PARTIAL OCCLUSION OF THE AORTA WITH SILK SUTURES, AND COMPLETE OCCLUSION WITH FASCIAL PLUGS. THE EFFECT OF LIGATURES ON THE ARTERIAL WALL.

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In experiments previously reported it has been observed that a partial or complete occlusion (either by a metallic band or ligature) of any large artery invariably results in a local death of the vessel wall. This observation is of fundamental importance alike to the surgeon and pathologist, who have heretofore accepted the view that intimal surfaces of large arteries will unite when properly approximated.

Since it had been observed that a coarcting ligature or band always resulted in the death of the arterial wall, the following experiments were performed in order to find a method of producing a partial or complete occlusion which would not cause a necrosis.

1. Partial Occlusion by Means of Plication Sutures of Silk.

(a) Method.—The aorta of dogs was used for these experiments. Under ether the lumen of the vessel was reduced to about one-third its normal size by means of numerous mattress sutures of doubled medium silk (Fig. 1). The aorta was temporarily occluded above and below the point of constriction. Usually there was almost no bleeding from the needle punctures on releasing the temporary occlu-

tion. In one instance a little piece of muscle was placed over the sutures in order to hasten complete hemostasis.

In this manner the thoracic aorta was partially occluded in two cases, and the abdominal aorta just above the inferior mesenteric artery in six cases.

(b) Effect on the Lumen.—The observations extended over a period of 2 to 8 months, and in each instance a partial occlusion persisted. As no means were employed to determine the narrowing of the lumen at the time of operation, it is impossible to know the alteration that occurred in it afterwards. It was, however, so slight that one may expect the lumen which is left at the time of plication to remain practically unchanged. In no instance did the vessel become completely occluded at the site of the operation. This observation is in accord with those of McLean, who observed that sterile silk threads anchored in the lumen of large arteries did not lead to the formation of a thrombus while infected threads always did.

(c) Effect of the Sutures on the Wall of the Vessel.—Each individual mattress suture has the same effect on the portion of the vessel it includes as does the encircling metallic band or ligature, and like them leads to the death of the vessel wall. Tightly tied sutures cause marked destruction of and frequently cut through the vessel; more loosely tied sutures cause necrosis as evidenced by loss of staining reactions, although the necrosed tissue may remain for several months. About all of these mattress sutures there occurs a dense fibrous, connective tissue reaction, as well as in the path of a cutting suture (Fig. 2).

(d) Effect on the Intima.—Where the intimal surfaces are brought into apposition by the plicating sutures the intima may proliferate, and by bridging the crevice tend to restore the circular appearance of the lumen (Fig. 2).

(e) Elastic Tissue.—The regeneration of elastic tissue is said to be a very slow process. In these experiments, we have not seen any evidence of a fibrous segment becoming substituted by elastic tissue. In our studies with metallic bands it was observed in one instance that the fibrous wall which formed external to the band showed

at the end of 16 months a few strands of reformed elastic tissue. They seemed to appear as isolated islands of elastic tissue in the new wall rather than as a growth from the points where the elastic wall was destroyed by the band.

2. Total Occlusion with Plugs of Fascia.

(a) Method.—A small strip of fascia taken from the anterior sheath of the rectus muscle is made into the shape of a sphere with the aid of fine silk sutures. Through a small longitudinal slit made in a segment of the aorta, previously isolated by clamps, this fascial plug is introduced. By means of through and through sutures of silk it is anchored, either at the site of its introduction, or above or below it. The opening in the vessel is carefully closed with interrupted sutures of fine silk.

Six experiments were performed. The average length of time between the performance of the experiments, which were carried out under ether, and the recovery of the specimens was 6 months. Complete occlusion resulted in every instance, and there was neither infection nor hemorrhage.

(b) Fate of the Fascial Plugs.—These remain as viable tissue and do not become substituted by fibrous tissue. The transplanted fascia presents the appearance and staining characteristics of living tissue. Where the fascial plugs come in contact with the blood stream they become covered by intima, so that, when the obstruction is viewed either from above or below, it has the glistening appearance that is characteristic of the normal intima (Fig. 3).

(c) Thrombosis and the Organization of a Thrombus.—In two instances a small clot formed above and below the plug of fascia. A study of the organization of one of these clots has proven of great interest. Through breaks in the media of the aortic wall, the connective tissue is crowding its way toward the organized thrombus.

This observation and those on the organization of a necrosed vessel wall beneath metallic bands suggest that the organization of a thrombus within an intact vessel may be mainly from the media and adventitia rather than, as generally believed, from the intima (Figs. 4 and 5).
PARTIAL AND COMPLETE OCCLUSION OF AORTA

(d) The Effect of a Plug on a Vessel Wall.—The wall surrounding an occluding fascial plug does not die, though it atrophies. This atrophy extends for a considerable distance below the occlusion, whereas above the wall retains its normal size and thickness. The atrophy below a plug is similar to that observed below a partially occluding band. In the latter case, as presumably in the subclavian artery distal to a cervical rib, this atrophy may have some bearing on the development of an aneurism. We have not, however, seen an aneurismal dilatation below a complete occlusion, either by a band or fascial plug. The atrophy of the vessel wall surrounding a fascial plug does not lead to compensatory proliferation in the adventitia. Here, owing to lack of pressure, the tissues are not called upon to make the same protective changes as in the case of a cutting band or ligature (Fig. 6).

The silk sutures used to anchor fascial plugs are tied very loosely. They do, however, damage the vessel wall included by them.

DISCUSSION.

In 1914, Dr. Goodpasture and I attempted to reduce the size of the portal and splenic veins by the method described for the plication of arteries in this paper. At human autopsies thrombosis of the splenic and portal veins had frequently been observed in cases of splenomegaly. It was our idea that the partial obstruction might lead to a chronic passive congestion of the spleen and perhaps, eventually to splenomegaly. At the end of several months we observed in every instance that the partially occluded veins had resumed their normal size and shape, the points of occlusion being scarcely perceptible. Partial occlusion of the veins when produced by plicating sutures does not persist. In the case of the thick walled arteries the partial occlusion remains. Thus, experimentally as well as clinically, it is observed that veins adapt themselves very much more readily to mechanical disturbances than do arteries.

That partial or complete occlusion of a large artery by compression always leads to the death of the vessel wall seems to be well established. But the rate of vessel destruction due to a ligature or a band depends upon several factors. Our experiments show that a tight ligature or band will cause a more rapid disintegration of the vessel wall
than one loosely applied. One strand of silk or a narrow band will cut through an arterial wall more rapidly than a piece of tape or a wide band applied with the same degree of tension. A tightly applied fine ligature or narrow band produces a greater local anemia of the arterial wall than does an equally tightly applied tape or wide band. It therefore cuts through more quickly, allowing nature a shorter time to repair the damage of the ligature by the formation of fibrous tissue. The plication of an artery is, for the tissues involved, the same as ligation, for the portion of the vessel wall included in the plicating sutures undergoes the same necrosis. Gentle plication over a long segment of the vessel, just as gentle complete occlusion with wide tapes or bands, prolongs the process of dying of the arterial wall until nature's reparative processes make permanent one's operative endeavor.

In dogs we have been able to occlude either partially or completely any artery, except the thoracic aorta, without secondary hemorrhage. Partial occlusion of the thoracic aorta with bands or ligatures cannot be done either in man or dogs without grave danger of fatal hemorrhage. Here the great pressure of the blood and the scant periarterial support hasten death of the arterial wall and prolong the period of repair with fibrous connective tissue. In two experiments a partial occlusion of the thoracic aorta has been accomplished, without hemorrhage, by plicating a long segment of the vessel with mattress sutures of doubled medium silk. In one case the sutures were reinforced with small pieces of muscle.

When balls of fascia are introduced into the lumen of an artery and anchored by a suture of silk, complete occlusion may be accomplished without much damage to the arterial wall save for some atrophy at the site of the plug. This plug produces complete occlusion and at its point of contact with the blood stream it becomes covered with intima. For such a method of occlusion there would seem to be no practical demand, for the arteries that commonly need to be occluded in the human being can be occluded by proper ligation. However, some modification of the method, as for example the introduction of a fascial ball with a small tube through its center, may be the best way of producing a partial occlusion of the human aorta.
PARTIAL AND COMPLETE OCCLUSION OF AORTA

The practice of surgeons in the preaseptic era, so beautifully depicted by Ballance and Edmunds, of ligating large arteries over a long distance with loosely tied cords or heavy tapes, has been improved by us only through the elimination of infection. Their practice remains the safest, even though their ideas of the process of destruction and repair were wrong. In Professor Halsted's clinic the complete occlusion of large arteries was always accomplished by the use of two or more loose ligatures of heavy tape or heavy silk, or by wide metallic bands; and secondary hemorrhage never occurred. The use of catgut for the ligation of large arteries was regarded as dangerous and was not permitted. It is highly desirable that the ligature material should remain exactly as placed until the damaged vessel wall becomes completely repaired. In the literature there are several cases of hemorrhage resulting from the ligation of large arteries with strands of catgut. In such cases the giving of the ligatures subjected the arterial wall to high pressure before its damaged wall was completely repaired. To depend on catgut in the occlusion of a large artery involves a risk of secondary hemorrhage that should not be assumed.

Whether the use of plication or fascial plugs will ever become of practical value in the treatment of human conditions remains yet to be seen. That these procedures or some modification of them may help us in our surgery on the human aorta does not seem unlikely.

SUMMARY.

1. Partial occlusion of the aorta of dogs may be produced by Halsted mattress sutures of silk. This occlusion persists.
2. A method of completely occluding the aorta of dogs by means of anchoring fascial plugs in the lumen is described.
3. The vessel wall below and at the site of an occluding fascial plug undergoes marked atrophy.
4. Ligatures used for ligating or plicating large arteries cause death of the arterial wall. The same is true for encircling metallic bands.
5. Catgut is dangerous to use for the ligation of large arteries, since it may give way before the necrosed vessel wall becomes completely substituted by fibrous tissue.
EXPLANATION OF PLATES.

PLATE 11.

Fig. 1. Thoracic aorta of a dog. Lumen reduced to one-third normal size by mattress sutures of silk. A-B, innermost line of sutures. An indentation has occurred in the normal wall opposite the sutures. Result after 6 months.

Fig. 2. The black silk suture (A) has cut through. In its track there is dense fibrous tissue. A wedge of proliferating intima (B) has formed in the crevice. Weigert's elastic tissue stain.

Fig. 3. Photomicrograph of a fascial plug covered by a thin layer of proliferating intima (A). At B, note the atrophy of the vessel wall. Hematoxylin and eosin stain.

PLATE 12.

Fig. 4. The organization of a thrombus just above a fascial plug. At points A, B, and C where there are breaks in the vessel wall the ingrowth of vascular connective tissue is very striking. Weigert's elastic tissue stain.

Fig. 5. The aortic wall substituted by fibrous tissue. An aluminum band produced the death of the vessel and cut its way into the lumen. Connective tissue growing around the lower edge of the band has substituted for some of the original vessel wall. A, site of metallic band. Weigert's elastic tissue stain.

Fig. 6. Longitudinal section through a fascial plug. Weigert's elastic tissue stain. Note the atrophy of the vessel wall at A, B, and C. D, a wedge of vascular connective tissue between the vessel wall and ball of fascia. Proximal to the occlusion no atrophy of the vessel wall occurred. In the encircled area the elastic tissue beneath the ligature appears normal, but at this point the nuclei do not stain with hematoxylin and eosin.
(Reid: Partial and complete occlusion of aorta.)
FIG. 4.

FIG. 5.

FIG. 6.

(Reid: Partial and complete occlusion of aorta.)