While the entomologist was a key person in that his training enabled him to locate the single species transmitting malaria and to concentrate efforts on that species, the rapidity with which control was achieved was actually the expression of teamwork on the part of various workers. Thus, in addition to the entomologist, a malariologist directed the overall program and an engineer carried out control operations.

Malaria control not only succeeded on Efate but also resulted in similar success on the many other islands of the South Pacific where specialists and organized methods were employed. The present day significance of these wartime achievements in the control of malaria is that they reemphasize the fact that a like approach in civilian communities is essential. With such methods, according to Russell,4 "One may reasonably hope that, with suitable organization, malaria will be eradicated from the United States within the next decade, and that in many tropical areas, even though economically depressed, this disease, now of the greatest importance, may become in the next half century one of the least of public health problems."

ANASTOMOSIS OF THE AORTA TO A PULMONARY ARTERY

Certain Types in Congenital Heart Disease

WILLIS J. POTTS, M.D.
SIEVY, SMITH, M.D.
and STANLEY GIBSON, M.D.
Chicago

In 1945 Blalock and Taussig1 introduced a new surgical procedure for the relief of anoxemia due to pulmonary stenosis or pulmonary atresia. By anastomosing the subclavian or innominate artery to either the right or the left pulmonary artery they have been able to increase the flow of blood to the lungs. Their work is an outstanding contribution to the relief of children whose outlook without aid is hopeless. Sacrifice of the subclavian artery for the anastomosis of its proximal end to the side of a pulmonary artery is associated with little danger to the circulation of the arm. Use of the innominate artery for such an anastomosis entails the hazard of an inadequate supply of blood to the brain.

The possibility of making a direct anastomosis between the aorta and the adjoining pulmonary artery was reviewed. Gross and Hufnagel2 and Blalock and Park3 concluded from their experimental work on animals that clamping off the aorta completely for any considerable length of time lacks in a fair percentage of experiments to paralysis of the hind legs caused by temporary anemia of the spinal cord. An anastomosis, therefore, between the aorta and the pulmonary artery can be performed safely only if a substantial amount of blood is flowing through the aorta during the procedure. This was made possible by the use of a new type of clamp which two of us have designed (W. J. P. and S. S.), which is illustrated in figure 1. The two flanges of this clamp encircle the aorta and, when closed, pinch off a small but sufficiently large portion of the aorta to allow room for an anastomosis. The major portion of the aorta lies in the hollow of the clamp and rests against it. Since each pulsation of the enclosed aorta is transmitted to the back of the clamp with the same force as that which acts against the portion of the aorta which is occluded, there is no tendency for the clamp to slip off. It is unnecessary to tighten the clamp beyond simple occlusion. When the clamp is closed the lumen of the aorta is reduced to approximately half its size.

Other instruments which we developed or designed for the aortic pulmonary anastomosis are illustrated in figure 2.

The details of aortic pulmonary anastomosis were worked out on approximately 30 dogs. This operation could not have been performed successfully on the human being without preliminary work on animals. Although the experimental work will be reported later, it is pertinent to state here that none of the animals showed any postoperative paralysis of the hind legs.

TECHNIC

Aortic pulmonary anastomosis has been performed on 3 children. Although there were slight variations in each operation, the technic in general was as follows:

Cyclopropane and oxygen anesthesia was used. In an operation of this type expert anesthesia is essential. This was given by Dr. Win. O. McQuiston.

A cannula was inserted into the saphenous vein at the ankle for the continuous administration of plasma and for the emergency administration of blood. The child was placed on its right side with the left arm abducted and fastened to the anesthetic shield. A curved incision was made below the left scapula from the edge of the erector spinae muscles to the nipple line (fig. 3 A). The chest was entered by an incision through the fourth interspace, and adequate exposure was obtained with a ribspear. The collapsed upper lobe of the lung was displaced from the operative field by a wet laparotomy pad.

The left pulmonary artery was identified and freed from surrounding structures by blunt dissection. Small tortuous veins overlying the artery were tied and cut. The artery was occluded for two minutes to determine whether the right pulmonary artery alone would carry sufficient blood to support life during the time required for the anastomosis. Detectable changes in color, pulse rate, respiratory rate and blood pressure were not observed in any case. The aorta was then dissected from its bed. With scissors an incision was made through the reflection of the parietal pleura over the lateral surface of the aorta, just distal to the arch. The vagus nerve was identified in its position between the aorta and the pulmonary artery and displaced posteriorly. The intercostal arteries arising from that portion of the aorta to which the clamp was later to be applied were doubly ligated with silk and cut between the ligatures. Two silk ligatures were placed around the pulmonary artery, each encircling the vessel twice. One was placed as far distally as possible, the other as far proximally as possible (fig. 3 B). The pericardial sac

6. From the Children's Memorial Hospital and the Department of Surgery, Northwestern University Medical School.
7. We wish to acknowledge the cooperation of Drs. A. J. Carlson and Dr. A. C. Ivy, as well as that of the resident and nursing staffs of the Children's Memorial Hospital.
8. The experimental work was aided by the Otto S. A. Sprague Memorial Institute and by the Northwestern University Women's Faculty Club Fellowship in Pediatric Surgery to Dr. Sidney Smith.
was not opened. The clamp was then applied to the aorta and slowly closed (fig. 3 C). In each patient after the clamp was closed a thrill was palpable distal to the clamp, indicating that blood was rushing through the constricted aorta. If a section of aorta sufficiently large for anastomosis did not protrude beyond the

flanges of the clamp as it was closed, the adventitia of the aorta was grasped and enough of the aorta drawn out to make suture technically possible. The adventitia was dissected only from that portion of the aorta protruding from the clamp. With an extremely sharp, small-blade knife a longitudinal incision \( \frac{3}{16} \) to \( \frac{5}{16} \) inches (8 to 9.5 mm.) long was made in the clamped-off portion of the aorta. While this incision was being made the rounded wall of the aorta was flattened by pressure with the spread prongs of a tissue forceps. Unless the wall of the aorta is cut squarely, the edges have a tendency to fray. The two ligatures doubly encircling the pulmonary artery were tied to the corners of the clamp, thus simultaneously occluding the vessel and affixing it with the aorta for anastomosis. Opposite the incision in the aorta an incision of similar size was made in the occluded pulmonary artery. This incision was made slightly diagonal so that at completion of the anastomosis the vessels in assuming their normal relationship would not produce a kink in the pulmonary artery (fig. 3 D).

The anastomosis was done with no. 5 Deknatel silk on a no. 9 curved atraumatic needle. The suture, beginning at the upper angle, was carried through the pulmonary artery from the outside in, then across through the aorta from the inside out—and tied (fig. 3 E). This brought the knot outside the vessels. In continuation of this suture, the posterior lip of the pulmonary artery was sewed to the posterior lip of the aorta by a running, over and over stitch. These stitches, approximately 1 mm. apart, included all layers of both vessels. In this portion of the anastomosis adventitia was brought to adventitia. At the lower angle of the wound the suture was locked and then continued as a running suture, bringing the anterior lip of the pulmonary artery to the anterior lip of the aorta, intima to intima. The long end of the suture was tied to the short end to complete the anastomosis. The ligatures holding the pulmonary artery to the clamp were cut, first the distal, then the proximal. The aortic clamp was then slowly released and removed. In no instance was there enough bleeding to require additional sutures. In each patient the thrill of blood flowing through the new opening could be felt.

The lung was reexpanded, and the incision in the chest was closed with three chromic gut sutures encircling the adjoining ribs. The muscles were reunited, and the skin was closed with silk.

**REPORT OF CASES**

We shall not undertake a discussion of the criteria for diagnosis of the tetralogy of Fallot. These criteria have been set forth by Blalock and Taussig, and we have attempted to select our cases in accordance with the principles which they have laid down.

**Case 1.—History and Examination.**—D. S., a girl, born Dec. 10, 1944, weighing 6 pounds and 10 ounces (3,005 Gm.), appeared to progress normally until she reached the age of 3 months. At that time the mother observed that the baby became blue around the lips during her feeding and seemed quite limp at the conclusion of her meal. The cyanosis increased gradually in intensity, was particularly noticeable after feeding, crying or fretting and eventually was observed even when the infant was at rest. Dyspnea became evident as time went on. Finally her condition became so poor that feeding was a serious problem. If she were fed a little too much or too rapidly she became extremely cyanotic and limp, her eyes became fixed, and she lapsed into unconsciousness. On two occasions the mother thought that the child was dead. The entire household was organized with the single thought of contributing to her comfort. Her 3 year old brother was kept from her room, and neighboring children were not allowed to play in the house.

Though the child had sat up at 6 months, she had never walked or stood alone. She had gained slowly in weight. She was first seen by us on Sept. 9, 1946 at the age of 21 months. Her weight at that time was 18 pounds 4½ ounces (8,291 Gm.). She was intensely cyanotic. The fingers were clubbed. Examination of the heart revealed a harsh systolic murmur along the left sternal margin. The electrocar-

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Fig. 1.—Clamp for anastomosis of the aorta to a pulmonary artery.

![Diagram](image1)

Fig. 2.—Essentially standard instruments modified to work in a small, deep cavity.

![Diagram](image2)
of the patient’s critical condition, oxygen saturation studies of the arterial blood were omitted. We believed that she presented the typical picture of a severe case of the tetralogy of Fallot.

Operation.—The operation was performed on Friday, Sept. 13, 1946. Cyclopropane anesthesia with a high concentration of oxygen was given by the closed method with a snugly fitting face mask. The child’s color improved greatly at the beginning of anesthesia and remained good throughout the operation.

The left pleural cavity was entered posteriorly through the third interspace. The incision was too high. Adequate exposure was not obtained until the fourth, fifth and sixth ribs were cut along the erector spinæ muscle. The pulmonary artery was identified and exposed without difficulty. Small, tortuous, dilated veins lying on the pleura over the aorta were tied and cut. On lifting the aorta from its bed, we observed an unusual number of small arteries, at least a dozen, arising from that small portion of the aorta where the clamp was to be applied. Some of them were intercostal arteries, and the rest presumably were vessels which had been dilated in response to a demand for collateral circulation to the lung. Isolating, ligating and cutting these vessels was the most tedious and time-consuming part of the operation.

Since the pulmonary artery lay in the same plane as the aorta, the incision in it was made parallel with its longitudinal axis. The actual anastomosis was performed without difficulty and required twenty-three minutes. When the clamp was removed a palpable thrill could be felt in the anastomotic channel. The chest was closed. The total operating time was three hours.

The blood pressure at the beginning of the operation was 95 systolic and 60 diastolic; at the close of operation it was 100 systolic and 60 diastolic. When the clamp was tightened on the aorta, the systolic blood pressure rose 10 points but in a few minutes returned to its previous level. The pulse rate remained practically constant throughout the operation at 120 to 132 beats per minute. The patient received 200 cc. of plasma during the operative procedure.

Postoperative Course.—The infant was brought to her room in good condition. She received 100,000 units of penicillin in the plasma which was being administered by vein. Thereafter she received 30,000 units of penicillin every three hours for ten days. In the first twenty hours following operation she received 200 cc. of 5 per cent dextrose in isotonic solution of sodium chloride and 625 cc. of a solution of 10 per cent dextrose in water. Her postoperative course was remarkably smooth. She was kept in an oxygen tent for three days. Vomiting did not occur. She began taking fluids twenty-four hours after operation and was given a soft diet on the following day. The lungs remained clear. Examination of the heart revealed a slight carry over of the murmur into diastole, though it was not comparable to the harsh continuous murmur which one hears in the typical patent ductus. The most striking feature was in her color and in her general behavior. She took her food without difficulty; when disturbed by her doctors she cried for several minutes without turning blue, and in the intervening time she was happy and playful. She gained a pound (454 Gm.) in the first eleven days after operation.

On the third day following operation her red blood cell count was 6,600,000 per cubic millimeter, hemoglobin content 14.3 Gm. and hematocrit reading 44. Subsequent counts at three day intervals gave substantially the same results. She was discharged from the hospital on October 2, nineteen days after operation. A later note from the mother states that the baby’s condition is excellent, and that her color compares favorably with that of the other children who now come in to visit her.

Case 2.—History and Examination.—G. M., a girl, born Jan. 21, 1935, made her first visit to our outpatient department at the age of 14 months because of inability to move her left arm and leg during the previous three days. Examination at that time revealed slight generalized cyanosis with a deeper color about the gums, lips and fingertips. A systolic murmur was heard over the precordium, maximal in the second and third interspaces on the left side along the sternal margin. A thrill was palpable. A left hemiappendix was present. The deep reflexes on the left were increased. Ankle clonus and positive toe flexion were present. The diagnosis at that time was congenital heart disease complicated by cerebral thrombosis. She was seen at intervals in the outpatient department. She became gradually more cyanotic, was very late in walking, and her mental progress was slow.

She was admitted to the hospital on Sept. 5, 1946, at the age of 11 years and 8 months. She was a small, thin child, weighing 24 pounds (24.5 Kg.). The left arm and leg were smaller than the right, with some squatting due to the cerebral accident which had occurred in infancy.

The entire skin was cyanotic with intense cyanosis about the eyes, lips and tips of the fingers and toes. Clubbing of the fingers and toes was well defined. Psychometric examination established her intelligence quotient at 66. Cardiac examination failed to reveal any enlargement. There was a short, harsh systolic murmur, best heard in the second and third interspaces on the left side and not widely transmitted. The roentgenogram showed slight cardiac enlargement, with a blunted, rounded apex. There was a concavity in the region of the pulmonary conus. Under the fluoroscope a pulmonary window was seen but pulsations were not observed in the pulmonary arteries. The electrocardiogram showed well defined axis deviation to the right. The red blood cell count was 4,000,000, the hemoglobin level 26.5 Gm. and the hematocrit reading 79. The oxygen saturation of the arterial blood was 87.8 per cent.

Operation.—The operation was performed on September 16. Under cyclopropane and oxygen anesthesia the intense cyanosis did not improve appreciably.

There was persistent and troublesome bleeding from the severed muscles of the chest wall. The left pleural cavity was opened through the fourth interspace, and adequate exposure was obtained without cutting any ribs. Each time the upper lobe of the left lung was retracted there occurred a "bronchial spasm" which made it momentarily impossible to force oxygen into the lungs with a pressure bag. After repeated episodes,
it became obvious to the anesthetist that the administration of intratracheal anesthesia was necessary. Because of the extreme anoxia it was necessary to close the chest and reexpand the lung before the intratracheal tube could be introduced safely. Under intratracheal anesthesia the operation was resumed.

The hilar of the left lung was covered with a mass of tortuous veins black with cyanotic blood. The pulmonary artery was exposed and isolated with great difficulty. Any tiny vein accidentally torn oozed tarry blood, which obscured the field. The aorta was easily freed. Five intercostal arteries were doubly tied and then cut to make room for the clamp. Too rapid closure of the clamp on the aorta resulted in a rise in the systolic blood pressure from 100 to 150 mm. of mercury. The clamp was released, and the blood pressure returned to 100. When the clamp was closed more slowly the systolic blood pressure rose to 110 mm. and remained at that level throughout the anastomosis. On completion of the anastomosis, a thrill was palpable but was less intense than in the previous patient. The actual anastomosis required forty-five minutes. During the operative procedure the child received intravenously 100 cc. of isotonic solution of sodium chloride, 200 cc. of whole blood and 300 cc. of plasma.

Postoperative Course.—The patient was in poor condition when returned to her room. She was placed in an oxygen tent, and 100,000 units of penicillin was administered in the intravenous fluids. Subsequently 30,000 units of penicillin was given intramuscularly every three hours. She roused slightly soon after operation, and it was then observed that she failed to use her right arm and leg. She remained in a semicomatose state. On the morning after the operation her color was distinctly improved. Some hours later she became dyspneic, and coarse moist rales were heard throughout the chest. Supportive treatment was ineffective, and she expired at 8:30 p.m. on September 17, thirty-six hours after the operation.

Postmortem examination revealed that the anastomotic channel was open. Leakage had not occurred. There was a small thrombus in the left pulmonary artery proximal to the site of anastomosis. The pleural cavity was dry. Thick mucopurulent secretion was present in the trachea and bronchi. The lungs were congested. A scar was found in the right frontoparietal region of the brain, obviously the result of the cerebral accident which the patient suffered at the age of 14 months.

On the left side a hemorrhagic infarct occupied the upper portion of the postcentral gyrus.

Case 3.—History and Examination.—B. K., a girl, born Aug. 5, 1938, weighing 6 pounds, 8 ounces (2,949 Gm.), was first seen in the outpatient department at the age of 3 weeks, at which time she had a loud systolic murmur over the precordium, maximal at the third interspace on the left side. There was no cyanosis. A tentative diagnosis of defect of the interventricular septum was made. When the infant was seen on March 8, 1939, at the age of 7 months, the mother reported that the baby became breathless when a large amount of food was taken at one time. On Sept. 30, 1939, examination revealed cyanosis on crying and slight clubbing of the fingers. She was then lost to the clinic until Aug. 11, 1945. At that time she was definitely cyanotic and tired easily on exertion. She had grown slowly and weighed only 27½ pounds (12 Kg.) at the age of 7 years.

She was admitted to the hospital on Sept. 21, 1946. The mother stated that the child had recently been able to exercise less than formerly and would squat down to rest after walking half a block.

Physical examination revealed a small, slender child who was decidedly cyanotic, with suffusion of the eyes and clubbing of the fingers. Her weight was 29½ pounds (13 Kg.).

There was a harsh systolic murmur over the precordium, best heard on the left along the sternal margin at about the third interspace. Roentgenologic examination showed the heart to be slightly enlarged with a rounded blunt apex and without fixation to the right homologous group. The aortic knob was visible to the left of the sternum. In the left anterior oblique position the pulmonary window seemed to visualize well. The electrocardiogram showed decided axis deviation to the right. The red blood cells numbered 9,890,000 per cubic millimeter, the hemoglobin content was 24.8 Gm. and the hematocrit reading was 67.

Operation.—The operation was performed on September 27. Intratracheal cyclopropane and oxygen anesthesia was administered by Dr. Wm. O. McQuiston. The patient's color was much better under anesthesia than it had been previously.

The left pleural cavity was entered through the fourth interspace posteriorly, and adequate exposure was obtained with a ribspreader. The pulmonary artery was easily separated from surrounding structures. That portion of the aorta immediately distal to the arch was exposed. Six intercostal vessels required ligation. One of them was at least 2 mm. in diameter. The blood pressure remained unchanged during slow closure of the clamp on the aorta.

Incision in the pulmonary artery was made at an angle so that on completion of the anastomosis the vessels lay in normal relationship to each other without kinking the pulmonary artery.

The pulmonary artery was rather large and consequently wrinkled by the two encircling, holding ligatures. The bite taken in suturing the anterior lip of the pulmonary artery to the anterior lip of the aorta was too large. When the anastomosis was completed and the clamp removed, some constriction of the pulmonary artery was apparent. While this probably made little difference in the flow of blood through the pulmonary artery, it was a technical error. A palpable thrill could be felt in the anastomotic channel. The lung was reexpanded and the chest closed. The child received 30 cc. of plasma intravenously during the operative procedure. Her condition at the close of the operation was excellent. The operative time was two hours and forty minutes.

Postoperative Course.—The patient was returned to her room in good condition. She was placed in an oxygen tent. One hundred thousand units of penicillin was given in the intravenous fluids which she received following operation, and 30,000 units of penicillin was given every three hours for fourteen days postoperatively. On the evening of the operation she took sips of fluid, and on the next day she received a soft diet. Her condition was good. On September 30 it was noticed that dulness and diminished breath sounds were present over the left side of the chest. Inasmuch as the left pulmonary artery was patent, paracentesis was not performed. However, the signs in the chest gradually increased, and on October 3 she appeared tired but was not distinctly dyspneic. A chest x-ray was performed, and 240 cc. of grossly bloody fluid was removed. From this point on, recovery has been uneventful and the roentgenogram reveals that the chest has cleared. At the present writing, seventeen days after operation, she is walking freely about the ward. She has only a slight cyanotic tinge. She requests second helpings at each meal. She has gained 4 pounds (1.8 Kg.) since the operation.

On the third day following operation, her red blood cell count was 6,640,000 per cubic millimeter, the hemoglobin content 18.6 Gm., and the hematocrit reading 50.5. Subsequent examinations gave essentially the same results. The oxygen saturation of the arterial blood on October 11 was 77 per cent. The heart was examined daily following operation, and we were somewhat disturbed by the fact that the murmur seemed to be identical with that which had been heard previously. When the dressings were completely removed, however, a soft but distinct diastolic blow in addition to the systolic murmur was audible.

COMMENT

One of the possible advantages of this operation lies in the fact that we are free to make the anastomotic channel whatever size seems proper. Only years of experience and observation will determine the answer to that question. Thus far we have been guided by the work of Blalock and Taussig and have attempted to make the openings approximately the size of either the innominate or the subclavian artery. It may be that an additional field of usefulness of this operation will be...
in younger children in whom it is desirable to avoid sacrifice of the innominate artery.

In the first child, aged 21 months, the incision in the aorta measured \( \frac{5}{16} \) inch (8 mm.); in the other 2 children, aged 8 and 10 years, respectively, the incision measured approximately \( \frac{6}{16} \) inch (9.5 mm.). These figures do not represent the diameter of the anastomotic channel. An 8 mm. cut in a vessel will produce on expansion of that vessel an opening approximately 5 mm. in diameter, and a 9.5 mm. cut will produce an opening slightly less than 7 mm. (Formula: Length of the incision \( \times \frac{\pi}{4} \times (\frac{3.1416}{2} = \text{diameter of the opening}. Will the anastomotic channel enlarge as the child grows, or will it remain fixed? Work has been planned to answer this question. At present it seems logical to gage the size of the opening by the age, weight and degree of anoxemia of the patient.

Vascular surgeons agree that it is desirable to suture all vessels intima to intima. However, from our experimental evidence we do not believe that in aortic pulmonary side to side anastomosis the complex technic of suturing intima to intima in the posterior row of sutures is necessary or desirable. Bleeding is less apt to occur from such a suture line between vessels which are opposed adventitia to adventitia. This fact is important in an anastomosis in which the posterior row of sutures is inaccessible after the anterior row has been completed. In 30 anastomoses on dogs and 3 on children bleeding from the posterior suture line was not present. Furthermore, we have found that intra-aortic pressure tends to oppose the inverted lips of the posterior row of sutures, leaving an almost negligible gap between the intimal edges. It is true that a running over and over stitch opposing adventitia to adventitia does expose more suture material to the flow of blood. This does not violate the principles of vascular surgery (Smith 5).

The suture material and the anastomotic margins are covered with a layer of endothelium within twelve to twenty-four hours (Carrel and Guthrie, 6 Smith 7 and Horsley 8). To date, in none of the animals which we have killed from one to eighty-one days following aortic pulmonary anastomosis have we found more than pinhead sized thrombi on the suture line. In fact, the anastomotic lumen of the dog killed after eighty-one days was entirely free from thrombi, and the silk was deeply covered with endothelium (figs. 4 and 5).

**CONCLUSION**

Only because we were backed by the fundamental principles set forth by Blalock and Taussig for the surgical relief of anoxemia in certain types of congenital heart disease did we have the courage to attempt this new operation. The operation is not a simple one. In attempting this new procedure it seemed only fair to choose those patients whose condition was such that without aid their future was hopeless. The 2 children who survived the operation have been tremendously benefited.

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**Epidemic Hepatitis.**—During this war epidemic hepatitis has attained pandemic proportions. Large outbreaks have occurred in many parts of the world and in the armies of a number of nations. The pathology of this disease as observed in the Army of the United States during the epidemic of 1942 has been dealt with in previous papers. More recently an acute form of epidemic hepatitis of intense severity terminating fatally in less than ten days has become prevalent; this we have termed the fulminant form. In a new series of 196 fatal cases occurring between August 1943 and April 1945 which we have studied at the Army Institute of Pathology, over half fall into this category. By contrast, in the previous series not a single equally fulminant case was encountered, and only 1 was reported in the great Swedish epidemic of 1927; the usual duration of the fatal disease was then from four to six weeks; in other words, the course of fatal hepatitis was predominately subacute. These divergences in duration reflect striking differences in the pertinent pathologic changes. Thus, in the more fulminant form the parenchyma of the liver is destroyed completely and uniformly, and this destructive process is accompanied with an intense inflammatory reaction. In the more subacute form seen in 1942 and also in about one fourth of the 1943-1945 series destruction of the liver is incomplete, the involvement characteristically not uniform, regenerative hyperplasias of surviving parenchyma leads to the production of much new tissue, and inflammation is less pronounced.—Lucke, Baldwin, and Mallory, Tracy: The Fulminant Form of Epidemic Hepatitis, Am. J. Path. 22:868 (Sept.) 1946.

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