ANGIOTACTIC SURGERY
PRELIMINARY STUDIES*

SANFORD F. ROTHENBERG, M.D., ERNEST J. PENKA, M.D.,
AND LOUIS W. CONWAY, M.D.

Division of Neurological Surgery, University of California Medical Center, Los Angeles, California

(Received for publication May 31, 1962)

The concept of angiotactic surgery originally was conceived by two of the authors, Drs. Sanford F. Rothenberg and Ernest J. Penka. The angiotactic instrument and internal sleeve were devised by Drs. Sanford F. Rothenberg and Ernest J. Penka, and Ted Shore.

ANGIOTACTIC INSTRUMENT AND INTERNAL SLEEVE

The angiotactic instrument consists of a 2 cc. syringe connected to a 4F Courmand Single Lumen cardiac catheter which in tum is connected to a carrier 3 mm. in diameter. The carrier consists of two metal hemispheres cemented to a Neoprene 65 bladder. The internal sleeve is made of polyester film bonded to itself by a thin layer of polyethylene. Six layers of polyester film are used to make the internal sleeve or implant, which may be of any cylindrical length and diameter. The length used in this experiment was 1 cm. and the diameter was 5 mm. The polyester sleeve is placed on the carrier by distracting the two hemispheres, then doubly folding the internal sleeve (Fig. 1).

The first fold is made with the bladder at the central point. The second fold is devised not only to decrease the diameter of the sleeve during excursion through the vascular channel, but also in order that the sleeve be captured by both hemispheres. The sleeve is released by distending the bladder with saline. The bladder, which is made of Neoprene 65, has the characteristic of first linear expansion and then circumferential expansion; this characteristic is ideal since the linear expansion permits the sleeve to be dis-engaged from the metal hemispheres, and the circumferential expansion permits the polyester sleeve to resume its original cylindrical form, which is facilitated both by the memory that freshly folded polyester maintains and the extrinsic force of molding supplied by the arterial wall (Fig. 2). After the appropriate size of sleeve has been released, the carrier is withdrawn and the cylindrical internal sleeve remains fixed within the artery (Fig. 2).

METHOD

Five dogs were used, varying from 16 to 25 kg., utilizing Nembutal anesthesia ½ gr. per kg. of body weight. The abdomen was prepared and draped in the usual sterile manner. A left mid-rectus incision was made from the costal margin to the pubis. The incision was surgically extended transperitoneally. After appropriate retraction of the viscera, the lumbar aorta was exposed. Ten cm. cephalad to the aortic trifurcation, a 2 cm. arteriotomy was made, after applying a vascular clamp cephalad and caudal to the intended site of arteriotomy. The carrier containing the internal sleeve was introduced through the arteriotomy and the caudal arterial clamp was removed. The carrier and sleeve were then introduced along the course of the aorta by advancing the catheter with a forceps through the arteriotomy wound. Release of the sleeve was made 3 to 10 mm. cephalad to the aortic trifurcation. The sleeve

was released by gentle pumping action of the plunger of the syringe to disengage the metal hemispheres, followed by the slow instillation of ½ cc. of saline to distend the sleeve into the desired position. The selected outside diameter of the aorta was approximately 5 mm. in all animals. The selected inside diameter of the polyester sleeve was 5 mm. in all cases. The release of the sleeve was identified grossly by the slight distention of the aorta visible at the site of the release; the carrier then was withdrawn without sleeve through the arteriotomy wound. The caudad arterial clamp then was replaced and the arteriotomy wound was closed with a continuous line of 5-0 arterial silk. No anticoagulant therapy was administered during these experiments.

In order to study carrier turn-capability, a plastic channel was devised, consisting of

\[\text{\ldots}\]
Fig. 6. (A) Mid-zonal region demonstrating reactive changes at surface of graft on its luminal aspect. (B) Changes at more central surface of graft.

-turns with the width between the limbs of the turn being that of the siphon of the internal carotid artery in man. Without difficulty, in dry passage, 2½ turns were accomplished by advancing the catheter and carrier through the translucent plastic channel.

RESULTS

Three animals were sacrificed at 5 weeks, 1 at 2 weeks, and 1 animal died of a peritoneal infection 5 days postoperatively.

Of the 5 implants, 4 were patent and 1 was associated with thrombosis of the vessel at the site of placement. In no instance did the implant migrate. Thrombosis occurred in the animal that was sacrificed at 2 weeks; prior to sacrificing this animal, paraplegia and superficial ulceration of the hind legs were evident.

HEALING DATA

Fig. 3 is a photograph of a 5-week-old implant. The aorta has been incised vertically

Fig. 6. (C) Changes at most peripheral area at surface of graft.
**Fig. 6.** (D) Section of graft showing lamellae of plastic bound together.

**Fig. 6.** (E) Area showing changes external to graft, corresponding to 6A.

(F) Area external to graft, corresponding to 6B.
occupied by the graft, removed to facilitate processing of the specimen. Extension of fibrin into splayed lamellae of graft is noted together with the newly deposited fibrotic intima rising up over the edge and luminal surface of the graft. The media is unaltered. There is no inflammatory reaction.

Fig. 5D reveals aorta at the opposite edge of the site of graft. The changes are similar to Fig. 5C with the exception of a pyriform tongue of organizing fibrin extending into a slit in the lamellae of the graft.

Figs. 6A, B and C demonstrate the reactive changes at the surface of the graft on its luminal aspect. The most peripheral (C) area consists of laminated spongy fibrin against the graft, covered by a dense fibrous connective tissue continuous with Fig. 5D. The more central surfaces (B) and mid-zonal region (A) consist of organizing fibrin demonstrating endothelialization of the surface preceding the fibrosis of the newly formed intima.

Fig. 6D is a microscopic section of the graft consisting of 6 dense continuous lamellae of plastic bound together and surfaced externally by a binding translucent plastic.

Figs. 6E, F and G are areas corresponding to A, B and C, external to the graft. These show a thin zone of degeneration and necrosis of the original intima, internal elastic lamella and superficial aortic media. There is a dense fibrosis of the adventitia with extension of fibrovascular strands into the outer third of the media. There is no inflammatory reaction.

**DISCUSSION**

Among the desired clinical applications of angiotactie surgery is the occlusion of an intracranial aneurysm from its parent artery via an approach at the cervical vessels under radiographic control. To mention other applications: Occlusion of a carotid-cavernous fistula; the purposeful production of cerebral lesions by internal-sleeve occlusion of specific branches of a parent vessel; the purposeful occlusion of vessels irrigating a neoplasm or an arteriovenous malformation; reconstituting the normal diameter of a stenosed vessel

---

**Fig. 6. (G) Area external to graft, corresponding to 6C.**

to visualize better the patent implant which has maintained its circular form and is held permanently in position by the intimal ingrowth lining the entire graft.

Fig. 4 is a photograph of a 5-week-old implant, completely sectioned longitudinally to reveal more clearly the intimal ingrowth lining the entire sleeve, showing, as well, the outer aspect of the graft which is composed of media and adventitia. The aforementioned structures encase the polyester implant permanently.

Microscopic pathology is illustrated by Figs. 5 and 6. Fig. 5A is a microscopic section of normal aorta, 1 inch cephalad to the implant, showing minimal fibrous connective-tissue thickening of the intima. Fig. 5B is aorta adjacent to the site of the graft, showing prominent intimal fibrosis, and hyperplasia of media (increased cellularity).

Fig. 5C shows aorta at one edge of the site of the graft. The evident space originally was
ANGIOTACTIC SURGERY

by attempted distention atrophy of an atherosclerotic plaque, or enlarging a congenital stenosis. There may be use of the carrier bladder per se to produce an avascular field or selective quantitative periods of ischemia.

SUMMARY

It has been demonstrated experimentally, for the first time, that an intravascular implant can be placed at a site remote from the arteriotomy wound through which an implant is introduced. The intravascular implant was accepted by the host without thrombosis or reaction of the host in 4 of 5 animals. Utilizing the appropriate size of implant for the selected vessel, the implant will become encased permanently by intimal ingrowth and media, and will not migrate. Further studies are in progress.

The authors wish to extend their appreciation to Leo Kaplan, M.D., Director of Pathology, Mt. Sinai Hospital, Los Angeles, California, who served as consultant for histopathological technical assistance and interpretation.

DISCUSSION

Dr. William MacMurray Loughood: I would like to compliment the authors on the excellence of their presentation and the instrumentation which has been very ingenious. I was intrigued with the thought that this apparatus might also be used without the sleeve, in obtaining better retrograde brachial arteriograms. Have the authors been able to navigate the tortuous course of the internal carotid artery intracranially? This certainly would prove to be a great advance for carotid fistula, but could one be able to get the instrument this far into the skull?

We have tried, in autopsy specimens, to place a catheter from the neck into the sigmoid portion of the internal carotid artery, and I have never been able to get past the second bend.

In patients with carotid thrombosis, after the thrombus has been removed, I have always found that the polyethylene catheter or even a rubber catheter would tend to stick in the interoosseous portion of the carotid artery. However, with the metal ball on the end of this cannula, being only 8 mm. in diameter, perhaps the authors have some trick in circumnavigating this difficult course.

As far as occluding the neck of the aneurysm is concerned, the internal carotid aneurysm would be the one to attack because oftentimes the neck of the aneurysm will come off in the long axis of the artery. There is a grave danger of the instrument entering the orifice of the aneurysm rather than the axis of the vessel itself.

A fourth point I wondered about was that it seems possible that blood might collect between the sleeve and the artery, thus forming a dissecting type of aneurysm and occlude the main lumen of the vessel. The film would suggest that the sleeve has enough resiliency to prevent this.

I would certainly like to compliment both authors on a very ingenious idea, and I think perhaps the future of this instrument is just not realized.

Dr. Louis W. Conway: I wish to thank Dr. Loughood for his very constructive and pertinent discussion.

In answer to his first question as to whether this instrumentation will navigate the sigmoid configuration of the internal carotid, we have not tried this in humans as yet. Obviously, the carotids of most animals are considerably smaller. We have, however, extruded rigid plastic tubing with a lumen of 3 mm. and a sigmoid curve approximating that of the carotid, with a total of 2½ turns of 127° each. Fully realizing that this is an artificial situation, this instrumentation will navigate through the plastic tube.

In answer to the question as to whether the instrument will enter an aneurysmal orifice, I do not think this would be a major problem, because we plan to insert these sleeves with roentgen-ray control.

Lastly, after the sleeve has resumed its original configuration, the external diameter of the sleeve is larger than the internal diameter of the vessel, and we have found that this not only prevents blood dissecting outside the prosthesis, but also prevents its migration.