially clamped with a systolic pressure of 80 mmHg, with the proximal anastomosis being carried out in the conventional manner. The distal anastomoses were carried out in the conventional manner. The procedure was performed off-pump using single lung ventilation.**

Results: **The mean age was 63.9 ± 10.66 years. Sixty-eight (68%) patients were males. Fifty-three (53%) were in functional class III or IV. Left ventricular function was normal in fifty-three (53%) patients. Forty-two (42%) had undergone previous angioplasty. A total of 153 anastomoses were performed, ranging from 1 to 3. The average ventilation time was 4.06 ± 4.08 hours. Seventeen (17%) patients had atrial fibrillation and eight (8%) had pneumonia. There were two deaths in this series.**

Conclusion: **Revascularization was safe with low mortality and morbidity. With the advent of new devices, this surgery may have a greater applicability. (Arq Bras Cardiol 2012;99(1):596-604)**

Keywords: **Myocardial revascularization; coronary artery bypass; off pump; video-assisted surgery.**

Introduction

The first reports of less invasive coronary artery bypass grafting (CABG) surgery come from early studies of off-pump surgeries through conventional sternotomy[1-4]. After this operation technique had been well-established and mastered with a beating heart, reports were made of coronary bypass surgery performed through a small left anterolateral thoracotomy[5-8], which aroused great interest among cardiovascular surgeons. However, the location where the incision was performed made it difficult to remove the left internal thoracic artery, presented low mobility of the intercostal space, which led to rib fracture, in some cases with severe pain in the postoperative period, and mainly limited this type of revascularization procedure to the anterior interventricular artery.

Because of these facts, this procedure was almost abandoned in the late 90s, and interest in less invasive operations grew again only recently, due to increased use of percutaneous interventions in the treatment of coronary heart disease. Patients and cardiologists want to find a less aggressive alternative than conventional surgery for cases of less extensive disease.

An optimal method for CABG has not been found. Although percutaneous treatments have proven to be quite effective in acute and localized coronary disease, late results are not equivalent to those of CABG surgeries[9-12]. This type of surgery has been slightly modified since its initial publications 40 years ago and is associated with a morbidity rate of around 15%, including infection, cerebrovascular accident, bleeding, low-output syndrome, pulmonary complications and atrial fibrillation[13-16]. Regarding the postoperative follow-up, there have been reports of decreased physical capacity after sternotomy[17,18] and some patients have chest pain for up to one year after the surgery [19,20]. Minimally-invasive coronary artery bypass grafting is a surgery performed through a small incision on the left side, from where the surgeon has comfortable access to the aorta, the left internal thoracic artery and the anterior, lateral and even posterior coronary branches of the left ventricle, thus allowing the full operation without the need for opening the sternum[21].

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Objective

To assess the outcome of the first one hundred patients undergoing minimally invasive coronary artery bypass grafting.

Methods

between January 2009 and December 2010, one hundred patients underwent minimally invasive coronary artery bypass grafting surgery. The contraindications for this procedure are emergency operations with hemodynamic instability, obesity, coronary reoperation, severe chronic obstructive pulmonary disease, where the patient cannot tolerate single lung ventilation, peripheral vascular disease with important impairment of the iliac-femoral system, which, in emergency transoperative situations, would prevent the use of extracorporeal circulation, and would cause the impairment of the right coronary artery and circumflex branch, without the presence of a high marginal branch.

Initial monitoring and anesthetic procedure followed the usual pattern as previously described [22]. Orotracheal intubation was performed using a dual lumen tube to allow the blocking of the left lung during the procedure. Patients were positioned in right lateral decubitus at 15-30°. The skin incision was made in the left midclavicular line, starting at the nipple line and moving laterally, with a length of approximately 6-8 cm (Figure 1). The pleural cavity is penetrated by the 4th or 5th intercostal space and the fat located around the pericardium is widely removed from the top to about 2 cm of the phrenic nerve.

The 6.5-mm 30° optical device is introduced into the same intercostal space at approximately 4 cm below the end of the incision. With the help of videothoracoscopy, the left internal thoracic artery is dissected in skeletonized manner to its origin, and, for that purpose, long instruments were used. Prior to sectioning the thoracic artery, heparin is administered at a dose of 2 mg/kg. In patients requiring anastomosis of the saphenous vein to the aorta, the dose should be administered first. For that, the pericardium is opened up only in the ascending aorta and pulled tight with separate cotton yarn, followed by extensive dissection of the aorta and pulmonary artery. With a systolic blood pressure of 80 mmHg, the aorta is pulled toward the incision and partial clamping is applied. Anastomosis of the saphenous vein with the aorta is carried out in conventional manner, using instruments longer only in older patients (Figure 2).

For that purpose, the pericardium is opened only in the ascending aorta and pulled tight with separate stitches, followed by extensive dissection of the aorta and pulmonary artery. With a systolic blood pressure of 80 mmHg, the aorta is pulled toward the incision and partial clamping is applied. Anastomosis of the saphenous vein with the aorta is carried out in the conventional manner, using longer instruments only in older patients (Figure 2).

At the end of the proximal anastomosis, the pericardium is opened widely toward the apex of the heart and its edges are given several points of tension. The distal anastomosis is performed with the aid of a tissue stabilizer using pressure. When grafts are placed on the lateral wall, the stabilizer is introduced into the cavity via a small subxiphoid incision (Figure 3) and the anastomosis is positioned above the primary incision itself.

The anastomosis is performed in the usual way, with a continuous suture using 7-0 suture thread (Figure 4). In most cases, the intracoronary shunt is used. Once the anastomoses are finished, heparin is completely neutralized, a review of hemostasis is performed and a chest tube is introduced, the intercostal block is performed with local anesthetic and the incision is closed per layer (Figure 5). In most cases, we tried to carry out tracheal extubation in the operating room. When it was not possible, the double lumen catheter was replaced by a conventional tube.

Statistical analysis

Student's t test for independent samples or the nonparametric Mann Whitney test was used to compare the groups regarding quantitative variables, when appropriate. The association between quantitative variables was evaluated by Chi-square or Fisher's exact test. The condition of normality of variables was assessed by the Shapiro-Wilks. P values <0.05 were considered statistically significant.

Results

One hundred patients with a mean age of 63.9 ± 10.66 years, ranging from 44 to 87 years were evaluated. Sixty-eight patients (68%) were male and 32 (32%) females. When we evaluated the risk factors for coronary disease, hypertension was present in 84 (84%) patients, diabetes in 37 (37%), smoking history in forty (40%) and high cholesterol levels in 31 (31%). Regarding the class of angina, five (5%) patients were in class I, 42 (42%) in class II, 32 (32%) in class III, and 21 (21%) in class IV. The left ventricular ejection fraction was normal in 53 (53%) patients, moderately impaired in 34 (34%) and showed major impairment in 13 (13%) patients. The EuroSCORE ranged from 0 to 13 points, with a mean of 3.83 ± 3.32. Forty-two (42%) patients had prior coronary angioplasty, and coronary angiography showed an average of 1.72 ± 0.68 vessels with lesions per patient, ranging from one to three.

The mean number of distal anastomoses per patient was 1.53 ± 0.57, ranging from one to three grafts per patients. The internal thoracic artery was used in 89 (89%) cases. The anterior interventricular branch was revascularized in all (100%) patients, followed by marginal branch of the circumflex artery in 27 (27%) and the diagonal branch in 26 (26%). There was no statistical difference between the number of lesions detected on coronary angiography and the number of anastomoses performed per patient (0.109). Surgical time ranged from 70 to 180 minutes, with a mean of 108.9 ± 25.66 minutes. The mechanical ventilation duration in the postoperative period ranged from 0 to 18 hours with a mean of 4.06 ± 4.08 hours. The mean length of stay in the Intensive Care Unit was 1.98 ± 0.60 nights and mean hospital stay was 5.99 ± 1.27 days, ranging from four to nine days. Table 1 shows some pre-and intraoperative variables.

Regarding the complications, three (3%) patients required orotracheal reintubation, eight (8%) patients had pulmonary

Figure 1 - *Left minithoracotomy*

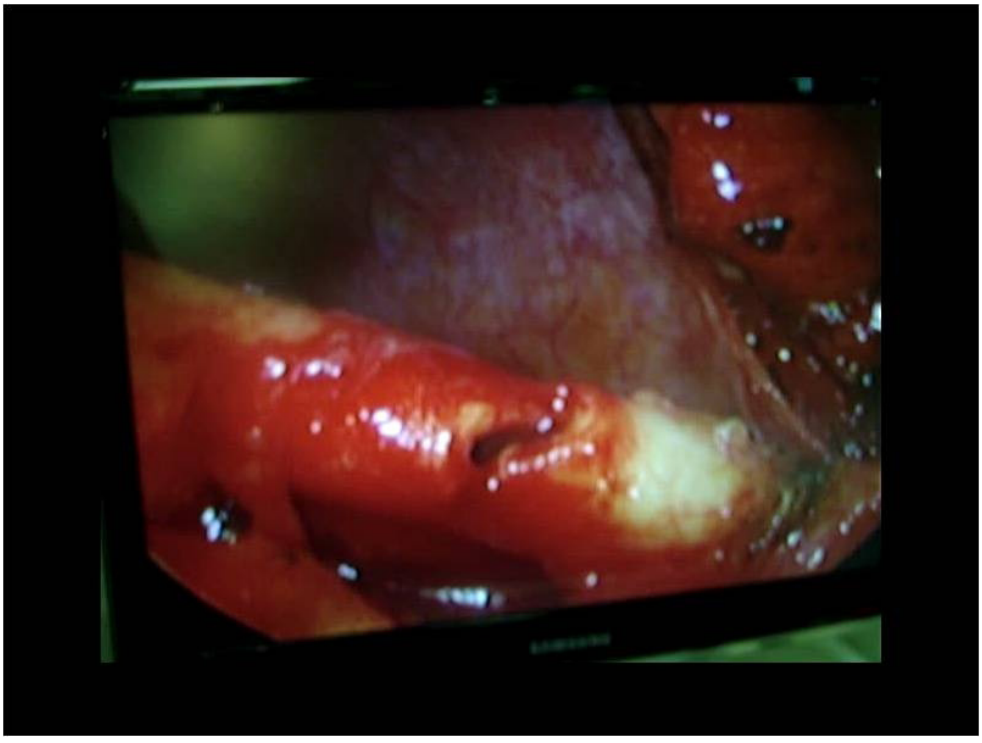

Figure 2 - *Aorta overview at the proximal anastomosis*

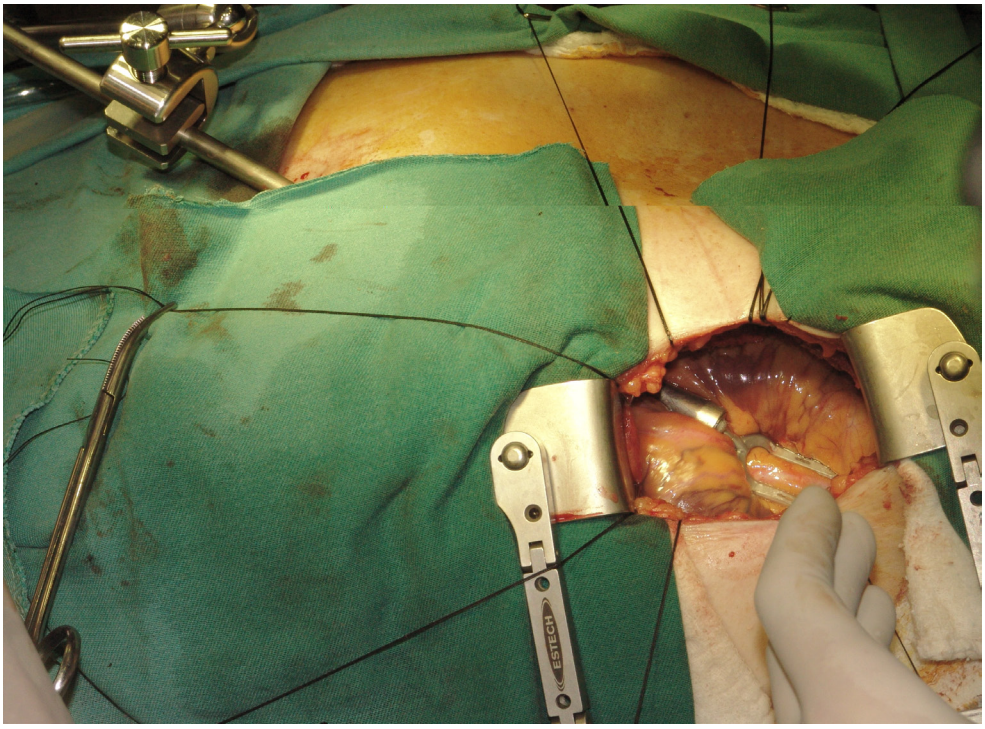

Figure 3 - *Exposure of LV lateral wall*

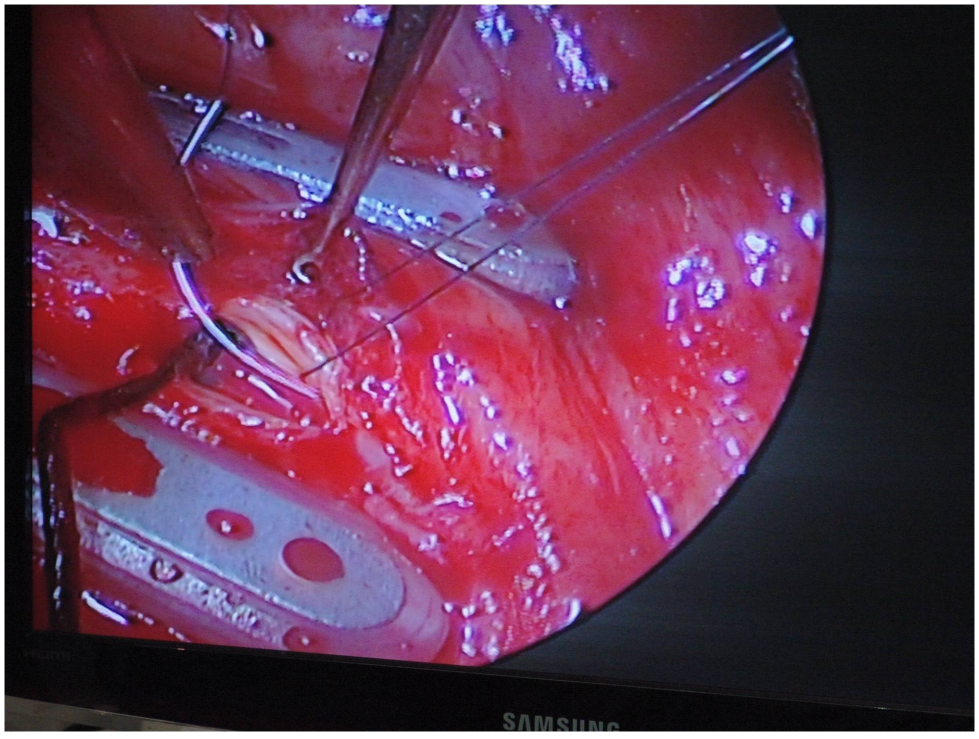

Figure 4 - *Proximal anastomosis*

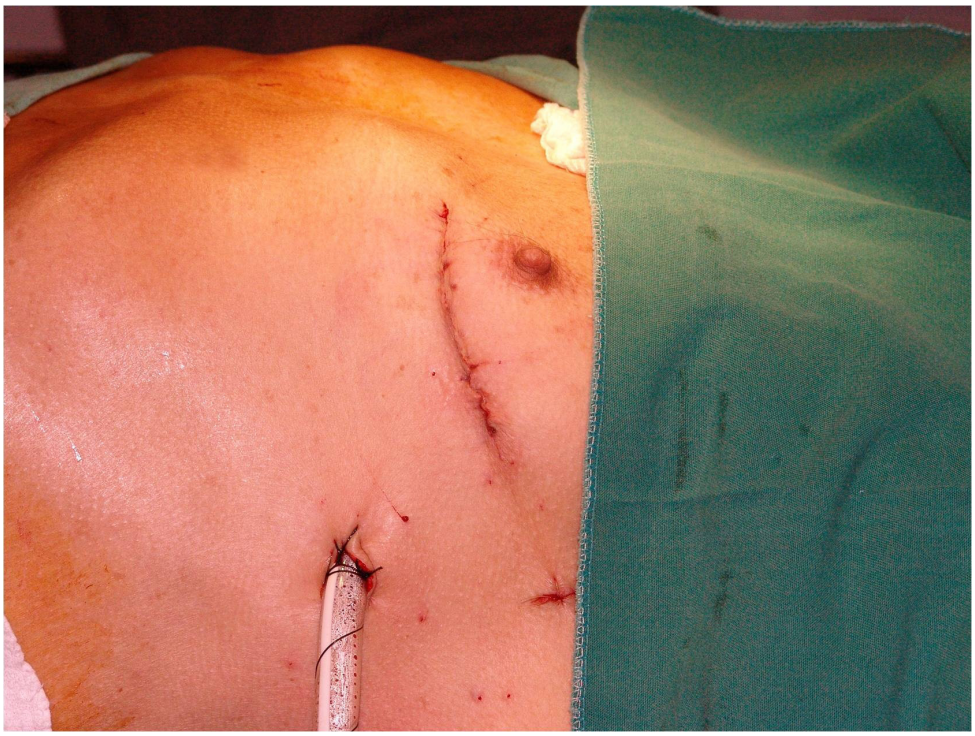

Figure 5 - *Final aspect of the operation*

Table 1 - Preoperative and intraoperative variables. Age in years, EuroSCORE points, ventilation time in hours, time of surgery in minutes, length of ICU in nights and days of hospitalization

	Mean	Minimum	Maximum	SD
Age	63,9	44	87	10,7
EuroSCORE	3,8	0	13	3,3
Time of ventilation	4,1	0	18	4,1
Time of surgery	108,9	70	180	25,7
Time at ICU	2	1	4	0,6
Hospitalization stay	6	4	9	1,3

infection, eleven (11%) had subcutaneous emphysema, 13 (13%) had low output syndrome requiring vasoactive drugs, and two (2%) required the use of intra-aortic balloon, and seventeen (17%) patients developed atrial fibrillation in the postoperative period.

Two (2%) patients underwent reoperation due to bleeding, one due to the internal thoracic artery branch clip release and one due to dehiscence of the distal anastomosis. In two (2%) patients it was not possible to perform tracheal intubation with double lumen catheter, who were then operated with cardiopulmonary bypass, so that the lung could be stopped. Table 2 shows the incidence of complications:

The possible factors for the onset of atrial fibrillation and pulmonary infection were analyzed separately. Regarding the presence of AF, the following were statistically significant: age > 72 years, female gender, mean EuroSCORE > 6, time of surgery > 130 minutes and duration of mechanical ventilation > 8.3 hours. Regarding the onset of lung infection, age > 77 years, mean EuroSCORE > 7.6, time of surgery > 130 minutes and mechanical ventilation > 9.6 hours were statistically significant.

Patients who had atrial fibrillation or pulmonary infection had a statistically significant stay in the ICU and hospital. The patients without pulmonary infection stayed a mean of 1.9 night in the ICU compared to 3.1 of those with pulmonary infection (<0.001) and remained in hospital a mean of 5.9 days *versus* 6.8 days for

Table 2 - Postoperative complications

	Frequency	Percentage
Reoperation due to bleeding	2	2%
Reintubation	3	3%
Pulmonary infection	8	8%
Low output	13	13%
Atrial fibrillation	17	17%

patients with pneumonia (0.035). In the case of atrial fibrillation, patients who did not have AF were 1.8 night in the ICU vs. 2.4 nights for patients with AF (0.001) and stayed 5.8 days in the hospital compared with 6.6 for patients with AF (0.001).

Two (2%) patients died in this series. The first death occurred on the 6th day postoperatively due to a cerebrovascular accident (CVA) that occurred one day after discharge from the ICU. The second happened seven hours postoperatively due to bleeding, caused by dehiscence of the distal anastomosis after an initially uneventful surgery, during which the patient was extubated before he left the operating room. There was no correlation of the deaths with any individual variable.

Comments

The coronary artery bypass grafting surgery, proposed in the late 60s, is one of the most common surgical procedures worldwide since its introduction and remains the gold standard therapy in selected cases. However, since its presentation, over 40 years ago, few innovations have been added to this therapy. Off-pump myocardial revascularization surgeries have been proposed in order to minimize the deleterious effects of ECC such as hemodilution, blood contact with foreign surfaces and the air and, thus, decrease the inflammatory response, resulting in fewer coagulation disorders and minor dysfunction of the involved target organs [23-26].

In the mid-1980s, two large series with more than five hundred patients were published [1,4], showing excellent results with off-pump myocardial revascularization. At the end of the 1990s, the biomedical industry provided a large number of surgical instruments that allowed the entire approach of the coronary system with minimum manipulation of the heart and hemodynamic stability maintenance, which made it possible to perform a complete off-pump myocardial revascularization. This fact led to a significant increase in the number of cases performed without the aid of the heart-lung machine, comprehending 30% of patients undergoing coronary artery in the United States [27].

There are currently available two large meta-analyses with more than 1,200 patients each, comparing coronary artery bypass grafting *versus* coronary angioplasty in patients with a single proximal anterior interventricular branch lesion [28,29]. Neither series reported any differences between the two methods when evaluating death, myocardial infarction or CVA. However, in a period of five years of follow-up, there was a three-fold higher incidence in the recurrence of angina and a five-fold higher incidence regarding the need to have a new procedure in the angioplasty group.

With the publication in December 2010 of the guidelines for coronary artery bypass grafting[30] by the European Society of Cardiology together with the European Association of Interventional Cardiology and European Association of Cardiothoracic Surgery, where evidence suggests that patients with lesions in one or two vessels and proximal impairment of the anterior interventricular branch are class IA for surgery *versus* IIB for angioplasty [28,29,31,32], CABG surgeries have shown a tendency to become less invasive in cases of lesser complexity. Patients with single lesion of the anterior interventricular branch or associated with other branches of the left coronary artery must have a less aggressive alternative than the sternotomy, an alternative that provides a shorter hospital stay and an early return to daily activities.

The CABG operation shown in this report is different from that proposed in the mid 1990s. At that time, access to the procedure was made through a small anterolateral thoracotomy, where the removal of the left internal thoracic artery was difficult, and sometimes it was not possible to obtain the entire length of the graft. Thus, in certain cases, some branches of the artery were kept connected with the chest wall, which may cause theft of flow. The region of the intercostal space where the pleural cavity was penetrated was too close to the sternum, giving less mobility to costal arches, which sometimes led to dislocations, rib fractures, and lastly, the exposure of vessels after opening of the pericardium allowed only the revascularization of the anterior interventricular branch. These facts made the procedure to fall into disuse, in spite of some series[33-37] with good results.

The results shown in this report series are from off-pump myocardial revascularizations performed through left thoracotomy, 6-8 cm in length, starting at the nipple area. This type of access has several advantages when compared to the previously proposed surgery. First, it allows a complete revascularization of the left side, not limited solely to the anterior interventricular branch. Second, as the incision is more lateral, it allows greater mobility of the ribs, providing a larger exposure without the occurrence of fracture or dislocation. Third, the approach provides a complete view of the coronary arteries, as the pericardium is widely opened. Fourth, the left internal thoracic artery can be completely dissected from its origin to its bifurcation. Fifth, this type of incision allows, in cases when it is necessary to perform a proximal anastomosis, to do it in a conventional manner in the ascending aorta, carefully carrying out the proximal anastomosis first, before the large opening of the pericardium.

The main benefits of this type of operation are the possibility of complete revascularization (in our series, there are patients who received three grafts), showing, in theory, a lower risk due to the fact that the procedure was performed in less time and less aggressively, with less time hospital stay, faster return to normal activity, as it was not necessary to wait 45 days to be able to drive, as it occurs after conventional sternotomy, for instance. Esthetically, it results in a better scar, and ultimately, fewer restrictions and less pain in the postoperative period.

Initially, this surgery was reported in 2009 by McGinn et al.[38], who presented the results of 450 patients from two centers. In this series, the authors showed a success rate without conversion of 96.2%, with a total mortality of 1.6%. The mean number of grafts per patient was 2.1 ± 0.7, and 79.8% of patients had two or more distal anastomoses. Complete myocardial revascularization was achieved in 94.9% of patients. The incidence of return to the operating room, transfusion, CVA, and atrial fibrillation was low. The authors also report a successful outcome of the surgical wound, with only one patient developing a superficial infection.

With a mean of twenty months of follow-up obtained in three hundred patients, need for a new coronary intervention was observed in ten patients (3%), and problems in the T anastomoses between the internal thoracic artery and saphenous vein were found in eight patients. In two patients, problems in the proximal anastomosis between the aorta and saphenous vein were observed. In their conclusions, the authors say that the applicability, complete revascularization, morbidity and safety are excellent, even in the initial phase of the procedure, and that this new, less invasive CABG exists and that it may have broad application, with results that are similar to the conventional procedures.

In our series, we evaluated the in-hospital evolution of one hundred patients undergoing minimally invasive coronary artery bypass grafting without cardiopulmonary bypass. The mean age of patients was 63.9 ± 10.66 years, and most of them were males. More than half of patients (53%) had angina class III or IV and 13% had a low left ventricular ejection fraction. The EuroSCORE shows that this group of patients consisted mostly of patients with low and medium operative risk, and preoperative coronary angiography showed that most patients had lesions in fewer than two vessels. Moreover, it also showed that almost half the group had undergone prior coronary angioplasty.

This group of patients evaluated here does not match the type of patient typically treated at cardiovascular surgery services. It is a group of selected patients, which is less than 10% of coronary patients operated on during study duration. Despite the relatively low number of distal anastomoses per patient, there was no statistical difference between the number of vessels with critical injuries assessed preoperatively and number of grafts performed. As this is an initial series, the number of anastomoses can be explained by the strict case selection, in the beginning single-vessel disease cases, and more recently, cases with multivessel disease. With more experience, we can currently approach the anterior and lateral walls of the left ventricle using this technique.

The use of the left internal thoracic artery was 89%, lower than what was expected for such patients. At the beginning of the series, there were lesions in three vessels, with two occurring during thoracotomy, with total rupture of the internal thoracic artery graft (ITAG) after opening the chest retractor, and one due to laceration of a proximal branch where a clip could not be suitably placed. Moreover, in the initial phase, we chose to use only the saphenous vein in older patients. In the last fifty patients, the LITA was not used only in two of them.

Severe pain in the postoperative period was not a factor reported by patients, differently from what occurred in the thoracotomy series, where the rib fracture was not uncommon, causing limiting pain in the postoperative period. Lichtenberg et al. [39] performed a study comparing lung function and postoperative pain in patients undergoing minimally invasive anterolateral thoracotomy in patients undergoing conventional surgery. In conclusion, the authors write that patients undergoing minimally invasive surgery had a higher preserved lung function; however, they had higher levels of postoperative pain.

With respect to pain, another report comparing less invasive surgeries with conventional procedures was published by Walther et al.[40]. The authors state that the level of pain in patients following heart surgery is relatively low, and that after the seventh day after surgery, there are virtually no reports of pain. Patients who undergo the less invasive surgery show earlier ambulation, and along with that, the report of pain disappears after the third day after surgery.

Regarding complications, the factors that were statistically significant for higher incidence of atrial fibrillation and pneumonia were: advanced age, higher EuroSCORE, time of surgery and prolonged duration of mechanical ventilation. The patients with these two complications stayed longer in the ICU and hospital. When evaluating the deaths that occurred, we could not identify any individual factor related to them. The high incidence of pulmonary infection in this series can be explained by the prolonged period of single lung ventilation due to a longer duration of surgery in the initial cases of the study. We believe that, as greater experience is gained, the total time of surgery can be greatly reduced and, thus, the incidence of pulmonary infection will also decrease.

When evaluating the results, we conclude that this type of surgery is quite interesting in less complex cases, such as in-stent restenosis. It is a relatively simple surgery to be performed. The professional used to carry out off-pump surgeries finds no major difficulties to perform rapid, reproducible anastomoses, with only a little more difficulty to dissect the internal thoracic artery and to perform the proximal anastomosis in the aorta. The postoperative outcome is quite satisfactory, with a short period of mechanical ventilation, ICU and hospital stay. Most patients returning for consultation within thirty days after surgery are satisfied with the cosmetic result of the surgery and virtually perform all their daily activities. The decrease in the time of surgery should reduce the incidence of pulmonary infection.

Conclusion

The minimally invasive myocardial revascularization is safe, effective and a good alternative for less complex patients. With the acquired experience and the arrival at our market of new retractors, heart stabilizers and positioners, the procedure may be more indicated for patients with multivessel disease with the same degree of safety of the conventional operation, with the same long-term results and a faster recovery and return to normal activities.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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There were no external funding sources for this study.

Study Association

This study is not associated with any post-graduation program.

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