Experimental Lung Resection During Vascular and Bronchial Occlusion*

N. J. DEMETRAKOPOULOS, M.D.** and F. J. LEWIS, M.D., F.C.C.P.
Chicago, Illinois

Introduction

Lung resections of less than a lobe are apt to be bloody and thus imprecise when the dissection is carried outside the segmental plane. If clamps are used to avoid a bloody and bubbling field and a wedge type of resection is done, some normal tissue is resected and other normal tissue is impaired by the repair. Better techniques are needed. This need is particularly apparent if multiple small lesions must be resected or if the disease passes over segmental planes. A lung with multiple emphysematous blebs, for example, presents these problems.

The technique we have employed to facilitate subsegmental lung resections is a simple one in which the lung is made bloodless and essentially airless prior to resection by clamping the blood vessels and the bronchus at the lung root.

Method

Thoracotomy was performed in 25 adult mongrel dogs through the right third or left fourth intercostal space. Anesthesia was obtained with pentobarbital sodium and morphine sulfate. Breathing was maintained with an automatic respirator.

The animals were divided into three groups. Group I consisted of six dogs in which the result of clamping the pulmonary arteries, veins and the bronchus in various combinations and sequences was observed in order that we might learn a satisfactory way to produce ischemia. In some dogs, the whole pedicle was clamped with one clamp, while in others, the pulmonary artery, the vein and the bronchus were clamped individually and in varying order.

In group II, consisting of 8 animals, the pedicle of the right upper lobe was freed and the pulmonary artery clamped with an occluding tape. Immediately afterwards, the inspiratory pressure produced by the respirator was raised from the usual level of 16 millimeters of mercury to 25-30 millimeters of mercury. This increased inspiratory pressure was applied intermittently for from 3 to 15 minutes, and finally, at the height of a forced inspiration, the pulmonary vein or veins and the corresponding bronchus were occluded with tape tourniquets.

Group III consisted of 11 animals in which the procedure of group II was repeated except that the whole left lung was made ischemic. After the components of the pedicle were clamped, wedge resections were done to make certain that the lung was ischemic. The defects of the lung thus

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*From the Department of Surgery, Northwestern University Medical School, Chicago, Illinois.
**Present address: U. S. Naval Hospital, St. Albans, New York.
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produced were sewed up. After a period of complete ischemia ranging from 60 to 90 minutes the pulmonary veins, the bronchus and the pulmonary artery were unclamped in that order.

Tape was used to occlude the vessels of the right upper lobe. However, the bronchus was clamped with either a straight Potts patent ductus clamp or a Satinsky vena cava clamp. These clamps were also frequently used to clamp the hilar vessels in order that one might determine whether or not this method was adequate for the experiment and innocuous to the clamped vessel.

The dogs in group II were sacrificed by exsanguination on 10 to 40 days and in group III in 42 to 66 days after the experiment.

Patency of the bronchial system of vessels was checked by x-ray films as follows: the thoracic portion of the aorta was ligated just beyond the arch and at the level of the diaphragm. About 100 milliliters of barium sulfate suspension were injected into the thoracic aorta, and then the heart, lungs and aorta were removed en masse from the chest cavity and x-rayed. The filled bronchial arteries were evident. The integrity of the previously clamped bronchi was checked by x-ray film taken after the main divisions of the main stem bronchi had been tied and both trachea and main stem bronchi filled with hypaque solution. Finally, the main vessels and bronchi were inspected and photographs taken.

As a further test of the functional capacity of the left lung which had been rendered ischemic, right pneumonectomy was done in four dogs of group II in 18, 19, 34, and 42 days after the ischemia experiment.

Results

Survival was not observed in group I, since the purpose was to perfect the technique of ischemia. Studies in this group suggested that the

FIGURE 1: The bronchus appears undamaged at the site of clamping which is indicated by the arrow.
optimal time for emptying the lung of the residual blood after the pulmonary artery had been clamped and before the corresponding veins and bronchus were occluded was at least five minutes.

All of the 19 animals of group II and group III had long healthy survival, except one animal of group III which died six days postoperatively of bleeding resulting from faulty suturing of the wedge resections done during surgery.

Patency of the previously clamped bronchi (Fig. 1, 2) and main vessels was the rule without exception. The bronchial vessels were also patent as seen in the x-ray films and in histologic sections (Fig. 3).

All four dogs subjected to pneumonectomy survived the operation, but one died 72 hours after surgery. Autopsy showed a heavy red, wet left lung and intussusception of about three fourths of the stomach into the esophagus presumably because of the abnormally decreased intrathoracic pressure resulting from the pneumonectomy. The left lung, also, had extensive dense adhesions to the chest wall as a result of the ischemic operation. The other three dogs were alive and well 9, 21 and 22 days after the removal of the right lung and 27, 59 and 64 days after the left lung had been rendered temporarily ischemic. Autopsy showed normal lung tissue and patent bronchi and main vessels.

Comment

Attempts at reducing the bleeding during resection of portions of lung tissue are recorded as early as 1876 when Kirchhoff\textsuperscript{5} exteriorized a diseased lobe, applied a tourniquet around the secondary hilus and excised the lobe. Since then, instruments\textsuperscript{6,7} as well as methods\textsuperscript{8} have been devised to render dissection through the lung tissue as bloodless as possible.

\textbf{FIGURE 2:} X-ray film showing that the left main stem bronchus has normal lumen without stricture many weeks after clamping (see text).
Some of the instruments as that of Garre and Quincke (1912) and of Shenstone (1937) were applied to the whole hilus, whereas that of Schumacher (1912) was applied upon any part of the lung distal to which pulmonary excision was to be performed.

An ingenious method of excising a diseased lobe was used by Sauerbruch and Schumacher (1911). They ligated the corresponding pulmonary artery one to two weeks before excising a bronchietatic lobe. This method was supposed to shrink the diseased lobe and render it almost entirely bloodless.

Modern thoracic surgeons have utilized temporary hilar ligation of the bronchus and the vessels in the excision of pulmonary arteriovenous fistulas and have studied the effects of occlusion of the hilus on the survival and pulmonary function of dogs. Whereas these surgeons have reported success in obtaining relatively avascular fields, Blades and his associates have repeatedly emphasized the fact that "in addition to individually ligating the main hilar vessels and the bronchus, further insurance of total ischemia was ... effected by placing a crushing tourniquet ... around the entire pulmonary hilus." It is our opinion that even then one cannot get a completely bloodless field which one gets, for instance, in hand surgery done with the help of an arm tourniquet. Each lung holds about 100 to 300 cc. of blood trapped in its vastly numerous capillaries, the total inner surface of both lungs being close to 700,000 square centimeters. In addition, in our group I experiments even after complete severance of the lung pedicle there was so much bleeding from wedge resections that one might think there was a hidden source of blood within that lung producing several milliliters of blood each minute.

Success was obtained in our efforts to produce a bloodless lung resection when we not only clamped all hilar structures tight, but also added the step of emptying the lung or lobe of the residual blood. As described under Methods, the pulmonary artery was first occluded and the inspiratory pressure was then increased to 25 to 35 millimeters of mercury and intermittently kept at this high level for at least 5 minutes. Only then would a cut into lung tissue resemble a cut through a moist sponge. This principle proved to be correct in the human cases in which it has been employed, and use of this technique especially in cases with emphysematous blebs will be reported later. Moreover, according to the present work, in the humans as well as in the dogs, clamping the pulmonary veins was necessary in spite of the low pressure within these vessels.

Another interesting fact was discovered in our studies. The lung tissue, canine or human, can withstand total ischemia for at least 60 minutes and probably more. Bosher doubted the statistical significance of the figures and the validity of conclusions of Blades that 30 minutes is the upper limit of safe vascular occlusion of the lung. We are inclined to agree with Bosher. Moreover, we have proved to our satisfaction that doubling that period, i.e. making it 60 minutes, would not be injurious to either canine or human lung tissue.

FIGURE 3: Normal histologic appearance of lung parenchyma and bronchus in one lung, examined during life. Arrow points to the barium filled bronchial vessel which was obviously patent long after the ischemia experiment.
SUMMARY

A perfected technique of producing temporary, complete pulmonary ischemia is described. Any sublobar lung resection can be done in a bloodless field by this technique. Its safety has been proved by experimentation in 19 dogs in which either a lobe or an entire lung were rendered ischemic for 60 minutes.

RESUMEN

Se describe una técnica para producir isquemia pulmonar completa y temporal. Cualquier resección sublobar puede hacerse en campo exangüe con esta técnica. Su seguridad se ha probado en 19 perros en experiencia y de los que se ha logrado que ya sea un lóbulo o un pulmón entero permanezcan isquémicos por 60 minutos.

RESUMÉ

Un procédé perfectionné de production temporaire d’ischémie pulmonaire complète est décrit. Toute résection sublobaire du poumon peut être faite dans un champ exsangue par cette technique. Son absence de danger a été mise en évidence par l’expérimentation chez 19 chiens, chez lesquels soit un lobe soit le poumon entiers étaient rendus ischémiques pendant 60 minutes.

ZUSAMMENFASSUNG

Beschreibung einer fehlerlosen Technik zur Herstellung einer temporären kompletten pulmonalen Ischämie. Mit dieser Technik kann jede sublobäre Lungenresektion in einer blutleeren Gebiet ausgeführt werden. Ihre Sicherheit wurde erwiesen durch Experimente an 19 Hunden, bei denen entweder ein Lappen oder eine ganze Lunge während 16 Minuten blutleer blieb.

REFERENCES

4 Garre, C., and Quincke, H.: Lungenchirurgie, Jena, Fischer, pp. 61 and 65, 1912.

PATHOLOGIC AND ANATOMIC CHANGES IN BRONCHIAL STUMPS AT DIFFERENT PERIODS FOLLOWING PNEUMONECTOMY AND LOBECTOMY

Histologic study of 30 bronchial stumps in patients who died at various periods of time after lung resection and lobectomy for different diseases has shown that in uncomplicated cases, the formation of the epithelial connective tissue adhesion takes place to the twelfth day postoperative-ly. The growth of the adhesion was markedly retarded by the development of suppurative processes in pleural cavities that complicated the postoperative course of the disease. The forma tion of the distal stump portions. Reactive inflammatory changes about tantalum clips were considerably less than that about silk ligatures, the very region where not infrequently suppurative processes start the development. Of 11 bronchial cysts studied in 7 cases, the cause of the origin was suppuration at suture site and ligature disruption; in 2, destruction of the stump tissue involved by cancer and associated with suppurative processes. In one patient in the region of the stump, the mycotic process has developed. In another patient, there was inadequate stump suture.