Healing of Cooley Double Velour Arterial Graft in Man

Kensuke ESATO, Etsuro ODA,
Nobuyoshi MORITA and Rikio YAMAKI

From the First Department of Surgery, Yamaguchi University School of Medicine, Ube, Yamaguchi, Japan
(Received January 29, 1979)

ABSTRACT

To evaluate the healing of Cooley double velour grafts, ten specimens were removed from the mid-portion of grafts implanted in patients with arteriosclerosis obliterans of the lower extremities for periods from ten days to 28 months and examined by light- and scanning electron micrographs. Within one month after implantation, the intraluminal surface of the graft was covered with a thin fibrinous membrane over many blood cells. A thin fibrin network had been formed in the period of 4 to 7 months after implantation. Pseudoneointima was completely formed in the period of 8 to 12 months. However, endothelium, having the antithrombogenic factors, was not found twelve months and longer after implantation. Therefore, continuation of anticoagulant therapy as long as possible is necessary in order to prevent the formation of thrombi on the intraluminal surface of the graft.

Key Words: *cooley double velour graft*; *pseudoneointima*; *outer and inner capsules*; *scanning electron micrograph*; *complete healing*

It is thought that the thinner and more porous an arterial graft is, the better will be the healing. However, complete healing of such a vascular graft has not yet been accomplished in man. Healing has only occurred within a few millimeters of each suture line and the intraluminal surface has persisted as a fibrinous lining. These findings are in marked contrast to the dog, pig and calf[1]. In these animals complete healing of various arterial graft has occurred over the intraluminal surface.

The purpose of this study was to evaluate the healing of Cooley double velour grafts (Meadox Medicals, Inc.) that were implanted in patients with arteriosclerosis obliterans of the lower extremities.

MATERIALS AND METHODS

The specimens studied are summarized in Table I. The implant periods ranged from ten days to 28 months; the sites were aortofemoral bypass, 3, iliofemoral and ilio-femoro-popliteal, 1 each, and femoropoplit eal, 5. The patients were divided into four groups by patency periods: group I, 1 month or less; group II, 4-7 months; group III, 8-12 months; group IV, over 12 months. The average patency period was 8.9 months. The sites were reopened and specimens were removed from the midportion of the implanted grafts and were examined by light- and scanning electron micrographs. In order to document the complete healing of these specimens, it was important to stain immediately after removal because of their extremely delicate endothelium. Therefore, hematoxylin and eosin staining was done as soon as possible. In this study, complete healing is defined as encapsulation with fibrous tissue all around the wall of the graft and endothelium covering the intraluminal surface.

Table I Synopsis of Cases

Group	Case No.	Age (Yrs)	Implantated Site	Patent Periods (Months)
I	1	69	Femoro-popliteal	0.3
	2	59	Femoro-popliteal	1
II	3	73	Femoro-popliteal	4
	4	51	Ilio-femoro-popliteal	4
	5	71	Femoro-popliteal	6
	6	75	Aorto-femoral	7
III	7	74	Ilio-femoral	8
	8	51	Femoro-popliteal	12
IV	9	52	Aorto-femoral	19
	10	67	Aorto-femoral	28

RESULTS

In group I, a large number of blood cells had accumulated on intraluminal surface of the graft and were covered with a thin fibrinous membrane. Fibroblasts and collagenous fibers were not found in any area of the graft. The outer capsule was incompletely formed (Fig. 1). Scanning electron micrographs showed that the intraluminal surface of the graft was covered with dense fibrin, in some portions of which the

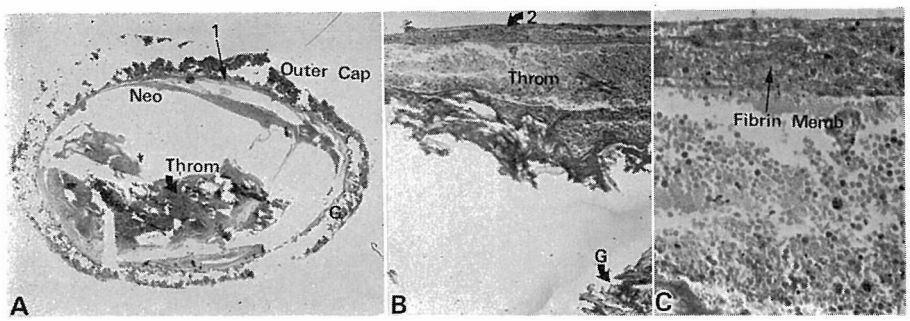

Fig. 1. (A) Photomicrograph of a cross-section of graft No. 1. A thin fibrinous membrane can be seen on the intraluminal surface. The outer capsule is incompletely formed. (B) The fibrinous membrane at "1" in A. A thin fibrinous membrane has formed on the accumulated blood cells. (C) The fibrinous membrane at "2" in B. Neo: Pseudoneointima; Throm: Thrombus; G: Graft; Fibrin Memb: Fibrin Membrane. (A; ×2, B; ×40, C; ×100).

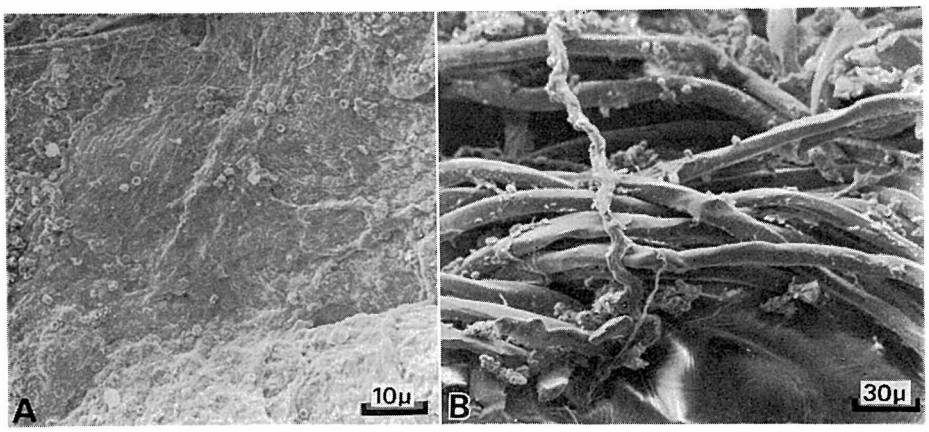

Fig. 2. Scanning electron micrograph of the intraluminal surface of graft No. 2. (A) Dense fibrin are seen (Original magnification, ×300). (B) Fibrils of fabric without a fibrinous membrane are completely exposed (Original magnification, ×1000).

knit pattern and fibrils of fabric could not be identified. On the contray, in other portions, fibrils of fabric without any fibrin or blood cells were completely exposed (Fig. 2). Pseudoneointima had not completely formed within a month after implantation. In group II collagenous fibers, containing fibroblasts, were found on the intraluminal surface of the graft, but the thickness of the layer was the same as in group I. The outer capsule in group II had became thicker than in group I. Fibrinous inner and

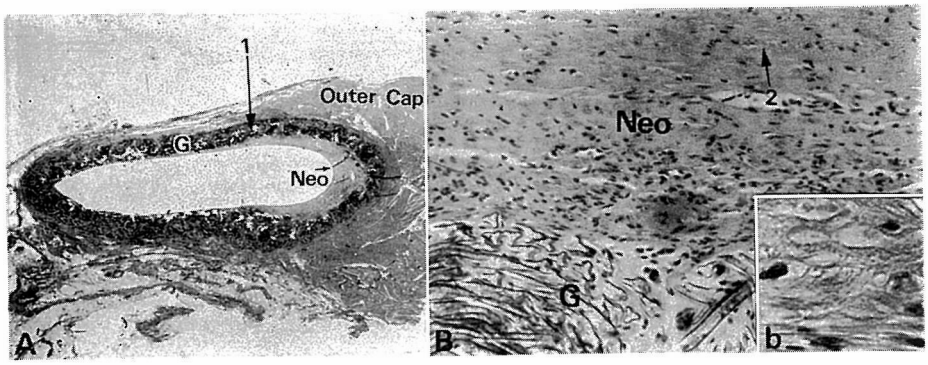

Fig. 3. (A) Photomicrograph of a cross-section of graft No. 6. Collagenous fibers with many fibroblasts are shown on the intraluminal surface. Well-established bridges through the interstices of the graft can be observed between the inner and outer capsule. (B) The collagenous fibers at "1" in A (arrow). (b) Higher magnification of "2" in B. Neo: Pseudoneointima; G: Graft; Outer Cap: Outer Capsule. (A; ×2, B; ×100, b; ×400).

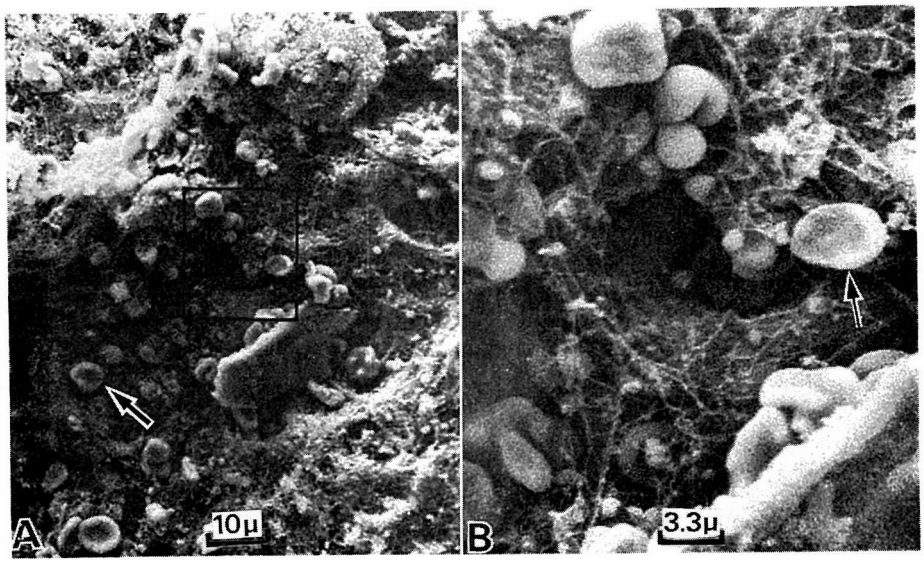

Fig. 4. Scanning electron micrograph of the intraluminal surface of graft No. 3. A thin fibrin network is shown on the blood flow surface. (A) Original magnification, ×1000. Arrow shows an erythrocyte. (B) Higher magnificatoin of the rectangular area in A, ×3000.

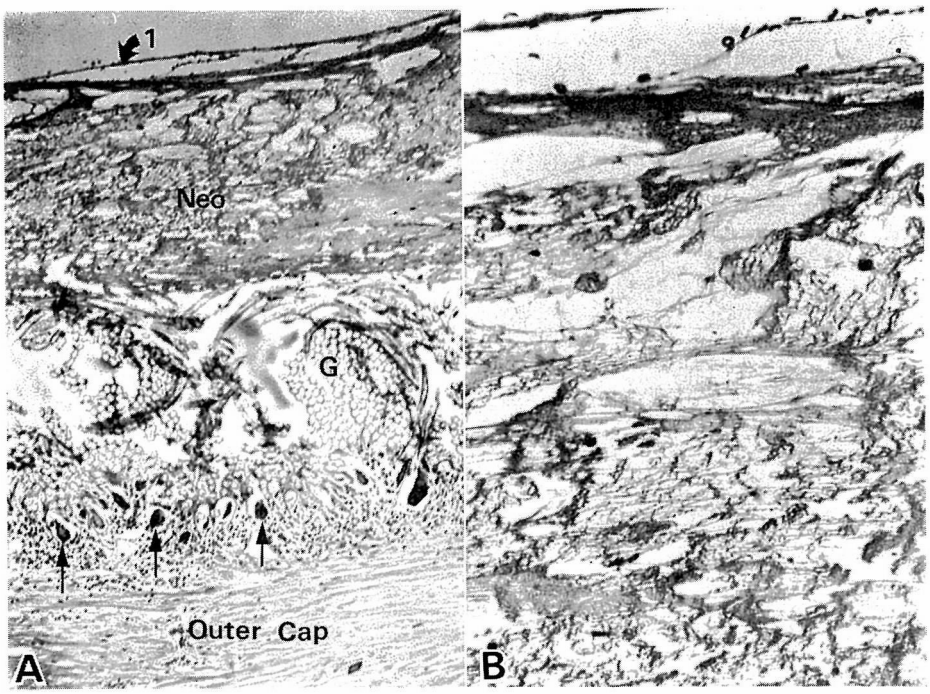

Fig. 5. Photomicrograph of a cross-section of graft No. 7. (A) The collagenous fiber layer is the same thickness as the graft. Foreign body giants cells can be identified in the interstices of the graft (arrow). (B) The collagenous fiber layer at "1" in A. Neo: Pseudoneointima; G: Graft; Outer Cap: Outer capsule. (A; ×100, B; ×400).

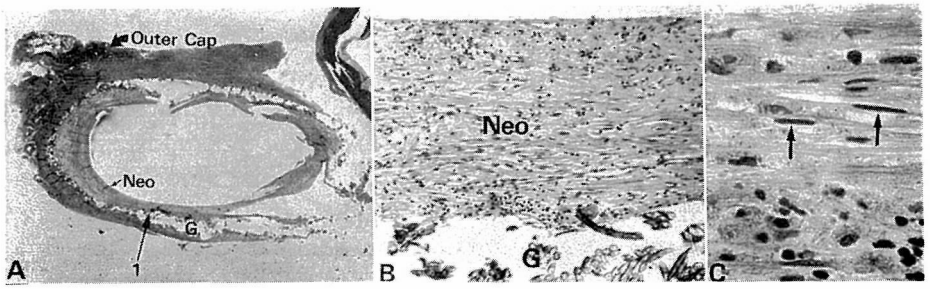

Fig. 6. Photomicrograph of a cross-section of graft No. 8. (A) The inner capsule is completely formed with infiltration of many fibroblasts and round cells. (B) The collagenous fibers at "1" in A. (C) Higher magnification of B. The fibroblasts are clearly enmeshed (arrows). Neo: Pseudoneointima; G: Graft; Outer Cap: Outer capsule. (A; ×1.5, B; ×100, C; ×400).

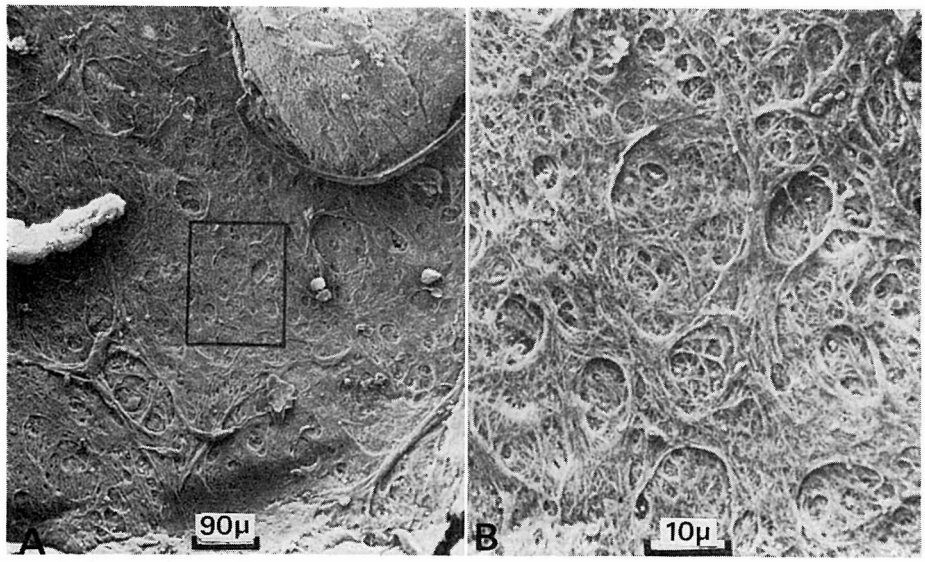

Fig. 7. Scanning electron micrograph of the intraluminal surface of graft No. 7. The fibrin networks are clearly established. Blood cells and endothelium are seldom seen. (A) Original magnification, ×100. (B) Higher magnification of the rectngualar in A, ×300.

outer capsules with well-established bridges could be identified through the interstices of the graft, though endothelium was not visible (Fig. 3). The intraluminal surface of the graft was not smooth, but a thin fibrin network had formed and many blood cells were visible in the micrographs (Fig. 4). Pseudoneointima was considered incompletely formed in the period from four to seven months after implantation, since endothelium could not be seen. In group III, a collagenous fiber layer with the same thickness as the graft, containing fibroblasts but fewer than in group II, was seen on the intraluminal surface. Foreign body giant cells were identified in the interstices of the graft and the outer capsule was more fully developed than in group II (Fig. 5). In the specimen eight months after implantation (case 7, the iliofemoral bypass) the inner capsule was completely formed with the infiltration of many fibroblasts and round cells (Fig. 6). In the scanning electron micrographs of group III, fibrin networks were clearly visible on the intraluminal surface of the graft. Blood cells were seldom found (Fig. 7). However, in certain cases, an abundance of thick collagenous fibers, arranged in the direction of the blood flow, were found on the intraluminal surface of the graft the absence of a fibrin network (Fig. 8). The outer and inner capsule had completely developed, although endothelium was not visible on

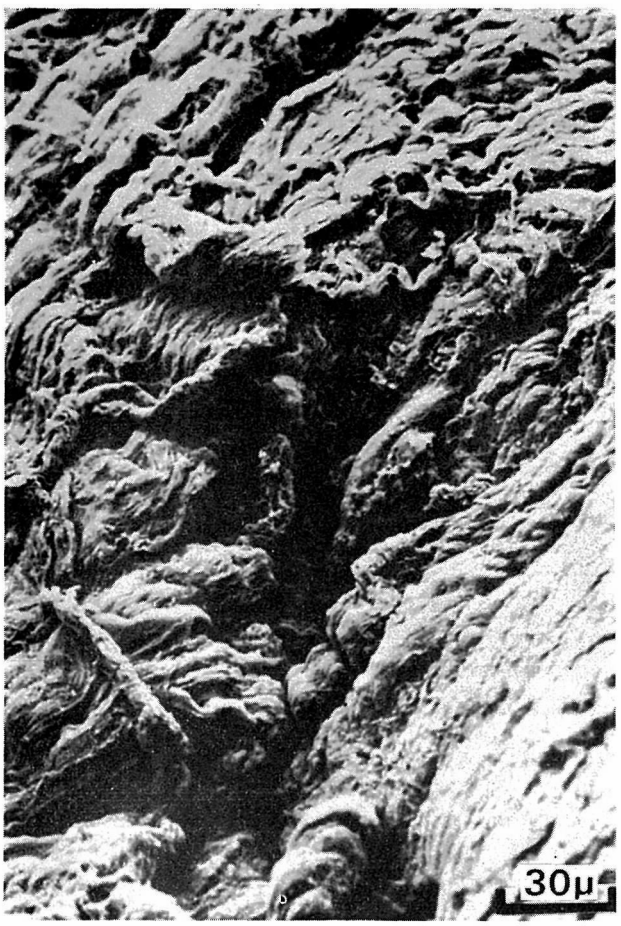

Fig. 8. Scanning electron micrograph of the intraluminal surface of graft No. 8. Thick collagenous fibers are arranged in the direction of blood. Fibrin networks cannot be seen (Original magnification, ×300).

the intraluminal surface, twelve months after implantation. In group IV, a collagenous fibrin layer twice as thick as the graft was visible on the intraluminal surface. In the middle of this layer, blood cells and fibroblasts were scarce. However, on the side near the intraluminal surface, blood cells had proliferated markedly, suggesting that they had gradually accumulated after implantation (Fig. 9). Scanning electron micrographs showed that the intraluminal surface of the graft was covered by a fibrin network much more dense than the ones seen in group III. However, endothelium was seldom found on any area of the intraluminal surface of the graft, the same finding as in group III (Fig. 10).

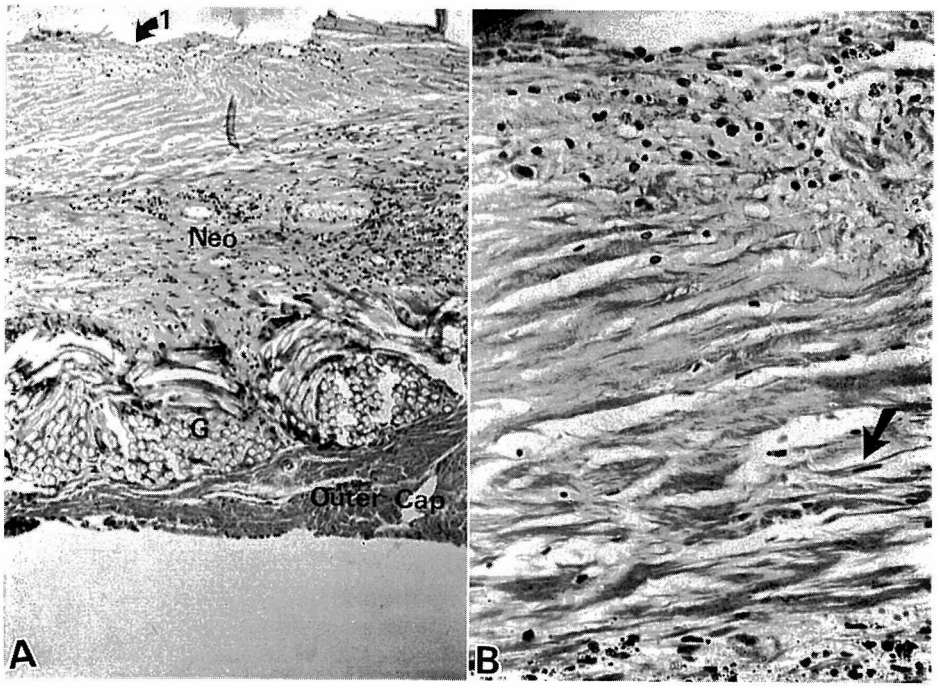

Fig. 9. (A) Photomicrograph of a cross-section of graft No. 9. The collagenous fiber is twice as thick as the graft. (B) The collagenous fiber layer at "1" in A. Blood cells can be seen on the side near the intraluminal surface, suggesting that blood cells accumulate with the lapse of time after implantation. Arrow shows the fibroblasts. Neo: Pseudoneointima; G: Graft; Outer Cap: Outer capsule. (A; ×40, B; 9×100).

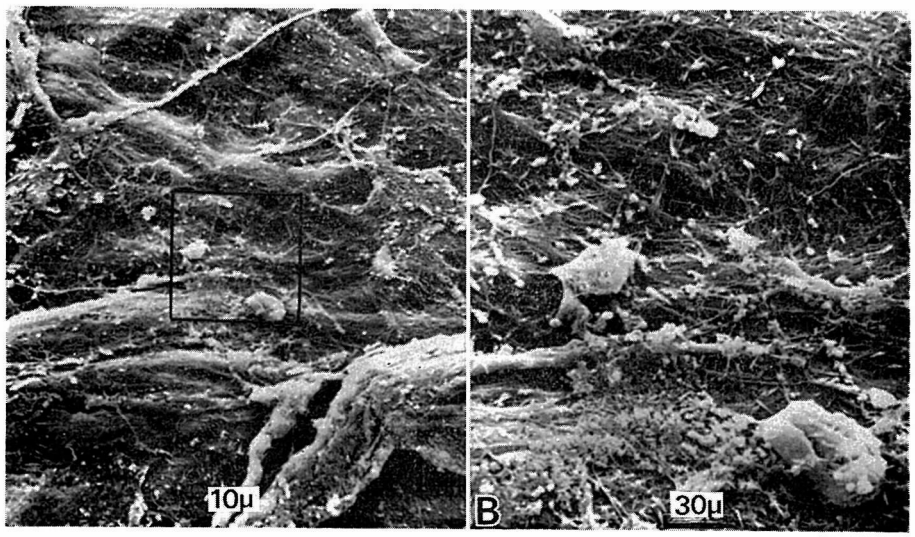

Fig. 10. Scanning eletron micrograph of the intraluminal surface of graft No. 9. A large fibrin network covers the intraluminal surface. Endothelium cannot be seen: (A) Original magnification, ×300. (B) Higher magnification of the rectangular area in B, ×1000.

DISCUSSION

Complete healing of conventional, relatively smooth, highly porous fabric vascular prostheses has not yet been accomplished in man except at the suture lines[2]. The synhtetic vascular graft is foreign body which the host tends to encapsulate completely. DeBakey and coworkers[3] examined Dacron Grafts which were removed 2 weeks to almost 7 years after implant and reported that the luminal substance in direct contact with the blood flow was fibrin in most of the cases. Wesolowski et al.[4] reported that a compact, inner layer of fibrin - an inner capsule - had formed ten days after implantation and that new blood vessels grew through the interstices of the synthetic vascular graft from the outer capsule into the inner fibrous capsule a month after implantation. In our cases, ten days after implantation, blood cells had accumulated on the intraluminal surface of the graft. over which a thin fibrin layer was found, but no new blood vessels had yet formed. Sauvage et al.[1] reported that it takes about 3 to 5 months for the outer collagenous connective tissue to penetrate the interstices of the external velour graft to form a luminal fibrous tissue layer in the human, although degree of the development of this layer depends on kinds of the host and the vascular graft. We used a Cooley double velour graft with a mean water porosity of 1500 ml/cm^2/min at 120 mmHg. Velour configuration is believed to favor healing because fibroblasts advance more rapidly and completely than they do in the conventional knitted graft with a relatively smooth wall. In specimens of the double velour graft four or seven months after implantation in humans collagenous connective tissue grew via the interstices from the outer capsule. However, the collagenous fibrinous layer, (in some portion of which hyaline degeneration had occurred) was twice as thick as the graft.

Sauvage et al.[5] accomplished complete healing of an arterial graft (implanted for 20 months in an axillary-femoral bypass) at points far from the anastomosis. Complete healing of the porous arterial graft in man is an attainable goal. Unless we reach this goal, these grafts will probably become obstructed by thrombi as time progresses after implantation. In our results, although collagenous fibrinous tissue and fibrin networks were well developed, endothelium was not found even 28 months after implantation. To decrease acute platelet adhesiveness, Sauvage and co-workers[6] used dextran for the first 2 days (500 ml/day) untill the patient was able to take oral agents. Then dipyridamole 100 mg/day and aspirin 15 grains/day or dipyridamole alone, 400 mg/day was given for 6 months. As the patency rate twelve months after implan-

tation was 47.3% (9/19) in our cases of femoropopliteal bypass using double velour Cooley grafts[7], it is important to continue anticoagulant therapy as long as possible after surgery.

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