

PERMANENT INTUBATION OF THE THORACIC AORTA.*

By ALEXIS CARREL, M.D.

(From the Laboratories of The Rockefeller Institute for Medical Research, New York.)

In a previous article¹ it was shown that a segment of vein could be grafted successfully on the thoracic aorta. While this procedure might prove to be the ideal treatment of aneurysms on peripheral arteries, the extirpation of the aneurysmal sac and the transplantation of a vascular segment upon the thoracic aorta would be complicated and dangerous. I have attempted, therefore, to determine the proper technique for intubating the aorta, as this operation is simpler and may prove more satisfactory than grafting.

The idea of introducing a tube into the lumen of a vessel is not original. In fact paraffined glass tubes are used in all physiological laboratories for securing an artificial circulation of blood, and the same method has been applied successfully by Brewer to the transfusion of blood in human beings. Some years ago Abbe tried to effect a permanent anastomosis between the cut ends of an artery by means of a glass tube. He presented at the Academy of Medicine of New York a cat in which he had cut the abdominal aorta and had united the ends of the vessel by a glass tube. In other cases coagulation of the blood took place after a short time. It appeared therefore that even if a foreign body could be put temporarily in a vessel without accident, thrombosis would occur sooner or later.

Nevertheless, it was conceivable that thrombosis was preventable, and that the conditions under which a foreign body could be used for repairing a vessel might be ascertained. I extirpated, therefore, part of the anterior wall of the abdominal aorta of a dog, and replaced it by a piece of rubber covered with vaselin. Fifteen months after the operation, the circulation was still normal. The

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¹ Carrel, *Jour. Exper. Med.*, 1912, xv, 389.

vessel wall was intact inside and outside of the rubber. It was found also that the circulation could take place for six days through a glass tube lying free in the abdominal aorta. Thrombosis occurred subsequently owing to displacement of the tube. Encouraged by these results, I operated upon a number of dogs with the purpose of learning the precautions that must be taken in order to make the intubation successful. In all instances the operations were performed on the thoracic aorta of medium-sized dogs. The thoracic cavity was opened under ether anesthesia by the method of Meltzer and Auer, and a glass or metal tube was inserted into the lumen of the descending aorta.

The animal was etherized and the hair on the left side of the thorax was removed by sodium sulphid. The skin was washed with alcohol and covered with 10 per cent. tincture of iodine. Then a catheter was introduced into the trachea and connected with a Meltzer and Auer apparatus which consisted of a foot bellows, an ether bottle, and a small manometer. Next the thoracic cavity was opened by an incision passing through either the eighth or the fourth intercostal space. As soon as the pleura was opened, silk compresses sterilized in vaselin were introduced in order to protect the left lung, and to wall off the pleural cavity. Then a retractor of Gosset was placed between the ribs and opened as much as was necessary. Another silk compress was introduced in the cavity in order to circumscribe completely the operating field. Since sponging irritates the pleura, it is very important that no blood should escape into the cavity.

The pleura was cut along the portion of the aorta that had to be intubated, but the aorta itself was not dissected, and its collateral branches were not ligated. Two ligatures of soft but heavy silk thread were passed around the aorta approximately at the points where the ends of the tube were to be fixed. A few centimeters above and below these two ligatures, two elastic forceps were kept ready for clamping the vessel. The elastic blades of the forceps were applied directly to the arterial wall, no rubber being interposed.

The wall of the aorta was then cut longitudinally. The edges of the incision were caught with two forceps and the tube was introduced into the lumen of the aorta. The tubes were made of glass

or aluminum. They were generally nine or ten millimeters in diameter and forty-five millimeters long. As the dogs were of various sizes, the tubes either distended the vessels, fitted them exactly, or were smaller than the caliber of the aortas. The tubes were straight, but their edges were slightly everted. The glass tubes were crude, their edges being often irregular and sharp. Before being used, the tubes were paraffined. As soon as the tube was inserted into the lumen of the vessel, the silk threads that had been put around the aorta previously, were tied. The ligature should be tight enough to prevent the tube from slipping, but not tight enough to cut the wall of the artery. This wall is easily injured.

The clamps were removed and the circulation was reestablished through the intubated segment. Generally there was no hemorrhage from the incision through the aortic wall, and in some cases the opening was not closed. In others it was sutured with fine silk. It is safer to close the opening carefully even if there be no bleeding. The pleura was then sutured along the aorta. The silk compresses were removed and the ribs were approximated by two silk ligatures. Before closing the thoracic cavity, slight compression was made on the trachea in order that the lungs might regain their normal size. The muscles and then the skin were united by continuous sutures.

Ten experiments were made. In one the introduction of a tube into a comparatively small aorta resulted in tearing the wall, and the animal was killed immediately by chloroform. The nine other cases will be briefly described.

Experiment 1.—Medium-sized bull terrier, No. 729. On January 18, 1912, 10:16 A. M., a transverse thoracotomy was made in the tenth intercostal space, under ether anesthesia by the Meltzer and Auer method; the lower part of the thoracic aorta was dissected. At 10:50 temporary hemostasis was caused by the two pairs of elastic jawed forceps. The aorta was incised and the paraffined glass tube 45 mm. in length and 9 mm. in diameter was introduced. The tube was fixed by an upper ligature of rubber and by a lower ligature of silk, both being very tight. The circulation was reestablished at 10:56. The incision in the arterial wall was not sutured, and the thoracic cavity was closed at 11:18. After the operation the femoral pulse was normal and the animal remained in excellent condition until January 26, when it appeared sick and no pulsation was felt in the right femoral artery. On January 27 the animal was again in good condition, but on January 29, at 10 A. M. it died suddenly.

Autopsy.—The thoracic cavity was filled with blood. The ligatures, which had been too tight, had cut the arterial wall and a sudden hemorrhage resulted.

The tube was in the aorta. No paraffin or fibrin could be seen on its wall. But on the wall of the aorta near the upper end of the tube, there was a slight laceration covered by a thin deposit of fibrin. There was no clot in the iliac arteries.

Experiment 2.—Black and white female dog, No. 769. On January 26, 1912, at 10:20 A. M., a transverse thoracotomy was made in the eighth intercostal space, under ether anesthesia by the Meltzer-Auer method. At 10:28 temporary hemostasis of the middle part of the descending aorta was caused. This was followed by a longitudinal incision of the vessel and the introduction of a paraffined glass tube 45 mm. in length and 9 mm. in diameter. The tube was fixed at each end by a ligature of heavy surgical silk, but the aortic incision was not sutured. The circulation was reestablished at 10:36, and at 10:55 the operation was ended. The animal remained normal until February 5, but on February 5, at 4 P. M. the pulsations of the femoral arteries disappeared, and the dog died shortly afterwards.

Autopsy.—There was no hemorrhage in the thoracic cavity, but a large clot was found adherent to the non-sutured incision of the aortic wall. Longitudinal incision of the aorta revealed the fact that the threads had not cut the arterial wall. The upper end of the tube, which was too sharp, had caused a slight laceration of the vessel wall. The tube was lined with fibrin, except in its lower part. The upper part of the aorta was open, but the lower part was completely obliterated by a thrombus. This had been produced by the fibrin in the lower end of the tube becoming loose and being swept by the blood stream into the lumen of the aorta.

Experiment 3.—Young, brown female dog, No. 798. On January 30, 1912, at 10:21 a thoracotomy was made through the eighth intercostal space under ether anesthesia by the Meltzer-Auer method. At 10:35 temporary hemostasis was caused in the middle part of the descending aorta. The wall was incised, and a paraffined glass tube was introduced. The tube was 45 mm. long and 9 mm. wide. Its caliber proved to be smaller than that of the aorta, and the edge of its upper end was slightly everted. A ligature of heavy silk was put around the aorta at the level of the upper end of the tube, but the lower end was not ligated. The tube fitted the aorta exactly, and the incision was not sutured. At 10:38 the circulation was reestablished, and at 11:05 the thoracic cavity was closed and the operation ended. The animal remained normal.

Experiment 4.—Young, white female dog. On February 6, 1912, at 10:31 under ether anesthesia by the Meltzer-Auer method, a thoracotomy was made through the eighth intercostal space on the left side of the animal. At 10:47 a thin-walled paraffined glass tube 40 mm. long and 9 mm. wide was introduced into the descending aorta by the usual procedure. The tube was fixed by two heavy ligatures which were tied loosely. The circulation was reestablished at 10:52, and at 11:10 the operation was ended. The animal remained normal for eight days, but died suddenly on February 14.

Autopsy.—The thoracic cavity was filled with blood, for the glass tube had broken in the middle, and hemorrhage had taken place through the aortic incision. There was no clot in the tube or in the aorta, and no paraffin or fibrin was seen on the glass wall. There was no ulceration of the aorta at the ends of the tube. In fact the aortic wall was in excellent condition.

Experiment 5.—White and brown female dog, No. 893. On February 9, 1912, at 10:22 A. M., a left thoracotomy was made through the eighth intercostal space under ether anesthesia by the Meltzer-Auer method. At 10:36 A. M. during temporary hemostasis a paraffined glass tube was introduced, and was fixed by two heavy silk ligatures, although the tube seemed too narrow for the aorta. The circulation was reestablished at 10:40. The aortic incision was then sutured. At 10:49 the thoracic cavity was closed, and at 11:02 the operation was ended. The animal remained in good health for twenty-three days, but on April 4, while the dog was running, its posterior limbs became suddenly paralyzed. After about three hours, it was again in normal condition. On April 7, 1912, it was found dead in its cage.

Autopsy.—The aorta was obliterated just below the lower end of the tube by a fibrinous clot. The thrombus originated apparently from a laceration produced in the aortic wall by the lower end of the tube, which was very sharp. The upper end had caused no laceration. The lumen of the tube was entirely free.

Experiment 6.—Black and white, long haired, male dog, No. 920. On February 13, 1912, at 10:25 A. M., under ether anesthesia by the Meltzer-Auer method, the thoracic cavity was opened and the descending aorta was prepared in the usual way. At 10:36 during temporary hemostasis, a paraffined aluminum tube 45 mm. in length by 10 mm. in diameter was introduced into the descending aorta. The tube was fixed by heavy silk ligatures but not very tightly. The caliber of the tube was markedly smaller than that of the aorta. The aortic incision was then sutured. The circulation was reestablished at 10:39, and the thoracic cavity was closed and the operation ended at 11:02. The dog remained in excellent condition. On March 25, the animal was apparently in good health. On March 26 it died rather suddenly.

Autopsy.—The pleural cavity was distended by a clear serosanguineous fluid. The intubated portion of the aorta was surrounded by a large tumor which was composed of granulation tissue. The tube was corroded and partially occluded by a clot of fibrin.

Experiment 7.—Brown female spaniel, No. 940. On February 16, 1912, at 10.13 A. M., under ether anesthesia by the Meltzer-Auer method, a thoracotomy was made on the left side. At 10:29, during temporary hemostasis in the descending aorta, the wall was incised and a paraffined aluminum tube was introduced. The aorta was small and the tube too large for it. At 10:31 the circulation was reestablished. The tube was fixed by two silk ligatures. On account of the distension of the aorta by the tube, the incision could not be sutured. The thoracic cavity was closed and the operation completed at 11 A. M. The animal remained normal for nine days, but on the tenth day (February 26) it died suddenly.

Autopsy.—There was no hemorrhage in the pleura. The tube, however, was occluded by a clot. The deposit of fibrin seemed to have started from a laceration of the wall at the level of the upper end of the tube. The laceration was apparently due in some measure to pressure exerted upon the wall, by the edge of the tube. The tube was corroded and the aortic wall and the surrounding connective tissue were very much thickened.

Experiment 8.—Black and white female dog, No. 992. On February 27, 1912,

at 10:06 A. M., under ether anesthesia by the Meltzer-Auer method, a left thoracotomy was made through the fourth intercostal space. The left part of the arch of the aorta was dissected and at 10:36 the aorta was clamped near the left innominate artery. Into the vessel a straight paraffined glass tube was then introduced. The tube was fixed by two silk ligatures, and at 10:38 the circulation was reestablished and the aortic incision sutured. The pleura was also sutured around the vessel, the operation being finished at 11:12. The animal remained in excellent condition for three days, but on the morning of March 2, it was found dead in its cage.

Autopsy.—The tube was found to be occluded by a clot. This tube was straight and its sharp edges had lacerated the aortic wall. The thrombus appeared to have started in the lacerated region.

Experiment 9.—Black and white female dog, No. 1017. On March 1, 1912, at 10:41, under ether anesthesia by the Meltzer-Auer method, a left thoracotomy was made through the fourth intercostal space. This was followed by dissection of the arch of the aorta, of the first part of the innominate artery, and of the upper part of the descending aorta. At 10:58, during temporary hemostasis, the aortic wall was incised and a curved paraffined glass tube 3 mm. in length and 10 mm. in diameter was introduced into the lumen of the vessel and fixed by two silk ligatures. The circulation was reestablished at 11 A. M. and the incision in the aorta was sutured. The thoracic cavity was then closed and the operation ended at 11:25. The dog remained in excellent condition for five days but died suddenly on March 7, 1912.

Autopsy.—The upper end of the tube was too sharp and had lacerated the wall. To this lacerated surface a clot that completely occluded the tube was adherent.

Thoracotomy, under ether anesthesia by the Meltzer-Auer method, and handling of the thoracic aorta are not dangerous. No post-operative pleuritis or other complication was observed, and during the first week following the operation, nearly all the animals remained in excellent health.

One animal (experiment 3) is living and normal at the beginning of the fourth month after the operation (April 3).² In this animal a glass tube of relatively small caliber with smooth edges was introduced into the descending aorta, and fixed there by a single ligature of coarse silk thread.

In two cases (experiments 1 and 4), the animals died of hemorrhage. In experiment 4 a thin-walled glass tube had been used. Eight days after the operation, the animal was apparently in excellent health, but died suddenly on this day. The pleural cavity was

²On May 2 the animal became suddenly paralyzed and was chloroformed. The autopsy showed that the upper edge of the tube had ulcerated the posterior part of the aortic wall, and that the tube was occluded by a fresh clot.

full of blood and the tube was found broken in the middle. The lumen was free from paraffin and fibrin. There was no ulceration of the aortic wall. In experiment 1 the tube had been fixed by two very tight ligatures which, after eleven days, cut the arterial wall, causing a sudden hemorrhage and the death of the animal. The use of a metallic tube and of ligatures properly tied would have prevented these accidents.

In experiment 6 the animal remained in excellent health for more than fifty days, but then became slightly ill and died rather suddenly, fifty-five days after the operation. Both pleural cavities were filled with a clear hemorrhagic fluid. Around the intubated portion of the aorta was a large tumor adherent to the posterior thoracic wall. This tumor was composed of granulation tissue in the center of which was found the aluminum tube. The tube was corroded and partially occluded by a deposit of fibrin. In experiment 7 an aluminum tube had also been used. The animal died rather suddenly twelve days after the operation. The tube was corroded. Its lumen was obliterated by a thrombus, and the intubated part of the aorta was very much thickened. In both cases the complications could probably have been prevented by the use of tubes made of gold instead of aluminum. In four other cases occlusion of the aorta or of the tube occurred. In three animals (experiments 2, 8, and 9) the deposit of fibrin was due to a laceration of the wall produced by the upper end of the tube. The tubes were too large and had distended the aorta. It is probable that tubes small enough to have produced no distension of the aortic wall would have caused no laceration. In the fourth animal in which an occluded aorta was found (experiment 5), a glass tube with sharp edges had been introduced into the descending aorta. This animal remained in excellent condition for fifty-eight days but then died rather suddenly. The aorta was occluded just below the lower end of the tube by a fibrinous clot that was adherent to a laceration of the wall produced by the edge of the tube. No laceration was caused by the upper end, and the lumen of the tube was entirely free from thrombus. This observation showed that blood could circulate for almost two months through a glass tube without the development of a thrombus. The laceration caused by the sharp edge seemed to be responsible for the obliteration of the vessel.

These experiments have shown that under certain conditions aortic blood can flow through a glass tube for more than three months without the occurrence of an obliterative thrombus. If the aortic wall was lacerated, a deposit of fibrin took place, and caused a partial or complete occlusion of the tube or of the vessel. The success or failure of the intubation depended upon the presence or absence of laceration of the vascular wall. It is probable that the use of a tube of proper caliber, form, and composition, for instance, a smooth edged, gold tube of relatively small caliber, would be followed by better results. It is possible also to line the tube with a vein in order to prevent more surely the occurrence of a thrombus. Further experiments will show whether complications can be completely eliminated, and whether the operation can be made safe enough to be used on human beings in case of aneurysms of the aorta.