Decreasing sternum microcirculation after harvesting the internal thoracic artery

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Abstract

**Objective:** The effect of harvesting the internal thoracic artery (ITA) on blood supply to the sternum is not completely understood. Using a novel laser Doppler flow meter, we evaluated changes in sternum microcirculation prior to and after ITA harvesting.

**Methods:** Forty-six patients (37 males, 69.4 ± 7.9 years) scheduled for coronary artery bypass grafting were enrolled into the study and divided into skeletonized (n = 23) and pedicled (n = 23) groups of patients with a left ITA. All right ITA were harvested using the skeletonized method. Sternal blood flow was measured presternally and retrosternally in the upper, middle, and lower sternal parts with a novel laser Doppler flow meter that measures blood flow at 1-mm depth using a 780-nm laser. Following median sternotomy, blood flow was measured before and after ITA harvesting.

**Results:** In all patients (46 left and 16 right ITA cases), the middle part of the retrosternal microcirculation deteriorated (middle: pre-2.71 ± 1.49, post-2.43 ± 1.01 ml min⁻¹ 100 g⁻¹; p < 0.05), while blood flow of other parts did not change. In patients with left ITA divided into skeletonized and pedicled groups, although middle retrosternal blood flow decreased after harvesting in both groups, there was no difference in deterioration between the groups. In patients with right ITA, the middle and lower retrosternal blood flow also deteriorated.

**Conclusions:** The degree of sternal microcirculation damage after ITA harvesting is not different between skeletonized and pedicled group patients, suggesting that skeletonization is not advantageous for maintaining sternal microcirculation.

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1. Introduction

It is well established that the internal thoracic artery (ITA) is the most reliable graft in patients undergoing coronary artery bypass grafting (CABG) due to its excellent long-term patency rate [1,2]. Recent evidence also indicates that bilateral ITA grafting further improves survival and reduces the need for repeat revascularization [2]. However, routine use of this technique is limited due to the potential for increased incidence of deep sternum wound infections [3–5]. Harvesting of the ITAs is considered to be associated with impairment of sternal perfusion [6]. Skeletonization of the ITA has been advocated to decrease the incidence of sternal infection, especially in patients with diabetes or those who have undergone bilateral ITA grafting [7,8]. By contrast, other studies suggest no difference in the incidence of sternum infection between patients with skeletonized ITA and conventional pedicled ITA [9,10].

Although there is experimental evidence suggesting that the harvest technique may affect sternum blood supply after harvesting of the ITAs [7], the effect of ITA harvesting on sternal blood supply in human subjects is not completely understood. Thus, the aim of this study was to evaluate the quantitative changes in human sternum microcirculation prior to and after harvesting of the ITA using different harvesting methods. To measure blood flow, we used a novel laser Doppler flow meter that measures the blood flow at a 1-mm depth by detecting the movement of red blood cells using 780-nm laser light.

2. Patients and methods

2.1. Patient characteristics

From January 2008 to December 2009, 46 patients who underwent CABG with ITA grafting were enrolled in this study (37 male and nine female; mean age 69.4 ± 7.9 years; range 49–84 years). The patients were divided into the pedicled left ITA (LITA) harvesting group (group P, n = 23; mean age 68.7 ± 7.0 years) and the skeletonized LITA harvesting group (group S, n = 23; mean age 70.1 ± 8.8 years), according to
the velocity and scatter angle. Tissue blood flow can be determined by the moving erythrocytes shifts in frequency, and is dependent on the ratio of the static tissue volume to the erythrocytes volume in the tissue sample.

2.3. Intra-operative protocol

After completion of a conventional median sternotomy, the laser Doppler flow meter probe was placed on the left upper, middle, and lower parts of the presternal side. When RITA harvesting was required, we also measured simultaneous blood flow on the right side. The tissue blood flow of the left upper, middle, and lower sternal parts of the retrosternal side was measured after dissection of fat tissue just below the sternum (Fig. 1(B)). Measurement of the right side was also performed after the removal of fat tissue below the right sternum. When harvesting of the LITA or RITA was completed, the patient received 300 IU heparin/kg body weight intravenously, and the LITA or RITA was divided. The probe was then placed on the same points as prior to harvesting, and tissue flow at each point was calculated as above.

2.4. Statistical analysis

Data were analyzed with the Statview 5.0 program (SAS Institute Inc, Cary, NC, USA). All values are expressed as mean ± standard deviation. The Mann–Whitney U-test was used for comparison of the continuous variables, and Fisher’s exact test was used for comparison of frequencies between the groups. Changes in blood flow after ITA harvesting compared with baseline were compared using Wilcoxon signed-rank test. Differences in tissue blood flow after ITA harvesting between the pedicled ITA group and the skeletonized ITA group were assessed using the Mann–Whitney U-test, and a p-value of less than 0.05 was used to select variables to enter in the multivariate model. Statistical significance was defined by a p-value of 0.05 or less.
3. Results

3.1. Patient and operative data

Baseline characteristics of the patients in both groups were similar except for urgency of the operation and the ratio of RITA harvest (Table 1); there were more urgent cases in the skeletonized group, while RITA was more frequently harvested in the pedicled group. Four patients required preoperative intra-aortic balloon pumping (IABP) for support of coronary perfusion. None of the patients needed preoperative inotropes and none showed hemodynamic instability.

The intra-operative and postoperative variables in both groups are shown in Table 2. There were no significant differences in the mean cardiopulmonary bypass time and the aortic cross-clamp time. In group P, one patient developed postoperative mediastinitis, while another patient had a postoperative cerebrovascular accident and re-exploration for bleeding. However, there was no statistical difference in postoperative morbidity between the two groups. All patients in this study, including patients with concomitant procedures, had stable blood pressure and cardiac output during the operation.

One patient with a deep sternal infection did not show any hemodynamic instability during the operation.

3.2. Sternal microcirculation

In all cases (LITA: 46 and RITA: 14), there was no change in the prestenral blood flow (upper: pre- 2.92 ± 1.59, post- 2.76 ± 1.35, middle: pre- 2.71 ± 1.49, post- 2.43 ± 1.01 ml min⁻¹ 100 g⁻¹; lower: pre- 2.53 ± 1.22, post- 2.46 ± 1.03 ml min⁻¹ 100 g⁻¹). After ITA preparation, blood flow declined significantly at the middle sternal part of the retrosternal areas (upper: pre- 4.17 ± 2.29, post- 4.41 ± 2.44 ml min⁻¹ 100 g⁻¹; middle: pre- 5.61 ± 3.45, post- 3.08 ± 1.56 ml min⁻¹ 100 g⁻¹, p < 0.0001; lower: pre- 4.34 ± 2.86, post- 3.47 ± 2.21 ml min⁻¹ 100 g⁻¹) (Fig. 2). In LITA cases (n = 46), the presternal blood flow did not change in either the pedicled group or the skeletonized group. Retrosternal blood flow was significantly decreased at the middle sternum in both groups, while there was no change in the upper and lower sternum blood flow (Table 3). There was no difference in deterioration of the retrosternal blood flow in the middle part of the sternum between the pedicled group and the skeletonized group. Right retrosternal blood flow was significantly decreased in the middle and lower parts after harvest of the RITA (middle: pre- 6.19 ± 4.23, post- 3.63 ± 1.91 ml min⁻¹ 100 g⁻¹, p = 0.043; lower: pre- 4.78 ± 3.53, post- 2.98 ± 1.51 ml min⁻¹ 100 g⁻¹, p = 0.016).

4. Discussion

Although the use of ITA for coronary revascularization is the gold standard due to its excellent long-term patency [1,2], harvest of the ITA can also cause postoperative complications due to deterioration of the sternal circulation [3–6]. This is considered a cause of postoperative deep sternal wound infections. Since the initial report showing improvement in long-term results using bilateral ITA over single ITA [2], the number of the patients with bilateral ITA grafting has increased. Nevertheless, several studies suggest that bilateral ITA is a risk factor for sternal dehiscence and mediastinal wound infection, especially in patients with diabetes [3–5]. With respect to the technique used for harvesting of the ITA, several reports have examined the incidence of postoperative sternal wound infection with various harvesting techniques. The use of the skeletonization

Table 2. Operative results.

<table>
<thead>
<tr>
<th></th>
<th>Group P (n = 23)</th>
<th>Group S (n = 23)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of distal anastomosis</td>
<td>3.3 ± 1.2</td>
<td>3.3 ± 1.1</td>
<td>0.79</td>
</tr>
<tr>
<td>Operative time (min)</td>
<td>408 ± 59</td>
<td>359 ± 71</td>
<td>0.02</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>162 ± 29</td>
<td>161 ± 37</td>
<td>0.94</td>
</tr>
<tr>
<td>Aortic cross-clamp time (min)</td>
<td>112 ± 30</td>
<td>108 ± 30</td>
<td>0.62</td>
</tr>
<tr>
<td>30 day mortality</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Postoperative complications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative MI</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Re-exploration for bleeding</td>
<td>1 (4%)</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Cerebral vascular accident</td>
<td>1 (4%)</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Deep sternum infection</td>
<td>1 (4%)</td>
<td>0</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Table 3. Blood flow changes in patients with left internal thoracic artery harvest.

<table>
<thead>
<tr>
<th></th>
<th>Group P (pedicled)</th>
<th>Group S (skeletonized)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Presternal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>2.41 ± 0.81</td>
<td>2.91 ± 1.37</td>
</tr>
<tr>
<td>Middle</td>
<td>2.33 ± 1.62</td>
<td>2.16 ± 0.75</td>
</tr>
<tr>
<td>Lower</td>
<td>1.97 ± 0.79</td>
<td>2.25 ± 0.63</td>
</tr>
<tr>
<td>Retrosternal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>4.19 ± 2.36</td>
<td>3.95 ± 1.96</td>
</tr>
<tr>
<td>Middle</td>
<td>4.23 ± 2.16</td>
<td>2.44 ± 0.99</td>
</tr>
<tr>
<td>Lower</td>
<td>3.38 ± 7.0</td>
<td>3.66 ± 2.48</td>
</tr>
</tbody>
</table>
procedure for ITA harvesting was reported to be effective for preventing postoperative wound infection, especially in patients with bilateral ITA and diabetes [7,8], while other studies suggest no relationship between harvest technique and the incidence of postoperative wound complications in patients without diabetes [9,10].

A greater residual retrosternal blood flow after minimized retrosternal tissue mobilization using the skeletonization technique has been shown in animal models of sternal microcirculation [7,15]. However, there are also data suggesting that the skeletonized and semi-skeletonized ITA-harvesting techniques caused a similar acute reduction in sternal perfusion during the early postoperative period [10]. In humans, increased sternal perfusion in skeletonized harvest of the ITA was reported in a randomized study using nuclear imaging [16]. In that study, the differential increase in perfusion was most pronounced in the upper third of the sternum, while there was no difference in perfusion in the middle- and lower third of the sternum between the skeletonized and the non-skeletonized techniques. In another study using a laser Doppler flow meter, a significant decrease in retrosternal microcirculatory blood flow was observed after pedicled ITA harvest, while the harvest of ITA did not influence microcirculation of the pre-sternal area [17]. These data are similar to the results of the present study showing that pre-sternal microcirculation did not change after ITA harvest. In our study, the retrosternal blood flow decreased significantly in the middle part of the sternum in the left side, and in the middle and lower parts of the sternum in the right side. These data are comparable to the previous reports using a laser Doppler flow meter, but are in contrast from the nuclear imaging study showing deterioration of perfusion in the upper third of the sternum. Anatomical studies indicate that the sternal and anterior intercostal branches of the ITA originate either directly or as a common trunk of the ITA [18]. It is generally considered that the substantial collateral flow developed to maintain the sternum blood flow. The pectoris major is the main collateral...
source for the presternal area, while there are no surrounding tissues in the retrosternal area. When the sternal—anterior intercostals trunk is left intact, it can also become a collateral source. The number of branches at the upper and lower part of the ITA is larger than that of the middle part. Therefore, it is valid to suggest that the blood flow to the sternum would be the least at the middle part of retrosternum after harvest of the ITAs.

In the present study, there was no improvement of preservation of presternal microcirculation or retrosternal microcirculation using the skeletonization technique compared with the pedicled technique. These data contrast to a previous study using a laser Doppler flow meter showing that deterioration of the retrosternal microcirculation was significantly less with the skeletonized technique than with the pedicled technique [19]. A potential reason for these contrasting data is the actual technique used for pedicled ITA harvesting technique in our institute, in which we leave as much fat tissue as possible to achieve minimum dissection. As a result, the sternal—anterior intercostals trunk is left intact even after the pedicled harvest of the ITA. There is also a previous study showing no relationship between sternal wound infection and the skeletonized harvest technique, while obesity and an age of greater than 75 years were risk factors for sternal infection [10]. In the present study, following RITA harvest, the retrosternal microcirculation deteriorated significantly in both the middle and lower parts. The length of the skeletonized RITA also tends to be longer as we always use RITA as an in situ graft to the left anterior descending artery or circumflex artery. This may be related to the decreased sternal flow at the middle and lower retrosternal parts. As the length of harvested ITA influenced sternal blood flow even when using the skeletonized ITA technique, we consider that the harvest technique did not have a major impact on sternal microcirculation at 1-mm depth, and that the harvest itself affected blood flow of the middle retrosternal part.

There were several limitations of this study. First, our method only measured superficial sternal blood flow and it is unclear how this reduction of microcirculation affects the clinical result. Further, the relationship between blood flow at 1-mm depth and hemodynamic condition is not known. Second, different devices for harvesting ITAs were used for each group, and this may have affected sternal blood flow. Third, there is still a possibility that change of the sternal blood flow may occur in different depth of the sternum. At least, our study revealed that the harvest technique of the ITA has no impact on maintaining sternal microcirculation at 1-mm depth. To clarify the importance of this change, further studies will be needed to compare different methodologies regarding sternal blood flow.

In conclusion, although our data result from a small cohort and should be interpreted with caution, tissue microcirculation in the middle part of the retrosternal area decreased significantly after harvesting the ITA. We were not able to find any difference in damage to the sternal microcirculation between patients with skeletonized ITA and pedicled ITA, suggesting that skeletonization is not advantageous for maintaining sternal circulation.

References