Endarterectomy, or Surgical Restoration of the Lumen of an Obstructed Artery in Arteriosclerosis Obliterans

A Preliminary Report

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Endarterectomy is an operation originally proposed by Dos Santos in which a thrombus and the portion of the arterial wall to which it is attached are removed and the lumen of the artery re-established. The technic of this operation is described. Case histories of several patients illustrating the results which the authors have obtained are presented.

Endarterectomy or the restoration of the lumen of an obstructed artery consists in the excision of a fixed thrombus together with the portion of the intima of the artery to which it is attached. In 1946 Dos Santos reported a case of thrombosis of the subclavian artery, in which endarterectomy was performed with success, thus proving the possibility of permanent surgical recanalization of an artery, aided by anticoagulants. Later observations by Leriche, Bazy, Huguier and Reboul proved the technic to be sound.

According to Dos Santos it is dangerous to underestimate the importance of this method by considering it as a mere removal of the obstruction in a canal. All cases should be completely observed, followed up and controlled by means of arteriography to demonstrate clearly the success of the operation.

Fundamentals of Endarterectomy

This new technic is based on anatomic, physiologic and pathologic considerations.

Anatomic Basis. The existence of a plane of cleavage between the endothelium and tunica media of arteries is the anatomic basis of endarterectomy.

The separation of the endothelium from the subendothelium of arteries is strictly histologic, since no macroscopic differentiation is possible. Together, they comprise the tunica intima or endarterial layer. Frequently the terms tunica intima, endartery and endothelium are employed without distinction.

There is a false plane of cleavage between the endothelium and the clot, but the true and best cleavage planes may be found (1) at the tunica intima, (2) in the subendothelium, (3) between the tunica intima and the elastica interna and (4) beyond the elastica interna, in the tunica media. (See fig. 1, after Arnulf.)

Physiologic Basis. Many factors play a role in the very complex mechanism of blood coagulation. In accordance with accepted facts, three factors are considered to contribute to intravascular coagulation: (1) slowing of circulation, (2) increased tendency to clotting and (3) injury to the intima.

When endarterectomy is performed, the new canal through which the blood runs has a rough surface, thus favoring thrombus formation, but experience has shown that the blood continues to flow without clotting, provided that sufficient anticoagulant substances, such as heparin and dicumarol, are administered.

Pathologic Basis. Arteritis usually begins, from an anatomicopathologic point of view, at the tunica intima, regardless of the etiologic agent. It generally begins to affect this inner coat, except in Monckeberg’s arteriosclerosis, where the tunica media is the one undergoing change. The arterial lesion, beginning in the intima, passes through several stages from proliferation through fibrosis, mucoid, hyalin...
and lipid degeneration to atheromatosis, calcification and real ossification. These lesions produce arterial obliteration with thrombosis, forming what Bazy called a sequestrum. It is a necrobiosis formed by the clot and the intima, and is easy to remove from the rest of the arterial wall.

**Indications**

Dos Santos is of the opinion that endarterectomy is indicated in cases of arterial thrombosis associated with the following conditions: (1) arteriosclerosis obliterans; (2) early endarteritis; (3) organized embolism; (4) thrombosis produced by scalenus anticus or costal compression; and (5) thrombosis caused by aneurysm.

The state of the arterial coat, as well as the plane of cleavage, are quite different in each of these conditions.

**Selection of Cases**

Once the clinical and arteriographic diagnoses are made, it is necessary to bear in mind several facts in order to decide whether the patient is a good surgical risk and the operation possible. Operative risk increases with the age or general deterioration of the patient. Previous heart disease, such as coronary thrombosis, and diabetes make the prognosis poor.

The operation may be considered in those cases having functional or ischemic disturbances, especially intermittent claudication. It should also be considered when organic disturbances such a necrotic ulcer or localized gangrene have occurred. Localization of the site and extension of an obstruction may be verified by arteriography.

It is necessary to study the whole length of the affected artery and its branches. This is effected by means of various arteriographic studies for the purpose of checking the patency of the distal segments, as well as the existence of other obliterated segments. These data must be considered, for they influence the anatomic and functional postoperative results.

The ideal indication is in arteritis of large vessels, especially when occlusion or marked narrowing is limited and the segment distal to the obliterated zone is patent. When thrombosis involves a long segment of an artery, the operation may be performed, but a complete restitution of flow will probably not be obtained as a result. However, an improved circulation through the vessels of the limb will be brought about by the opening up of many collateral arteries, since these tend to keep their patency for a longer time than the main trunks.

**Fig. 1. Planes of cleavage in endarterectomy (after Arnulf).**

The extent of the arterial lesion is also of great importance. The most favorable results are obtained by operating on arteries whose walls are still soft and elastic, rather than on those whose walls are hardened by calcium or atheromatous infiltration.

**Anesthesia**

A choice may be made from the types of anesthesia that produce sympathetic block, such as, spinal or epidural for the lower extremity, or brachial plexus block for the upper extremity. The general condition of the patient...
FIG. 2. Illustration of the technique in endarterectomy. A. The artery has been exposed and the arterial wall is opened until the intima is prolapsed. B. The anterior incision is continued until the obliterated zone is passed. C. Circumferential dissection of the thrombus with the adhering intima. D. Transverse section. E. Excision of the thrombus and intima.
Fig. 3. Illustration of the technic in endarteriectomy (continued): F. Complete extirpation of the obliterated zone. G. Aspect of the arterial wall after elimination of the thrombosed zone. H. Longitudinal incision of the intima in the permeable zone. I and J. Fixation sutures of the intima. K. Suture of the arterial wall.
should determine the choice of the anesthetic to be used.

Operative Technique (Figs. 2 and 3)

The patient’s position, the incision and the exposure of the vessel will vary in accordance with the location of the obstructed artery. Once the artery is exposed, the extent of the thrombus is determined by palpation or by puncture. The vessel should be freed one inch beyond the proximal and distal ends of the obliterated segment. Temporary hemostasis should be effected by proper clamping of the main artery proximally or distally to the thrombus and of any important collateral arteries.

An incision is made in the arterial wall following its longitudinal axis by Reboul’s (continuous) or Dos Santos’ (interrupted) method. We have used the former because of its advantages in the search for the plane of cleavage. We make a small longitudinal incision (fig. 2A) in the arterial wall 1 or 1.5 cm. above the proximal end of the thrombus. A prolapse of the intima is produced between the edges of the incision.

This incision is kept open by holding the edges with toothless tissue forceps, and, with the help of thin pointed scissors (fig. 2B) introduced between the prolapsed intima and the rest of the arterial wall, the intima and media are separated for a distance of 1 to 2 cm. and the overlying arterial wall is then incised. This procedure is repeated to a point 2 or 3 cm. below the distal end of the thrombus.

The intima is then dissected in its total circumference (fig. 2C) at its proximal end. It is cut transversely (D) and the thrombus is liberated with slight traction, and by the use of a thin curet the thrombus is scraped off (E) together with the coat formed around it by the endothelium. This is done as far as 2 cm. beyond the distal end of the thrombosed segment. A transverse section (fig. 3F) is made at this point in order to eliminate the whole obliterated zone. The artery, thus freed from obstruction, looks flattened and has some transverse striae (G) probably produced by the muscle fibers. Collateral arteries may bleed and hemostasis by clamp may again be necessary. The intima is then cut longitudinally (H) all the way to the end of the incision in the artery and sutured to the other layers of the artery wall by means of Kunlin’s sutures (I and J) in order to prevent thrombosis or obstruction which develops if the cuffs of intima are left free in the blood stream.

The artery is closed (K) with a running suture which may be interrupted at several spots. One or 2 cm. before reaching the end of the suture, the proximal clip is taken off. The blood will flow by its own pressure, carrying out the endothelial particles that may be left. After replacing the upper clamp the suture is finished, the artery being previously washed with the heparin solution. Clamps are removed, and if there is bleeding at the site of the sutures, hemostasis is usually obtained by temporary compression. If not, additional sutures are applied. The wound is closed in layers.

Throughout the operation we continue lavage of the artery with a solution composed of 1000 cc. of normal saline solution, 1 million units of penicillin, 1 Gm. of streptomycin, 5 Gm. of Novocain or procaine and 100 mg. of heparin.

Postoperative Measures

The most important factor in the postoperative course is the administration of anticoagulants during the first seven days to prevent secondary thrombosis. This favors the formation of new endothelium. We have used the following plan: heparin is given intravenously during the first 24 hours in doses of 50 mg. every four hours. We do not test the clotting time. As soon as the patient leaves the operating room, he is given 200 or 300 mg. of dicumarol; further administration of dicumarol depends on prothrombin time. To prevent the wound from oozing, the patient’s feet should be kept at a slightly higher level than the rest of the body. Extreme temperatures should be avoided because of the vasoconstrictor effect of cold and the increased tissue metabolism which results from heat.

Complications

The complications which have been reported after endarteriectomy are:
(1) Hemorrhage at the site of operation. Arnulf\textsuperscript{11} has reported several instances of large hematomas, secondary operation having been necessary to evacuate them. These hemorrhages are due either to the rupture of the arterial suture or to the use of anticoagulants.

(2) Secondary thrombosis. Sometimes a blood clot larger than the first one is formed, despite anticoagulant therapy.

(3) Aneurysms. The arterial wall may dilate as a result of its thinness after curettage.

RESULTS AFTER ENDARTERECTOMY

The possibility of maintaining the patency of an artery is a proved fact. Dos Santos' patient still has a pulsating artery after three years.

Arnulf\textsuperscript{11} states that Champy's observation of the anatomic state of the restored segment is of the greatest interest. He has reported a case in which a histopathologic study of a previously operated artery was made. It was seen that the endothelium, starting from the proximal and distal ends and from the opening of the collateral arteries, had regenerated. It is a curious fact that white blood cells form a layer that covers the inner surface. This pseudoepithelial leukocyte wall prevents the formation of a clot inside the new vessel.

When complete patency is achieved, the results are amazing; the pulse reappears, pain and coldness disappear and trophic lesions heal. Even when only partial patency is brought about, an evident functional improvement is obtained, since there is better blood circulation due to the liberation of many collateral
arteries, the periarterial sympathectomy, and the eradication of the reflex effects.

It is not yet possible for us to evaluate the latest results. Arnulf states that, "Observations on endarteriectomy are still very recent. Its technic will undoubtedly be modified but its first results are of undeniable dogmatic value. The path opened by Dos Santos seems to be full of promise and to lead to a new and attractive field in vascular surgery."

The immediate postoperative result was the reappearance of arterial pulse in the posterior tibial and dorsalis pedis arteries.

Arteriography (fig. 5) on March 11, 1950 showed complete patency of the femoral artery. At the present time all previous symptoms and signs have disappeared, and pulse is present at the femoral, popliteal, posterior tibial and dorsalis pedis arteries.

**Report of Cases**

*Case 1.* M. P. C., a 46 year old Negro man, was admitted to the University Hospital with a history of intermittent claudication, numbness of the toes, coldness and cramps in the right calf of two years' duration. On the dorsal surface of the big toe there was a necrotic ulcer 0.5 cm. in diameter. Arterial pulse was present in the femoral artery but absent in the popliteal, posterior tibial and dorsalis pedis arteries. Slight cyanosis of the toes was observed. Oscillometric readings of the right limb showed 1 at thigh, 0 at leg and 0 at foot. Arteriography (fig. 4) demonstrated decreased caliber of femoral artery and typical notching of arteriosclerosis.

Endarteriectomy was performed on Jan. 24, 1950. A thrombus 15 cm. long was excised. Microscopic section revealed an organized coagulum with fragments of intima. Heparin was administered during the first 24 hours and thereafter dicumarol, controlled by daily prothrombin time determinations.

Oscillometric readings are now as follows: thigh 2; leg 1.5; and foot 1.

*Case 2.* S. G., a 53 year old white man, was admitted to the University Hospital with the following history: Two and a half years before admission he had felt a sudden pain in the right iliac fossa, accompanied by nausea, vomiting and coldness of the right leg. Gangrene, which soon appeared, necessitated the amputation of the leg at the middle third of the thigh. Three months later, he began to feel pain, coldness of the fingers and numbness of his
left hand, which became progressively paler. In November, 1949, he underwent another episode, with pain in the left leg, together with coldness and numbness followed by intermittent claudication, absence of pain in the whole left leg and decrease of temperature. Oscillometric readings were 0 from the femoral artery down. Aortography (fig. 6) revealed diminished caliber of the terminal portion of the aorta and complete obstruction of both common iliac arteries. Arteriographic studies were made in the femoral artery in the direction of, and also contrary to, the blood stream, thus determining the exact location of the thrombus and patency of the segment distal to the thrombosed zone.

Endarteriectomy was performed on Jan. 26, 1950. A thrombus, together with the tunica intima, was removed from the terminal portion of the aorta and both common iliac arteries (fig. 7). Histologic study of the removed specimen revealed crystals of cholesterol, hyalinized clots, fragments of intima, atheroma and elastoid intima.

Postoperative course: Heparin and dicumarol were administered after the scheme outlined in case 1. The pulse at femoral, popliteal, and posterior tibial arteries reappeared and the temperature of the limb increased. The patient died five days after operation.

Necropsy showed a large retroperitoneal hematoma and massive atelectasis of left lung caused by blood clots in the bronchi. Prothrombin time one hour prior the death was 20 per cent of normal. Clotting time was normal. This suggests that death was due to pulmonary embolism and retroperitoneal hemorrhage caused by a small leakage at the line of suture in the artery.

Case 3. J. V. Y., a 65 year old white man, was admitted to the University Hospital, March 16, 1950. His previous history revealed intermittent claudication and coldness of the left leg of three years' duration with gangrene of the second and third toes which necessitated amputation.

On admission he had intermittent claudication...
and coldness and burning pain in a necrotic ulcer at the stump of the amputated third toe. The femoral pulse was present, but no popliteal, posterior tibial and dorsalis pedis arterial pulses were found. Oscillometric readings were: thigh, upper third, 3; thigh, middle third, 3; thigh, lower third, ¾; leg, 0; and foot, 0.

Arteriographic study showed a complete obstruction of the femoral artery in its middle third with typical arteriosclerotic lesions (fig. 8). Several collagenous plaques were present. Post-operative arteriography showed the main trunk of the femoral artery to be occluded, but there was a noticeable increase in the number of collateral branches (fig. 9).

Case 4. U. A. T., a 60 year old white man, was admitted to the University Hospital, April 3, 1950. Two months before he had felt rest pain in the left foot and also intermittent claudication in the left leg which made it impossible for him to walk one block. Physical examination revealed a decrease in temperature of the leg and in the amplitude of the femoral pulse, with absence of pulse from the posterior tibial, popliteal and dorsalis pedis arteries. Arteriographic study showed diminished caliber of the femoral artery in its upper and middle third with notches typical of arteriosclerosis (fig. 10).

Endarterectomy was performed on April 18, 1950, with excision of a thrombus 18 cm. long. Post-operative course: after reconstruction of the artery and removal of temporary hemostatic clamps, inspection and palpation showed the existence of pulse waves in the major branches immediately distal to the suture. The pulses of the posterior tibial, popliteal and dorsalis pedis arteries have not reappeared. Arteriography was not performed in this patient after surgery. At the present time, nine months after operation, all previous signs and symptoms have disappeared.

**SUMMARY**

1. Our patients upon whom endarterectomy was performed are presented. In one a good anatomic result was obtained; in two good functional results were obtained; and one patient died after operation.

2. In arterial curettage, the thrombus is excised together with the endothelium and sometimes part of the muscular coats. It is impossible to determine the precise plane of cleavage during the operation.

3. The best results are obtained in arteritis of main arterial trunks, especially if the obstruction is limited in length and is accompanied by patency of the distal segments of the artery. This operation may be performed in patients with extensive lesions since it achieves noticeable improvement in the circulation of the diseased limb by reopening new arterial channels.

4. Arteriographic study is necessary to determine the exact location of the obstruction and the patency of the distal segments.
5. Anticoagulant therapy, properly used, is essential in obtaining satisfactory results.

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