The Trendelenburg Operation: Pulmonary Artery Embolectomy

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THE TRENDELENBURG OPERATION:
PULMONARY ARTERY EMBOLECTOMY

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In reading the discussion of Neuhof's paper on pulmonary embolectomy presented at the 1944 meeting of the American Surgical Association, it is easy to detect a lack of enthusiasm for the operation, and a dim outlook as to its future. There was good reason for this at the time, in addition to the lack of success which the procedure had met in this country. The use of methods for the detection of post operative phlebothrombosis such as the Homan's sign had become widely disseminated. The introduction of femoral vein ligation proximal to the thrombus, early ambulation, and to a lesser extent prophylactic bandaging of the legs gave reason to think that with the proper vigilance, emboli could be prevented from entering the pulmonary artery, or thrombosis in the leg veins minimized. The introduction of heparin therapy by Murray and Best in Toronto and its first use in this country by McClure and Lam gave further hope that prevention of pulmonary emboli was an attainable goal. In reviewing statistical surveys it is difficult from our vantage point now to assess accurately the impact which these measures have had on the incidence of serious sequelae of leg vein thrombosis in the postoperative period. One thing is certain, however, the problem of fatal pulmonary embolism is still with us. Each year a large surgical service will have to deal with a number of massive embolizations to the pulmonary artery. For this reason surgical thinking in this institution and elsewhere has come back to the consideration of pulmonary embolectomy.

Recently this operation, proposed by Trendelenburg in 1908, was carried out in this hospital for the first time. Although a massive clot was removed from the main pulmonary trunk and from the right and left main branches, the patient succumbed with residual thrombus in the distal pulmonary arterial tree.

F. S., a 42 year old man, reentered the hospital on 5/25/60 for the treatment of severe ulcerative colitis. He had had recurring attacks of diarrhea with bleeding which were refractory to medical management. Upon admission he was in an acute exacerbation of his illness. He had continuous bloody diarrhea, abdominal distention, and had lost 20 pounds during the preceding three weeks.

The patient was operated on by Dr. John Wylie on 6/3/60. A one stage subtotal colectomy was carried out and an ileostomy was constructed. The patient's postoperative course was initially characterized by improvement with a functioning ileostomy and good fluid and electrolyte balance. His progress was uneventful until the seventh postoperative night. At about 10 P.M., following a walk in the corridor, he was forced to take to his bed because of a sudden feeling of being unable to breathe combined with a sensation of tightness in the anterior chest. When closely questioned at this time the patient thought that there was a peculiar sensation in his left leg, but denied any pain or tenderness in that location. There was no increase in the diameter of the leg and Homan's sign was absent. The patient presented the picture of a disaster stricken man. His pulse rate was between 140 and 160 per minute. His respirations...
were rapid. His blood pressure was 70 systolic. He was covered with a film of cold perspiration. No murmurs were heard over the precordium and no unusual quality of the cardiac sounds was noted. No rales were audible in the lung fields. The abdomen, aside from the changes relative to the recent operation, was negative.

The impression of the examiners was that the patient had sustained an acute massive pulmonary embolization. Treatment of an emergent nature for this condition was instituted with administration of oxygen by nasal catheter, and the injection of morphine and levophed. An electrocardiogram taken at this time demonstrated incomplete right bundle branch block.

After a period of observation the patient was transported to the operating room in his bed. The patient was placed on a cooling blanket and the skin of the chest was prepared prior to the introduction of an endotracheal tube. Following induction of anesthesia a midline sternal incision was made which was carried down through the sternum with the Lebsche knife. The pericardium was also opened longitudinally. The heart was beating regularly although feebly. The right ventricle in particular was dilated, lending support to the diagnosis of acute obstruction of its outflow, although palpation of the main trunk of the pulmonary artery did not demonstrate a thrombus in its lumen. It was thought worthwhile at this point to gain control of the venous inflow to the right atrium preparatory to opening the pulmonary artery, as is done in the current operation

Figure 1
Emboli removed from the pulmonary trunk and the right and left main branches.
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of normothermic pulmonary valvotomy. Snares were placed around the superior and inferior venae cavae. The main pulmonary trunk was then dissected away from the root of the aorta and a cotton tape placed around it. Traction sutures were placed on either side of the proposed arteriotomy site. The venae cavae were temporarily occluded prior to opening the pulmonary artery. This maneuver was repeated with each subsequent exploration of the interior of the pulmonary artery. A metal suction tip was inserted into the main pulmonary trunk and directed into the right branch and, on withdrawing it, fragments of thrombus were removed. This was repeated a second time, directing the instrument to the left, and another sizable thrombus was recovered (Figure 1). On a total of three subsequent occasions the metal suction tip and hard rubber catheters were inserted deep into the right and left branches of the pulmonary artery, but no further clot was obtained. Each period of caval occlusion lasted from one to two minutes. Upon opening the caval snares at the conclusion of each period the pulmonary artery opening was closed with a curved Potts clamp. The heart action, which remained regular throughout, become more vigorous following the extraction of the thrombus. However, it subsequently became weaker and the right ventricular dilatation noted at the outset became more pronounced, and did not respond to the injection of epinephrine, calcium chloride and cedalanid more than temporarily. After a prolonged period of resuscitative efforts the heart remained unable to maintain an effective beat and the operation was finally terminated.

Post mortem examination showed the main pulmonary trunk and the initial portions of the right and left main branches to be free of thrombus. Distal to these areas, however, there was organized thrombus extending far down into the pulmonary arterial tree on both the right and left.

DISCUSSION

A median sternotomy was used instead of the T shaped incision with resection of portions of the third and fourth ribs proposed by Trendelenburg. The swift opening of the midline of the sternum achieved by the Lebsche knife, offering excellent exposure of the outflow tract of the right ventricle and the pulmonary artery, has much to recommend it and is the incision we would employ again. It has additional advantages in allowing manipulation of the ventricles in resuscitative maneuvers. Access to the cavae is also good. However, at a future operation we would omit placement of snares around the cavae to control the venous inflow to the heart as an unnecessary step. The right heart is already obstructed and simple clamping of the artery at about the level of the valve would be sufficient to keep right ventricular blood from the field during the short periods of opening the vessel.

With an adequate incision in the main pulmonary trunk large clots were removed from the main trunk and from the right and left main branches. When the arteriotomy was closed with a clamp and the heart allowed to empty itself, the gross right ventricular dilatation persisted. Because of the time during which the obstruction had been in effect, it was thought possible that the right ventricle had dilated and stretched so that it was not capable of initiating a forceful contraction after removal of the clot. In fact, however, its outflow was still obstructed, not at its origin, but in the distal portions of the pulmonary arterial tree. Thus the use of cardiac muscle stimulants
was not effectual in restoring a purposeful emptying contraction in the right ventricle. Just how long the right ventricle can be completely obstructed and yet able to resume a competent pumping action is not clear, but it would seem, on the basis of this instance, that residual right ventricular dilatation probably means residual thrombus in the pulmonary artery distal to that already removed.

Neuhof and also Beck proposed performing the embolectomy via the right ventricular outflow tract rather than through the pulmonary artery itself as stipulated by Trendelenberg. Mistakes of orientation were cited in which the surgeon opened into the aorta rather than the pulmonary artery. In view of the status of familiarity of surgeons with structures in juxtaposition to the heart at that time this suggestion was undoubtedly a reasonable one. At present, when this region is a commonplace operating site of the thoracic surgeon, the direct approach through the pulmonary artery seems most advantageous. The instruments stipulated by Trendelenburg for use in this procedure were: 1. A rubber tube tourniquet for insertion through the transverse sinus for elevating the great vessels, 2. A hooked sound designed for retrieving the end of the rubber tube, 3. Forceps for dilating the arterial opening, 4. Clot removing forceps, 5. A
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Figure 3
Metal suction cannulas photographed against a 1:1 outline drawing of lateral pulmonary angiogram.

flat bladed clamp for closing the opening in the pulmonary artery. Some of these instruments are obsolete because of the progress in cardiovascular instrumentation. For example, the Potts clamps can be used in preference to a flat bladed clamp. Others seem unnecessary such as the tourniquet for occluding and elevating the great vessels via the transverse sinus, and forceps for holding apart the incision in the pulmonary artery. What would be more useful are catheter tips and extracting tools for manipulation of thrombus in the distal portions of the pulmonary artery. The orientation of the pulmonary artery is unlike that of an artery in a limb, deviating from a straight line by angulation in two planes. In the case reported by Neuhof, as in our case, the insertion of rubber catheters into the pulmonary artery did not succeed in extracting the
clot in spite of being passed for long distances down the artery on both sides. Neuhof stated, "A metal tube with an appropriately hollowed end would probably be more effective in engaging and extracting the thrombus." We, in fact, did use a curved metal suction tip, but because of its small bore and the angulation of the vessel, were unable to bring it into effective apposition to the more distal portions of the thrombus. A glance at the pulmonary artery angiograms illustrated in Figures 2 and 4 will serve to illustrate the angulation of the pulmonary arteries. We have attempted to surmount this difficulty by construction of metal suction tips of graded diameters and lengths based on measurements of the pulmonary arteries as they progress toward the periphery of the lung. These suction cannulae are angled in the same fashion as the lumen of the artery and are malleable so that they may be altered on the operating table. (Figure 3). The tube of larger diameter is designed for the vessel down to the point at which the upper lobe branch is given off. The tube of smaller diameter and greater length is for the vessel distal to that point. In addition we have made loops for stripping the thrombus from the vessel wall (Figure 5) and angled forceps for extracting the thrombus.
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Figure 5

Thrombectomy loops photographed against 1:1 outline drawing of posterioranterior pulmonary angiogram. These have malleable shafts.

Following a successful embolectomy it would no doubt be advisable to interrupt the venous pathways from the lower extremities. In the case recounted here we had planned to proceed with bilateral femoral ligation. An inferior vena caval ligation might be preferrable in certain situations, but we thought that the postoperative abdominal situation in this case made this undesirable.
The physiological mechanisms in pulmonary embolization have been well worked out and related to the clinical picture of the condition by Churchill and Giertz and Crafoord. The rationale of the Trendelenburg procedure in the treatment of massive acute embolization is clearly set forth in these and other papers and need not be reviewed here. Nevertheless the place of pulmonary embolectomy in modern surgery has been a stormy one. Possibly a critical factor in its eclipse aside from the operative technicalities has been the problem of correct diagnosis. A representative statement regarding this phase of the problem is made in Lindskog's popular textbook of thoracic surgery: "Since the clinical picture of massive pulmonary embolization may be simulated by sudden heart failure resulting from coronary occlusion or even by massive internal bleeding, it follows that extreme caution is necessary in suggesting this operation... A final unpredictable element is the fact that critically ill cases of pulmonary embolism may suddenly improve and eventually recover." At the moment the attitude cited seems to represent a position of relative negativism. No doubt, however, most surgeons electing to perform the operation will use all of their diagnostic care to assure that a clot will be waiting for them when they open the pulmonary artery.

The time period elapsing between the lodging of the thrombus in the pulmonary artery and its removal must be an important factor in achieving a successful result. In the case reported here approximately two hours intervened between the manifestations of embolization and the surgical procedure. During this time the initial embolus had opportunity to propigate distally and create a situation difficult to undo. Trendelenburg himself was evidently an advocate of quick operation, although he was never rewarded with a complete success. An example of the degree of initiative prevailing in his clinic at Leipzig can be gleaned from the following statement, "Die Stationschwester, die gleich an eine Embolie dachte, fuhr den Kranken sofort im Bett nach dem Operationssaal." On the other hand, the successful cases carried out by Crafoord in Stockholm were not achieved by haste in intervention, but by waiting at the bedside of the patient following the onset of the embolization until the certainty of the diagnosis made anesthesia unnecessary. Crafoord said, "It is permissible in doubtful cases, as our new experience shows — without therefore losing the patient — to postpone the operation so long that even to the greatest skeptic the diagnosis of obstructive embolism becomes clear and also the prognosis — if the patient be left alone becomes certain."

Nevertheless, it is probable that reluctance to undertake prompt action has at times mitigated against the chance of success of the procedure when finally performed. Pertinent to this is the recent successful procedure carried out by Richard Warren in Boston (the first successful pulmonary embolectomy in this hemisphere) which was called to our attention following our own operation. His patient, a 64 year old woman who sustained a massive embolization at 3:30 in the afternoon following cholecystectomy and choledochostomy, was operated on 45 minutes from the time of onset of the initial symptoms. In regard to the time factor Warren states, "The case has taught us, however, that although we should be wary of operating on a patient in whom the diagnosis may be incorrect, we must consider that we have reached a stage of progress where, once the diagnosis has been confidently made, we should be permitted to perform the operation without waiting until we are sure that the patient will not survive without it. The attitude, as described by Churchill, which in the past prompted one operating
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team to remain alerted for 17 hours following embolism, to operate only as the patient died, should be a thing of the past.'

SUMMARY AND CONCLUSIONS

A patient who developed acute massive pulmonary embolization following subtotal colectomy was treated by pulmonary embolectomy. Although thrombus was removed from the pulmonary artery and its right and left main branches, the patient succumbed with right ventricular obstruction from residual thrombus in the distal pulmonary arterial tree. Some of the pertinent factors pertaining to this procedure are discussed and modifications in the instruments used for the Trendelenburg procedure are suggested.

REFERENCES


