

Myocardial revascularization without cardiopulmonary bypass: historical background and thirty-year experience

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Myocardial revascularization without cardiopulmonary bypass (CPB) was introduced into surgical practice years after conventional coronary artery bypass surgery utilizing CPB. The initial series of consecutive patients revascularized without CPB were reported by a few groups, showing the possibility of achieving similar results via a less invasive approach. The technique, however, did not gain immediate widespread acceptance due to difficulties in performing coronary artery anastomoses on a beating heart. Two decades later, controversy still remains regarding case selection, advantages and pitfalls of the technique. The historical background of the development of off pump coronary surgery is herein presented, as well as points of view regarding training, long-term results, and applicability.

Historically, among several indirect myocardial revascularization procedures, only the Vineberg operation developed at McGill University in Montreal, Canada by Dr. Arthur Vineberg, showed promising results. At that time he performed the procedure without knowledge of coronary artery anatomy [1]. Direct myocardial revascularization was later made possible with the introduction of coronary angiography by Mason Jones at the Cleveland Clinic in the early sixties [2]. Rene Favaloro, in the same Institution, pioneered direct coronary artery revascularization with the use of reverse saphenous vein, utilizing CPB and cardiac arrest. His initial reports focused on selection of patients and technical challenges with the operation. It is to be noted that Garret et al, in November 1964, performed a coronary bypass grafting with a segment of saphenous vein, instead of endarterectomy, without knowledge of the coronary anatomy, thereby antedating Rene Favaloro. A successful seven-year follow up of this patient was later published [4].

The familiarity of surgeons with CPB circuits and the development of myocardial protective strategies led

surgeons to perform myocardial revascularization procedures on CPB, despite the fact that the coronary arteries are located on the surface of the heart. Also, the operation was performed on an arrested, rather than beating, heart. The idea of constructing a coronary artery bypass anastomosis on a beating heart was conceived, and performed long before saphenous vein grafting under CPB and cardiac arrest. In 1953, Demikhov [5], in Russia, and Murray et al. [6], in Canada, simultaneously performed left internal mammary artery anastomoses to the left anterior descending coronary artery in a beating heart.

Goetz et al. [7], in 1961, continued experimental direct myocardial revascularization with the mammary artery and mechanical suture with tantalum ring. Kolesov & Potashov [8,9] reported in the Russian literature in 1965, and later in the United States in 1967, the first clinical experience with mammary artery coronary bypass to the left anterior descending coronary artery in a beating heart via left thoracotomy. Mechanical suture was utilized in a few cases. All these operations were performed without the benefit of angiography, which had not been developed at that time. Years later, Trapp & Bisarya [10] in Canada and, in the same year, Ankeny [11] in Western Reserve – Cleveland, independently reported acceptable results using this technique. Technical difficulties and the fear that occlusion of a coronary artery could lead to ischemia and myocardial infarction, hampered the acceptance of this procedure. Complex perfusion devices were considered necessary, as illustrated in a paper published by Trapp & Bisarya, outlining some of the obstacles for construction of the distal coronary artery anastomoses under these conditions [10]. Years later, Buffolo et al. [12] and independently, Benetti [13] reported consecutive series of patients undergoing saphenous vein or mammary artery bypass grafting to left

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anterior descending, diagonal and right coronary arteries on a beating heart. The feasibility and safety of this alternative of myocardial revascularization was later confirmed by others [13-16]. Technical maneuvers were described in order to facilitate construction of the distal anastomoses, such as anesthesia expertise, pharmacological “stabilizers” to reduce heart rate and position of the operating table. During the next years other reports demonstrated the advantages of myocardial revascularization without CPB [17,18].

However, there was no widespread acceptance by the local and international communities of cardiac surgeons. One of the main concerns continued to be the possibility of myocardial ischemia and myocardial infarction during coronary occlusion. This was not observed in the initial clinical experience, when coronary occlusion was less than 10 minutes, with the use of pharmacological agents to reduce oxygen consumption, such as beta blockers or verapamil. This led Rivetti & Gandra [19] to develop a temporary intra luminal shunt, trying to maintain coronary perfusion and, thereby, avoiding myocardial ischemia. Anterior arteries of the heart, such as the left anterior descending or diagonal branches, and the right coronary artery in the right A-V sulcus, were accessible for off pump surgery. Lateral coronary arteries remained a challenge, preventing complete myocardial revascularization on a beating heart. An important contribution was made by Dr. Ricardo Lima, who described pericardial sutures that allowed exposure of the marginal branches (Lima “stich”), expanding the applicability of this alternative method of revascularization [20]. As a result, some surgeons performed near 90% of their revascularization procedures off pump [21].

Despite evidence for feasibility and safety of off pump CABG, conventional revascularization procedures continued to be used by most surgeons. Concerns about the quality of the anastomoses, and ability to perform complete revascularization off pump persisted. Off pump CABG surgery remained dormant, being performed by few surgeons, until Benetti et al. [22] proposed mammary artery-to-LAD anastomosis on a beating heart via a small left thoracotomy incision. He presented his initial experience in a meeting on arterial conduits in Rome, organized by Possati & Calafiore in 1994. The procedure was named MIDCAB (minimally invasive direct coronary artery bypass). The clinical experience was disseminated worldwide by Benetti, and was popularized by others. Calafiore et al. [23], in Chieti, described details of this attractive strategy and named this procedure “LAST” (Left anterior small thoracotomy). This led to renewed interest in beating heart coronary artery bypass surgery, as it was realized that it was possible to perform excellent anastomoses, not only via LAST operation, but also via median sternotomy.

In 1982, there were only five reports on off-pump coronary artery surgery. By 1992, there were 18, and in 1998, there were approximately 18,423 publications. This reflects important subsequent developments, such as the concept of hybrid approach, and the development of mechanical stabilizers [24-26]. In the hybrid approach, the mammary artery was first anastomosed to the left anterior descending coronary artery (LAD) via a small left thoracotomy (MIDCAB). Before or after this procedure, percutaneous angioplasty was performed to other stenotic coronary arteries [27-29]. Stabilizers, either using compression or suction, facilitated construction of the distal anastomoses, providing regional coronary artery stability. Suction devices, allowed for displacement of the heart anteriorly, like an ectopia cordis, further facilitating exposure of the marginal coronary branches.

During the next decade, there were mainly observational studies and few randomized clinical trials comparing on and off pump coronary artery surgery in terms of morbidity, mortality, inflammatory response, patency rates, stroke, blood transfusion, costs, hospital mortality in high risk patients, and others [30-41]. Controversial results from these studies led to different opinions regarding the routine application of off pump coronary surgery [42-48]. This seemed to be mostly due to improper training, case selection and excessive enthusiasm, as surgeons attempted to apply this alternative of revascularization to all patients. Such is the case of report that appeared in the *New England Journal of Medicine* by the Rooby group [49]. In that report, it becomes apparent that it is important to have the proper indication and training, despite technological advancements. One has to consider that, conventional CABG offers excellent results, and off-pump coronary surgery has to demonstrate either equal or superior results to achieve widespread acceptance.

In our experience, the limitations of off pump coronary artery surgery are related to patients with hypertrophic left ventricles, diffuse atheromatous coronary arteries that will need coronary endarterectomy, intramyocardial coronary arteries, and unstable patients. Improper indications may cause unacceptable conversion rates, usually associated with worse outcomes [50]. More recently Guida et al. [51] proposed multivessel revascularization on a beating heart via antero-lateral thoracotomy, in a track program fast. It is expected that applicability of off pump coronary artery bypass surgery will increase, as technology develops. In the USA applicability of beating heart coronary artery bypass surgery is 17%-20%, indicating that the majority of cardiac surgeons still prefer the conventional approach.

Retrospective analysis of our total experience with off-pump myocardial revascularization during 30 years showed reduction in mortality, stroke, major postoperative complications, hospital stay, and lower costs [52]. The

differences between on and off pump coronary artery surgery regarding mortality and morbidity can be shown only in high risk patients, such as those with co-morbidities, calcified aorta, pulmonary and renal insufficiency, previous strokes, and elderly patients among others [53].

In recent years, Totally Endoscopic Coronary Artery Bypass (TECAB) was developed using port access and robotic technology [54-57]. Few centers have experience with this rather expensive procedure, and it is used in selected patients.

Our routine use of OPCAB surgery indicates that this alternative of myocardial revascularization offers excellent, and perhaps superior results compared to conventional coronary surgery. The technique has become part of the armamentarium that surgeons can use to revascularize the heart. It is possible to anticipate that, with a new generation of stents, the hybrid approach will gain acceptance, with mammary artery to LAD via a minimally invasive approach, and coronary stenting for other coronary arteries. As the demand to reduce invasiveness of surgery, future generation of cardiac surgeons will have to further develop new alternatives for surgical myocardial revascularization, going beyond beating heart coronary surgery, hybrid approaches, robotic surgery, and other procedures to be developed.

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