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An Intraluminal Shunt for Off-Pump Coronary Artery Bypass Grafting. Report of 501 Consecutive Cases and Review of the Technique

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ABSTRACT

Background: Clinical or subclinical manifestations of coronary ischemia may occur when the target vessel is temporarily occluded during revascularization of the beating unsupported heart. Laboratory evidence has shown that even when the surface electrocardiogram is normal, action potential duration, conduction velocity, and regional electrocardiogram patterns change during clamping of the target coronary artery. In addition, local trauma to the endothelium and/or adjacent atherosclerotic plaque by encircling snares or mechanical clamps can lead to plaque disruption and late stenosis in the native vessel.

Methods: The authors report their experience with a continuous series of patients undergoing coronary grafting on the beating heart using an intraluminal shunt. This simple device maintains distal perfusion and prevents ischemia while at the same time protects the anastomosis from potential suturing errors. The shunt also keeps blood from obscuring the operator's vision and thus makes snares and clamps unneccesary. Smooth unhindered removal of the shunt immediately confirms patency of the finished anastomosis.

Results: Off-pump coronary grafting was performed in 501 consecutive patients utilizing an intraluminal shunt. Three hundred and seventy-three men (74.5%) and 128 women ranging from 34 to 92 years old (mean 60.4 years) underwent a total of 196 internal mammary artery grafts and 596 saphenous vein grafts (1.58 grafts per patient) from November 1983 to December 1996 at the Santa Casa de São Paulo Hospital and Hospital Samaritano. Mean shunting time was 14 minutes per anastomosis. Thirty day hospital mortality was 1.39% (7 patients) and all deaths were from non-cardiac causes. Perioperative myocardial infarction occurred in 7 other patients (1.39%), all of whom survived.

Conclusions: In selected cases coronary grafts can be safely constructed on the beating heart without ischemia using a simple and inexpensive intraluminal shunt. The device is easily inserted and removed without damage to the native coronary. In a large series of patients, operative mortality and morbidity were lower than with conventional heart-lung support and cardioplegic arrest.

INTRODUCTION

In recent years there has been a sudden rediscovery of beating heart surgery. The concepts are not new and are in fact decades old. Virtually all of the original cases of coronary artery revascularization reported in the late 1950s and early 1960s were done on the beating, unsupported heart [Murray 1954, Kolessov 1967, Ankeney 1972, Sabiston 1974, Connolly 1978,]. Cardiopulmonary bypass (CPB) was introduced in 1953 but it took several more years for this technology to see widespread use. By the time coronary bypass surgery was introduced clinically in the late 1960's most surgeons were already familiar with the advantages of extracorporeal circulation (ECC). Surgeons soon developed a clear preference for the hemodynamic support and elective cardiac asystole offered by the heart-lung machine and the concept of beating heart surgery for coronary bypass was quickly left behind. It is commonly thought that the bloodless, motionless operative field characteristic of ECC and the arrested heart presents strong advantages over the technical rigors of beating heart graft surgery. For nearly four decades, CPB and diastolic arrest remained the world wide standard for coronary graft construction. Research and development stepped forward with many advances in the safety of heart-lung bypass and myocardial protection bringing sharp reductions in overall operative mortality and morbidity.

Despite true improvements in CPB physiology, technology, and safety, there are still significant sequelae from exposing patients to extracorporeal circulation (ECC). Vasoconstriction, coagulopathy, capillary leak, third space fluid excess, pulmonary capillary injury, systemic inflam-

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Table 1. CABG without CPB, Recent Publications

Era	Author	N	Mortality (%)	Peri-op Infraction (%)
1993	Fanning	59	3.4	1.6
1992	Pfister	220	1.4	5.5
1991	Benetti	700	1	0.14
1991	Corso	203	1	
1991	Arsiwala	3	0	0
1989	Laborde	38	0	0
1985	Buffolo	160	3.1	2.5
1984	Archer	191		
1984	Akins	11		
1975	Trapp	63		
1972	Ankeney	143		
Total		1,791		

matory reaction, and neurologic complications remain as relative deterants to the use of CPB. In the elderly or those with co-morbid diseases these side effects may not be well tolerated. Renal insufficiency, a history of prior cerebrovascular events, atherosclerotic degeneration of the aorta, bleeding diathesis, or respiratory failure are conditions where exposure to CPB may hasten complications and impair recovery.

Despite nearly universal acceptance of CPB in the field of coronary surgery there remained a few centers where beating heart techniques were continued [Buffolo 1985, Benetti 1991, Corso 1991, Pfister 1992, Fanning 1993]. Until recently only a few scattered reports were available on the outcomes achieved by this technique (see Table 1). A modern resurgence of world wide interest in beating heart surgery began with the recent introduction of minimally invasive or limited access procedures for coronary bypass. In 1995 Clive Robinson reported the first laboratory model of beating heart minimally invasive CABG while Frederico Benetti reported the first clinical case (assisted by endoscopy) [Benetti 1995, Robinson 1995]. The entire cardiac surgical community is now focusing its attention on these procedures and the concept that grafting the beating heart can be safely performed. In just a few short years, most centers are now either considering or using some form of beating heart surgery to eliminate complications of ECC and extend the safe margins of coronary grafting in high risk patients. This shift in operative strategy is largely due to the steadily rising mean age and comorbidity seen in the recent surgical candidate pool. In addition, current economic pressures have redirected programs to bring costs under control with reconsideration of the known expenses of CPB equipment and treatment for the sequelae of ECC.

One of the great challenges in off-pump coronary grafting is to limit ischemia and maintain hemodynamic stability during the period of coronary artery occlusion. Recent experiences with minimally invasive direct coronary artery bypass (MIDCAB) have shown that not all patients manifest ischemia when the target vessel is occluded. However, ischemic electrocardiographic changes, hypotension, and ventricular fibrillation still do occur in an unpredictable fashion. Pfister et. al estimated that intraoperative ischemic events during temporary occlusion occur in 4.5% of cases [Pfister 1992]. The right coronary artery (RCA) appears to be the most vulnerable with bradycardia, heart block, and hypotension occurring even after short periods of occlusion. Studies in our laboratory have shown that acute occlusion of a coronary vessel in pigs is associated with changes in action potential duration and conduction velocity even before abnormalities appear in the surface electrocardiogram (ECG) [Gandra 1995]. Intraoperative transesophageal echo during MIDCAB can also reveal hypocontractility as an indicator of ischemia during coronary clamping.

Although most intraoperative ischemic episodes can be managed with anesthetic and pharmacological agents, there is a certain precarious balance which plagues this part of the case. If ischemia could be avoided altogether during beating heart CABG, safe and unhurried anastomotic construction could be performed with the same perfection offered by CPB and cardioplegia.

Since 1983 the authors have utilized an intraluminal shunt which simplifies many aspects of beating heart CABG. The stimuluous to consider shunting arose when one author (LAR) noted cyanosis and hypocontractility of the ventricle while observing another experienced surgeon perform beating heart CABG. Using commercially available silicone tubing, an intraluminal device was fashioned which immediately demonstrated multiple advantages during off-pump grafting. An initial cohort of 63 patients undergoing CABG with this shunt was reported previously [Rivetti 1997]. This current publication updates our entire series of patients over a 13 year period.

MATERIALS AND METHODS

Clinical parameters

Coronary artery bypass grafting on the beating heart was performed in 501 consecutive patients using an intraluminal shunt from November 1983 to December 1996. The study group included 373 men (74.5%) and 128 women ranging from 34 to 92 years old (mean age 60.4 years). All surgeries were performed by one team operating

Table 2. Off-Pump CABG using Intraluminal Shunt N = 501
Preoperative Indications for Revascularization

Indication	N	%
Unstable Angina	170	34
Post Infraction Angina	142	28
Stable Angina	86	17.5
Post Thrombolytics	85	17
Post Angioplasty Ischemia	18	3.5

at both the Santa Casa de São Paulo Hospital and Hospital Samaritano in São Paulo, Brazil. The first 63 cases were performed under protocols approved by the Institutional Human Research Committee of Santa Casa de São Paulo Hospital and were reported previously [Rivetti 1997].

Clinical indications for surgical intervention are summarized in Table 2. The majority of cases were operated for unstable or postinfarction angina. Only 17.5% were referred for treatment of stable angina. Eighteen cases were operated for acute angioplasty failure with ongoing ischemia.

Severe left ventricular dysfunction (ejection fraction (EF) < 0.3) was present in 13.5% of this series (68 patients). Moderate left ventricular dysfunction (EF between 0.3 and 0.5) was present in 35.7% (179 patients). EF greater than 0.5 was present in 50.6% (254 patients). All patients had angiographic evidence of coronary artery stenosis greater than 70% of luminal diameter in a major arterial branch or evidence of persistent ischemia on resting electrocardiogram prior to surgery.

Selection criteria for off-pump revascularization have been broadened slightly since our first series of patients [Rivetti 1997]. At present, we consider candidates for transsternal off-pump CABG to be those with:

- Lesions limited to the LAD, Diagonal, proximal RCA, or high first OM.
- Target vessel diameter of at least 1.5 mm diameter at the site of proposed anastomosis.
- Absence of stenotic lesions, calcified lesions, or diffuse plaque disease distal to the proposed anastomotic site.
- Evidence of rest or provokable angina symptoms or persistant ECG evidence of ischemia.
- At least 70% proximal stenosis in the native coronary

The left anterior descending (LAD) and proximal right coronary artery (RCA) were the most frequent target sites for off-pump grafting. Occasionally a prominent diagonal branch of the LAD or an early first marginal branch of the circumflex were included. No attempt was made to revascularize lateral wall targets in this study.

Shunt Design

The shunt device used in this entire series consisted of a single 3 cm segment of polished medical grade Dow Corning silicone tubing with beveled ends (#602–175 or #602–205; Dow Corning; Midland, Michigan). A 4-0 polypropylene retension suture was tied at the midpoint of the device to facilitate removal (see Figure 1, ◎). The durometry of these silicone segments was sufficient to prevent the shunt from collapsing while inside the coronary artery and yet flexible enough for easy removal. Shunts were constructed from different tubing diameters ranging from 1.5 to 3.0 mm (outer diameter). Sterilization was by ethylene oxide gas. Placement of the intraluminal shunt was greatly facilitated by a 45 degree bevel cut at each end (see Figure 1, ◎). The bevels are created at opposite angles to facilitate entry first into the proximal and then lastly into the distal coronary lumen.

Surgical Technique

No mechanical stabilizers were used in this series of patients, most being operated on before the era of MIDCAB or fixation devices. It was always helpful to draw the pericardium forward with heavy, pledget-supported sutures placed just above the phrenic nerve when grafting the LAD or diagonal. Support and stabilization of the coronary artery was also improved by passing either 4-0 polypropylene sutures or silicone tapes (Retract-O-Tapes; Quest Medical, Dallas, Texas) underneath the target vessel proximal and distal to the proposed suture line. Proximal and distal snares were used in the early years of this experience to obtain a bloodless field prior to shunt insertion. After confirmation of endothelial and medial lesions by these snares [Gerola 1987, Gundry 1992], the routine use of snares was abandoned.

Heparin 2 mg/kg was administered intravenously. When saphenous grafts were used as conduits, the proximal anastomoses were always constructed first using partial occlusion clamp techniques. This permitted immediate reperfusion of the ischemic bed(s) as soon as the distal anastomoses were completed. For construction of the distals, relative bradycardia was induced pharmacologically with 5 mg boluses of intravenous verapamil to a target heart rate of 50–60 beats per minute. The arteriotomy was always performed with a #69 Beaver blade.

Shunt sizes were preselected based on the appearance of the external wall of the vessel in comparison with the outer diameter of the different shunts. After incision of the target coronary, temporary control of vessel bleeding is obtained by proximal finger pressure over the coronary until the shunt is inserted. Probes can be used to precisely measure the vessel diameter at this stage if needed. The proximal coronary is intubated first with the bevel facing upwards. Once engaged into the coronary it is very common to see a vigorous jet of pulsatile blood exit the open end of the shunt confirming that the flow is adequate to maintain distal bed perfusion (see Figure 2, ◎).

Using two vascular forceps, the distal shunt is folded until the downward facing beveled tip can be engaged into the distal portion of the arteriotomy. At this time, visible bleeding typically stops as flow is diverted to the distal bed through the shunt lumen. If there is a coincidental septal perforator or branch vessel in the zone of the arteriotomy some residual backbleeding can occur. In most cases, the surgical field remains entirely bloodless while the shunt is in place (see Figure 3, ◎).

Table 3. Off-Pump CABG using Intraluminal Shunt N = 501 Postoperative Complications

Complication	N	%
Atrial Fibrillation	42	8.3
Bronchopneumonia	28	5.5
Mediastinitis	8	1.5
Bleeding	6	1.1
Reexploration for bleeding	2	0.3
Hemiplegia	3	0.5
Wound Dehiscence	3	0.5
Pulmonary Embolism	2	0.3

Standard anastomotic techniques are used with an emphasis on precise intimal-to-intimal apposition. Continuous suturing with 7-0 polypropylene is our standard approach. With the shunt in place, ischemia is avoided and thus there is no need to hurry or to accept anything less than a perfect technical result. Only a minor amount of irrigation is occasionally needed to keep a clear view of the intimal layers. Gas blowing devices were never used.

Suturing usually begins at the heal and proceeds around the far wall and toe until reaching the midpoint of the near wall. At this point the last 3 or 4 suture loops are loosened to create a gap large enough for both limbs of the shunt to exit. Slow steady traction on the retension suture causes the shunt to fold at its midpoint allowing safe removal (see Figure 4, ◎). The anastomosis is then completed by drawing up on the final suture loops. No patient suffered damage to the coronary wall, conduit wall or suture placements during extraction. Unhindered removal also immediately confirms full patency of the anastomosis in both directions without the need for vascular probes or other manipulations. Protamine is routinely used to reverse heparin prior to wound closure.

RESULTS

A total of 792 distal coronary grafts were constructed in 501 patients for an average of 1.58 grafts per patient. There were 196 left internal mammary artery (LIMA) grafts and 187 saphenous grafts to the LAD. An additional 115 grafts were placed to the diagonal, 281 grafts to the RCA and 13 grafts to high marginal branches.

Mean shunting time was 14 minutes per anastomosis. No intraoperative thrombosis occurred in any shunt device. In this series, there were only 7 hospital deaths (1.39%) within 30 days of surgery. None of these deaths were cardiac in nature (pulmonary embolism, sternal wound infection, and pneumonia). There were only 7 perioperative myocardial infarctions (1.39%). All complications are detailed in Table 3 and were similar in frequency to other series reported in the literature.

DISCUSSION

For the past 4 decades, cardiopulmonary bypass has been the standard means of supporting the circulation during construction of distal coronary artery bypass grafts. The advantages of elective diastolic arrest with cardioplegia permitted surgeons to work in a bloodless, motionless environment while suturing on small target vessels. This technique has been universally successful. As improvements in pump technology, cardioplegia, anesthesia, and surgical techniques gradually developed, the operative mortality and morbidity for conventional CABG has fallen. In fact, the results have improved to the point that mortality has decreased in spite of the higher risk case mix seen in the most recent decade.

Despite these remarkable accomplishments, realistic and definable morbidity from cardiopulmonary bypass remains. Sheer forces induced at the aortic cannula tip are felt to be responsible for dislodgement of atheroemboli. Aortic clamping is associated with an additional risk of embolic stroke. Cardioplegia provides a motionless environment but also induces transient changes in myocardial contractility, local vasoregulation, and possibly spasm. Blood-material interactions with the oxygenator are known to release vasoactive substances from activation of the coagulation cascade along with white cell and platelet degranulation. Vasodilatation, hypotension, and secondary organ changes may result. Renal, pulmonary, and neurologic end organ effects of cardiopulmonary bypass are well described phenomena and may be poorly tolerted in elderly patients or those with established medical conditions such as diabetes, chronic obstructive pulmonary disease, or peripheral vascular disease.

A few surgeons have chosen to continue performing CABG without heart-lung assist in selected cases [Buffolo 1985, Benetti 1991, Corso 1991, Pfister 1992, Fanning 1993]. Their work has confirmed that patients with proximal disease of the left anterior descending (LAD) and right coronary artery (RCA) can be successfully grafted without extracorporeal circulatory support. In the past decade, over 1,700 offpump cases have been reported using both saphenous and/or mammary conduits (Table 1). Off-pump CABG has been shown to be feasible in both primary cases as well as reoperations [Fanning 1993]. Improved morbidity and mortality in the elderly have been noted [Pfister 1992, Benetti 1991]. Reduced mortality, hospital stay, operative times, transfusion requirements and incidence of low-output syndrome have also been reported [Pfister 1992].

Although these pioneering surgeons have continued off-pump grafting for most of their careers, the vast majority of practicing surgeons in the world today have little or no experience working on the beating heart. Thus there are many challenges facing surgeons who are just now migrating into beating heart surgery, not the least of which is learning to work under conditions of potential ischemia and hemodynamic instability. A key dilemma in this modern era of beating heart surgery is myocardial protection during graft construction. The authors believe that intraluminal shunting is the safest and most cost-effective answer to this concern.

Intraluminal shunts were found to be protective against ischemia in many of the early animal models of coronary

surgery. For example in canines, Lary demonstrated that acute occlusion of the circumflex was associated with high operative mortality which was eliminated by the use of a distal perfusion shunt [Lary 1974]. From 1954 to 1981, there were laboratory devices made of glass, steel, polypropylene and silicone, but most without successful application in man. In 1975, Trapp and Bisarya described a temporary intraluminal shunt used in human patients but their technique was somewhat complicated and never widely utilized [Trapp 1975]. In 1977, Franzone et al. clearly showed that surface electrocardiograms in the region of the target coronary were altered by acute intraoperative occlusion but returned to baseline after insertion of an intraluminal shunt similar to the one used by the author of this current report [Franzone 1977].

The work published in this paper began as a thesis project in early 1983 with the original 63 patients being reported in a previous publication [Rivetti 1997]. As a result of the favorable response seen in this initial series of patients, the author's team has continued to perform all off-pump CABG cases with the assistance of the same intraluminal shunt device. The series now reported here totals more than 500 patients with an extremely low operative morbidity and mortality. Since the cutoff date for this current report (December 1996), the series has continued to expand. We now have performed this procedure on more than 600 patients with an overall 30-day hospital mortality of 0.9%.

Although our patient population contains mostly single or double-vessel disease rather than severe multivessel disease, the simplicity and safety of performing off-pump CABG with this technique is well demonstrated by our results. The shunt permitted the surgeon to avoid both ischemia and bleeding so that an unhurried anatomosis could be performed with the same technical perfection expected from an arrested heart. By placing the intraluminal shunt, encircling snares or vessel clamps were not needed and thus local vessel trauma avoided. The decision to minimize the use of snares was based on the work of Gerola et al. who reported moderately severe intimal-medial lesions and plaque disruptions when snares were used [Gerola 1987]. In a later report Gundry also pointed out that traction on silastic tapes could cause native coronary lesions during off-pump CABG [Gundry 1992]. For this reason we now avoid tightening any sutures around the target coronary and exclusively use the intraluminal shunt to control bleeding in the surgical field. The sub-coronary polypropylene sutures used in the later part of this series were for presentation and mild stabilization of the target coronary only.

Even though we have not measured quantitative flow rates in these shunts, the physiologic benefits of continued distal perfusion are quite obvious in the operating room. In the vast majority of cases, there was no evidence of ischemia, hypocontractility, hemodynamic instability, cyanosis, or color change in the ventricle during the shunting interval. Stable surface ECG recordings and the absence of primary or reperfusion arrythmias again confirmed the value and physiology of distal perfusion. In a rare patient, ischemia could be found when flow to a major septal perforator was impeded by the shunt. This could be solved by creating a slit down the back wall of the shunt to restore septal artery perfusion.

It is a legitimate criticism that we do not have quantitative flow measurements in this device. However, there is now modern evidence from invasive cardiology procedures that even a small amount of distal flow is better than none. One of the most successful interventional cardiology devices is the perfusion balloon. This device has clearly shown that acute ischemia from angioplasty failure can be immediately resolved by perfusing the distal bed (with an internal diameter even smaller than our shunts). Perfusion balloons were so successful in relieving acute ischemia from angioplasty failure that they remained the standard of care until intracoronary stents were invented. The authors believe that the same protective effect is seen in the operating room when intraluminal shunts are used for beating heart CABG.

There are surgeons who feel strongly that shunts are either useless or meddlesome. This parallels the divisive behavior of carotid surgeons, many of whom proudly belong to either the "shunt" or "no shunt" philosophic camp for carotid endarterectomy. It is clear from transcranial doppler studies that a shunt is usually not necessary for hemisphere perfusion during carotid endarterectomy. However, it is difficult to predict which patients are the ones who will need to be shunted and no surgeon wishes to cause a stroke as the only way of establishing proof.

As intraluminal coronary shunts become more known and more available, cardiothoracic surgeons are also dividing into "shunters" and "non-shunters". There are advantages to both. It is the author's contention that the advantages (summarized below) clearly outweigh the disadvantages.

Advantages of intraluminal shunting for beating heart CABG:

- Provides distal perfusion and prevents ischemia.
- Reduces the need to rush and rewards careful, meticulous suturing.
- Reduces or prevents bleeding into the surgical field.
- Obviates the need for crushing clamps or snares to control bleeding.
- Dilates and holds open the coronary arteriotomy.
- Keeps the opposite wall and floor of the coronary artery protected from accidental missuturing.
- Unhindered removal immediately proves full patency of the finished anastomosis.
- Inexpensive and simple alternative to CPB in selected situations.

Shunting removes the pressure to complete a delicate anastomosis in a hurry. Most clamp-and-go surgeons are time conscious with a realistic concern that ischemia could worsen until the patient eventually becomes hypotensive or arrythmogenic. To compensate for transient hypocontractility, inotropic drugs or vasopressors are often used. To counteract the coronary spasm induced by direct vascular manipulation and/or vasopressors, nitrates

are then added. This polypharmacy approach can lead to oscillating hemodynamics which in turn cause the surgeon to "worry and then hurry". This is a setting in which mistakes are prone to occur.

The opposite scenario exists when using an intraluminal shunt. Franzone, et al. clearly proved that perioperative ischemia and myocardial infarction rates were reduced by the use of an intraluminal shunt [Franzone 1977]. Thus, all time pressure is removed. Ischemia and hemodynamic instability are not a concern. There is no (or minimal) blood in the field and thus visualization is excellent. The shunt expands the arteriotomy keeping the opposite wall and floor of the coronary safely out of harms way. These factors all combine to an easy, safe, and precise anastomosis without hurry or anxiety. Final confirmation of the technical patency is beautifully illustrated when the shunt is extracted without resistance, as if a probe was pulled backwards through the suture line. Without a shunt, the surgeon may be inclined to pass a probe anterograde into the suture line with some risk of injury to the newly constructed anastomosis if the probe doesn't glide smoothly.

Our data in a large series clearly shows that morbidity and mortality rates are very low when an intraluminal shunt is used to perform beating heart CABG. Avoidance of ECC, cannulation, decannulation, and exposure of the patient's blood to artificial surfaces saves not only operative time but equipment expense and morbid side effects. Although not every case requires a shunt, routine use of intraluminal shunting is safe and certainly relaxes the surgical team who can then focus on the precision and reliability of the anastomosis without distractions or risk.

The authors have continued development of the shunt concept with a series of commercial models. A new "T" shaped model has been recently approved by the Food and Drug Administration. This design is based on the original shunt and yet incorporates a side-limb for possible external perfusion in the event of total obstruction of the proximal native coronary. A second model designed for implantation in close proximity to a significant plaque is also available. We believe that familiarity with intraluminal shunting is vital as surgeons prepare to explore complete endoscopic CABG. If port access CABG is to ever be successful without undue expense or morbidity, CPB must not be used routinely. If performed without CPB, sudden ischemia, hypotension, or ventricular fibrillation in a port access or closed chest procedure is a potentially fatal complication. To prevent this, the authors have designed a transportal variant of their shunt for use in off-pump port access CABG.

In summary, intraluminal shunting is a simple technique which provides an additional margin of safety when performing coronary artery bypass grafting on the beating heart.

REFERENCES

1. Ankeney JL. Coronary vein graft without cardiopulmonary bypass. Surgical motion picture presented at the annual meeting of The Society of Thoracic Surgeons, Jan 1972 (from Pfister).
2. Benetti FJ, Naselli G, Wood M, and Geffner L. Direct myocardial revascularization without extracorporeal circulation. Experience in 700 patients. Chest 100:312–16, 1991.
3. Benetti FJ, Ballester C. Use of thoracoscopy and a minimal thoracotomy, in mammary-coronary bypass to left anterior descending artery, without extracorporeal circulation. Experience in 2 cases. J Cardiovasc Surg (Torino) 36(2):159–61, Apr 1995.
4. Buffolo E, Andrade JCS, Succi JE, Leao L, Cueva C, Branco JN, Carvalho ACC, and Galluci C. Direct myocardal revascularization without extracorporeal circulation: technique and initial results. Tex Heart Inst J 12:33–41, 1985.
5. Connolly, JE. The history of coronary artery surgery. J Thorac Cardiovasc Surg 76:733–744, 1978.
6. Corso PG. Cardiopulmonary bypass and coronary artery bypass graft. Are the risks necessary? Chest 100(2):298–9, Aug 1991.
7. Dobell ARC, and Jain AK. Catastrophic hemorrhage during redo sternotomy. Ann Thorac Surg 37:273–279, 1984.
8. Fanning WJ, Kakos GS, and TE Williams Jr. Reoperative coronary artery bypass grafting without cardiopulmonary bypass. Ann Thorac Surg 55:486–9, 1993.
9. Franzone AJ, Wallsh E, Stertzer SH, DePasquale, NP and Bruno MS. Reduced incidence of intraoperative myocardial infarction during coronary bypass surgery with use of intracoronary shunt technique. Am J Card 39:1016–20, 1977.
10. Gandra SMA. Avaliação experimental do grau de isquemia regional em cirurgia de revascularização do miocardio sem circulação extracorporea, com e sem o uso da derivação intraluminal temporaria. Doctorate thesis presented at Faculdade de Ciencias Médicas da Santa Casa de São Paulo 1995.
11. Gerola LR, Leao LEV, Moura LAR, Buffolo E, Soares HC, Gallucci C. Garroteamento da arté ria coroná ria na revascularização do miocárdio. Relação entre o grau de aterosclerose e a leão vascular: estudo experimental. Rev Brasil Cir Cardiov 2:64–69, 1987.
12. Gundry, S in discussion of Pfister AJ, Zaki S, Garcia JM, et al. Coronary artery bypass without cardiopulmonary bypass. Ann Thorac Surg (54):1085–92, 1992.
13. Kolessov VL. Mammary artery-coronary artery anastomosis as a method of treatment of angina pectoris. J Thorac Cardiovasc Surg 54:535, 1967.
14. Lary BG, Sherman RW, Glasser SS, McDermott J, and Gollan F. Experimental vein angioplasty of the circumflex coronary artery. J Surg Research 17:10–214, 1974.
15. Lary BG. Coronary artery incision an dilatation. Arch Surg 15:1478–1480, 1980.
16. Murray G, Porcheron R, Hilario J , and Rosemblau W. Anastomosis of a systemic artery to the coronary. Can Med Assoc J 71:594–597, 1954.
17. Pfister AJ, Zaki MS, Garcia JM, Mispireta LA, Corso PJ, Qazi AG, Boyce SW, Coughlin TR Jr, et al. Coronary artery bypass without cardiopulmonary bypass. Ann Thorac Surg 54:1085–92, 1992.
18. Rivetti LA, Gandra SMA. Initial experience using an intraluminal shunt during revascularization of the beating heart. Ann Thorac Surg 1997 63: 1742–7, 1997.
19. Robinson MC, Gross DR, Zeman W, Stedje-Larsen E. Minimally invasive coronary artery bypass grafting; a new method

using an anterior mediastinotomy. J Cardiac Surg 10(5):529–536, Sept 1995.
20. Sabiston DC. The coronary circulation. John Hopkins Med J 134:314–329, 1974.
21. Trapp WG, and Bisarya R. Placement of coronary artery bypass graft without pump oxygenator. Ann Thorac Surg 19:1–9, 1975.
22. Walker WS, and Sang CTM. Avoidance of patent anterior grafts at revisional coronary artery surgery: use of a lateral thoracotomy approach. Thorax 41:692–5, 1986.