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Experimental study on vascular graft. I. Replacement of inferior vena cava with crimped woven Tetoron (polyester) grafts and those reinforced with stainless steel coil

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Experimental study on vascular graft. I. Replacement of inferior vena cava with crimped woven Tetoron (polyester) grafts and those reinforced with stainless steel coil*

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Abstract

Experimental replacement of inferior vena cava with crimped woven Tetoron arterial graft was performed in dogs. Bypass-graft to thoracic inferior vena cava was not successful in two animals. Total repacement of thoracic inferior vena cava was attempted in four animals, and thoracoabdominal long implantation to inferior vena cava through diaphragm behind liver, followed by excision of thoracic inferior vena cava between the anastomoses, was done in 12 animals. Of these 16 animals, the graft was patent or not occluded in nine at autopsy between the 30th and the 451st day after implantation. Similar thoracoabdminal implantation of a graft reinforced with a steel coil was made in seven animals. Two grafts were patent at autopsy after 37 and 251 days, respectively. Abdominal vena cava replacement with a graft reinforced with a coil was undertaken in three animals. Two grafts were patent at autopsy after 117 and 142 days, respectively. On the whole, long term survival without occlusion over 30 days was obtained in fifteen/twenty-eight animals. Aside from the instances of simple bypassgraft and obvious technical errors in early experiments, it was in fifteen/ eighteen, and the graft was completely patent in ten/eighteen animals. The failures within 30 days resulted mostly from either lung complications or technical errors, and the latter were remarkable in the thoracoabdominal group where the graft reinforced with coil was used, but the application of the coil was very effective in protecting the graft against the compression by the adjacent organs. Tissue reaction to Tetoron was not noticeable and to the silk thread it was very slight and seemed not to affect long term success. By the present method even the total replacement of theracic inferior vena cava can be performed safely under normothermia and thoracoabdominallong implantation to inferior vena cava is also possible with considerable success. In order to prepare a more suitable synthetic graft for vein, it requires further search for harder, lighter, more elastic and physicochemically more stable material. The fabric of venous graft should be preferably more porous and thinner than that of the arterial graft available at the present in order to make the organization within the shortest time possible.

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EXPERIMENTAL STUDY ON VASCULAR GRAFT
I. REPLACEMENT OF INFERIOR VENA CAVA WITH CRIMPED WOVEN TETORON (POLYESTER) GRAFTS AND THOSE REINFORCED WITH STAINLESS STEEL COIL*

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There are many studies on replacement of vena cava with synthetic prosthesis and recently fairly favorable results have been reported, mostly in superior vena cava. However, the replacement of inferior vena cava has been found to be more difficult in comparison with that of superior vena cava (1). Nevertheless, we need a long bypassgraft or replacement of inferior vena cava in the patients with the Budd-Chiari's syndrome or inferior vena cava occlusion. The purpose of this paper is to report the results of experimental studies on vena cava replacement with Tetoron grafts.

A crimped woven Tetoron graft was inserted into thoracic inferior vena cava by way of bypassgrafting it to the vena cava and making subsequent division or excision of the vena cava in one group. In another group a long graft was bypassgrafted to thoracoabdominal inferior vena cava with subsequent division or excision of thoracic vena cava to maintain blood flow through the graft alone. In other groups the grafts were reinforced with a stainless steel coil and applied to thoracoabdominal inferior vena cava in a similar manner as above mentioned or to abdominal vena cava distal to renal veins. These experiments were safely performed under normothermia. Of each group fairly favorable results were obtained and especially successful was the attempt with reinforced grafts.

MATERIALS AND METHODS

Twenty-eight adult mongrel dogs, weighing 8 to 12 kg, were used for the study. Anesthesia was attained with intravenous administration of pentobarbital sodium 25 to 30 mg per kg. While thorax was open, an endotracheal tube was

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inserted and respiration was maintained by a mechanical respirator. The grafts were crimped woven Tetoron ones*. The ends of the graft were heat-sealed by an electric flatiron. The coil for reinforcement was made of a molibdenum stainless steel wire, S. U. S. 32 made in Japan, similar to A. I. S. I. 316 made in U. S. A. Anastomosis was made by continuous over and over suture with 6—0 silk**. A particular attention was paid to make anastomosis wider. At the closure of thorax penicillin 400,000 units and streptmycin 0.5 gm were spread into thorax. A chest tube was inserted until the closure of thorax was completed, and removed after aspiration of thorax. No anticoagulants were used either during or after operation.

Group A: Bypassgrafting to thoracic inferior vena cava was attempted in two animals. Right thorax was opened through the 7th intercostal space and inferior vena cava exposed. One animal underwent simple bypassgrafting by end-to-side anastomosis. The ends of the graft were cut at right angle. The other animal had the same bypassgrafting and inferior vena cava was ligated with a silk thread at the midway between the anastomoses.

Group B: Total replacement of thoracic inferior vena cava was attempted in four animals. Ends of a graft were cut at right angle and anastomosed to inferior vena cava, one at the portion near the entrance of right atrium, and the other at the portion above diaphragm, each end-to-side. After the completion of anastomosis, the middle portion of inferior vena cava was divided or a portion was removed between ligatures as to have the graft straightened and the replacement completed.

Group C: Replacement of thoracoabdominal inferior vena cava was attempted in 12 animals. Right thorax was opened through the 7th and 11th intercostal spaces, the posterior portion of diaphragm was incised and divided radially, and retracting liver anteriorly, abdominal vena cava was exposed. An oblique end of a graft (10 to 11 cm in length, 10 to 12 mm in diameter) was anastomosed to the right wall of vena cava just above renal veins. The other end of the graft was cut at right angle and anastomosed to the right wall of inferior vena cava close to right atrium in thorax. Soon after the completion of anastomosis, thoracic inferior vena cava was divided or a portion was removed between ligatures, and the clamps applied to the lateral wall of vena cava longitudinally for making anastomosis were removed. Diaphragm was sutured and closed leaving some space to prevent the graft being compressed. Thoracic vena cana was constricted about 2 months before the experiments in two animals. Proximal anastomosis was performed proximally to the constriction end-to-end under the complete occlusion with a clamp. Distal anastomosis was not so difficult in them in spite of enlarged liver because inferior vena cava was also enlarged.

Group D: Replacement of thoracoabdominal inferior vena with a graft reinforced with a coil, was attempted in seven animals. A coil made of hard wire of 0.4 to 0.6 mm in diameter, was bent in proper angle and set around a graft, in contact with the hollow of its crimp, for the distance of 3 to 5 cm, about 5 mm

* Product of the Toyo Rayon Co., Nakanoshima, Osaka, Japan.
** Product of the Nitcho Kogyo Co., Tokyo, Japan.

away from the obtuse corner of its oblique distal end. The ends of the coil were sutured and fixed to the graft (Fig. 1). The grafts were placed in identically the same way as in group C. In some instances, the distance from the obtuse corner to the coil needed to be more contracted by suture after the completion of anastomosis.

Group E: Replacement of inferior vena cava distal to renal veins with a graft reinforced with a coil, was done in three animals. Vena cava was exposed through the midline incision and excised from the junction of iliac veins to renal veins, leaving a cuff of vein for suture at each end. A graft of 10 mm in diameter and 5 cm in length was reinforced externally in the entire length with a finer coil than in the case of group D. The graft was anastomosed end-to-end, excluding the coil in order to facilitate the handling of suture. The graft was covered in place with peritoneum, then the graft, coil and peritoneum were fixed together with two or three interrupted sutures.

Gavograms were taken for the evaluation of patency of grafts by injecting about 10 ml of 76% Urographin into a greater saphenous vein at varying periods postoperatively. Thirteen animals died of various causes postoperatively and the other fifteen survived and were sacrificed later. Autopsy was performed in all these animals. The longest term of observation was 451 days. Histological studies were conducted with longitudinal and also cross paraffin sections of the specimens, with and without removal of the prosthetic fabric before embedding. The inner layer of the graft was usually broken and fragmented in the case with the fabric. The studies were carried out with hematoxylin and eosin, Van Gieson's, silver nitrate and Azan stains.

RESULTS

Group A: Two animals; both died of graft occlusion by fresh thrombus at one hour and on the third day after the experiment, respectively.

Group B: Four animals; one died of graft occlusion by white thrombus on the third day. Another died suddenly on the 19th day and fresh intraluminal thrombus was found but no mural constriction of the graft was observed at autopsy. The remaining two survived over 30 days and were sacrificed on the 30th and the 451st day, respectively. The grafts were patent in both.

Group C: 12 animals; one died of bleeding from the suture line soon after the removal of clamps. One died of graft occlusion by fresh thrombus formed by inadequate control of the bleeding from the distal suture line soon after the removal of clamps. One died of cerebral damage after the shock due to prolongation of the operation and the bleeding from the operation field, at 5 hours postoperatively. Two others died of intrathoracic infection on the second day and the 19th day, respectively. The remaining seven survived over 30 days, of which three were sacrificed because of the formation of ascites, on the 30th, the 95th and the 147th day, respectively and the grafts were found to be compressed behind liver and lungs were atelectatic in various extent. In the other four the grafts were patent at the time of sacrifice after 36, 38, 88 and 421 days, respectively. In all these seven no constriction was found at the site of anastomosis. In the last case a small amount of calcification was present on the well-organized inner layer near the proximal end.

Group D: Seven animals; one died of bleeding from the distal suture line. In this case the coil was applied to the very end of the graft, which made anastomosis technically difficult. One died of rupture and bleeding from the distal suture line where excessive tension was produced after the removal of clamps because of the graft being too short. One died of mis-implantation of the graft in torsion, causing its occlusion and subsequent increase of blood pressure in the distal and bleeding from the suture line. One died of pneumothorax due to the technical error at closure of thorax. One was sacrificed because of symptoms of ileus on the 16th postoperative day and diaphragmmatic herna was observed at the autopsy, which occurred because the diaphragm was inadvertently left unsutured, but the graft was patent (Figs. 2, 3, 27, 28). The remaining two survived over 30 days and were sacrificed on the 37th and 250th day, respectively. The grafts were both patent and not constricted.

Group E: Three animals; one had occlusion of the graft, as revealed by the cavogram on the third postoperative day. Although its general conditions were good, it was sacrificed on the 29th day. The graft was found isolated and abscess was present around it. The remaining two were sacrificed on the 117th and the 142nd day, respectively. The grafts were patent in both and the inner layer was somewhat thicker than that of the graft implanted in thorax.

DISCUSSION

There are several important problems to be taken into consideration in making venous graft success: first, relating to the technical aspects and second, to the quality of grafts. It is desirable to have venous graft inserted as straight as possible to obtain a smooth blood flow, and an attention need be given to the fact that bypassgraft is easily occluded. Acute complete occlusion of inferior vena cava proximal to renal veins is fatal. Instead of excision and immediate replacement under complete occlusion, the author attempted to replace thoracic inferior vena cava by bypass-grafting the graft under partial occlusion and making subsequent division or excision of vena cava between the anastomoses. A long graft was also

Table 1 Repacement of inferior vena cava with Tetoron (polyester) grafts

Dog No.	Dog weight (Kg)	Graft length (cm)	Graft diameter (cm)	Time of follow up	Patency of graft	Cause of death	Remarks
Bypassgraft to thoracic inferior vena cava							
1	9	6	0.8	3 days	Occluded	Occlusion of graft by fresh thrombus	
2	12	6	1.2	1 hour		Occlusion of graft by fresh thrombus	
Replacement of thoracic inferior vena cava							
3	9	5	1.0	3 days	Occluded	Occlusion of graft by white thrombus	Pyothorax
4	9	5	1.0	30 days	Patent	Sacrifice	
6	8.5	6	1.0	19 days	Occluded	Occlusion of graft by fresh thrombus	Hydrothorax
7	9	4	1.0	451 days	Patent	Sacrifice	
Replacement of thoracoabdominal inferior vena cava							
5	9	10	1.0	0		Bleeding from anastomosis	
8	12	10	1.2	0		Occlusion of distal anastomosis by fresh thromous	
9	12	10	1.2	2 days	Patent	Pneumonia	Hydrothorax
10	10	10	1.2	5 hours		Cerebral damage	
11	10	10	1.2	147 days	Plattened	Sacrifice	Ascites & infection of operation wound
12	12	10	1.2	95 days	Plattened	Sacrifice	Ascites
13	8	10	1.0	88 days	Patent	Sacrifice	
# 14	10	10	1.2	30 days	Plattened	Sacrifice	Ascites & infection of operation wound
# 15	10	10	1.2	19 days	Patent	Pyothorax	
16	10	10	1.2	421 days	Patent	Sacrifice	
17	11	10	1.2	38 days	Patent	Sacrifice	
18	11	11	1.2	36 days	Patent	Sacrifice	
Replacement of thoraceabdominal inferior vana cana, applying a coil							
202	10	11	1.2	0		Bleeding from anastomosis	
203	10	11	1.2	250 days	Patent	Sacrifice	
204	10	10	1.2	1 hour		Bleeding from anastomosis	Rupture of anastomosis
205	11	12.5	1.2	16 days	Patent	Sacrifice	Diaphragmmatic hernia
206	11	12	1.2	1 days		Bleeding from anastomosis	Misimplantation of graft in torsion
207	11.5	11	1.2	37 days	Patent	Sacrifice	
208	9	10	1.2	0		Pneumothorax	
Replacement of abdominal vera cava, applying a coil							
301	8	5	1.0	29 days	Occluded	Sacrifice	Infection around graft
302	10	5	1.0	117 days	Patent	Sacrifice	
303	9	5	1.0	142 days	Patent	Sacrifice	

Animal contricted of thoracic inferior vena before the experiment

implanted to inferior vena cava between the portion just proximal to renal veins and the entrance of right atrium, followed by division or excision of thoracic inferior vena cava. The author tried to apply a coil to a graft and to cover the implanted graft with peritoneum or diaphragm, paying an attention to fix the graft in a suitable place. A considerable leakage from the suture line following the removal of clamps is readily checked by compression with gauze. However, because of venous wall being vulnerable to injury, the suture should be performed by atraumatic handling and be secure so as to avoid the necessity of reclamping. In practice, it is difficult to reclamp the vein without injuring it under bleeding in deeper areas such as the portion just proximal to renal veins. The causes of early failures of the experiments were mostly dependent on bleeding from the suture line, which occurred in five animals. The bleeding was, in brief, brought about by technical error in operation and each resulted in immediate death of the animal. Namely, in the first case, the distal suture was ruptured by an excessive tension immediately after the removal of clamps because of too short graft. As for the second case, the distal suture was twisted immediately after the removal of clamps as the result of the graft being misinserted in torsion, which caused an increase of the venous pressure in the distal part and bleeding from the suture line. Based on the experience with this case, thereafter each end of the graft was marked on one and the same side with a tie of black thread to avoid torsion. In the third case, the distal suture was insufficient. The handling of suture was disturbed by the coil applied to the very end of the graft. Therefore, in the case of thoracoabdominal implantation of a graft by this method the coil should be applied about 5 mm away from the distal end of the graft. In the fourth case, the direct cause of death was interruption of blood flow by an acute thrombus formed at the distal anastmosis, during the control of the bleeding. In the fifth case, the suture was insufficient due to inexperience with the technique. Another remarkable cause of the failures in early stage was lung complications because of the difficulty in handling of the animals. Besides the two cases that died obviously of intrathoracic infection on the second and the 19th day (Figs. 4, 5, 6, 29), respectively, in most instances, lung atelectasis was found at autospy in varying degrees. The intrathoracic fluid accompanied with lung atelectasis or infection seems to prevent the formation of the inner layer of the graft and sometimes to cause the separation of the once formed inner layer from the graft.

Size of the graft: The thickness of the fibrinous inner layer formed on the internal surface of the graft was about 1 mm. In this respect grafts were used mostly of about 2 mm larger size in diameter than the host vein. With a graft too large, anastomosis becomes difficult, and another disadvantage is stagnation of blood flow in the graft. With a too short graft, the host vein near the suture line is narrowed by the traction of the graft. For the purpose of thoracoabdominal implantation the distal end of a graft should be cut or shaped in parallel with the host vein before the use.

Rigidity of the graft: With rigid end of a graft the handling of suture is difficult, but in order to resist the compression by adjacent organs and also to prevent from falling into fibrous constriction, a proper rigidity is necessary for the synthetic graft (2), as MacLean *et al.* (3) and Benvenuto *et al.* (4) have reported of the high patency rate of graft by application of rigid Lucite rings. However, it is thought that the rigidity must be obtained without thickening of the wall; namely, the fiber itself must have a proper rigidity, because making the wall simply thick incurs a disadvantage of its porosity being low. It would be better to combine some rigid fibers with the soft ones presently available for the graft. As a step in such an attempt, in this series of experiments, a relatively fine hard steel coil was applied. This fine coil seemed not to interfere with the effective adhesion of adjacent tissue to the graft and was effective in protecting the graft from falling into fibrous constriction and against the compression of the adjacent organs (Figs. 7—10). As for crimp of a graft, it seems to be indispensable for the available synthetic graft to resist its kinking or collapsing in venous systhem, especially when it is placed in curved form. It is desirable to have the crimp as stable as possible.

Friction coefficient of the graft material: In order to make the organized inner layer of a graft adhere to the graft as firmly as possible, the graft should be porous as to be mentioned later and at the same time its internal surface needs not to be slippery. The friction coefficient of Teflon is lower than that of Tetoron and for this reason an organized fibrous tissue may be more apt to peel off in the case with Teflon than with Tetoron.

Porosity of the graft: The internal crevices of an implanted graft are at the first stage inlaid with coagulated blood, then coated and smoothened with the precipitation of fibrin. In a few days after the implantation this thin layer of coagulated blood and fibrin show the sign of organization at the suture line. In the other area, the organization is somewhat delayed but homogenous. Even after the lapse of days the organization from the suture line does not extent beyond several mm. The difference in the degree of organization between the suture area and elsewhere decreases along with the lapse of days and at 30 days there can no longer be detected any difference. At this stage the fibrinous layer seems to be organized throughout the entire length into an immature coarse connective tissue (Figs. 11—13), having no relation to the length of the graft. This layer is termed inner layer by WARREN and McCOMBS (5), or inner capsule or neointima or pseudointima by others. Generally, the process of the organization of fibrinous layer is shown firstly by new capillaries growing through the interstices of the graft (Figs. 27—29). The organized inner layer, having connection with the outer layer through the interstices of the graft (Fig. 14), becomes more compact with the passing of time (Figs. 15—26). These findings agree with the opinion of WESOLOWSKI *et al.* (6, 7) in that the inner capsule becomes organized via interstices of the graft in the case of artery. In some instances, the inner layer of the graft and the adjacent venous wall are clearly distinguished from each other at the suture line (Fig. 20) and in some instances the inner layer at the junction is relatively thin (Fig. 17). The endothelial lining of the graft and the host endothel are connected with each other, stained similarly and hardly distinguishable from each other (Figs. 22, 25). These observations support the hypothesis that extension of the host endothelium is the source of the graft endothelium as studied by MEIJNE (8), MACKENZIE and LOEWENTHAL (9), FLOREY and associates (10), STUMP and associates (11), and YOUNG *et al.* (12) on the graft placed in artery. Therefore, the origin of this lining is thought to be quite different from that of the fibrous inner layer. Because the inner layer is organized through the interstices of the graft, the time for the organization may naturally have relation with the degree of porosity, as described by PHILLIPS (13).

With too low porosity the inner layer of fibrin may be delayed in organization and turned necrotic, and further the tissue growing in the interstices of the graft and connecting with the inner layer to make it adhere to the graft also may not be sufficient. This point seems to agree well with the opinion of JORDAN and associates. On the other hand, with too high porosity the inner layer of fibrin or coagulated blood may become so thick as to check bleeding and consequently it may be delayed in organization. Finally, venous graft would preferably be more porous than the graft used in this study, and even on the consideration of the bleeding from the interstices of the graft, venous graft can be more porous than arterial one.

Specific gravity of the graft material: It would be desirable to use a lighter material for the synthetic graft. While steel has a heavy specific gravity, in our experience we have encountered no failure in the use of a steel coil with synthetic graft. However, if a light and suitable material for the graft like Teflon and Dacron or Tetoron with a proper rigidity is available, it would be more useful. Tetoron is more advantageous than Teflon as far as its light specific gravity is concerned.

SUMMARY AND CONCLUSION

Experimental replacement of inferior vena cava with crimped woven Tetoron arterial graft was performed in dogs. Bypass-graft to thoracic inferior vena cava was not successful in two animals. Total repacement of thoracic inferior vena cava was attempted in four animals, and thoracoabdominal long implantation to inferior vena cava through diaphragm behind liver, followed by excision of thoracic inferior vena cava between the anastomoses, was done in 12 animals. Of these 16 animals, the graft was patent or not occluded in nine at autopsy between the 30th and the 451st day after implantation.

Similar thoracoabdminal implantation of a graft reinforced with a steel coil was made in seven animals. Two grafts were patent at autopsy after 37 and 251 days, respectively. Abdominal vena cava replacement with a graft reinforced with a coil was undertaken in three animals. Two grafts were patent at autopsy after 117 and 142 days, respectively. On the whole, long term survival without occlusion over 30 days was obtained in fifteen/twenty-eight animals. Aside from the instances of simple bypass-graft and obvious technical errors in early experiments, it was in fifteen/eighteen, and the graft was completely patent in ten/eighteen animals. The failures within 30 days resulted mostly from either lung complications or technical errors, and the latter were remarkable in the thoracoabdominal group where the graft reinforced with coil was used, but the application of the coil was very effective in protecting the graft against the compression by the adjacent organs. Tissue reaction to Tetoron was not noticeable and to the silk thread it was very slight and seemed not to affect long term success. By the present method even the total replacement of theracic inferior vena cava can be performed safely under normothermia and thoracoabdominal long implantation to inferior vena cava is also possible with considerable success. In order to prepare a more suitable synthetic graft for vein, it requires further search for harder, lighter, more elastic and physicochemically more stable material. The fabric of venous graft should be preferably more porous and thinner than that of the arterial graft available at the present in order to make the organization within the shortest time possible.

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Fig. 1 Crimped woven Tetoron arterial graft applied with a molibdenum stainless steel coil.

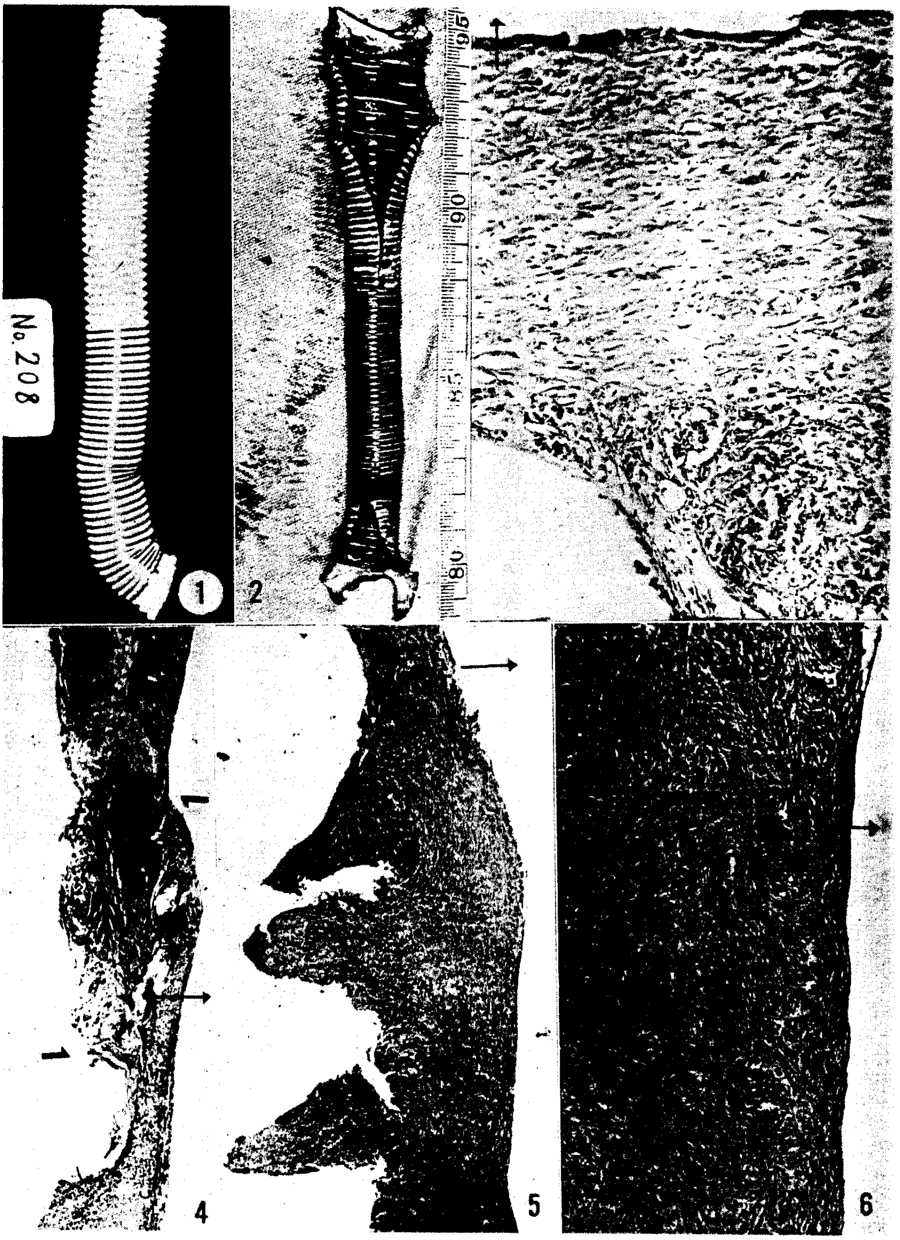
Fig. 2 Dog No. 205, gross specimen of Tetoron graft, *16 days after implantation* into thoracoabdominal vena cava. Note the completion of a smooth fibrinous inner layer. The rupture occurred during preparation of the specimen for photography.

Fig. 3 Photomicrograph of the inner layer shown in Fig. 2. Longitudinal section showing an area near the suture line (arrow indicates the lumen of graft). The specimen was embedded in paraffin after removal of the fabric in order to avoid the inner layer from breaking in cutting. H & E, (hematoxylin and eosin stain). ×40.

Fig. 4 Dog No. 15, photomicrograph of the inner layer of Tetoron graft, *19 days after implantation* into thoracoabdominal inferior vena cava. Longitudinal section showing anastomosis (arrows). The fabric was removed before fixation. Silver stain, ×8.

Fig. 5 Photomicrograph showing the area continuous from Fig. 4.

Fig. 6 Photomicrpgraph of a greater magnification of the same area in Fig. 5. ×25.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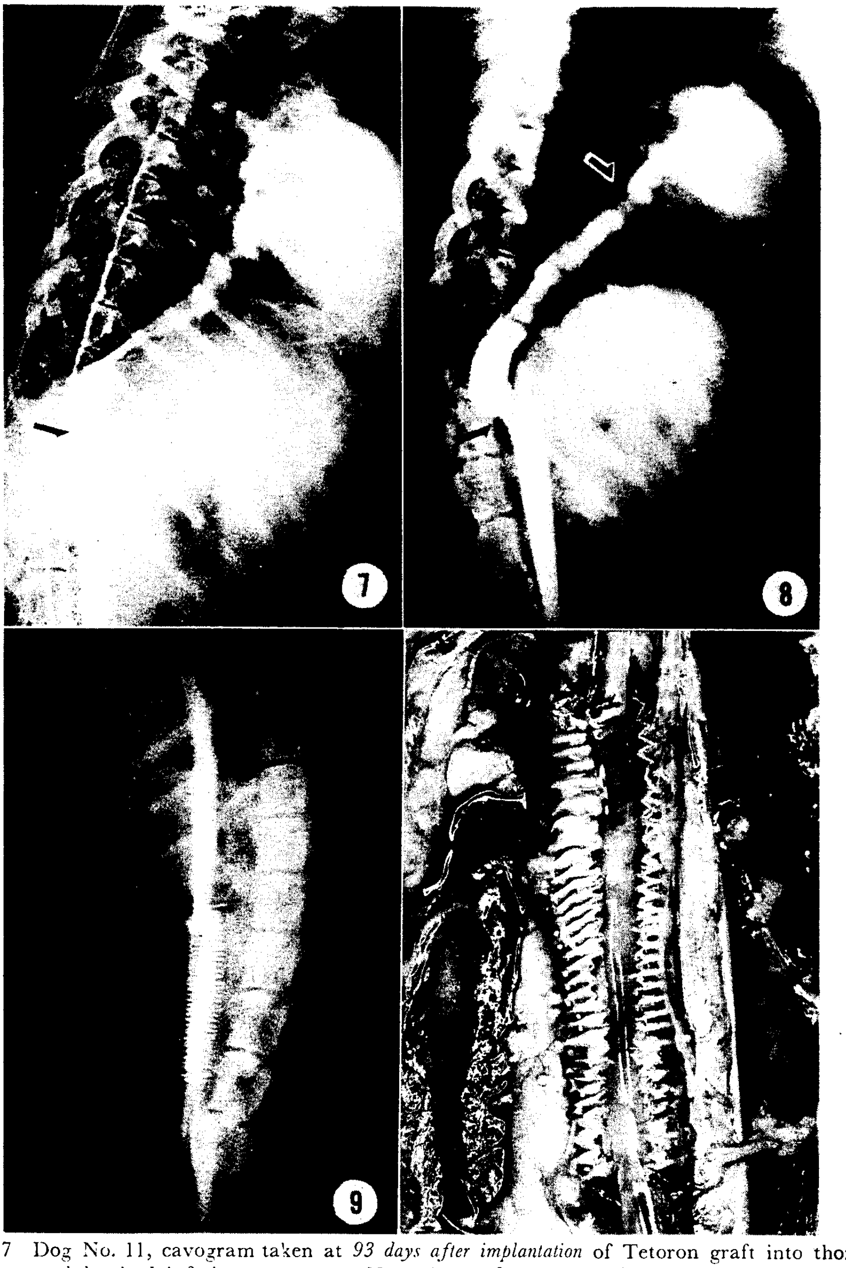
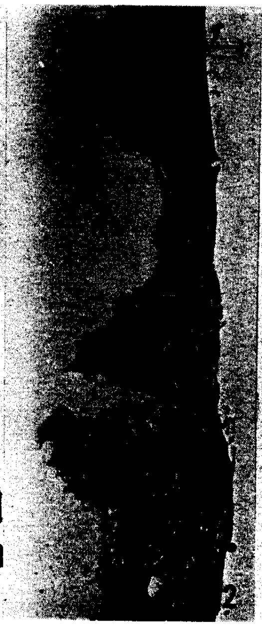


Fig. 7 Dog No. 11, cavogram taken at *93 days after implantation* of Tetoron graft into thoracoabdominal inferior vena cava. Note the graft compressed by liver.

Fig. 8 Dog No. 203, cavogram taken at *250 days after implantation* of Tetoron graft reinforced with a coil (arrows). No compression is found of graft.

Fig. 9 Dog No. 303, cavogram taken at *142 days after replacement* of abdominal inferior vena cava with Tetoron graft. Coil is applied to the entire length of graft.

Fig. 10 Gross specimen of the graft in Fig. 9, showing no constriction. Size of graft is 10 mm in diameter.



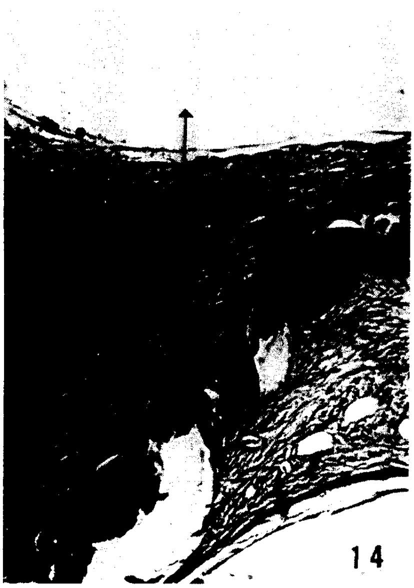


Fig. 11. Dog No. 14, gross specimen of Tetoron graft, *30 days after implantation* into thoracoabdominal inferior vena cava, showing distal anastomosis. Inner surface is covered by a smooth glistening inner layer.

Fig. 12. Photomicrohraph of the inner layer shown in Fig. 11. Longitudinal section showing anastomosis (arrow). The fabric was removed before fixation. Azan stain, ×8.

Fig. 13. Another photomicrograph of the inner layer shown in Fig. 11. Longitudinal section showing its middle portion made of immature organized connective tissue. The fabric was removed before fixation. ×8. Time of organization seems to have no direct relation to the length of graft.

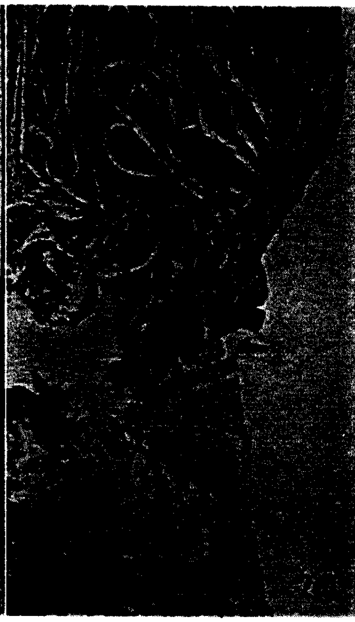
Fig. 14. Dog No. 11, photomicrograph of Tetoron graft. *147 days after implantation* into thoracoabdominal inferior vena cava. Longitudinal section. Note the connection between the inner layer and the outer layer, through the interstices of fabric. H & E, ×20.

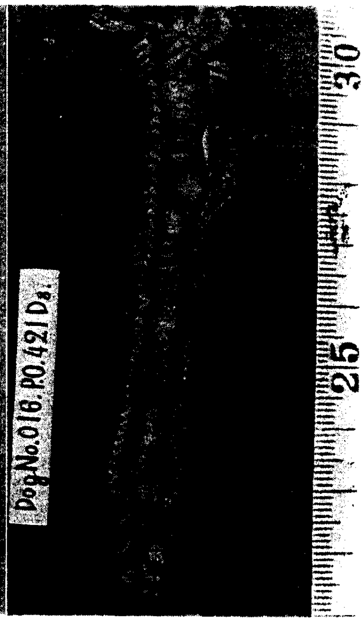
Fig. 15. Dog No. 13, cavogram taken at *88 days aftre implantation* of Tetoron graft into thoracoabdominal inferior vena cava (arrows). The animal died by the cavography.

Fig. 16. Gross specimen of the graft shown in Fig. 15. Inner layer is more compact than that in Fig. 11. Size of graft is 10 mm in diameter.

Fig. 17. Photomicrograph of the inner layer shown in Fig. 16. Longitudinal section showing anastomosis (arrow). The fabric was removed before fixation. H & E, ×8.

Fig. 18. Another photomicrograph of the inner layer shown in Fig. 16. Longitudinal section showing its middle portion made of complete fibrous tissue. The fabric was broken in cutting. H & E, ×20.





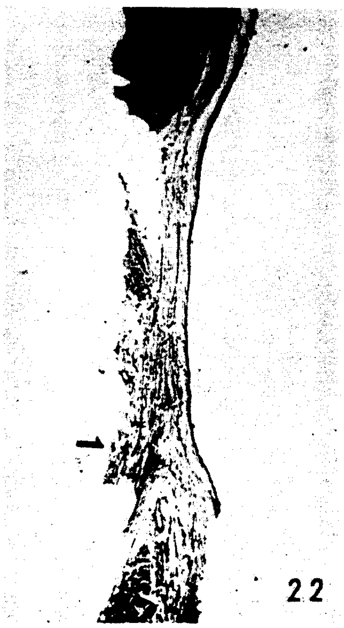


Fig. 19. Gross specimen of the graft in Fig. 8, *250 days after implantation* into thoracoabdominal inferior vena cava. The coil was removed for opening the specimen. Neither constriction nor calcification is present.

Fig. 20. Photomicrograph of the specimen in Fig. 19. Longitudinal section showing anastomosis (arrow). The fabric was broken in cutting. H & E, ×16.

Fig. 21. Dog No. 16, gross specimen of Tetoron graft, *421 days after implantion* into thoracoabdominal inferior vena cava. Slight calcification is present near the suture line.

Fig. 22. Photomicrograph of the specimen shown in Fig. 21. Longitudinal section showing anastomosis (arrow). The fabric was removed before fixation. H & E, ×10.

Fig. 23. Photomicrograph of another longitudinal section of the specimen in Fig. 21, showing well organized inner layer. The fabric was removed before fixation. H & E, ×16.

Fig. 24. Dog No. 7, cavogram taken at *116 days after total replacement* of thoracic inferior vena cava with Tetoron graft (arrows).

Fig. 25. Photomicrograph of the graft shown in Fig. 24, *451 days after implantation.* Longitudinal section showing anastomosis. A cut surface of silk suture is found at the midportion, without tissue reaction (arrow). The fabric was removed before fixation. H & E, ×20.

Fig. 26. Photomicrograph showing another area of the same section in Fig. 25, ×16.

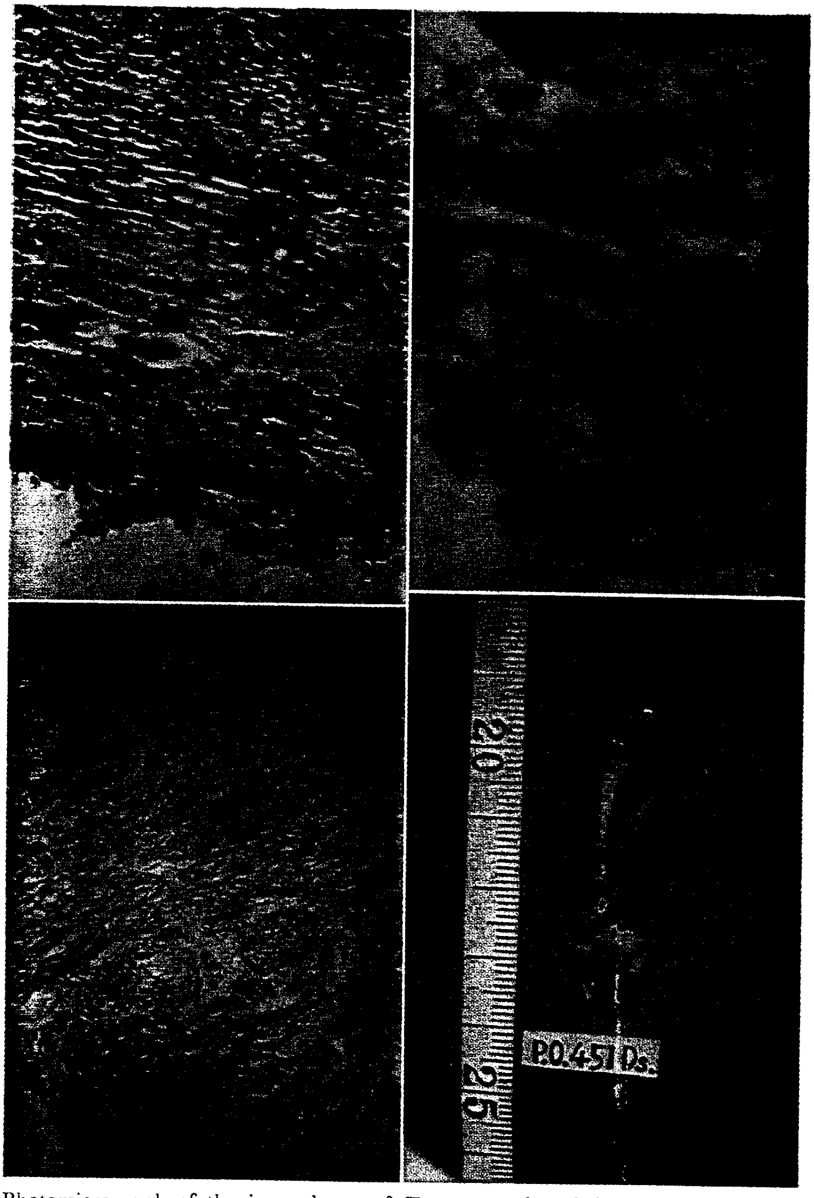


Fig. 27. Photomicrograph of the inner layer of Tetoron graft, *16 days after implantation* into thoracoabdominal inferior vena cava. Cross section. The fabric was removed before fixation. Note the organization more advanced in the basal area than in the area adjacent to the lumen. H & E, ×40.

Fig. 28. Photomicrograph of a greater magnification of the same area in Fig. 27. Note the blood capillary newly formed in the basal area of the inner layer (arrow), ×160.

Fig. 29. Photomicrograph of the inner layer of Tetoron graft, *19 days after implantion* into thoracoabdominal inferior vena cava. Longitudinal section. The fabric was removed before fixation. Note more advanced organization in the basal area. H & E, ×40.

Fig. 30. Dog No. 7, gross specimen of Tetoron graft, *451 days after total replacement* of thoracic inferior vena cava. Note the longitudinal constriction.