Intracoronary shunt prevents left ventricular function impairment during beating heart coronary revascularization

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Received 21 September 1998; received in revised form 23 November 1998; accepted 30 November 1998

Abstract

Objective: Beating heart coronary revascularization is becoming increasingly popular worldwide. Temporary occlusion of the coronary artery is often required in order to perform the anastomosis. An alternative method to maintain perfusion is to use an intracoronary shunt. In this study, we monitored global left ventricular function and regional wall motion in the presence or absence of a shunt using transesophageal echocardiography (TEE).

Method: Left ventricular wall motion score index (WMSI), wall motion score (WMS) in the left anterior descending (LAD) coronary artery territory, and ejection fraction (EF%) were measured by multiplane TEE during construction of the left internal mammary artery (LIMA)-LAD coronary artery anastomosis in 40 patients undergoing revascularization with or without the use of a shunt. WMSI was assessed preoperatively, 1, 3 and 6 min during the construction of the anastomosis and after 5 min of reperfusion. WMS was assessed at 6 min during anastomosis and after 5 min of reperfusion. EF% was calculated preoperatively, 5 min into the construction of the anastomosis, and 5 min after reperfusion.

Results: During construction of the anastomosis, when the shunt was used, there were no changes in WMSI, WMS in the LAD territory or EF%. A significant decline in these parameters was seen in the group in which the shunt was not used, although on reperfusion all the values returned to baseline control.

Conclusion: (i) occlusion of the LAD to perform the anastomosis results in temporary impairment in left ventricular function with complete recovery on reperfusion; (ii) the use of an intracoronary shunt presumably by maintaining myocardial perfusion prevents deterioration in ventricular function; (iii) from this data it seems therefore advisable to use an intracoronary shunt in patients with unstable angina, poor left ventricular function, or in cases in which a longer time to perform the anastomosis is anticipated. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Transesophageal echocardiography; Beating heart coronary surgery; Intracoronary shunt

1. Introduction

Coronary artery bypass grafting without the use of cardiopulmonary bypass, both through a sternotomy or a small anterior thoracotomy, is now being reported from different centers all over the world, with good results [1–3]. Nevertheless, concerns still exist regarding occlusion of the coronary artery, which is necessary to control blood flow when performing distal anastomoses. This can produce temporary regional ischemia in the myocardial territory supplied by the occluded vessel. Intravascular coronary shunts have been introduced into clinical practice in order to maintain perfusion and allow the construction of the anastomosis in a bloodless field [4–6].

The development of myocardial revascularization on the beating heart has found in transesophageal echocardiography (TEE) a useful tool for intraoperative decision making. TEE can detect regional ischemia and the resultant impairment of global and regional myocardial contractility often earlier than electrocardiographic monitoring [7–11].

In this study, TEE was used to monitor global and regional wall motion in the presence or absence of an intracoronary shunt, in patients undergoing beating heart coronary artery revascularization.
2. Material and methods

Forty consecutive patients (M/F: 32/8; mean age: 62 ± 7.1 years) undergoing a single left internal mammary artery (LIMA) to left anterior descending (LAD) coronary artery bypass graft on the beating heart via median sternotomy were prospectively recruited. An intracoronary shunt was used in every alternate patient. Inclusion criteria were patients with stable angina refractory to medical therapy, with no history of recent myocardial infarction (<2 months), previous coronary artery bypass surgery or associated valvular disease. An occluded LAD was an exclusion criteria. The study was approved by the hospital Ethical Committee. Patients’ informed consent was obtained.

2.1. Operative technique

Anaesthetic technique was standardized for all patients. Subdural anesthesia as a single injection (2 mg morphine) was used at the level of T11 to L3. General anesthesia consisted of intravenous anesthesia with Propofol infusion at 3 mg/kg per h combined with Remifentanil infusion at 0.5–1 mg/kg per min. Neuromuscular blockade was achieved by 0.1–0.15 mg/kg Pancuronium Bromide or Vecuronium and the lungs ventilated to normocapnia with air and oxygen (45–50%) without positive end expiratory pressure (PEEP). Volatile agents were delivered in 50% air-O2 mixture for maintenance. Systemic hypothermia was avoided by adjusting operating room temperature and infusing warm solutions. Neither beta- or calcium-blockers were used to slow the heart rate. Alpha stat acid-base management was adopted and partial anticoagulation was accomplished with 1 mg/kg body weight of heparin which was reversed at the end of the operation by protamine sulphate.

All patients were operated on through a midline sternotomy, and all a LIMA-LAD coronary artery bypass grafting performed on beating heart. Hemostatic tourniquets (5–0 Prolene) above and below the chosen point of anastomosis on the LAD and a blower with gas line and administration set (Visisflow, Baxter, Midvale, USA) were employed to obtain a bloodless anastomotic field. The hemostatic tourniquets were tightened just after arteriotomy and no precon-ditioning protocol was applied. In all patients a CTS retractor (CardioThoracic Systems, Cupertino, CA) was used to stabilize the LAD, and the anastomosis was performed with a single 8–0 Prolene continuous suture. In the shunt group, after opening the LAD an intracoronary shunt (2.0, 2.5, 3 mm according to the lumen of the LAD) (Anastaflow Intravascular Shunt, Research Medical, Midvale, USA) was insertedatraumatically into the coronary artery, and the hemostatic tourniquets were then released.

2.2. Intraoperative TEE

After endotracheal intubation, a multiplane 5.0 MHz phased array transducer mounted on the tip of a flexible gastroscope was introduced into the esophagus and connected to a Vingmed System 5 ultrasonograph (Sonotron, Bedford, UK). Continuous two-dimensional echocardiograms were monitored throughout the periods from endotracheal intubation to the end of the operative procedure. In order to monitor all the left ventricular segments, cross-sectional echocardiograms were recorded on videotape at the mitral valve (basal segments), papillary muscle (middle segments) and apical (distal segments) levels. Two and four chamber views were also recorded. Left ventricular contrac-tility was analyzed according to the method described by Segar et al. [12]. This technique involves dividing the left ventricle into 16 segments, which are then graded using the score: 1 (normal), 2 (hypokinetic), 3 (akinetik) and 4 (dys-kinetic). The wall motion score index (WMSI) is then calculated as the sum of the scores of the left ventricular segments divided by the number of segments evaluated, with higher numbers representing increasing degree of left ventricular wall motion abnormalities. Ejection fraction was calculated by the area-length single flow method obtained with the TEE probe in the mid oesophageal portion and the transducer oriented to 0°. In this way, it was possible to obtain a four chamber view including the whole apical segment of the left ventricle [13].

Wall motion score index was assessed before occlusion of the LAD as the control value, then 1, 3 and 6 min during the construction of the anastomosis and after 5 min of reperfusion of the LAD with the LIMA graft. Wall motion score in the LAD territory was also calculated using the same method. This relatively simple scoring scheme allows the operator to assign a number to the examination which is proportional to the severity of the left ventricular wall motion abnormalities. Ejection fraction was calculated by the area-length single flow method obtained with the TEE probe in the mid oesophageal portion and the transducer oriented to 0°. In this way, it was possible to obtain a four chamber view including the whole apical segment of the left ventricle [13].

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All values are expressed as the mean ± standard error of the mean (SD). Data were compared with the χ2 or Fisher’s exact test as appropriate. Differences between the measured echocardiographic parameters were assessed by analysis of
variance (Fisher’s protected least significant differences) using a Statview package provided on a Macintosh personal computer. A P-value less than 0.05 was considered statistically significant.

3. Results

There were no deaths in the study. The clinical information is presented in Table 1. The two groups were similar with respect to sex, age, preoperative ventricular function, extent of coronary artery disease, time of LIMA-LAD anastomosis, ITU and hospital stay. Furthermore the control WMSI and WMS in the LAD territory was similar in the two groups.

During construction of the anastomosis, when the shunt was used, there were no significant changes in WMSI, WMS in the LAD territory and EF% compared with the control values. However, a significant decline in these parameters was seen in the group in which the shunt was not used (Figs. 1–3). The decline in WMSI started soon after occlusion of the LAD at 1 min of ischemia, continuing to fall at 3 min and decreased significantly from control values at 6 min during construction of the anastomosis. Similar changes were seen in WMS in the LAD territory (Fig. 2). The EF%, measured after 5 min of regional ischemia, was also significantly reduced compared with baseline levels. After 5 min of reperfusion, with the LIMA-LAD graft, WMSI, WMS in the LAD territory and EF% returned to control values.

4. Discussion

TEE has a pivotal role in the perioperative management of patients undergoing conventional CABG, especially for the analysis of segmental wall motion abnormalities associated with global or regional ischemia [7–12,14–17]. This study is the first to apply TEE to the perioperative assessment of left ventricular contractility, in patients undergoing coronary artery revascularization on the beating heart. The temporary occlusion of the coronary to perform the anastomosis is a model of regional ischemia totally independent from factors such as the type of cardioplegic solution used, myocardial temperature, the use of cardiopulmonary bypass and different reperfusion protocols. In the context of beating heart surgery, TEE offers several advantages when investigating myocardial function in response to ischemia and reperfusion: (a) the immediate detection of segmental wall motion abnormalities and global myocardial mechanical response to the ischemic insult as it is applied; (b) the effectiveness of compensatory collateral circulation; and (c) the immediate evaluation of functional recovery after revascularization.

The potential damaging effects of regional ischemia necessary to create a bloodless field for coronary bypass grafting is one of the main concerns of beating heart revascularization. In a previous study [18] we have shown that temporary occlusion of the LAD for periods up to 14 min, in patients undergoing beating heart coronary revascularization, did not cause significant metabolic changes, as demonstrated by preserved levels of intracellular ATP, ADP and total amino acids in ventricular biopsies. Nevertheless, it is evident from this study that occlusion of the LAD to perform the anastomosis is associated with a significant impairment in left ventricular function which returned to baseline values on reperfusion.

The most important finding in this study was the observation that the use of an intracoronary shunt prevented any deterioration of left ventricular function during construction of the anastomosis. Since its introduction into clinical practice in 1975 [4], the temporary intracoronary shunt has been used during conventional and beating heart coronary bypass surgery. Rivetti and Gandra [6] reported excellent short- and long-term results in more than 400 off-pump CABG cases with the use of an intracoronary shunt. With this device, several of the technical hazards of off-pump CABG can be dealt with or prevented. The shunt effectively avoids

<table>
<thead>
<tr>
<th>Variable</th>
<th>Shunt group</th>
<th>Non-shunt group</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>63.2 ± 6.5</td>
<td>62.1 ± 6.1</td>
</tr>
<tr>
<td>Sex (m/f)</td>
<td>18/2</td>
<td>19/1</td>
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<td>2</td>
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<td>Previous MI</td>
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<td>5</td>
</tr>
<tr>
<td>Proximal LAD stenosis (≥ 60%)</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Mid LAD stenosis (≥ 60%)</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>40.0 ± 5.8</td>
<td>40.7 ± 3.5</td>
</tr>
<tr>
<td>Anastomosis time (min)</td>
<td>11.2 ± 1.2</td>
<td>9.9 ± 0.9</td>
</tr>
<tr>
<td>Intensive care stay (days)</td>
<td>1.0 ± 0.0</td>
<td>1.08 ± 0.02</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>5.7 ± 1.6</td>
<td>5.8 ± 1.5</td>
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*Data is expressed as mean ± standard error (SD).
ischemia during the construction of the anastomosis. It also allows work in a bloodless anastomotic field, prevents inadvertent stitching of the back wall of the coronary artery and it allows the removal of the occlusive coronary snare which have been reported in same cases to be responsible for coronary artery damage [19].

In patients in whom the shunt had not been used, on opening of the LIMA-LAD anastomosis, there was an immediate improvement in contractility in those regions that had become hypokinetic or akinetic during LAD occlusion, with a complete return of WMSI and EF to preoperative levels. This picture differs substantially from the extensively described transient depression of ventricular contractility which is common after myocardial revascularization with cardioplegic arrest and cardiopulmonary bypass [20]. This mechanical dysfunction, which is usually reversible within 24–48 h, is most likely caused by myocardial stunning, which in subgroups of high risk patients may have serious effects on morbidity and mortality. The observation that coronary revascularization on the beating heart is not associated with post operative global or regional myocardial stunning, makes this technique appealing, especially in patients with depressed preoperative left ventricular function.

5. Conclusions

The information derived from TEE has a definite influence on anaesthetic and surgical decision making during beating heart coronary artery bypass grafting. The use of an intracoronary shunt prevents impairment in left ventricular function during construction of the LIMA-LAD anastomosis. It seems therefore advisable to use an intracoronary shunt in patients with unstable angina, poor left ventricular function, or in cases in which a longer time to perform the anastomosis is anticipated.

References

Appendix A Conference discussion

Dr R. Dion (Brussels, Belgium): I would just like to make a remark on one of your slides. What you showed is that there is a four times higher level of troponin I excretion in conventional bypass surgery, but the absolute amount of troponin I excretion is nearly nothing. Of course it is nothing in MIDCAB, but it is four times nothing in conventional cardiac surgery, and therefore it is clinically irrelevant.

Dr Angelini: No, I don’t agree with you, in fact I totally disagree, because what you get in the group who were put on bypass, are regarded as significant value of ischemia. It doesn’t mean these patients had suffered a myocardial infarction. Troponin only comes out from cells which actually die. Now, only a few cells may die, so you don’t get a value enough to say you have had an MI, but that doesn’t mean there hasn’t been damage.

Dr Dion: But your scale didn’t go to 1.5, did it?

Dr Angelini: But there was what is considered significant value of ischemia.

Dr V. Subramanian (New York, USA): How did you choose the shunt group here? Was it blinded or was it random you chose the shunt group? It is important, I think.

Dr Angelini: Every other patient. It wasn’t a proper randomization study. Every other patient got a shunt.

Dr Subramanian: Why didn’t you blind it?

Dr Angelini: We did not think it was necessary.

Dr Subramanian: We have been using intra coronary LAD shunt for the past 9 months routinely. One of the significant advantages we have seen is an internal stabilization effect of a shunt. The anastomotic problem which is the main problem, because then you occlude the native flow. However, I find also that you are doing an anastomosis with something in the middle, so the view sometimes is not so good. Of course, you also have vessels which are very diseased with atheroma, and to put a shunt in those cases may be a recipe for disaster.

Dr Subramanian: I agree with you.

Dr Y. Jawali (Bangalore, India): From October 1995 until today, we have done 152 MIDCABs. I have two quick comments. Comment number one, from the case one, we have been doing troponin studies in the immediate postoperative period, and we noticed in the era of shunts that those shunts which caused injury requiring a stitch, they always showed a slight rise in the troponin, and we are not really able to find any good clinical correlation of the LV shown by troponin. Number two, like Dr Subramanian, for the last 3 months we have started putting shunts for every patient, because it has taken away the need for us of putting shunts, and we are very happy with it.

Dr R. De Simone (Heidelberg, Germany): You used a wall motion score based on transesophageal echocardiography.

Dr Angelini: Transesophageal.

Dr De Simone: You did it with transesophageal echocardiography, but that score is only validated for transthoracic echocardiography. The reason is that you are missing some myocardial regions, for example, the apex. How did you compensate for this? This method has been only validated on transesophageal echocardiography.

Dr Angelini: First of all, don’t shout at me because I am not an echocardiographer. I just read the paper before giving this talk. But what I understand is two things; that in this way you can have a short axis taken at three levels: one is at the level of the mitral valve, one is at the level of the papillary muscle, and one is at the level of the apex. Then you can take long axis, and you can have a four-chamber view. When you are comparing a patient as a control and after intervention, you have to maintain the angle and the distance of your scope, which in this case was kept the same distance with the incisive teeth. As far as I know, this is a well-recognized method.

Having said that, even if it wasn’t a validated method, what in the study was compared was each individual patient to start with. So each individual patient is his own control. So if you get a value and then as long as it’s reproducible, when you do an intervention you get a different value, you have a difference.

Dr De Simone: I agree with you, it is not validated, but you can use it for serial examinations.

Dr F. Benetti (Santa Fe, Argentina): We have the same experience with troponin, and also now we are doing a study with fast MRI that shows clearly that the patient that you put on pump also with different methods have edema in the myocardium and not in the patient without pump. So I think there are a couple of studies also, we did myocardial biopsies 20 years ago that showed clearly that there is a difference between these two situations.

Dr Angelini: We just did some biopsies as well, again, patient on pump or off pump, and you get significant changes on bypass during reperfusion, which you do not see if you do them off pump, and this is direct ventricular biopsy.

Dr S. Wu (Katowice, Poland): In stenosis or occlusion of LAD, we quite often observe the development of collateral circulation between LAD and RCA. My question is: did you take into consideration the collateral circulation between the right coronary and LAD?

Dr Angelini: No, we didn’t, but this is a very good point, and in fact we have seen, not in this group of patients but in patients in whom you got a suboccluded right coronary, if you got an LAD which supplies blood to the right or vice versa, then it is easier to get into trouble if you don’t have a shunt.