Presence of Endothelium in an Axillary-femoral Graft of Knitted Dacron With an External Velour Surface

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An axillary-bilateral common femoral graft of knitted Dacron with an external velour surface was examined within one hour after the patient's death from non-graft-related causes. The prothesis, implanted for 20 months, was patent and was completely healed over 32% of the flow surface—that is, full wall fibrous tissue encapsulation of the graft had occurred, and 32% of the flow surface was endothelialized. The remaining flow surface was formed of fibrin, but fibrous tissue healing had reached the inner surface of the graft material, and the fibrin overlay was very thin. The healed portions of the graft included not only the areas adjacent to the anastomoses, but were scattered throughout the 45 cm length of the prosthesis. To our knowledge, this is the first report of complete healing (fibrous tissue encapsulation and endothelialization) documented at points beyond the pannus ingrowth at the prosthesis-artery anastomosis.

TO OUR KNOWLEDGE, complete healing (see Fig. 1) of conventional, relatively smooth-walled porous fabric vascular prostheses has not been demonstrated in man except within a few millimeters of each suture line.[1,7] Here it develops by transinterstices ingrowth from the perigraft tissues and by pannus extension across the suture line from the host artery. Our specimens indicate that pannus ingrowth extends only about 6-10 mm in man. Between these limited areas adjacent to each suture line, the inner surface of conventional porous prostheses has consistently been covered with compacted fibrin. The specimens studied have all been recovered from patients who died of nongraft causes, and all were patent at time of death.[1,7]

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Previously, we reported[5] the presence of what was probably complete healing at 182 days (6 months) in a man having a non-crimped external velour knitted Dacron aorto-bilateral common femoral bypass graft. The word "probably" is used here, because, while other criteria for complete healing were present, endothelium could not be demonstrated on the luminal surface. However, endothelium is very delicate, and it must be stained almost immediately in order to be identified. In this case, several hours had elapsed between the time of death and silver staining of the specimen.

In this paper, we report the presence of islands of endothelium scattered throughout another graft of the same type—knitted Dacron with an external velour surface—but with a random crimp configuration. This graft, a left axillary-bilateral common femoral artery bypass graft, was removed upon death of the patient 20 months postoperatively. Islands of complete healing were found scattered throughout the 45 cm long prosthesis. Thirty-two per cent of the flow surface was covered by endothelium, and the remainder by compacted fibrin.

Although complete healing was attained in only about one-third of the area of the graft, to our knowledge this is the first description of such healing in man at sites far removed from the limited areas of pannus ingrowth adjacent to the anastomoses to the host artery. In 1964, DeBakey and colleagues reported endothelium on fibrin in a graft which had been in a patient for almost 4 years.

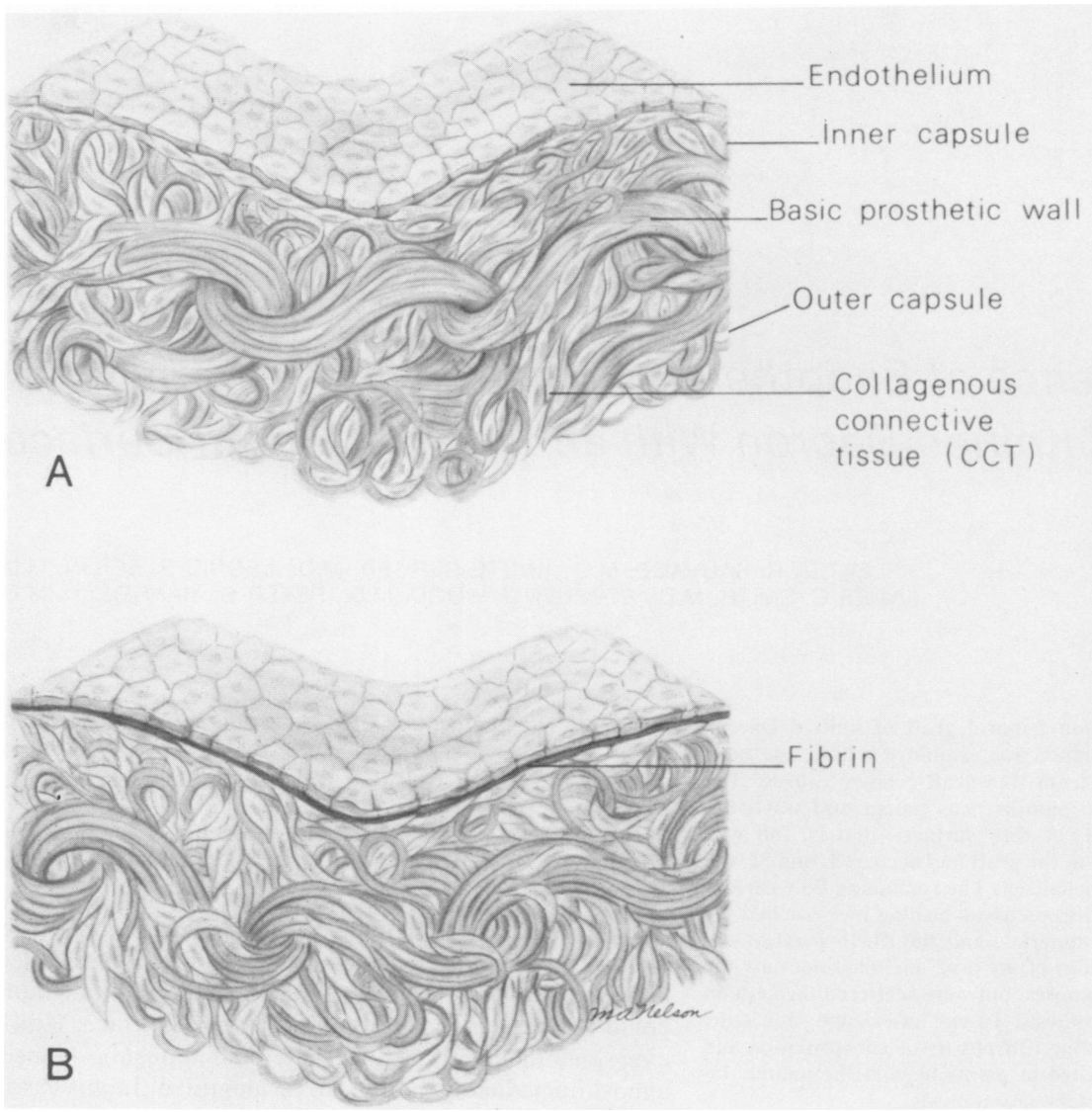

FIG. 1. Diagrammatic representation of the term "complete healing" of a vascular prosthesis wall, as used in this paper. Complete healing means that the wall of the graft is completely encapsulated in fibrous tissue, and that the flow surface is covered by endothelium. The endothelium may be lying directly on the CCT (A), or there may be a layer of fibrin beneath it, no more than the equivalent of a few cells thick (B).

The distance of the endothelium from the suture line was not specified.[2] In the prosthesis herein reported, patches of complete healing were demonstrated all along the 45 cm length of the prosthesis, and we therefore believe this case to be highly significant.

Case Report

The patient, a fragile 75-year-old Caucasian man, when seen by us on the 14th of May, 1971, had severe rest pain and impending gangrene of his right foot, as well as signs of severe ischemia of his left foot. Femoral pulses were weak, particularly on the right, and systolic murmurs were present at both groins and over the iliacs. No pulses were palpable below the groin. Translumbar aortography showed severe bilateral aortoiliac stenosis that was greater on the right than on the left, bilateral superficial artery occlusion, diseased but patent popliteals, and extensive occlusive changes in the run-off vessels of the lower leg. We considered this patient a poor risk for an aorto-bilateral common femoral artery bypass graft because of his advanced age, general fragility, and poor physical condition, which included hypertension, emphysema, coronary heart disease and extensive radiation fibrosis of the right side of the abdomen secondary to radiotherapy administered in 1948 for cancer of the right testicle. Because of these risk factors, we elected to perform a left axillary-bilateral common femoral artery bypass graft. The procedure was performed on May 26, 1971, using a 6mm diameter random-crimped prosthesis of knitted Dacron with an external velour surface (USCI, Inc., of Billerica, Mass.)

The patient tolerated the axillary-femoral procedure without difficulty and was discharged on the ninth postoperative day with markedly improved circulation of both lower legs and feet. For the ensuing 20 months, he was able to walk for 3 to 4 blocks (the limit of his general strength) without claudication and his feet remained viable and painless. Then, in late January 1973, the patient began to fail rapidly and after a few days developed severe abdominal pain. When brought to the hospital by ambulance he was in a near-terminal state on February 1, 1973 with evidence of congestive failure, small bowel obstruction, and peritonitis. The graft was patent, as indicated by pulsations along its course.

Although the risk of abdominal exploration was considered very high, the outlook without correction of the intra-abdominal pathology appeared hopeless. As the abdomen was opened, profound circulatory collapse occurred. Unsalvageable mesenteric infarction was present and the patient expired shortly. Permission was obtained from the family for removal of the graft in the operating room. The graft was

exposed through a continuous incision along its entire length. Perigraft tissues were very securely attached to the wall, forming a flexible outer capsule that blended into the perigraft tissues without a distinct boundary.

The entire graft, including the anastomoses to the axillary and common femoral arteries, was removed within 30 minutes of death. It was then flushed gently with 5% dextrose and water and carefully opened throughout its length. Postmortem thrombus had formed to cover the flow surface in some areas, but not in others. The surface where postmortem thrombus had not formed was glistening, smooth, whitish, and sufficiently thin (circa 100 microns) that the fibers on the underlying prosthetic wall could be seen. Thrombus that was obviously postmortem was gently removed from the other portions of the graft, revealing the underlying wall in these areas to be thicker and less translucent than in those areas where postmortem thrombus had not formed.

The graft was then submerged in 0.25% silver nitrate for two minutes. The elapsed time between the patient's death and silver nitrate staining for endothelium identification was approximately one hour. After completion of the silver stain, the flow surface was scanned under the stereomicroscope and the specimen placed in 10% formalin. After fixation, the flow surface was studied from one end to the other under the stereomicroscope and the location of the endothelium was accurately mapped on a scaled reproduction of the opened graft (Fig. 2). Photographs of the flow surface were taken at points near the upper anastomosis, and in the middle of the graft, where they were taken in areas representative of non-endothelial coverage as well as in areas representative of endothelial coverage.

Tissue blocks were cut from many areas, including those areas photographed to document the presence or absence of endothelium. These blocks were fixed for histologic study, and sections stained with hematoxylin and eosin and Masson's trichrome. Examination of these sections showed that endothelium was present only in those areas where full fibrous tissue encapsulation had occurred. Endothelium lay both on the collagen itself and on a very thin layer of fibrin on top of the collagen. Surface and cross sectional findings from the graft locations indicated in Fig. 2 are shown in Figs. 3 through 6.

Complete healing was present not only in the proximal portion of the graft adjacent to the axillary artery (Figs. 3 and 4), but also in islands, scattered throughout the length of the graft (Figs. 3 and 5). Thirty-two per cent of the flow surface of the prosthesis was covered by endothelium, as measured by planimeter on the scale drawing.

In contrast to the healing shown in Figs. 3, 4 and 5, Fig. 6 shows an area of incomplete healing, representative of 68% of the graft surface, from location "h" (Fig. 2) in the midst of an endothelial island. In these areas, although there was fibrous tissue ingrowth the full thickness of the graft wall, including a layer covering the inner surface of the fabric, this tissue was nonetheless beneath a layer of compacted fibrin approximately 0.25 mm thick, which formed the flow surface.

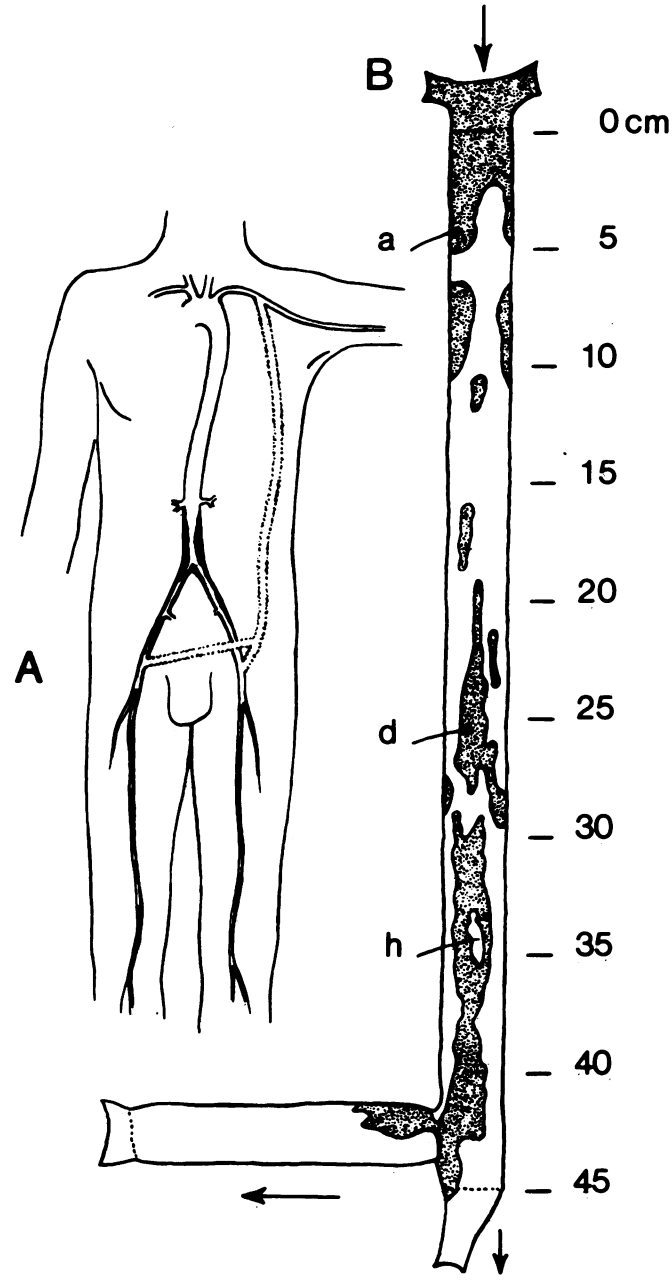

FIG. 2. (A) Location of left axillary bilateral common femoral external velour bypass prosthesis. (B) Surface tissue map of graft after recovery from patient 20 months postoperatively. Stippled areas indicate tissue. "a": pannus at proximal end; "d": island of tissue covered by endothelium; "h": area of tissue covered by thin red thrombus.

Discussion

The extraordinary thrombus-resistant characteristics of an intact, healthy endothelial flow surface make it the desired lining for a prosthetic arterial graft. Unfortunately, such a flow surface is exceedingly difficult to obtain on arterial prostheses in man. In fact, until we observed the prosthesis reported in this paper, we were not certain that an endothelialized flow surface on top of a fibrous tissue base was an attainable objective in man. It is reassuring to know that complete healing is possible with current prostheses, even if it is a slow and unreliable process.

Our human specimens of the external velour prosthesis show that it takes about 3 to 5 months for perigraft collagenous connective tissue to penetrate the interstices of these prostheses to form a luminal fibrous tissue layer. At first, this layer is discontinuous and patchy. It may not become fully continuous until about two years have passed, or ever, for that matter. Our observations of smooth-walled prostheses are too few in the 3 to 5-month period to allow a comparison of healing with the velour or filamentous type of graft for this time of implantation.

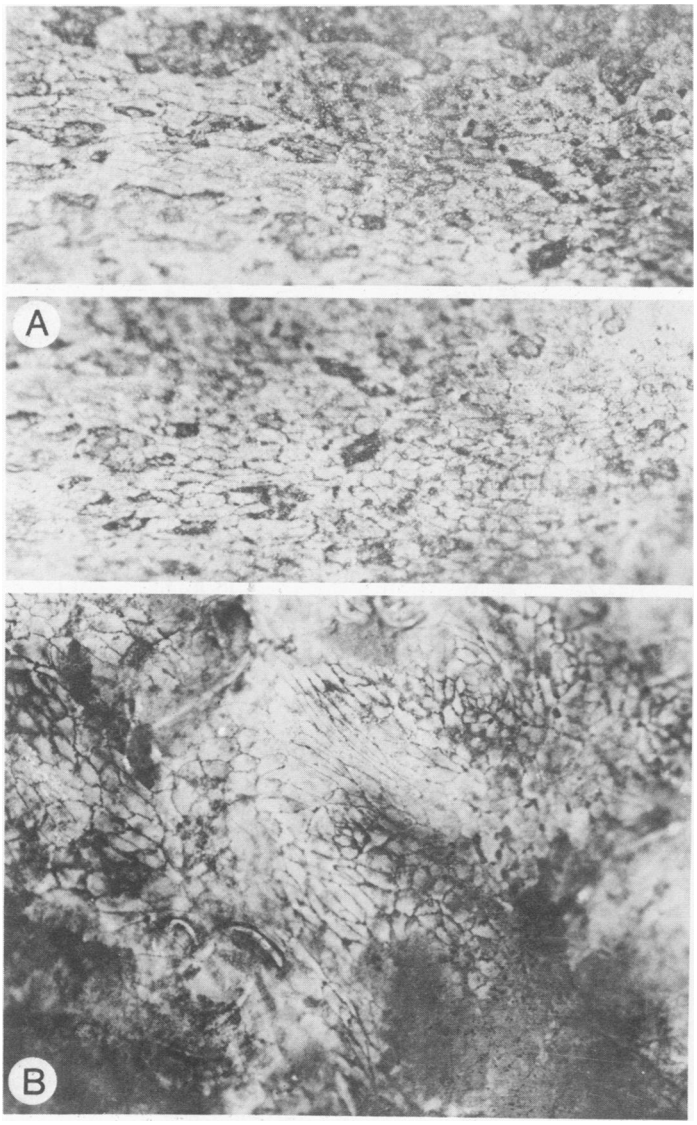

FIG. 3. (A) Surface photographs of endothelium near distal edge of pannus "a" in Fig. 2. (B) Endothelium at "d" in Fig. 2. Coverage is thin and translucent. Note underlying knit pattern and fibrils of fabaric.

Our objectives now are to determine how to assist man in healing porous arterial prostheses in a more reliable and rapid manner. In earlier papers,[4-7] we compared the design of the wall of current porous arterial prostheses, which seems to have an important effect upon healing, particularly in man. In comparative healing studies of specimens beyond 3 to 5 months we have found that the filamentous (external) velour prosthesis, as observed in this case report, heals more rapidly and completely than do conventional knitted porstheses with relatively smooth walls. It appears that cells are better able to migrate on a trellis of loosely-knit filaments than through a wall composed of tightly compacted fiber bundles.

We believe that the full potential of the trellis concept of graft construction embodied in the filamentous design of the prosthesis being reported has yet to be achieved, and that this design should be investigated further. The findings herein reported are encouraging, as they indicate that it is possible for man to completaely heal a filamentous velour knitted artrial prosthesis, whereas our previous findings[1] indicated that man apparently cannot completely heal a smooth-walled knitted prosthesis. Even with the filamentous prosthesis, the process of healing is too slow and erratic. Of the two cases in which we have reported complete healing, the short-term graft (182 days) showed more even healing than the longer-term graft (20 months). A prosthesis is no stronger than its weakest link, and if it is incompletely healed in some areas, it remains liable to thrombotic closure.

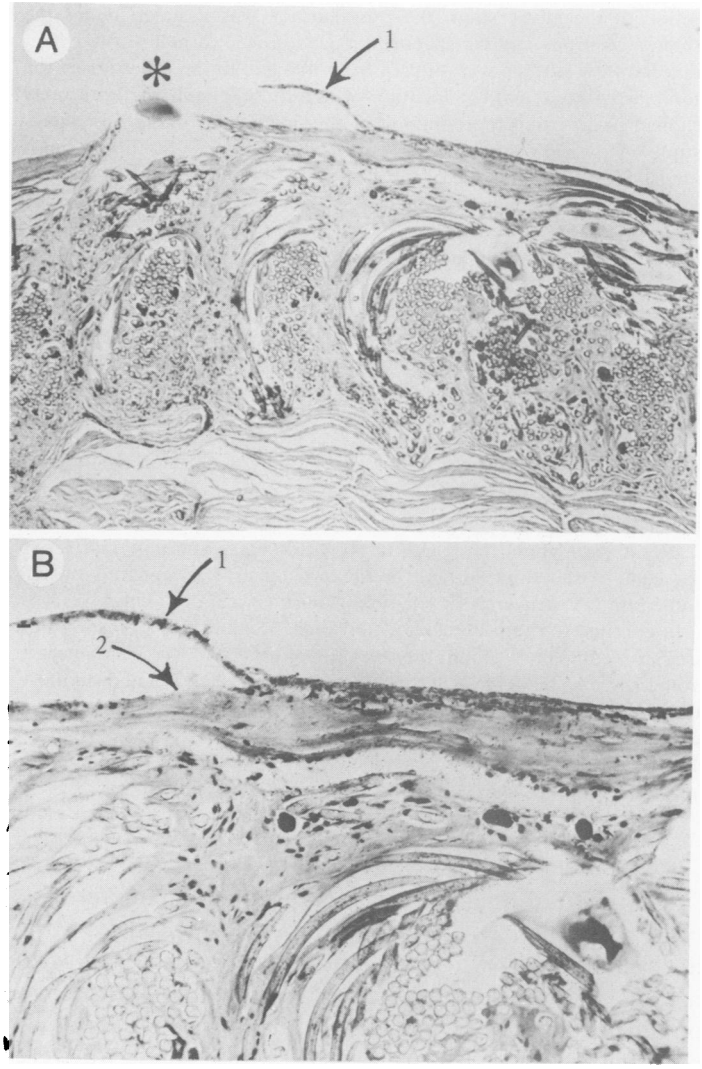

FIG. 4. Sections through "a" of Fig. 2.. A: Section through area photographed in Fig. 3A. Thin tissue present at cutting artefact (*). Capsular formation and transinterstices growth are similar to that shown in Fig. 5. Endothelium has fortuitously lifted (arrow #1). (B) Higher magnification at arrow #1 shows endothelial cell nuclei and silver-stained intercellular "lines." Arrow #2 points to collagen on which the endothelium rested. Elsewhere in same section there is a thin layer of fibrin between the endothelium and the fibrous tissue.

There is need for better prostheses for the large and medium caliber arteries. And unless grafts can be substantially improved, they will not serve as successful substitutes for small caliber arteries such as the tibials and coronaries.[3,4] But the evidence presented in this paper suggests that we should maintain some optimism concerning the development of successful arterial prostheses for small caliber vessel replacement.

Summary

For the first time, we have seen in man areas of complete healing of an arterial prosthesis at points far removed from the anastomoses. (We define complete healing as full wall fibrous tissue encapsulation with a flow surface of endothelium.) Complete healing was observed scattered throughout the length of a knitted Dacron prosthesis with an external velour surface that had been implanted for 20 months as a left axillary-bilateral common femoral artery bypass graft. This observation indicates that complete healing of a porous arterial prosthesis is an attainable goal for man. The filamentous wall of the prosthesis reported in this paper appears to have been of substantial aid to the advanced healing observed. However, the fact that complete healing was not continuous throughout the length of the graft indicates that additional means of accelerating healing must be sought.

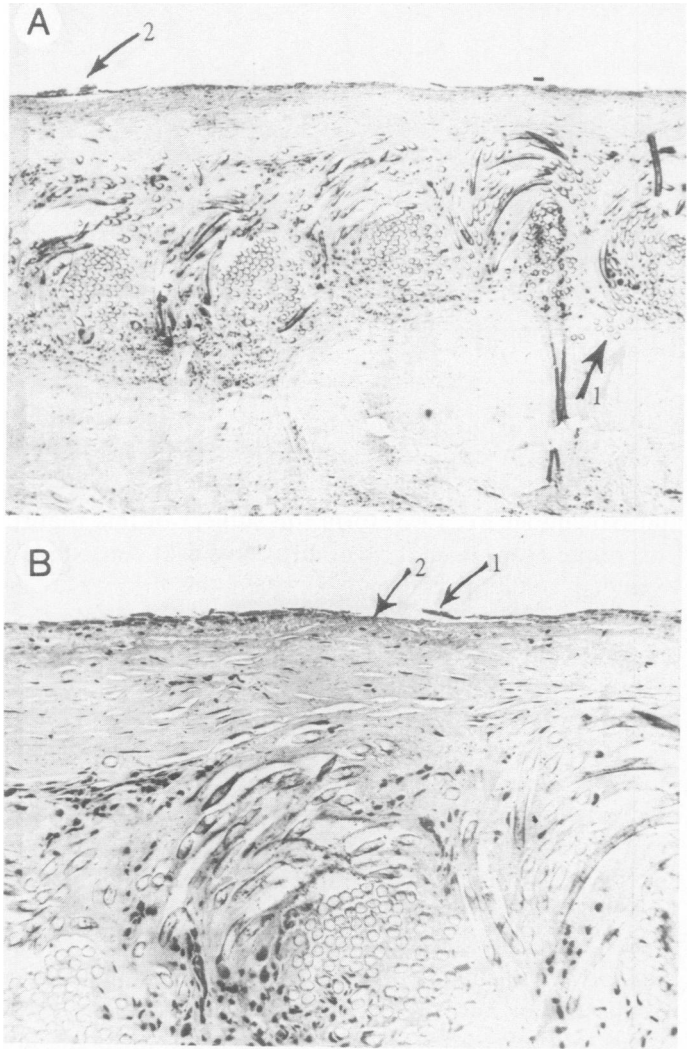

FIG. 5. (A) Section at island "d" of Fig. 2 shows fibrous inner and outer capsules with well-established bridges through the interstices. Note external velour fibrils locked in outer capsular fibrous tissue (arrow #1), accounting for firm bonding. The inner capsule is variably surfaced with thin fibrin (arrow #2) and endothelium. (B) Higher magnification showing fragmented silver-stained endothelial layer at arrow #1. The endothelium rests upon a thin layer of compacted fibrin (arrow #2) which is still undergoing fibroblastic organization.

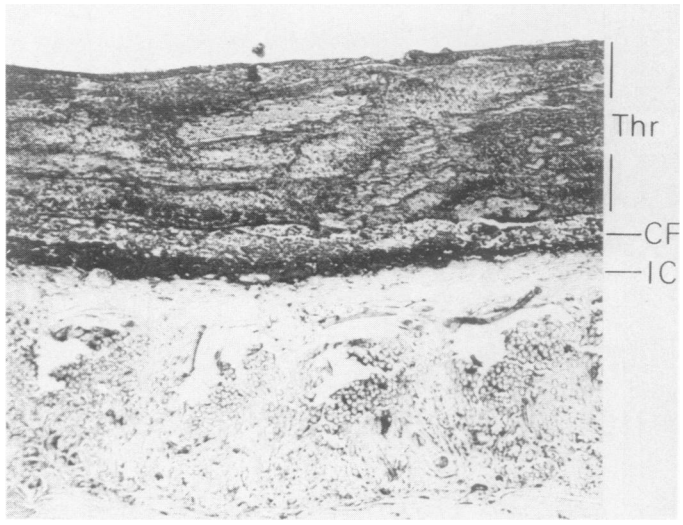

FIG. 6. The white areas of the tissue map (Fig. 2) showed varying degrees of organization and thrombotic coverage. Here at "h," a tissue inner capsule (IC) has formed. This, in turn, is surfaced by a layer (black at CF) of compacted fibrin. This compacted fibrin is covered by a more recent layer of laminated whole thrombus, here 0.5 mm thick. In other sections, the luminal aspect of the fabric was covered solely by compacted fibrin with organization only part way through the interstices.

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