Scanning Electron Microscopic Appraisal of a New Micro T-Tube

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SUMMARY A new micro T-tube, 0.6 mm in outer diameter, has been constructed. Use of this tube has allowed 1-mm common carotid artery (CCA) bypass for periods of time up to 22 minutes. After bypass, scanning electron microscopic observation of sutured CCA endothelium showed widespread destruction, scattered attached platelets and other formed blood elements, as well as microthrombi both at suture lines and in areas in contact with T-tubes. Despite microthrombi, 41 of 42 CCAs were patent after anastomosis. Silicone cuffs and 8-0 ties secured T-tubes inside vessels with no apparent difference in underlying endothelial destruction.

Methods
We used silicone tubing with diameters of 0.64 mm (outer) and 0.3 mm (inner) in the T-tube construction* shown in figure 1, suturing it end-on into 0.6 mm holes in separate sections of tubing with 10-0 suture, sealing it with silicone cement,† and securing it to blunted 25-gauge needles with single 10-0 ties.

We anesthetized 22 Sprague Dawley rats weighing 250 to 450 gm with Nembutal, 6 to 7 mg/100 gm. Both the left and right CCA, measuring 0.9 to 1.5 mm in diameter, were exposed, and tracheostomies were performed as previously described.²

The CCA were clamped, severed, and irrigated with diluted heparin solution (10 U per cubic centimeter of saline). Silicone cuffs cut from tubing with diameters of 0.64

References

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*Silastic medical-grade tubing manufactured by Dow Corning Corporation, Midland, Michigan.
†Silastic medical adhesive, Silicone type A, manufactured by Dow Corning Corporation, Midland, Michigan.
TABLE 1 Times Involved in Placing a Micro T-Tube

<table>
<thead>
<tr>
<th>No. CCAs</th>
<th>Cuffs used to hold T-tubes</th>
<th>Time</th>
<th>Mean (minutes)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>First clamp</td>
<td>40</td>
<td>2.5-7.0</td>
</tr>
<tr>
<td></td>
<td>Suturing</td>
<td></td>
<td>9.0-22.0</td>
</tr>
<tr>
<td></td>
<td>Second clamp</td>
<td></td>
<td>1.5-5.0</td>
</tr>
<tr>
<td></td>
<td>Bleeding</td>
<td>none</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>8-0 Tie-sutures used to hold T-tubes</th>
<th>Time</th>
<th>Mean (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First clamp</td>
<td>4</td>
<td>2.5-3.0</td>
</tr>
<tr>
<td></td>
<td>Suturing</td>
<td></td>
<td>9.5-13.0</td>
</tr>
<tr>
<td></td>
<td>Second clamp</td>
<td></td>
<td>1.5-2.5</td>
</tr>
<tr>
<td></td>
<td>Bleeding</td>
<td>none</td>
<td>0.5</td>
</tr>
</tbody>
</table>

mm (inner) and 1.19 mm (outer)* were next slipped over the sutured CCA (40 arteries). Nylon ties (8-0) were used separately (for four arteries). The T-tubes were then maneuvered within the ends of cut CCA and held with a single 10-O suture between the ends of the severed artery. Finally, the tubes were secured within the vessels by sliding silicone cuffs over or tying 8-0 nylon ties down on each half of the divided CCA. We then removed the clamps and recorded the first clamp time.

Diluted heparin (10 U per cubic centimeter of saline) was pumped through the T-tubes, using Harvard pump settings‡ to allow blood flow to continue while suturing with a 70-μ needle. We noted the suturing time, reapplied the clamps, and pulled the T-tubes after removing the cuffs (or ties). Anastomosis was completed with one to three sutures, and the second clamp time was then recorded. The bleeding time from suture lines was also noted.

We observed the rats from one to eight hours before killing them with intracardiac buffered 3% glutaraldehyde (pH 7.4), and the specimens were fixed and prepared for SEM as previously described. The endothelial areas were observed and photographed, omitting clamp sites. A previously reported series of sutured CCA without T-tubes served as our controls. After scanning observations had been made, we divided the rats into two groups, depending on whether cuffs (Group 1) or tie-sutures (Group 2) had been used to hold the T-tubes in place.

Results

Group 1

Although we found that we could place and secure the T-tubes in 2.5 to 3.0 minutes after some practice, difficulty in this maneuver was reflected in prolonged mean first clamp times, as indicated in table 1. Placement of a single suture between severed CCAs, in addition to cuffs over vessels, prevented T-tube slippage or blood leakage in all of the rats.

Ten to 12 sutures could be placed circumferentially around vessels by rotating free T-tube arms. However, the presence of the tubes made suturing more difficult when compared to controls, as shown by prolonged total suturing times (i.e., suturing time plus second clamp time). Suture lines were generally tight, as seen in the short bleeding times which were comparable to those in the control series.

Although blood flow through the T-tube was continuous during suturing, it was erratic, and frequent change of Harvard pump settings was required to keep the tubes open. After T-tube removal and flush, small bits of platelets and fibrin collected at the proximal (nearest to the heart) tubes in every experiment. Although a single CCA was completely thrombosed after four hours of observation, the other 39 CCAs in this group exhibited good pulsation and expansion at the suture line through one to eight hours of observation (a mean of four hours).

SEM examination of all other CCAs revealed consistent widespread endothelial destruction extending from the suture lines as far as T-tube contact had occurred (fig. 2). The endothelial folds were completely effaced in most areas, except for a single CCA that showed normal fold patterns.

FIGURE 2. Collections of platelets (arrow) on an endothelial background with no recognizable bridges or folds (×1,000).
with little or no damage. Clumps of platelets, formed elements, and fibrin were scattered throughout all endothelial surfaces in contact with T-tubes (figs. 3 and 4). Cuff marks could not be seen in most specimens, although they were apparent in a few areas (fig. 5).

We observed microthrombi attached to endothelium in 19 separate CCAs: located at the suture line (three CCAs); extending from the suture line to endothelium in contact with the T-tube (six CCAs); attached to the area of the cuff (seven CCAs); and in two separate areas on the same vessel (three CCAs). Although some microthrombi were large enough to be observed without magnification; others were as small as 75 to 250 μ (figs. 6 and 7). Although thrombi associated with suture lines usually arose from an irregularly placed suture, those associated with T-tube contact were attached to relatively undamaged areas.

Group 2

While mean clamping, suturing, and bleeding times were shorter in this smaller series of four arteries, as shown in table 1, these were the last vessels sutured in the study and they benefited from our previous experience.

Although it was easier to place the 8-0 ties around the vessels to hold the enclosed T-tubes than it was to make a similar maneuver with silicone cuffs, the tie-sutures appeared to cut into the vessel walls and left a recognizable bruise after removal, whereas the cuffs did not. However, observation of these vessels by SEM did not reveal differences from those in Group 1. Endothelial destruction, scattered platelets, and formed elements were seen in areas of T-tube contact in all CCAs (fig. 8). In addition, two vessels exhibited microthrombi at both the suture line and the area of one tie-suture.
Discussion

We corrected flow problems that occurred through the micro T-tube by adjusting the Harvard pump apparatus during suturing. However, such continual adjustments would be awkward during an operative procedure. Despite uninterrupted flow, formed blood elements collected at proximal tube ends in all the experiments, and therefore we believe that the T-tube design must be improved. Also, because platelet adhesion to artificial surfaces was inhibited after heparin coating, perhaps application of this coating technique to 0.6-mm diameter tubes would improve flow, lessen the platelet and fibrin collection, and eliminate the need for pump adjustments.

Although this study was intended to demonstrate possible endothelial surface differences between the use of stiff tiesutures and more elastic silicone cuffs, no difference in fact was found. Our SEM study of both groups showed similar endothelial alteration as well as microthrombosis in more than 50% of CCAs. However, a point in favor of the tiesuture was its easy placement.

An explanation for occurrence of microthrombi at the suture lines may be irregularity in the suture line, although equal numbers of thrombi were apparent away from suture lines. Despite this frequency of microthrombosis, 41 of the 42 sutured vessels were patent after a mean of four hours of observation. Whether or not these microthrombi would later cause complete thrombosis, of course, is speculative.

The present study indicates that it is possible to bypass 1-mm vessels for periods of time more than 20 minutes and still maintain patency of the vessel. It also demonstrates that damage to endothelial surfaces does occur following the use of the T-tube.

References

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