Complete arterial coronary revascularisation using radial artery conduit for double thoracic artery inlet flow: arterial sling operation

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Abstract

Background: Coronary artery bypass graft surgery with arterial revascularisation of all diseased coronary vessels is considered highly efficient because arterial grafts have an excellent long-term patency compared with venous grafts. However, problems to reach the infero-lateral wall with the in situ internal thoracic arteries usually require alternative techniques. We present the first results of a new surgical principle using a free radial artery segment to complete the arterial coronary revascularisation and concomitantly connect the internal thoracic arteries.

Methods: In patients referred for coronary bypass surgery and three-vessel disease an end-to-end anastomosis of the right internal thoracic artery and the radial artery segment preceded cardiopulmonary bypass, during which side-to-side anastomoses of the radial artery segment were used to revascularise stenotic branches of the right coronary and circumflex arteries. The left internal thoracic artery was used for revascularisation of stenotic branches of the left anterior descending artery, and finally an end-to-side anastomosis of the radial artery segment to the left internal thoracic artery was performed. Coronary artery blood flow was measured in 41 patients with Doppler flow probe.

Results: One hundred and ninety-two coronary anastomoses (an average of 4.2 per patient) were performed in 46 patients. We measured a mean total blood flow in the arterial sling graft of 104 ml/min (range 35–221 ml/min), compared with 69 and 68 ml/min of the single inlet right and left internal thoracic arteries, respectively (P<0.01). Flow capacities of 104 and 120 ml/min of the right and left internal thoracic arteries were measured during clamp of both the aorta and the contralateral internal thoracic artery. The mean crossclamp duration was 77 min (range 51–113 min). Postoperative angiography demonstrated patent graft anastomoses to all coronary arteries. There were no perioperative deaths or myocardial infarctions. One patient had a minor postoperative stroke.

Discussion: Complete arterial revascularisation can be achieved by the arterial sling operation with an acceptable crossclamp time and a high early rate of graft patency. The double arterial inlet provides a 50% higher blood flow to the beating heart and two-fold increase in the flow reserve compared with a single inlet. Although further research including long-term follow-up of this new principle is required, the present findings seem promising and suggest that the arterial sling operation has a potential role for complete arterial coronary revascularisation.

Keywords: Arterial revascularisation; Radial artery conduit; Arterial sling operation

1. Introduction

Coronary artery bypass surgery using the in situ internal thoracic artery has substantially improved graft patency compared with revascularisation with saphenous vein grafts [1–3], and it appears that the use of multiple artery grafts is of clinical benefit for the patients [4]. Total arterial coronary revascularisation is now possible with a low mortality and morbidity. As a result, exclusive use of arterial conduits has been the goal for many cardiac surgeons, although no long-term experience with this principle exists, and randomised trials to demonstrate its superiority to the combined arterial/venous graft operation are lacking [5,6].

Both the in situ epiploic artery and a free radial artery can aid to achieve total arterial coronary revascularisation [7,8]. The radial artery can even constitute one leg of an arterial Y or T graft by its end-to-side insertion onto the in situ left internal thoracic artery [6]. By employing these techniques all branches of the coronary tree can be reached, and side-biting clamps on the ascending aorta omitted. On the other hand, the use of the left internal thoracic artery as the only proximal bypass graft inlet makes the poststenotic myocardial blood flow totally dependent on the flow capacity of this internal thoracic artery and its proximal sources, a capacity...
that is or may become limited in some patients e.g. those developing left-sided subclavian artery stenosis.

In order to obtain a double arterial inlet to the myocardium to be revascularised, the radial artery can be used as a connecting conduit between the internal thoracic arteries. This technique may prove particularly efficient in patients in whom the myocardium requires a high blood flow distal to the coronary stenoses, e.g. patients with a severe left main coronary artery stenosis or patients with multivessel disease. In addition, the technique may prove superior in patients with a low flow in the left internal thoracic artery (e.g. women).

2. Methods

2.1. Patients

The indication for the arterial sling operation was the wish to perform total arterial coronary revascularisation in patients with three-vessel disease and a left ventricular ejection fraction >35%. In addition, patients with saphenous veins unsuitable for grafting were offered this operation. A prerequisite was a normal Allen’s test on the arm from which the radial artery was harvested, and a difference in blood pressure in the brachial arteries (measured sphygmomanometrically) less than 10 mmHg to avoid a steal phenomenon through the sling graft in patients with unilateral subclavian artery stenosis.

From February 2000 to January 2001, 46 patients (ten females), aged between 29 and 82 years (mean 60 years) with stable angina pectoris despite medical treatment underwent complete arterial coronary revascularisation with the arterial sling operation. All patients had significant (>50%) stenoses of both the left anterior descending, circumflex and right coronary artery or their major branches. Seven patients had insulin dependent and four non-insulin dependent diabetes mellitus. All patients consented to undergo the arterial sling graft operation after detailed information.

2.2. Surgical technique

All patients underwent revascularisation using cardiopulmonary bypass in normothermia. After median sternotomy the right internal thoracic artery was harvested without transection of its proximal end, followed by simultaneous harvesting of the left internal thoracic artery also without proximal transection and a segment of the radial artery. In right-handed patients the radial artery segment was harvested from the left arm and vice versa. It was harvested using electrocautery or ultrascision [9]. The radial artery segment was anastomosed end-to-end to the right internal thoracic artery before cardiopulmonary bypass was commenced. During cardiopulmonary bypass the radial artery segment was used to revascularise branches from both the right and circumflex arteries. The mean distance from the right internal thoracic/radial artery and the radial/posterior descending artery anastomoses was 3 cm. All anastomoses between the radial artery segment and the peripheral right coronary artery and marginal branches were done perpendicularly side-to-side (diamond shape). Then the left internal thoracic artery was anastomosed end-to-side to the left anterior descending artery and perpendicular to the diagonal branch(es) whenever indicated. Finally the radial artery was anastomosed end-to-side to the left internal thoracic artery (Fig. 1).

Nitroglycerine was administered intravenously in a dose of 0.5 mg/kg/min for 16–20 h after surgery, and 5–10 mg of oral amlodipine was given for 3 months.

Angiography of the native coronary arteries and bypass grafts was performed 7–12 days postoperatively.

2.3. Measurements

Coronary artery blood flow was measured using 3.0 mm perivascular Doppler flow probes (Medi-Stim, Oslo, Norway) around the proximal internal thoracic arteries dissected free of surrounding tissue. Sterile gel was used for acoustic coupling. Measurements were performed bilaterally with and without clamping of the contralateral internal thoracic artery with the aortic crossclamp in place, and repeated 10 min after removal of the crossclamp, when the cardiopulmonary perfusion was terminated.

3. Results

The mean duration of cardiopulmonary bypass perfusion was 102 min (SD 17 min) and the mean crossclamp time 77 min (SD 15 min). Overall 192 distal coronary anastomoses were performed in 46 patients (average 4.2, range 3–7 per patient).
Table 1
Number and patency of coronary artery bypass anastomoses evaluated by coronary angiography 8–12 days postoperatively

<table>
<thead>
<tr>
<th>Target coronary artery</th>
<th>Graft LITA/radialis</th>
<th>Patency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>46/0</td>
<td>38</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>25/6</td>
<td>25</td>
</tr>
<tr>
<td>Diagonal 2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0/13</td>
<td>11</td>
</tr>
<tr>
<td>Marginal 1</td>
<td>0/16</td>
<td>14</td>
</tr>
<tr>
<td>Marginal 2</td>
<td>0/31</td>
<td>25</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>0/11</td>
<td>9</td>
</tr>
<tr>
<td>Posterior descending</td>
<td>0/37</td>
<td>30</td>
</tr>
<tr>
<td>Right coronary</td>
<td>0/5</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>73/119</td>
<td>158</td>
</tr>
</tbody>
</table>

* LITA, left internal thoracic artery.

There were no perioperative deaths or myocardial infarctions. The maximal postoperative rise in the CK-MB enzyme ranged from 10 to 79 μg/l (mean 39 μg/l).

One patient had a superficial infection in the sternum wound, but no patients had problems with healing of the sternum. We experienced no complications after harvesting of the radial artery segment. One patient developed left-sided hemiplegia before discharge that resolved almost totally within 3 months after surgery.

Four patients refused to have a postoperative angiography performed, and in four patients it was regarded contraindicated due to advanced age, recent stroke or allergy to the contrast medium. Thus, 38 patients had a postoperative angiography performed in whom all grafts and anastomoses were found patent (Table 1).

Flow monitoring could not be performed in five patients because the equipment was not available. The results of measurements in the remaining 41 patients are delineated in Table 2. Clamping of both the aorta and contralateral internal thoracic artery showed a flow capacity of the right and left internal thoracic arteries of 104 and 120 ml/min, respectively, compared with the internal thoracic artery flow competing with both the native coronary artery flow and the contralateral internal thoracic artery flow (Table 2).

The blood flow in the sling graft represented by the sum of the simultaneous flow in the two internal thoracic arteries was on an average 104 ml/min (50 + 54 ml/min) compared with 69 and 68 ml/min in the two internal thoracic arteries measured during contralateral clamping (Table 2).

4. Discussion

Our measurements showed a considerable higher flow in the internal thoracic arteries during clamping of both the aorta and the contralateral thoracic artery, a flow that was 52–76% higher than that measured after removal of the crossclamp, and 108–122% higher than flow measured after removal of all clamps. This capacity represents a myocardial blood flow reserve that could be of potential benefit and warrants further attention.

The arterial sling graft represents a novel approach in coronary revascularisation. All stenotic branches of the coronary arteries can be reached with the radial artery segment forming an anastomosing connection between the two internal thoracic arteries. Thus, instead of being an end artery it represents an arterial arcade with double inlet (Fig. 1). This double artery supply will minimise the consequences of reduced flow in one of the inlets due to either narrowing of one of the anastomoses or progression of atherosclerotic disease in the artery with time.

With two well-functioning arterial inlets, one segment of the radial artery may turn out to have low flow due to competing blood supply from the left and right internal thoracic artery sources and even from a grafted native coronary artery branch with a non-significant stenosis, and closure of the segment may ensue. Although this may cause discontinuation of the ‘sling’, we consider such a closure as the result of sufficient alternative blood supply.

In case a subclavian artery stenosis develops or worsens causing ‘steal’ of coronary blood supply to the upper limb, flow direction in the arterial sling graft may change. Should the radial artery segment remain open in its total course when such a flow change occurs, the consequences will potentially be less severe because of the double artery inlet.

Total arterial revascularisation using the left internal thoracic artery together with the free right internal thoracic or a radial artery segment as the leg of a Y graft is indicated in patients without veins of the limbs suitable for grafting, and the immediate results of this technique is well described [6]. We measured a 50% higher blood flow in the sling graft than through a single internal thoracic artery to the beating heart. Flow measurements of the left internal thoracic artery during and after aortic clamping in our study are therefore comparable with those described by Royse et al. [10].

Revascularisation of a stenotic left anterior descending artery with the in situ left internal thoracic artery has proved safe and efficient with respect to the long-term prognosis [1,2]. The use of two internal thoracic arteries seems to decrease both the risk of death and reoperation and the need of later angioplasty [4], and total arterial revascularisation can be performed with excellent short-term results.
[5,6]. However, randomised studies to elucidate the benefit of coronary revascularisation using the right or even bilateral in situ internal thoracic arteries in comparison with the usual combination of the left thoracic internal artery and saphenous vein segments have never been performed.

Connecting the right internal thoracic artery to the radial artery and anastomosing this to the left internal thoracic artery completes the arterial sling and allows complete arterial coronary revascularisation. The present results indicate that this surgical technique operation is safe and provides a high capacity of blood flow to the heart. The potential benefits of the operation in comparison with other current techniques will be evaluated.

Acknowledgements

John B. Christensen was the inventor of the new technique. Together with Jens T. Lund he planned the study, performed the operations and wrote the draft of the paper. Eli Kassis collaborated in the data collection and performed the angiograms together with Henning Kelbæk, who supported the data analysis and interpretation and supervised revisions of the paper.

References