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Usefulness of Applying Temporary Intracoronary Shunts for Myocardial Revascularization

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Abstract

The latest literature review on application of intracoronary shunts in anastomoses for myocardial revascularization in patients with coronary heart disease has been presented here. Advantages of the use of this technique (continuous myocardial perfusion, improved anastomosis location visualization, unlimited time for bypassing), which minimize any possible complications have been analyzed.

Keywords: Cardiac ischemia; Myocardial revascularization; Intracoronary shunts

Introduction

Improvement of coronary heart disease (CAD) treatment options, including patients suffering from acute myocardial infarction (AMI), is a pressing issue, in particular in terms of surgical myocardial revascularization techniques [1-13]. At the moment, coronary angioplasty, involving stenting, and coronary artery bypass graft surgery (CABG) are the basic myocardial revascularization techniques. CABGs are cardiopulmonary bypass surgeries or surgeries on a beating heart. For the purpose of limiting post-op complications and mortality, new surgical myocardial revascularization techniques have been developed now. It is well known that coronary surgery appeared as a surgical interference on a beating heart and then was expanded in the form of CABG, including cardiopulmonary bypass or excluding any cardioplegia, and it has been the basic surgical treatment method for patients with coronary heart diseases for over three decades [14]. However, further surgery evolution led to a reviving interest in operations on a beating heart again, as long as the cardiopulmonary bypass does not pose a danger for a number of complications [5-13,15-20]. Myocardial revascularization techniques on a beating heart, excluding cardiopulmonary bypass and cardioplegia, obviously have a potential advantage, allowing for minimization of any possible complications.

So far, ca. 25% of all coronary bypass surgeries are done globally on a beating heart [1-3]. An OPCAB (Off-Pump Coronary Artery Bypass) technique is used in 90% of cases at most cardiosurgical centers of the United States and Europe. The possibility of myocardial revascularization in patients that were denied the operation before, due to significant calcification of their ascending aorta and arterial sclerosis of carotid arteries and vessels of other systems against chronic respiratory and kidney disease, is one of advantages of this technique [14,20,21].

Introduction of special devices into clinical practice facilitated development of myocardial revascularization techniques on a beating heart. The use of local myocardial stabilization systems of vacuum and compression types allows for bypassing on a beating heart for practically all accessible coronary arteries. The effect of revascularization, based on regional and total myocardial contraction parameters, is usually already evident on the operating table, which is very important in patients with pronounced, but reversible ischemic myocardial dysfunction.

Advantages of Applying Temporary Intracoronary Shunts

It is common knowledge that any manipulations on a beating heart may lead to a hemodynamic and electrical instability of the heart [17,18]. There are a number of key techniques available to ensure hemodynamic and electrical stability while the anastomosis is done is one on a beating heart. The use of temporary intracoronary stents during application of distal anastomoses is one of them [22,23]. Intracoronary stents are designed to ensure distal coronary blood flow during the bypass procedure. Earlier models were rather coarse—they were difficult to install and remove, they tended to bend, blood-flow parameters were low, and small models were not available. The latest generation models are more comfortable, that is, they are equipped with atraumatic tips, their blood flow specification is improved, and they are available in different sizes up to 1 mm [24,25].

Some surgeons use intracoronary stents on a regular basis, while the others make it an exceptional case when there is high risk, for example, a bypass of the anterior descending aorta involving collaterals in the proximal and distal parts, or large right coronary artery, and if clamping of the coronary artery leads to obvious ischemic or hemodynamic changes. Followers of this technique believe that minimized ischemia time improves the hemodynamic stability during the OPCAB and eliminates any rush during the bypass surgery [10-12]. The following is still debatable: do intracoronary stents ensure a sufficient distal blood flow, in particular in arterioles? The effect of the stunt on the endothelium is also under discussion. Some authors shared their observations of a significant damage to the endothelium, while the others found minimum effect only [15-17].

As already mentioned, creation of the dry surgical field and regional ischemia minimization are the key components of a successful bypass on a beating heart. Naturally, clamping of coronary arteries (CA) triggers an ischemic reaction. The patients usually tolerate well temporary clamping of a subtotally stenotic or occluded CA, provided there is a sufficient collateral blood flow. If there are not enough collaterals available, the ischemia may lead to a regional myocardial hibernation, somnolentia, and even infarction. This may lead to arrhythmias, hemodynamic instability, and a cardiopulmonary bypass may be necessary [3-21,24-28].

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It is useful to use temporary intracoronary stents to prevent regional ischemia. J. Murray was successful in using an aortal coronary stunt for surgeries on a beating heart in dogs already in 1954. The intracoronary stunt was introduced into surgical practice in 1975 to make it possible to do a bypass surgery on the dry surgical field [27].

Since the moment they have been introduced, temporary intracoronary stents have been used for classic CABGs and myocardial revascularization on a beating heart. The use of such stents allows us to avoid any left ventricular dysfunction during the bypass surgery, create the dry surgical field, and prevent any complications that are associated with the damage to the coronary artery wall while it is clamped (Capasso F. *et al.*) [4,19]. Temporary intracoronary stents are preferred for patients with unstable angina, poor left ventricular function, and in cases, when the bypass surgery takes a long time. Moreover, the use of intracoronary stents is indicated for patients with a thin-walled or calcified coronary artery, in which case the stunt serves as a coronary artery stabilizer and prevents its posterior wall from being sewn [4,28]. Intracoronary stents prevent arrhythmic episodes and hemodynamic instability [2]. Stents also serve as a bypass calibrator, that is, if the stunt can be removed easily, the bypass is working (L. Rivetti *et al.,* 1997) [24]. There are stents of the following types available: (a) aortal coronary and (b) intracoronary. Depending on the number of openings, there are the following stents available: with one opening (aortal coronary), with two openings, and with three openings.

The size of an intracoronary stunt, which requires a sufficient segment of the intact coronary artery to be available to install and remove the stunt freely, is a certain disadvantage of the intracoronary stunt. Moreover, any manipulations with the stunt may lead to intima dissection, especially in the areas of plague deposition, and require the surgeon to be careful. In other words, it is important for the stunt to be elastic, easily insertable and removable, accordingly, and to have radio-opaque heads. As it was mentioned previously, the earliest models had a lot of disadvantages; however, modern stents are more comfortable: they are equipped with atraumatic tips, their blood flow specification is improved, and they are available in different sizes up to 1 mm. It is very important to have a set of stents of various sizes available all the time. This allows for choosing the right stunt in each particular case and for avoiding plague dissection. Flo-Thru intracoronary stents of the latest generation satisfy these requirements.

Clinical Evaluation of the Use of Temporary Intracoronary Shunts According to Clinical Trials

As was mentioned above, intracoronary shunts ensure a good visualization in the place where distal anastomoses are applied, improve blood flow in the bypassed arteries, and prevent myocardial ischemia. However, there are still some issues unresolved, such as: Are intracoronary shafts clinically useful? Do they really ensure the adequate blood flow in the arteries? and Does their implantation cause any endothelium damage?

Some authors that practice coronary artery clamping during application of distal anastomoses as a part of CABG on a beating heart consider this technique to be technically easy, as long as it ensures the dry surgical field better versus intracoronary shunts; besides, a short ischemic period is usually tolerated well by the myocardium. Moreover, insertion and further removal of the shunt from the artery presents extra technical difficulties that may cause damage to the vessel intima. A longer time of application of the distal anastomosis is another disadvantage of intracoronary shunts.

O. Dapunt *et al.* and S. Gandra and L. Rivetti [19,24,25] presented independent experimental data on the usefulness of temporary intracoronary shunts. Each of the studies was based on outcomes of surgical treatment of two groups of pigs (a bypass between the internal thoracic artery and anterior interventricular artery on a beating heart was done). Temporary intracoronary shunts were used in the first group, and classic clamps of coronary arteries were used in the second group. O. Dapunt *et al.* [19] demonstrated that cardiac output decreased significantly in the second group during bypassing with further reduction of left ventricular contractile function [9-13,15-19]. S. Gandra *et al.* [6,7] studied biochemical ischemic markers and showed that more enzymes (CPK, CPK-MB, catalase, troponin-I) were released in animals that underwent bypassing that involved clamping of coronary arteries.

F. Capasso *et al.* [4] compared the results of myocardial contractile function with the aid of transesophageal echocardiography in two groups of patients that underwent the bypass surgery using the intracoronary stunt or clamping coronary arteries. There were not any significant changes of global and regional myocardial contractility observed in patients where intracoronary shunts were used. To the contrary, a deterioration in myocardial contractility was recorded in patients with clamped coronary arteries at the very beginning of anastomosis formation. Myocardial contractility was back to normal just in 5 min after reperfusion started in this group of patients.

M. Yeatman *et al.* [16] measured hemodynamic parameters in patients with multiple lesions of coronary arteries that underwent bypass surgery on a beating heart, whether using intracoronary shunts or not. These patients were divided into two groups. The first group (20 patients), using a stunt, and the second group (20 patients), clamping coronary arteries. Hemodynamic parameters were measured before and after distal anastomoses were applied. A critical damage to three coronary arteries and left ventricular EF over 40% was observed in all patients. Patients suffering from the acute myocardial infarction, emergency surgeries, and repeated surgeries were not included in the study. Application of the anastomosis on the anterior interventricular artery was accompanied by a significant decrease in stroke volume (SV), cardiac index (CI), a decrease in blood pressure (BP), an increase in pulmonary capillary wedge pressure, and systemic vascular resistance in the second group. During application of the anastomosis on the posterior interventricular branch of the right coronary artery, a decrease in SV and CI was observed, while central venous pressure (CVP) increased in both groups; at the same time an increase in cardiac rate, pulmonary capillary wedge pressure, and systemic vascular resistance was observed in the second group only. The most prominent hemodynamic changes, such as: a decrease in SV, CI, systemic BP and an increase in CVP, pulmonary capillary wedge pressure, and systemic vascular resistance were observed in both groups during application of the anastomosis on the circumflex branch of the left coronary artery. These changes were intermittent in all cases and returned to their initial values after the heart was placed back in its anatomical position while SV and CI remained reduced in the second group, and systemic vascular resistance was high in all cases. However, there was not any significant difference in postoperative mortality level, number of perioperative myocardial infarctions, or need of cardiotonic agents, or duration of staying at the ICU among the patients of these study groups observed.

A. Gürbüz *et al.* [1] presented their research, aiming to evaluate the effect of intracoronary shunts on myocardial damage based on cardiac markers during isolated bypassing of the anterior interventricular artery. Forty patients made the study group, and they were divided into two groups (20 patients with an intracoronary shunt applied and 20 patients with no intracoronary shunt applied). Cardiac markers (troponin I, CPK, CPK-MB) were measured 24 h before the surgery and a day after the surgery. There was not any significant difference between CPK and CPK-MB levels found before and after the surgery, and post-op troponin I level was much higher in the group, where intracoronary shunts were not used. The authors concluded application of intracoronary shunts to facilitate reduced myocardial ischemia and minimize any myocardial damage.

Thus and so, the literature data attest to the fact that the use of temporary intracoronary shunts during application of the distal anastomosis in surgical revascularization on a beating heart ensures hemodynamic stability and protects the myocardium against ischemia, as compared to the bypass, involving coronary artery clamping, where reduction of left ventricular contractile function is observed. Nevertheless, it is significant that the above study did not reveal any differences in the clinical outcome of both bypassing techniques. One should point out that the study was done for a group of low-risk patients. There are not any findings of randomized clinical trials for high-risk patients, such as with poor left ventricular contractile function (EF 30%), acute coronary syndrome, or repeated surgeries published yet.

The Effect of Intracoronary Shunts on Endothelium Condition

It is well known that endothelial cells play a key role in regulating vascular homeostasis (L. Perrault) [14,20]. Any mechanical contact with the endothelium damages the endothelium. There are some data available that the use of intracoronary shunts is associated with a mechanical damage to the endothelium of coronary vessels. However, the damage to the endothelium during the surgery may also be triggered by the use of locking sutures around coronary arteries, clamping the artery with a bulldog clamp and clips, as well as gas insufflation in the area of anastomosis (L. Perrault *et al*. 1997) [20]. This factor must be considered by all cardiothoracic surgeons and requires extra careful manipulations on the vessels from such surgeons.

L. Perrault *et al.* [20] experimented and inflated a balloon via an endovascular access inside coronary arteries of pigs and thus caused a dysfunction of the epithelium of such vessels 30 days prior to the surgery and then compared the results of action on the vessel wall after the use of intracoronary shunts and clamping of arteries with silicone sutures. There were not any significant differences found between the use of these techniques, that is, spastic vascular function did not undergo any changes, and the integrity of main smooth muscle cells of coronary arteries was preserved.

J. Wippermann *et al.* [22] used intracoronary shunts and clamps of coronary arteries in their experiment on pigs. These pigs were killed 3 months after the surgery, and their vascular endothelium was studied using an electronic microscope. The authors demonstrated the damage to the intima of coronary arteries to be observed in both cases.However, such endothelial damage was more prominent in the vessels that were once clamped. According to them, the integrity of coronary arteries is better preserved if intracoronary shunts are used. Nevertheless, one should not ignore any damage to the endothelium and subendothelium by pressure of convex ends of intracoronary shunts (especially when too big shuts are used). However, there are not any persuading data provided on the effect of intracoronary shunts on the muscle layer and adventitia of coronary arteries, while a damage to all layers of a vessel may be the outcome of clamping such vessel.

The Effectiveness of Blood Flow in the Intracoronary Shunt

It is important to choose an intracoronary shunt of the right diameter, depending on the initial coronary artery opening. An increasing possibility of a mechanical damage to the arterial endothelium with a bigger stunt, and inadequate blood flow and inability to create a dry surgical field with a small stunt must be considered.

This issue was studied by R. Demaria *et al.* [5]. An experimental study was done on normal coronary arteries in pigs to evaluate the endothelium morphology after intracoronary stents of three different sizes have been installed. Moreover, the intensity of bleeding from the coronary arteries during implantation of the stents of different sizes was determined. Finally, it was determined that the optimum stunt size is 75% of the artery size, for example, a 1.5 mm stunt is adequate for a 2 mm vessel. This correlation is practically ideal for the creation of the dry surgical field, endothelium damage prevention, and for the adequate blood flow through the stunt.

Grunenfelder *et al.* [10] studied a correlation between pressure in a coronary artery and volumetric flow rate through a stunt in vitro. They showed that flow rate via a 1.5 mm stunt is 40 ml/min against systemic pressure of 75 mm Hg and, correspondingly, over 40 ml/min with larger stents. According to these data, 1.5 and 2.0 mm stents can provide for an adequate myocardial perfusion even at blood pressure of 75 mm Hg.

Thus and so, the use of intracoronary stents as an alternative to clamping coronary arteries during surgical myocardial revascularization on a beating heart is still open for debate. Many surgeons are certain of the usefulness of intracoronary stents, as long as they allow for more precise bypassing [1-10,22,23,25-28]. The right stunt that fits the corresponding coronary artery ensures hemodynamic and electric myocardial stability, dry surgical field, and prevents the risk of sewing the rear wall of the vessel. However, there are some data available about damage done to the intima of coronary arteries after intracoronary stents were used. Moreover, according to some surgeons, certain technical issues that are associated with limited needle movement and stunt sewing arise during the use of intracoronary shunts, and placement of the stunt inside the stunted coronary artery requires extra careful manipulation, consequently leading to a prolonged bypass procedure.

Thus and so, current development of the coronary surgery dictates a much deeper research of the intracoronary stunting technique in terms of their safety and efficiency.

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