ENDO-GIA Staplers for Side-to-Side Anastomosis of Veins

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Objective. To study the application of ENDO-GIA staplers for the side-to-side anastomosis of veins.

Materials and Methods. An animal study was conducted. Five dogs received side-to-side anastomosis of allograft IVC by ENDO-GIA staplers (Group 1). In addition, five received the same operation with right renal vein reimplantation to allograft IVC (Group 2). Five dogs, receiving the same operation as in Group 1 using polypropylene sutures (control group, Group 3). An autopsy was performed if the dogs survived more than 8 weeks.

Results. The IVC anastomosis remained patent in four subjects (80%) for Group 1, in five subjects (100%) for Group 2 and in four subjects (80%) for Group 3.

Conclusions. From the results of our experiment, ENDO-GIA staplers can be considered for use in the side-to-side anastomosis of large veins such as piggyback cavacaval side-to-side anastomosis in cadaveric orthotopic liver transplantation (OLT) or side-to-side splenorenal shunt in portal hypertension.

Keywords: Auto-suture; ENDO-GIA staplers; Cadaveric liver transplantation; Inferior vena cava; Splenorenal shunt.

Introduction

A number of reports of stapled vascular anastomoses have been presented, however no study focusing on side-to-side anastomosis of veins with ENDO-GIA staplers has been reported. Examples of clinical applications for side-to-side vein anastomosis include side-to-side cavacaval anastomosis in cadaveric orthotopic liver transplantation (OLT) and side-to-side splenorenal shunt in portal hypertension. We therefore undertook this study to determine if ENDO-GIA staplers could be used for vein-to-vein anastomosis with a safe and acceptable outcome.

Materials and Methods

Materials

Thirty mongrel dogs weighing 10–15 kgs were included in this study. The dogs were divided into three

Operation

Two dogs were fasted over midnight before the day of operation. The inferior vena cava (IVC) was harvested from the donor through a midline incision. The harvested segment of the IVC was from the confluence of common iliac veins to the infra-hepatic level. Heparinized saline was injected to check for leaks. For the recipients the segment of IVC from the confluence of common iliac veins to infra-hepatic level was isolated, and lumbar veins were ligated. Vascular clamps were applied to the two ends of the segment of IVC and renal veins. Then three kinds of procedures were
performed. For Group 1 ($n=5$), a 1 cm transverse venotomy over the lower end of the clamped IVC was performed. One arm of the ENDO-GIA staplers was inserted into the recipient’s IVC, and the other arm placed in the allograft IVC. Side-to-side anastomosis was performed after closing the two arms. Then longitudinal incision of the upper end of the recipient’s side of IVC was performed. U-shape anastomoses of both ends of the IVCs were performed by continuous 6-0 polypropylene sutures (Fig. 1). For Group 2 ($n=5$), the operations continued with right renal vein reimplantation into the allograft IVC by 6-0 polypropylene sutures. For Group 3 ($n=5$), the allograft IVC was detubulized and tailored to a triangular-tip vein patch, and then a longitudinally incision of the recipient’s IVC was done and side-to-side anastomosis using 6-0 polypropylene running sutures. The times for side-to-side IVC anastomosis for both ENDO-GIA (Group 1 and 2) and polypropylene sutures (Group 3) were recorded.

**Post-operative care and specimen retrieval**

The recipient dogs had food after recovery from general anesthesia. Cefamandol 1 g was given intramuscularly during surgery and then daily for 2 days. Immunosuppressants or anti-platelet drugs were not used. An operation for specimen retrieval was performed if the dog survived more than 8 weeks. The retrieval operation was performed to remove the segment of IVC from the supra-hepatic (including liver) to the confluence of iliac veins with kidneys and bowels in Group 1 and 3. In Group 2, only the segment of IVC from infra-hepatic to the confluence of iliac veins was removed but with the right kidney. The specimens were taken for examination including examination with venography, gross inspection of anastomosis and pathological examination of the allograft IVC. The venography was performed using a catheter inserted via the lower end of the IVC to prove the patency of anastomoses. The gross inspection of anastomosis was done by opening the IVC

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**Fig. 1.** The illustrations of operations in Group 1 and 2. ENDO-GIA staplers were used for side-to-side IVC anastomosis (A). After completion of ENDO-GIA anastomosis, a small longitudinal incision of the recipient’s anterior wall above the anastomosis was done (B) then polypropylene running sutures for anastomosis of both ends of allograft IVC to the recipient’s IVC. This maneuver was to avoid dead space of allograft IVC (C). In Group 2, the right renal vein was reimplanted to allograft IVC (D). Abbreviations: RIVC, recipient’s IVC; DIVC, donor’s IVC segment; RK, right kidney.
longitudinally to check the anastomoses. The diameter of the anastomoses were measured. The anastomoses were also examined grossly for the presence of fibrin and thrombus and were graded using the following fibrin/thrombus score: 0 = no evidence of fibrin or thrombus; 1 = fibrin present; 2 = slightly raised thrombus (or organized blood clot) producing less than a 10% reduction in luminal diameter; and 3 = well-formed, raised thrombus (or organized blood clot) causing a > 10% reduction in luminal diameter with or without fibrin. Then the allograft IVC was excised along the staplers of ENDO-GIA and embedded in formalin for histological examination.

Histologic examination

The specimens were processed by fixation using formalin, cross-sectioned in 0.5 μm sections. Then the specimens were stained with hematoxylin-eosin and examined by light microscopy. Two parameters are evaluated. First, the presence or absence of intimal and medial injury, which are characterized by loss of nuclei, cellular hypereosinophilia, and loss of usual cellular detail. Second, the extent of acute and/or chronic inflammation and foreign body giant cell reaction are assessed using the following inflammation score: 0 = no evidence of inflammation; 1 = mild, focal inflammation; 2 = moderate inflammatory cell infiltrate; and 3 = marked inflammation.

Expression of the Data

The data are expressed as means ± standard error. Mann-Whitney tests, Kruskal-Wallis tests and Fisher’s exact tests were used to compare the data. *P* < .05 was considered significant.

Results

All the recipient dogs survived more than 8 weeks. The results are shown in Table 1. The time for side-to-side anastomosis of IVC was shorter in Group 1 and 2 (p = 0.008). A patent IVC anastomosis was noted in four subjects (80%) for Group 1 and 3, in five subjects (100%) for Group 2 (p = 1.000) proved by IVC venography and gross examination (Figs. 2A and 2B). The diameter of the patent anastomosis ranged from 1 cm to 2 cm in Group 1 and 3, but was

<table>
<thead>
<tr>
<th>Group</th>
<th>Time for IVC anastomosis (min)</th>
<th>Patency of IVC anastomosis (%)</th>
<th>The diameter of the patent anastomosis</th>
<th>Fibrin/thrombus score for IVC anastomosis</th>
<th>Intimal and medial injury</th>
<th>Inflammation score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>1 ± 0.5 min (n = 5)</td>
<td>80</td>
<td>1.5 ± 0.5 cm</td>
<td>0 (n = 2), 1 (n = 2)</td>
<td>no (n = 4)</td>
<td>2 (n = 4)</td>
</tr>
<tr>
<td>Group 2</td>
<td>2 ± 0.5 min (n = 5)</td>
<td>100</td>
<td>2.5 ± 0.5 cm*</td>
<td>0 (n = 3), 1 (n = 2)</td>
<td>no (n = 5)</td>
<td>2 (n = 5)</td>
</tr>
<tr>
<td>Group 3</td>
<td>3 ± 2 min* (n = 5)</td>
<td>80</td>
<td>1.5 ± 0.5 cm</td>
<td>0 (n = 2), 1 (n = 2)</td>
<td>no (n = 4)</td>
<td>2 (n = 5)</td>
</tr>
</tbody>
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Abbreviation: IVC: inferior vena cava. *means statistically significant.
wider in Group 2, which ranged from 2 cm to 3 cm ($p = 0.017$). For the fibrin/thrombus score for patent IVC anastomoses, intimal and medial injury and inflammation score of allograft, no significant difference was noted among the three groups. The microscopic examination showed the vascular wall as a picture of acute rejection (Fig. 3).

Discussion

Hand-sewn anastomosis with polypropylene suture remains the most common method and gold standard of vascular anastomosis. Other techniques for vascular anastomosis, such as metallic non-penetrating vascular staples$^{1-3}$ and penetrating microvascular anastomotic coupler systems$^{4-7}$ also have been reported with excellent results. The advantages of GIA autosutures over the hand-sewn method are that they save time and are less surgeon-dependent. The GIA autosutures have never been reported in vascular anastomosis, and the reasons may be related to fear of injury of intima of vessels, difficulty in application due to size mismatch between vessels and GIA instruments and few suitable occasions of vascular side-to-side anastomosis. For the fear of intima injury, the microvascular anastomotic coupler system is also intima penetrating, although the patency of anastomosis is excellent.$^{4}$ For the size mismatch between vessels and traditional GIA instrument, the ENDO-GIA instrument can conquer this problem. As for suitable clinical applications for vascular side-to-side anastomosis, piggyback side-to-side cavocaval anastomosis

in OLT and side-to-side splenorenal shunt in portal hypertension are the applicable clinical situations.

We believe ENDO-GIA staplers for the above-mentioned side-to-side venous anastomosis is safe, time-saving and has a good patent rate for several reasons. First, this method is tension-even when closing the arms of the ENDO-GIA staplers, which avoids vein tears. The stapled anastomosis is wider than the hand sewn one. The stapled technique is also quick and not technically demanding. One disadvantage of ENDO-GIA staplers is that insertion of the instruments could be technically demanding, although it can be overcome by modifying the sizes of the instruments.

We found similar patency rates for our stapled and hand sewn anastomoses, however, the size of anastomosis was larger in Group 2 than in Group 1. Actually, the condition in Group 2 was designed to simulate the piggyback side-to-side cavocaval anastomosis in OLT.

When a cadaveric liver graft is large for the recipient’s abdominal cavity, hepatic venous outflow reconstruction is difficult. Under this circumstance, piggyback side-to-side cavocaval anastomosis is easier to perform for good exposure.$^{9}$ However, in some cases, tearing of sutures will occur if there is tension over continuous hand-sewn sutures. ENDO-GIA staplers can conquer this problem, although total clamping of IVC is needed for about 5 minutes. Of course, the insertion of the instruments is technically demanding however it can be overcome by modifying the sizes of the instruments. As for the side-to-side splenorenal shunt in portal hypertension, the insertion of the instruments is not a problem.

In conclusion, our experiment shows ENDO-GIA staplers are applicable to side-to-side vein anastomosis with satisfactory results. Although the results of clinical application in humans are not yet available, we will apply the ENDO-GIA staplers to suitable cases and report the clinical results in the near future.

References

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**Fig. 3.** The microscopic examination of allograft IVC around the ENDO-GIA staplers. Moderate amount of lymphocytes infiltration was noted around the media of vessel wall (*) (50X, H&E stain). The intima was normal. Abbreviations: I, intima; M, media.


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