Intimal injury of ultrasonically skeletonized internal thoracic artery by a vessel clamp: morphological analysis

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Abstract

The skeletonized internal thoracic artery (ITA) has several advantages over a pedicled one in coronary artery bypass grafting. A skeletonized ITA, which lacks surrounding tissue, thus seems more susceptible to the mechanical force exerted by a vessel clamp than the pedicled ITA. The purpose of this study was to assess the detrimental effect of vessel clamps on the intimal integrity of the ultrasonically skeletonized ITA. We skeletonized twelve ITAs with an ultrasonic scalpel in patients who underwent coronary artery bypass grafting, and thereafter two types of clamp, namely a metal clamp and a fibrous jaw clamp, were applied to the terminal portion of the ITA for 30 min. The intimal integrity of the ITAs was morphologically assessed using scanning electron microscopy. A metal clamp can cause serious intimal injury which disrupts the internal elastic lamina, and thus should be avoided for the temporary clamping of the skeletonized ITA. A fibrous jaw clamp, however, hardly ever causes intimal injury, and its clinical use for the temporary clamping of the ultrasonically skeletonized ITA is therefore recommended. Vessel clamps can cause intimal injury of the ultrasonically skeletonized ITA, and the degree of the injury depends on the type of the clamp used.

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1. Introduction

The internal thoracic artery (ITA) has been the most reliable graft material in coronary artery bypass grafting (CABG), and its skeletonization has been reported to have several advantages over the pedicled ITA [1]. An early graft failure after CABG occurs mainly as a result of thrombogenesis [2] especially at the site of intimal injury. Intimal injuries of a graft, which may occur during the preparation of the graft, by applying a vessel clamp on the graft, and at an anastomotic site, can all trigger such thrombogenesis, thereby leading to graft occlusion. During anastomosis, a graft needs to be temporarily interrupted by applying a vessel clamp. A skeletonized ITA, which is devoid of surrounding tissue, tends to be more susceptible to the mechanical force exerted by a vessel clamp than a pedicled ITA. An ultrasonic scalpel (Harmonic Scalpel; Ethicon Endo-Surgery, Cincinnati, Ohio) allows ITA skeletonization to be easily and quickly performed, and its safety in clinical use has been well documented [3, 4]. However, no previous study has yet investigated the effect of a vessel clamp on the intimal integrity of the ultrasonically skeletonized ITA. We thus applied two types of commercially available vessel clamps on the ultrasonically skeletonized ITA, and then morphologically evaluated the intimal integrity using scanning electron microscopy (SEM).

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2. Materials and methods

Ultrasonically skeletonized ITAs harvested from twelve consecutive patients undergoing elective CABG were the subjects of this study. Table 1 details the clinical characteristics of the patients. Informed consent was obtained from all patients participating in this study, and our institutional ethics committee on human research approved this study.

2.1. Operative technique

After performing a standard median sternotomy, the ITA was harvested in a skeletonized fashion using an ultrasonic scalpel. We used a dissecting hook type blade (Harmonic Scalpel; dissecting hook type; Ethicon Endo-Surgery, Cincinnati, Ohio) and set the output of the ultrasonic scalpel at level 2. Higami et al. previously described these procedures in detail [5]. In brief, after a longitudinal incision on the endothoracic fascia about 1 cm medial to the ITA, the medial satellite vein is then swept away from the ITA by moving an ultrasonic scalpel quickly (namely, the ‘quick touch’ method), and then the branches of the ITA are exposed. Next, by placing the tip of the blade on the branch at least 1 mm away from the ITA itself for 3–4 seconds, we are thus able to divide the branch by protein coagulation (namely, the ‘close coagulation’ method). In this way the ITA is fully skeletonized from its origin to 1 cm beyond the bifurcation. After the administration of heparin,
Table 1

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>12</td>
</tr>
<tr>
<td>Mean age ± S.D. years</td>
<td>70 ± 11</td>
</tr>
<tr>
<td>Male gender</td>
<td>8 (66.7)</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>3 (25.0)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>11 (91.7)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>5 (41.7)</td>
</tr>
<tr>
<td>Obesity (body mass index ≥ 25)</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>Smoking</td>
<td>7 (58.3)</td>
</tr>
<tr>
<td>Old myocardial infarction</td>
<td>5 (41.7)</td>
</tr>
<tr>
<td>Cerebro-vascular disease</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>1 (8.3)</td>
</tr>
<tr>
<td>Renal dysfunction (Cr ≥ 1.5)</td>
<td>1 (8.3)</td>
</tr>
</tbody>
</table>

Percentages are shown in parentheses.

two types of commercially available vessel clamps, a metal clamp (Group M, FB 328 R; Aesculap AG & Co. KG, Tuttingen, Germany) and a fibrous jaw clamp (Group F, model G 6052; Applied Medical Resources, Santa Margarita, CA) (Fig. 1), are applied to the terminal portion of each ITA just proximal to the bifurcation for 30 min. Thereafter, the terminal portion of the ITA is cut over the area where the clamps have been applied, and then it is subjected to an SEM study to evaluate its intimal integrity.

2.2. Preparation for scanning electron microscopy (SEM)

The clamping sites are marked on the adventitia of ITA with a pen. The ITA cylinders were cut longitudinally and then were immediately and gently washed with a physiologic solution, and thereafter were immersed in 2.5% glutaraldehyde for 24 hours. All samples were washed in cacodylate buffer, postfixed in 1% Osmiumtetroxide (OsO₄), and thereafter were further dehydrated in ascending concentrations of ethyl alcohol, and dried in CO₂ at a critical point. After drying, all samples were mounted on specimen stubs using colloidal silver and coated with gold using argon, and finally were observed by SEM (Nippon Denshi JSM-25511). One blinded pathologist examined all specimens and described the intimal injury according to the modified score system as proposed by Durand et al. [6] using the following criteria; Grade 0: no endothelial injury, Grade I: cellular disorientation and disorganization of the endothelium, Grade II: at least one breach on the endothelial layer, and/or a contusion of the intima. Grade III: the presence of endothelial detachment. Moreover, samples presenting Grade III intimal injury were further subjected to a pathological study using light microscopy to determine the depth of the injury.

2.3. Statistical analysis

Analysis was performed using Statview 4 51 software package (SAS Institute, Cary, North Carolina). Two group comparisons were performed by Mann–Whitney test. A P < 0.05 was considered to be statistically significant.

3. Results

The normal endothelium was well preserved in 10 ITAs in Group F, and only two ITAs showed Grade I intimal injury (Fig. 2). In Group M, two ITAs showed Grade I, six ITAs showed Grade II (Fig. 3), and four ITAs showed Grade III intimal injury (Fig. 4). In a specimen presenting Grade III intimal injury, the clamp disrupted the internal elastic laminae and the injury reached the medial layer (Fig. 4). The intima of ITAs in Group M were more severely injured showing Grade III or IV intimal injury compared with ITAs in Group F (P < 0.0001).

4. Discussion

In the present study, we confirmed that vessel clamps could cause intimal injury of the ultrasonically skeletonized ITA, and the degree of the injury depended on the type of vessel clamp. A metal clamp can cause serious intimal injury which disrupts the internal elastic lamina of the ultrasonically skeletonized ITA.

The ITA is a gold standard graft conduit in CABG because of its long-term superior patency rates in comparison to those of the saphenous vein graft. The endothelial functions of the ITA, such as an ability to produce large amounts of nitric oxide and prostacycline, are considered to contribute

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Fig. 1. A metal clamp (left) and a fibrous jaw clamp (right).

Fig. 2. Grade I Intimal injury. Scanning electron microscopy showing the disorganization of the endothelium (white arrows). (Left: lower magnification, Right: higher magnification.)
to the high patency rate observed in this graft [7–9]. Except for the technical failures in an anastomosis, thrombogenesis seems to be the principal cause of graft occlusion early after CABG [2]. In general, thrombus develops as a result of intimal injury, which may occur during a dissection of the ITA, at the vessel clamp site on the ITA, and at the anastomosis to the coronary artery. The skeletonized ITA has several advantages over the pedicled ITA [1], however, it lacks surrounding tissue such as satellite veins and adipose tissue, and thus seems to be more susceptible to the mechanical force exerted by a vessel clamp. We, therefore, designed this study to assess the detrimental effects of a vessel clamp on the intimal integrity of the ultrasonically skeletonized ITA.

As shown in this study, a metal clamp almost always causes severe intimal injuries in contrast to the use of a fibrous jaw clamp. Fonger et al. reported the temporary clamping of the ITA to cause the endothelial injury both functionally and morphologically, and such injuries occurred more severely with a metal clamp followed by a soft jaw clamp and a fibrous jaw clamp [10, 11]. The fibrous jaw clamp used in this study (model G 6052) had been designed to reduce the external occlusive force by half in comparison to that of the fibrous jaw clamp (model FOG 6050; Applied Medical Devices, Languna Hills, CA) used in the experiment by Fonger et al. [11]. The fibrous jaw clamp (model G 6052) preserved a normal endothelial cell lining in 10 out of 12 specimens in the present study. As a result, this vessel clamp seems to better protect the intima than the fibrous jaw clamp (model FOG 6050) used by Fonger et al. On the other hand, a metal clamp caused serious intimal injury which thus disrupted the internal elastic lamina and exposed the medial layer. In the present study, the ITAs were cut for a morphological study before releasing the vessel clamps after temporary clamping. If the blood flow is resumed after clamping the ITA with a metal clamp, then the coagulation cascade will be activated, which aggregates the platelets leading to thrombus formation at the site where the intimal injury has occurred [12], and thus resulting in graft occlusion. Moreover, the intimal injury triggers and accelerates atherosclerosis, which can also result in stenosis and occlusion of the graft in the distant future [2]. As a result, a vessel clamp which protects the intima should be used for temporary clamping. With this objective in mind, we therefore recommend the use of a fibrous jaw clamp for the temporary clamping of an ultrasonically skeletonized ITA.

5. Limitations

At first we used the terminal portion of the ITAs for temporary clamping in the present study, and this portion has a thinner wall than the proximal site of the ITA where a clamp is applied to in a real CABG. Therefore, the intimal injury caused by the temporary clamping in this study may overestimate the detrimental effects of the clamps. However, the distal portion of the ITA shows the elastomuscular pattern and it also has the same number of elastic laminae in comparison to the proximal portion of the ITA [13]. We, therefore, think that the site of the ITA for clamping would thus be negligible. Second, we applied clamps on the ITA arbitrarily for 30 min. This duration may be longer than the normal clamping time needed to perform a distal anastomosis of the ITA to a coronary artery, and thus our results may somewhat exaggerate the effects of the temporary clamping on the intimal integrity of the ITA. However, it takes around 20–30 min to cut and prepare the ITA, to incise the coronary artery, and to anastomose the ITA to the coronary artery. We, therefore, consider that the ITA clamping time of 30 min used in this study to be reasonable. Finally, the intimal injury caused by vessel clamps seems to be dependent on the occlusive force of clamps, however, each manufacturer has not published the occlusive force of the clamps used in this study.

References


