Experimental Studies in Nonsuture End-to-side Microvascular Anastomosis

Sen YAMAGATA, L. Philip CARTER, Hajime HANDA*, Yasuhiro YONEKAWA*, Waro TAKI*, Yoshito IKADA** and Hiroyo IWATA**

Department of the Microsurgical Laboratory, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, AZ, U.S.A. *Department of Neurosurgery, Kyoto University Medical School **Institute for Chemical Research, Kyoto University

Summary

A fast, easy anastomotic technique with a high patency rate would facilitate the development of microvascular surgery. This article describes a new nonsuture method of end-to-side microvascular anastomosis using a soluble polyvinyl alcohol (PVA) T-shaped tube as an internal stent and plastic adhesive. Two kinds of T-shaped tubes were used: Type I tube had a short straight tube connected to a long straight tube at the midpoint and the Type II tube was a long bent tube with a short straight tube connected to it. The walls of each tube consisted of three concentric layers made of two PVA's with different solubilities. Seventy end-to-side anastomoses were performed using both common carotid arteries of rats. These consisted of three groups, I, IIA, and IIB. I and II were the types of T-tubes employed, and A had less plastic adhesive than B. Evaluations were performed 2 weeks and 3 months after surgery. The anastomotic technique was easily accomplished, taking approximately 8 minutes to complete. On the first evaluation the patency rates were more than 90% in all groups, but anastomotic aneurysms developed in I (7%) and IIA (19%). No aneurysms were observed in IIB where the anastomotic sites were reinforced by adding plastic adhesive after the blood flow was reestablished. Moreover, a high patency rate (95%) was maintained even at the second evaluation in IIB.

Key words: Microsurgery, vascular anastomosis, cyanoacrylate, vascular surgery, polyvinyl alcohol

Introduction

The principal advantage of a nonsuture vascular anastomosis technique is to reduce the time to complete the procedure and to facilitate the anastomosis. These concepts should be emphasized in microvascular anastomosis which demands a refined technique that can be accomplished in a minimal amount of time. Some investigators have reported microvascular anastomosis without sutures, but most of these involved end-to-end anastomoses. Reports of nonsuture end-to-side anastomosis, even in the anastomosis of large diameter vessels, are rare.8,13,20)

We have reported a new nonsuture method of end-to-end microvascular anastomosis in vessels with outside diameters of less than 1.5 mm employing soluble tubes made of polyvinyl alcohol as an internal stent and plastic adhesives.21) In this paper, a new nonsuture method of end-to-side microvascular anastomosis is introduced combining a soluble “T”-shaped tube manufactured with the same materials as in our previous article, polyvinyl alcohol (PVA) with plastic adhesives.

Materials and Methods

I. Materials

T-shaped soluble PVA tube: Two kinds of T-shaped soluble PVA tubes were manufactured. The Type I tubes were fabricated by connecting a short straight tube to a long straight tube at its midpoint (Fig. 1B). The Type II tubes were constructed by first bending a long straight tube 60~90° and then connecting
A short straight tube to the bent portion (Fig. 1A). The walls of these tubes consisted of three concentric layers, each of a PVA with a different solubility (Fig. 2). The PVA used for the thin, inner and outer layers of the tubes were 88% saponified with a degree of polymerization of 550. The PVA of the thick middle layer was 82% saponified with a degree of polymerization of 120. The tubes had an inside diameter of 0.60 mm and an outside diameter of 1.00 to 1.30 mm.

Adhesives: The plastic adhesives employed were 2-cyanoacrylates with alkyl groups of ethyl or isopropyl.*

II. Methods
Surgery was performed on 70 Long-Evans rats weighing 250 to 350 gm under an operating microscope.* The rats were anesthetized with intraperitoneally administered pentobarbital. The skin of the neck was incised longitudinally. To dissect both common carotid arteries, both sternomastoid muscles were partially incised. The right common carotid artery, the donor artery, was ligated at the common carotid bifurcation and clamped at the proximal end of its exposure. It was transected just proximal to the ligature, passed between the trachea and sternohyoid muscle, and then reclamped at the left side of the trachea with a large clamp to prevent it from recoiling. After flushing with heparinized saline, the adventitia was carefully removed. Two small longitudinal incisions were made, one at 12 o'clock and one at 6 o'clock perpendicular to the approximating edge. A small teflon background was placed beneath the left common carotid artery, the recipient artery, to isolate the anastomotic segment from the surrounding tissue. The approximating clamps were applied and the artery was incised longitudinally between the clamps. Any frag-

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*These materials were supplied by ALPHA TECHNO Co., Osaka, Japan.
*J. K. Hoppl Co. Model No. 801A212, U.S.A.
Fig. 3  Technique for nonsuture end-to-side anastomosis. The appearance of both the common carotid arteries before anastomosis. To facilitate the anastomosis, adequate vessel length must be obtained (A). The insertion of the T-shaped tube into the vessels (B, C). The application of adhesive with a hypodermic needle to the lateral side (D) and to the medial side (E) of the anastomosis. After completing the application of adhesive (F), clamps are released. A small stream of blood is seen in the T-shaped tube (G). The last clamp is released about 5 minutes after the second one (H). Magnification set at 14×.

ments of adventitia along the incision were removed. A recipient vessel was flushed with heparinized saline and then the area around the anastomotic site was dried with a small piece of cotton or suction (Fig. 3A). The vertical segment of the T-shaped tube was inserted into the right common carotid artery (donor artery) (Fig. 3B). Then, the horizontal segment was inserted into the left common carotid artery (recipient artery) (Fig. 3C). The two incisions
on the donor artery were adjusted to the distal and proximal edges of the incision on the recipient artery. The edges of the vessels were approximated with forceps. A minute amount of cyanoacrylate monomer was applied with a 27 gauge hypodermic needle to the lateral side of the anastomosis (Fig. 3D) and then to the medial side (Fig. 3E). The anastomotic site was completely covered by adhesive (Fig. 3F). The distal clamp on the recipient vessel was released after application of plastic adhesive. The proximal clamp on the recipient artery was then released when the Type I tubes were employed. When the Type II tubes were used, the clamp on the donor vessel was removed secondly (Fig. 3G). To control bleeding from the anastomotic site and to decrease the possibility of embolism caused by the remaining PVA tube in the vessel, the third clamp was removed approximately five minutes after the release of the second clamp (Fig. 3H). Other than pentobarbital, the only drug administered to the animals in this study was a topical cephalixin to the wound upon closure.

Seventy cases were divided into three groups: 30 cases in Group I, 20 cases in Group IIA, and 20 cases in Group IIB. In Group I, Type I tubes were employed. The adhesive was initially applied only along the suture line. If bleeding occurred, the clamps were reapplied and adhesive was added until the bleeding was controlled. In Group IIA, Type II tubes were used and a small volume of adhesive was applied only along the suture line. If bleeding occurred after release of the clamps, it was controlled by compression with small pieces of cotton or the addition of a minimal amount of adhesive. In Group IIB the same tubes and volume of adhesive were used as in Group IIA. However, in Group IIB additional adhesive was added as reinforcement around the vessels at the anastomotic site after the blood flow was restored and the tube was completely dissolved.

**Results**

The anastomoses were easily accomplished, taking approximately 8 minutes to complete, provided that the initial dissection of the vessels was adequate. In most cases, the blood flow was reestablished through the PVA T-shaped tube in the anastomosed vessels immediately after the release of the clamps. In only one instance was more than 15 minutes required for flow to be restored through the tube.

Postoperative evaluations were performed twice, the first 14 days and the second 3 months after surgery.

Seven of the 70 rats died before the first evaluation. Three rats were in Group I and died within 24 hours after surgery. Four rats were in Group IIA; one died 2 days, one 4 days and two 10 days postoperatively. In Group IIB, no rats died before the first evaluation. The anastomotic sites in all dead rats were explored. Hematomas at the anastomotic site were observed only in Group IIA where they were found in three out of four rats.

**First follow-up study, two weeks postoperatively**

The results of the first study on 63 rats are shown in Table 1. Twenty-five of 27 cases in Group I were patent with the development of anastomotic aneurysms in two of these patent cases. In one of the two occluded cases the donor vessel was occluded just proximal to the anastomotic site. In the other case, complete occlusion at the anastomotic site was observed. In Group IIA, all 16 cases were patent but anastomotic aneurysms were found in three of them (Fig. 4). Nineteen out of 20 cases in Group IIB were patent. No anastomotic aneurysms developed in this group. Simple patency rates in the first evaluation were 93% in Group I, 100% in Group IIA, and 95% in Group IIB.

### Table 1 Results of first evaluation (2 weeks postop.)

<table>
<thead>
<tr>
<th>Group</th>
<th>Case No.</th>
<th>Cases died before expl.</th>
<th>Cases occl.</th>
<th>Simple pat. rate</th>
<th>Cases with aneu.</th>
<th>Successful anast. rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>30</td>
<td>3</td>
<td>2</td>
<td>93% (25/27)</td>
<td>2 (7%)</td>
<td>85% (23/27)</td>
</tr>
<tr>
<td>IIA</td>
<td>20</td>
<td>4 (3)*</td>
<td>0</td>
<td>100% (16/16)</td>
<td>3 (19%)</td>
<td>81% (13/16)</td>
</tr>
<tr>
<td>IIB</td>
<td>20</td>
<td>0</td>
<td>1</td>
<td>95% (19/20)</td>
<td>0</td>
<td>95% (19/20)</td>
</tr>
</tbody>
</table>

*Number in parentheses represents cases in which hematoma was observed at the site of anastomosis.
However, the development of anastomotic aneurysms is a significant complication and might lead to an occlusion or hemorrhage; therefore, these animals were eliminated. The successful anastomoses rates were 85% in Group I, 81% in Group IIA and 95% in Group IIB.

In all cases slight granulomatous tissue was observed around the anastomoses. No differences were found between the two kinds of cyanoacrylates used.

At this first evaluation 10 rats were sacrificed, seven for the histological study and three for occlusion of the anastomotic vessels. In addition, three rats died from deep anesthesia.

Second follow-up study, 3 months postoperatively
Fifty patent cases including two cases that developed anastomotic aneurysms were followed for 3 months. No rats died between the first and second evaluations. The two rats which had developed anastomotic aneurysms by the first evaluation remained patent at the second evaluation. The results from the 48 rats evaluated after 3 months which were patent and free from aneurysm formation at the first evaluation are shown in Table 2. Of the 20 cases in Group I, one rat developed an anastomotic aneurysm, and an occluded donor vessel was found in another rat in this group. In Group IIA there was one case in which the donor vessel was occluded. All rats of Group IIB were free from aneurysm formation and patent (Fig. 5). Successful anastomoses from the first evaluation to the second evaluation decreased by 10% in Group I and in Group IIA. The total successful anastomoses rates were determined by multiplying the successful anastomoses rates of the first evaluation with those of the second evaluation for each group. They were 77% in Group I, 74% in Group IIA and 95% in Group IIB.

Discussion
End-to-side anastomosis is a basic technique utilized in all forms of vascular surgery. However, reports of nonsuture methods of vascular anastomosis of this type are rare. The reason for this is the difficulties in fabricating adequate devices to improve the execution of end-to-side anastomoses. Only a few reports of nonsuture end-to-side anastomosis techniques in vessels with external

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**Table 2** Results of second evaluation (3 months postop.)

<table>
<thead>
<tr>
<th>Group</th>
<th>Case No.</th>
<th>Cases occl.</th>
<th>Simple pat. rate</th>
<th>Cases with aneu.</th>
<th>Successful anast rate</th>
<th>Total successful anast. rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>20</td>
<td>1</td>
<td>95%</td>
<td>1</td>
<td>90% (18/20)</td>
<td>77%</td>
</tr>
<tr>
<td>IIA</td>
<td>11</td>
<td>1</td>
<td>91%</td>
<td>0</td>
<td>91% (10/11)</td>
<td>74%</td>
</tr>
<tr>
<td>IIB</td>
<td>17</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>100% (17/17)</td>
<td>95%</td>
</tr>
</tbody>
</table>
diameters of less than 1.5 mm have appeared in the literature.4,7,20) These techniques are complex and have lower patency rates than the suture method.

Since we reported the feasibility of nonsuture end-to-end microvascular anastomosis using PVA soluble tubes and plastic adhesives,21) experiments involving end-to-side anastomosis were begun. Initially, two major technical difficulties occurred. One was the manufacture of an ideal tube for this purpose. We developed two kinds of "T"-shaped tubes. The walls of both types of T-tubes consisted of three layers of PVA as opposed to the two layered PVA straight tubes which were employed in the end-to-end anastomosis study. Three layers were used because more time is required to complete the end-to-side anastomosis. The second problem was the selection of a vascular model. Ample dissected segments of anastomotic vessels are required to allow the procedure to be more easily accomplished. Ultimately, the common carotid arteries in rats were selected because of the uniform size of the vessels in spite of limited dissecting areas. Some of the rats operated on early in the study developed respiratory disturbances after dissection of the vessels as fully as possible. This probably caused the deaths of four rats, three in Group I and one in Group IIA.

A prime concern in this project was the development of anastomotic aneurysms. Anastomotic aneurysms were observed in two out of 27 cases (7%) in Group I. However, in Group IIA they developed in three out of 16 cases (19%). Moreover, in this group aneurysms might have occurred in another three rats that died before the first evaluation. The technical differences between these two groups were the volume of plastic adhesive and the type of T-tubes used. It was our feeling that the latter factor had less influence on the development of aneurysms than the former. Therefore, in Group IIB we increased the volume of plastic adhesive in an attempt to prevent the formation of anastomotic aneurysms. This additional adhesive was added after complete recovery of the flow. As a result, anastomotic aneurysms were prevented. In addition, only one out of 20 cases in this last series was occluded.

There have been some reports which related the development of aneurysms to the application of cyanoacrylate plastic adhesives to vessels.3,6,11,14) However, in most of the reports, aneurysms occurred after the repair of arteriotomies with plastic adhesive or after end-to-end anastomosis in which methyl 2-cyanoacrylate was employed. Carton et al.3) pointed out that it was possible to prevent aneurysms by reinforcing the vessel at the arteriotomy site with a circumferentially wrapped fascia patch and plastic adhesives. Judging from our experience and the experience of others,9,16,18,21) it seems that the frequency of aneurysm development after end-to-end anastomosis using plastic adhesives is no greater than that after conventional suture methods.1,5,10) However, the development of aneurysms in these cases appeared to be related to the type and amount of adhesives applied. It has been reported by some investigators that the use of other types of cyanoacrylates such as ethyl 2-cyanoacrylate or isobutyl 2-cyanoacrylate did not cause the development of aneurysms after end-to-end anastomosis or after the repair of arteriotomy.2,15,16,19) Until now there have been no data available on the formation of aneurysms after end-to-side anastomoses in which plastic adhesives were employed. In this study anastomotic aneurysms developed at a high rate, especially in cases in which a minimal amount of plastic adhesive was applied, despite the use of ethyl or isopropyl 2-cyanoacrylate as the plastic adhesive. In human cases involving graft-artery anastomoses, it has been observed that the majority of anastomotic aneurysms occurred after end-to-side anastomoses.12,17) In this regard, Nunn et al.12) theorized that the energy resulting from turbulence and the change in blood flow rate can be a significant factor adding to the risk of infection and to blood leaks from the suture line. In our experiment in which rats were utilized, this factor may play a more important role in the development of anastomotic aneurysms.1,10) Our Group IIB, in which there were no anastomotic aneurysms and only one occluded case, demonstrates that it is possible to prevent anastomotic aneurysms and to maintain a high patency rate if suitable plastic adhesives are employed and proper volumes are applied as reinforcement of anastomosis.

Further studies will be required in a larger
population of experimental subjects so that more valid conclusions can be drawn, and the long term efficacy of this technique can be established.

Conclusion

A new nonsuture method for end-to-side microvascular anastomosis was developed combining a soluble T-shaped tube made of polyvinyl alcohol with plastic adhesives. Using this technique anastomoses were performed in 70 rats using both common carotid arteries. The rats were divided into three groups according to the type of T-tubes utilized and the volume of plastic adhesive applied at the anastomatic site. The anastomosis technique was easily accomplished and took approximately 8 minutes to perform. In the groups in which the least amount of plastic adhesive was applied, anastomatic aneurysms developed. However, these could be prevented by adding plastic adhesive as reinforcement around the anastomatic site after the blood flow was reestablished. A 95% patency rate was maintained up to three months postoperatively.

This is the first report of a nonsuture microvascular end-to-side anastomosis technique with a high patency rate and elimination of anastomatic aneurysms.

Acknowledgment

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References


18) Tschopp, H. M.: Small artery anastomosis

