Surgical Myocardial Revascularization without Extracorporeal Circulation

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Objective – *To assess the immediate postoperative period of patients undergoing myocardial revascularization without extracorporeal circulation with different types of grafts.*

Methods – *One hundred and twelve patients, 89 (79.5%) of whom were males, were revascularized without extracorporeal circulation. Their ages ranged from 39 to 85 years. The criteria for indicating myocardial revascularization without extracorporeal circulation were as follows: revascularized coronary artery caliber > 1.5 mm, lack of intramyocardial trajectory on coronary angiography, noncalcified coronary arteries, and tolerance of the heart to the different rotation maneuvers.*

Results – *Myocardial revascularization without extracorporeal circulation was performed in 112 patients. Three were converted to extracorporeal circulation, which required a longer hospital stay but did not impact mortality. During the procedure, the following events were observed: atrial fibrillation in 10 patients, ventricular fibrillation in 4, total transient atrioventricular block in 2, ventricular extrasystoles in 58, use of a device to retrieve red blood cells in 53, blood transfusion in 8, and arterial hypotension in 89 patients. Coronary angiography was performed in 20 patients on the seventh postoperative day when the grafts were patent.*

Conclusion – *Myocardial revascularization without extracorporeal circulation is a reproducible technique that is an alternative for treating ischemic heart disease.*

Key words: myocardial revascularization, coronary artery disease, ischemia

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Cardiovascular surgery has evolved in the last 3 decades, mainly in regard to the treatment of coronary heart disease, aiming at the surgical treatment of myocardial ischemia consequent to coronary artery obstruction and improvement in the quality of life of the patients.

In the last century, myocardial revascularization procedures began. In 1910, Carrel [1] carried out procedures in dogs by using arterial and venous grafts, and Vineberg [2] implanted left internal mammary artery grafts in the myocardium.

Goetz et al [3] were the first to use an anastomosis of the right internal mammary artery with the right coronary artery without extracorporeal circulation.

Myocardial revascularization surgery received a boost after the appearance of selective coronary angiography [4].

Favaloro [5] initially proposed the interposition of a segment of the internal saphenous vein to replace the impaired coronary artery segment; in the following year [6], he used the internal saphenous vein as a bridge, with proximal anastomosis to the aorta and distal anastomosis in the terminolateral coronary artery after the obstructive lesion of that vessel.

In Brazil, Zerbini et al [7] carried out the first studies on myocardial revascularization according to the Vineberg technique and the Bailey technique as modified by Senning. Jatene et al [8] were the first to perform myocardial revascularization by using internal saphenous vein bypass.

Since the beginning of coronary surgery, the Russian physician Kolesov [9] played an important role in myocardial revascularization without extracorporeal circulation. After an experimental study with dogs, that physician operated upon 6 human patients, in whom the left mammary artery was anastomosed to the anterior interventricular coronary artery or to the circumflex coronary artery. Ankeney [10] and, in the 1980s, Benetti [11] and Buffolo et al [12] systematized the procedure of myocardial revascularization without extracorporeal circulation and began to use it in patients at higher risk, avoiding extracorporeal circulation and aorta handling to reduce postoperative complications. The difficulties in performing anastomoses with a beating heart or the difficult access to the lateral and posterior coronary

arteries has often limited this type of procedure. At the beginning, myocardial revascularization without extracorporeal circulation was used to treat single-vessel lesions in critically ill patients [13-15]. Intracoronary shunt is an alternative for minimizing myocardial ischemia during the myocardial revascularization procedure without extracorporeal circulation [15,16]. Other studies have shown that the use of intracoronary shunts produces endothelial lesions [17,18]. This ischemia is clinically recognized as a ventricular dysfunction that improves with myocardial reperfusion [19]. In a second phase, with the appearance of stabilizers, the approach to myocardial revascularization of the lateral and posterior arteries improved [20,21]. In a third phase, myocardial revascularization without extracorporeal circulation was completed with the use of arterial grafts, avoiding aorta handling [22,23].

Myocardial revascularization without extracorporeal circulation has gained greater importance, and more and more surgeons have become adept at this surgical technique. In 1997, Lobo Filho et al [24] reported that 99% of their patients were revascularized without extracorporeal circulation. Aguiar et al [25] reported that 23% of the surgeries performed did not include extracorporeal circulation, although surgery with extracorporeal circulation was a safe and well-established procedure [26-31]. The major purpose of myocardial revascularization without extracorporeal circulation is to reduce surgical risk and the consequences of using extracorporeal circulation. The intraoperative complications observed in myocardial revascularization without extracorporeal circulation are as follows: ventricular extrasystoles, atrial fibrillation, ventricular fibrillation, need for blood transfusion or autotransfusion, atrioventricular block, and need to convert to myocardial revascularization with extracorporeal circulation [22,25,31,32].

This study aimed at assessing the immediate postoperative period of complete myocardial revascularization without extracorporeal circulation and also at analyzing its intra- and immediate postoperative complications.

Methods

We studied 112 patients with ischemic heart disease hospitalized at the Real e Benemérita Sociedade Portuguesa de Beneficência de São Paulo, during the period from March 1999 to July 2000 (Committee on Ethics Ref.: Protocol number 096/00). Cases of myocardial revascularization without extracorporeal circulation in patients with impairment in 1, 2, 3 or more vessels were included in the study, and the access route used was median thoracotomy with longitudinal sectioning of the sternum, use of a mechanical stabilizer with suction, and arterial grafts, preferably. The patients were clinically and laboratorially assessed, and, in some cases, coronary angiography was used with the patient's permission.

Of the 112 patients studied, 89 (79.5%) were of the male sex and 23 (20.5%) of the female sex, with ages ranging from 39 to 85 (mean of 64.5 and median of 66).

Table I shows the pathological antecedents of the patients.

Of the clinical manifestations, stable angina was present in 49 (43.8%) patients, unstable angina in 59 (52.7%), and 4 (3.6%) patients were asymptomatic.

Myocardial infarction affected 43 (27.6%) patients, 21 (18%) within 30 days of surgery.

The acute phase of acute myocardial infarction was diagnosed through clinical findings, enzymatic alterations in the CK-MB fraction of creatine phosphokinase, and the electrocardiographic tracing.

The criteria for indicating myocardial revascularization without extracorporeal circulation were as follows: patients with lesions $\geq$ 70% of the coronary artery lumen, coronary artery diameters > 1.5 mm, and no suspicion of intramyocardial vessels on coronary angiography. These criteria were complemented during surgery, observing the hemodynamic stability resulting from the usual maneuvers to perform the proposed technique.

Table II shows the distribution of patients according to coronary angiography.

All patients were prepared for surgery according to a myocardial revascularization protocol, but the material for extracorporeal circulation remained in the operating room in case surgical reversion to extracorporeal circulation was required.

In all 112 patients, median thoracotomy with longitudinal sectioning of the sternum was the access route. The left internal mammary artery was dissected in 105 (93.8%) patients, and the right internal mammary artery in 11 (9.8%), from its origin to the sixth left or right intercostal space. In some patients, aiming at taking advantage of the artery's length and using its best segment, the artery was skeletonized, which resulted in an approximate 2-to-3-cm increase in the artery's length.

The right gastro-omental artery was used in 2 (1.8%) patients. Its dissection was performed through the same incision at the inferior extremity, opening the parietal perito-

Table I - Pathological antecedents of the patients

Pathological antecedents	Patients
Essential arterial hypertension	77 (68.8%)
Peripheral vascular insufficiency	6 (5.4%)
Myocardial infarction: Within 30 days of surgery	21 (18.8%)
After 30 days	22 (19.6%)
Chronic renal failure	5 (4.5%)
Chronic obstructive pulmonary disease	9 (8%)
Smoking	55 (49.1%)
Diabetes	33 (29.5%)

Table II - Distribution of the patients according to cine coronary angiography

Number of coronary lesions	Patients
Single-vessel	17 (15.1%)
Double-vessel	53 (47.3%)
Triple-vessel	41 (36.6%)
Quadruple-vessel	1 (0.9%)
Total	112

neum, followed by traction of the stomach, initiating dissection by releasing the greater curvature of the stomach. This artery may be used in situ or as a free graft; when used in situ, it is passed through an orifice in the muscular portion of the diaphragm, and is usually anastomosed with the right coronary artery or one of its inferoposterior branches.

The radial artery, usually the left, was used in 72 (64.3%) patients and dissected after the Allen test was performed. Its dissection started after the interosseal branch and finished in its distal extremity. Prior to its removal, the test for proximal occlusion was performed again and the distal pulse was observed. After proximal sectioning, retrograde flow was assessed.

At the end of the procedure, the right and left internal saphenous veins were removed through incisions intercalated with segments of skin.

To improve exposure of the marginal and diagonal coronary branches and the right coronary branches, a 2 "0" Mersilene suture thread was passed between the inferior vena cava and the right superior pulmonary vein, according to Lima et al [33].

Some stitches were made in the pericardium close to the trajectory of the phrenic nerve, fixed in the operating field or in the retractor, allowing better exposure of the proximal and distal coronary segments approached.

Usually exposure of the anterior interventricular coronary artery is the beginning. In the most appropriate site for anastomosis, a transmyocardial subcoronary silicone thread is passed through a latex tube in the proximal portion of the site of anastomosis, serving as a tourniquet in the coronary artery, interrupting the coronary flow. With an ischemic preconditioning of 2 to 3 minutes, hemodynamic, electrocardiographic, and arrhythmic alterations are observed during blood flow interruption. If the alterations are not significant, or if the occasional alterations respond to drugs (dopamine, lidocaine, and volume), anastomosis is continued. In some cases, the intraarterial bypass proposed by Rivetti and Gandra [15] is used. It consists of inserting a silicone tube with a diameter equivalent to that of the coronary artery, this way avoiding applying the tourniquet, and, therefore, reducing the time of ischemia.

Currently, as a routine, the Octopus II stabilizer is used (fig. 1) according to Spooner et al [20]. Longitudinal incision of the coronary artery with application of the tourniquet was performed, and anastomosis was initiated with the 7"0" or 8"0" polypropylene thread. Once the anastomosis was completed, the coronary flow was re-established when the coronary tourniquet was released and the Glover tweezers were released from the mammary artery. To perform anastomosis in the marginal or diagonal arteries, the patient was placed in the Trendelenburg position, and adequate traction of the band was performed, previously fixed to the pericardium between the inferior vena cava and the right inferior pulmonary vein, to obtain a rotation that allowed adequate exposure of these vessels for anastomoses. Fixation of the coronary region was obtained with the mechanical stabilizer (Octopus II).

When the graft was arterial (radial artery, right internal mammary artery or right gastro-omental, as a free graft), proximal anastomosis was performed in the left internal mammary artery in a terminolateral Y with the 8"0" polypropylene thread, or the anastomosis of those arteries was performed in the saphenous vein in Y (vein with artery). When the anastomosis of the radial artery in the aorta was performed with the 6"0" polypropylene thread, lateral clamping of the aorta was performed. In the case of calcified aortas, the anastomoses were performed in the brachiocephalic trunk. Once the anastomoses were completed (figs. 2 and 3), pleural and mediastinal drainages were performed followed by closing of the thoracic wall by planes.

The patients were extubated according to our service's protocol, abiding by the appropriate extubation criteria. Myocardial enzymatic assessment was performed with measurement of the CK-MB isoenzymes (creatine phosphokinase in its MB fraction) every 6 hours. Electrocardiography was performed on the patient's arrival at the intensive care unit, and later, once a day. Myocardial infarction was confirmed by the presence of CK-MB values > 50 IU and the presence of a Q wave on the electrocardiographic tracing.

Cine coronary angiography was performed on the seventh postoperative day in 20 (18.3%) patients to assess whether the grafts were patent and adequate.

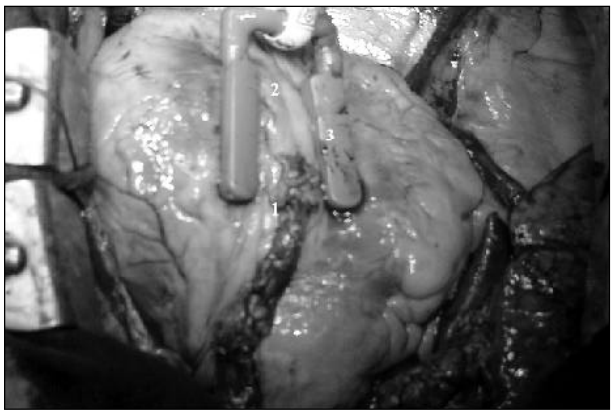

Fig. 1 – LITA Anastomosis (1) with the anterior interventricular branch (2) and "Octopus II" stabilizer (3).

Fig. 2 – Final result of the anastomoses of the radial artery (1) and in the aorta.

Fig. 3 – Proximal anastomosis of the internal saphenous vein with the ascending aorta. 1. internal saphenous vein; 2. aorta.

This study used descriptive statistical methods and methods of inference based on the parameters of binomial distribution, and a 95% confidence interval was adopted.

Results

Myocardial revascularization without extracorporeal circulation was performed in 112 patients, 3 (2.7%) of whom required extracorporeal circulation due to hemodynamic instability. These results indicated that the probability of performing myocardial revascularization without extracorporeal circulation in the patients with the clinical and surgical criteria adopted in our methodology ranged from 92.4 to 99.4%.

Table III shows the distribution of patients according to the revascularized coronary arteries and the grafts used, and table IV shows the types of proximal anastomoses performed.

The following complications were observed during surgery: atrial fibrillation in 10 (8%) patients, ventricular fibrillation in 4 (3.6%), and ventricular extrasystoles in 58 (51.8%), usually present at the moment of rotation of the heart for exposure of the posterior vessels. Those complications improved with the use of lidocaine or the release of the arterial tourniquet, with defibrillation through electrical shock of up to 10 Joules with a continuous current and the FC-710 U model defibrillator (Fukuda Denshi CO. Ltd), and cardiac pacemaker implantation in 2 patients with transient total atrioventricular block. Three patients required extracorporeal circulation for the procedure.

Episodes of hypotension were observed in 89 (79.5%) patients and corrected with vasoactive drugs. The device to retrieve red blood cells was used in 53 (47.3%) patients, and 8 (7.1%) required homologous transfusion. Table IV summarizes the complications.

All patients were extubated in the intensive care unit within the first 6 postoperative hours. Electrocardiographic alterations were observed, with elevation of the ST segment in 7 patients, which was reverted to normal in 5 patients, maintained equal in 2, and later, the presence of a Q wave (acute myocardial infarction). In 6 (5.4%) patients, atrial

Table III - Distribution of the revascularized coronary arteries and the corresponding grafts

Revascularized artery	Grafts	Number of patients	Percentages
Anterior interventricular artery	Left internal mammary artery	96	85.7%
	Right internal mammary artery	1	0.9%
	Radial	1	0.9%
	Saphenous vein	6	5.4%
	Left internal mammary artery + radial	1	0.9%
	Left internal mammary artery	7	6.3%
Diagonal artery	Radial	13	11.6%
	Saphenous vein	7	6.3%
Diagonal artery	Right internal mammary artery	1	0.9%
	Radial	2	1.8%
	Saphenous vein	2	1.8%
Left marginal artery 1	Left internal mammary artery	3	2.7%
	Right internal mammary artery	4	3.6%
	Radial	28	25%
	Saphenous vein	14	12.5%
Left marginal artery 2	Radial	1	0.9%
Coronary artery	Radial	4	3.6%
Posterior branch of the circumflex	Saphenous vein	1	0.9%
coronary artery	Right internal mammary artery + Radial	1	0.9%
Right coronary artery	Right internal mammary artery	2	1.8%
	Radial	15	13.4%
	Saphenous vein	16	14.3%
	Right internal mammary artery + Radial	1	0.9%
Posterior descending branch of	Right internal mammary artery	1	0.9%
the right coronary artery	Right gastro-omental	2	1.8%
	Radial	3	2.7%
	Saphenous vein	13	11.6%
Posterior ventricular	Radial	2	1.8%
branch of the right coronary artery	Saphenous vein	2	1.8%

Table IV - Complications observed during surgery

Complications	Patients	
Conversion to ECC	3	2.7%
Atrial fibrillation	10	8.9%
Ventricular fibrillation	4	3.6%
Total transient AV block	2	1.8%
Total transient AV block	58	51.8%
Use of the device to retrieve red blood cells	53	47.3%
Transfusion	8	7.1%
Hypotension	89	79.5%

ECC – extracorporeal circulation; AV block – atrioventricular block

fibrillation was reverted to sinus rhythm with antiarrhythmic drugs. Four patients had bronchospasms, which improved with medicamentous treatment. One patient (0.9%) had postoperative bleeding due to a right ventricular lesion caused by the mediastinal drain.

Eleven (9.8%) patients required homologous transfusion. One patient had clinical findings compatible with stroke in the postoperative period.

Table V shows the complications of the patients in the immediate postoperative period, and figures 4 and 5 depict the evolution of the enzymatic measurements and drainage volume.

All 20 patients undergoing cine coronary angiography in the first week (7th day) showed patency of the grafts. Therefore, based on the confidence interval of binomial distribution, and with a 95% likelihood, the surgical procedure adopted was estimated to lead to similar results in, at least, 83.2% of the cases.

Discussion

Since the very beginning of cardiac surgery, myocardial revascularization without extracorporeal circulation has been contemplated. With technical advances like extracorporeal circulation and methods for myocardial protection, such as the protective cardioplegic solutions, the initial idea was forgotten. However, Benetti [11] and Buffolo et al [12] drew attention to this technique once again, systematizing it and showing its advantages. However, the technical difficulties inherent in the performance of the anastomoses with the heart beating, allowed only the revascularization of the right coronary artery and the anterior and diagonal interventricular branches. The posterior coronary arteries were not revascularized with this technique and required extracorporeal circulation. In studies comparing groups of patients operated upon with and without extracorporeal circulation, such as the study by Gundry et al [34], with a 7-year follow-up, equal survival was observed in both groups, and 20% of the patients operated upon without extracorporeal circulation required another procedure as follows: another surgery in 5% of the cases and coronary angioplasty in 15% of the cases.

Buffolo et al [31] compared 30 patients undergoing myocardial revascularization without extracorporeal circulation with 30 patients undergoing myocardial revascularization with extracorporeal circulation. In the postoperative coronary angiography performed prior to hospital discharge, 93.4% of the grafts were patent in both groups.

Twenty patients were studied on the seventh postoperative day with cine coronary angiography, which showed patency of the grafts used.

Buffolo et al [35] reported that no difference existed with or without extracorporeal circulation in regard to the occurrence of infection and the incidence of perioperative acute myocardial infarction. They also reported that the incidence of pulmonary complications due to surgery was 9.7% for the group using extracorporeal circulation versus 3.2% for the group not using extracorporeal circulation. In regard to neurological complications, their incidence was 3.8% with the use of extracorporeal circulation versus 1.1% without it.

In our case series, 3 (2.3%) patients experienced perioperative acute myocardial infarctions with a Q wave accompanied by enzymatic alterations, isoenzyme of creatine phosphokinase with muscle and brain subunits (CK-MB) > 50. In 1 of these patients, the electrocardiographic

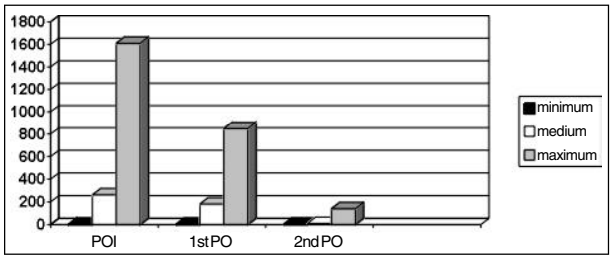

Fig. 4 – Postoperative enzymatic alteration in the 112 patients undergoing MR without ECC.

Table V - Complications observed in the immediate postoperative period

Complication	Patients	
Postoperative transfusion	11	9.8%
Stroke	1	0.9%
Postoperative atrial fibrillation	6	5.4%
Bronchospasm	4	3.6%
Alteration in ECG (supra)		
Reversed	5	4.5%
Maintained	2	1.8%
Reoperation due to bleeding	1	0.9%

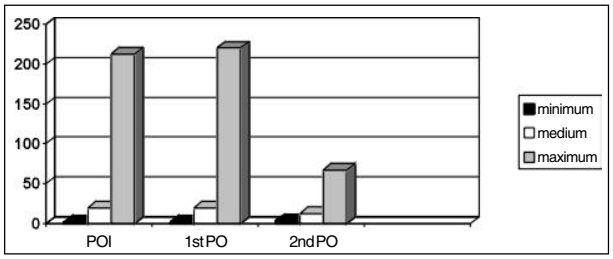

Fig. 5 – Postoperative drainage observed in the 112 patients undergoing MR without ECC.

tracing became normal, although the enzymes remained elevated, and the 2 others maintained the electrocardiographic and enzymatic alterations. In regard to neurological complications in our case series, 1 (0.9%) ischemic stroke was observed.

Braile et al [36] reported the advantages of measuring troponin I as a marker of myocardial damage after myocardial revascularization without extracorporeal circulation. In our patients, the isoenzyme of creatine phosphokinase with muscle and brain subunits (CK-MB) was measured.

Rivetti et al [15] recommend the use of an intracoronary shunt to avoid myocardial ischemia and its complications during myocardial revascularization without extracorporeal circulation.

In our case series, intracoronary bypass was used in 20 patients, mainly in lesions of the anterior interventricular branch or of the right coronary artery, in which a reduction in ischemic alterations was observed, such as an electrocardiographic tracing within the range of normality and the lack of hemodynamic alterations.

In our service, 1,190 patients underwent myocardial revascularization surgery in a period of 18 months, 1,033 with extracorporeal circulation and 157 (13.19%) without it.

According to Benetti et al [37], myocardial revascularization without extracorporeal circulation requires the following: a coronary diameter of at least 1.5 mm, a noncalcified wall, and the absence of intramyocardial trajectory. In our case series, these requirements were observed, in addition to the degree of tolerance to the movements of rotation of the heart for myocardial revascularization procedures without extracorporeal circulation.

With the appearance of stabilizers of compression or epicardial aspiration by suction, Calafiore et al [22] and Hart et al [23] managed to perform arterial grafting without extracorporeal circulation more often, and the posterior coronary arteries began to be revascularized.

In our case series with 112 patients studied, the anastomoses were performed with the aid of a mechanical suction stabilizer (Octopus II), the revascularized patients had 1 or more impaired coronary arteries, and several types of grafts were used (left and right internal mammary artery, right gastro-omental artery, radial artery, and saphenous vein).

Spooner et al [20] revascularized multiple vessels by using the stabilizer (Octopus II). One hundred and fifty-four patients underwent revascularization with grafts for 2 coronary arteries, 102 patients for 3 coronary arteries, and 23 patients for 4 arterial and coronary branches. In the cited cases, at least 1 arterial graft was used in 99% of the patients. Conversion to extracorporeal circulation was required in 13 (2.8%) patients; homologous transfusion in 20.6% of the patients; reoperation due to bleeding in 1%; atrial fibrillation in 13.3%; cerebral stroke in 0.2%; perioperative infarction in 0.8%; and the intra-aortic balloon was required in 0.4% of the cases. Mortality in 30 days was 0.2%.

In our case series, 112 patients underwent myocardial revascularization, which was single-vessel in 17 (15.1%) patients, double-vessel in 53 (47.3%) patients, triple-vessel in 41 (36.6%) patients, and quadruple-vessel in 1 (0.9%) patient. A mean of 2 to 3 bypasses were performed per patient. Three (2.7%) patients required conversion to myocardial revascularization with extracorporeal circulation.

Regional myocardial ischemia, consequent to applying the coronary artery tourniquet with an interruption in the coronary flow may produce hypotension, arrhythmias, or myocardial infarction during surgery. The use of shunts, which maintains the distal coronary flow, diminishes these events [15,16,38].

Benetti et al [39], Buffolo et al [31,40] , and Calafiore et al [22] reported that revascularized patients with the use of a shunt had good results with low indices of perioperative myocardial infarction and low morbidity and mortality.

Perrault et al [17] and Chavanon et al [18] studied the procedures experimentally during myocardial revascularization with the use of intracoronary clamps or shunts and showed that those procedures caused endothelial dysfunction, which prevented coronary artery relaxation, and that application of a tourniquet did not cause endothelial alterations.

Proximal and distal tourniquets were used in the first 50 patients, and afterwards, in the upcoming patients, only proximal tourniquets were used with 4"0" Prolene or silicone elastic thread passed through a rubber tube; intracoronary shunting was performed in 20 cases, but currently, it is used in all patients, mainly in the right coronary artery and anterior interventricular artery. This surgical maneuver reduces ischemic events, translated as alterations in the electrocardiographic tracing, such as ventricular extrasystoles, ventricular fibrillation, bradycardia, and atrioventricular block.

In conclusion, this study allows the following conclusions: 1) the method and technique used are reproducible; 2) the diameter of the revascularized coronary arteries should be greater than 1.5 mm; 3) the hemodynamic alterations with rotation maneuvers and exposure of the coronary arteries do not prevent performing the procedure according to the protocol used; 4) complete myocardial revascularization without extracorporeal circulation is an alternative for the treatment of ischemic heart disease.

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