The American Surgeon 23:455, 1957

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THE MANAGEMENT OF PENETRATING WOUNDS OF THE INFERIOR VENA CAVA

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Survival after missile injury of the inferior vena cava is apparently rare. The first case report appeared in 1917,[7] and in 1945 Kidd[5] was able to find only 4 such cases with recovery, in the literature, including a shell fragment injury of his own. Since 1945, three additional successfully treated missile lacerations of the inferior vena cava have appeared in case reports, the injury having been caused by a bullet in 2 instances[1, 3] and by a shell fragment in the third.[4] In addition, there have been 7 patients surviving stab wounds or blunt trauma lacerations of the inferior vena cava.[2, 5, 6] Treatment in these cases of caval injury consisted either of suture of the rent in the vessel, ligation, or application of clamps directly on the cava (with subsequent removal several days later). With a single exception,[3] the sites of injury were below the entrance of the renal veins. In no instance was there evidence of subsequent caval thrombosis, or dislodgement of emboli to the lung.

During a recent 5 month period at Jackson Memorial Hospital, three gunshot wounds of the inferior vena cava have been encountered and repaired successfully. In each patient there was severe concomitant visceral injury. In one patient the contiguous aorta was also ruptured by the bullet and repaired. In another patient the inferior caval laceration was above the renal veins, the second such case with survival of which we have knowledge.

From our experience and from the collective experience of previous workers, certain principles have evolved concerning the management of this potentially exsanguinating type of wound. The objective of this report is to enumerate these principles.

Case 1. This intoxicated 27 year old previously healthy Negro man was admitted to the emergency room at noon on Sept. 8, 1956. He had been shot at close range with a .22 caliber pistol a few minutes before arrival. He was in obvious shock, with a feeble rapid pulse. A cutdown was immediately placed in the leg and plasma started. After nearly 1000 ml. of plasma had been given and 500 ml. of blood started, his blood pressure was 90/60 and his pulse 120 per minute. Gastric aspiration yielded bright red blood and food. Feces in the rectum was nonbloody. Urinalysis was normal. Hemoglobin was 13.6 gms and hematocrit 47.

The patient had a wound of entry midway between the umbilicus and the xiphoid, just to the left of the midline. The bullet could be felt in the subcutaneous tissue of the right costovertebral triangle, approximately 1 inch below the twelfth rib. There was evidence of peritoneal irritation. No bowel sounds were present.

He was taken directly from the emergency room to the operating room where additional resuscitative measures were carried out on the operating table. By 1:45 p.m., 1000 ml. of plasma and 1000 ml. of blood had been given. His blood pressure was 114/80 with a pulse of

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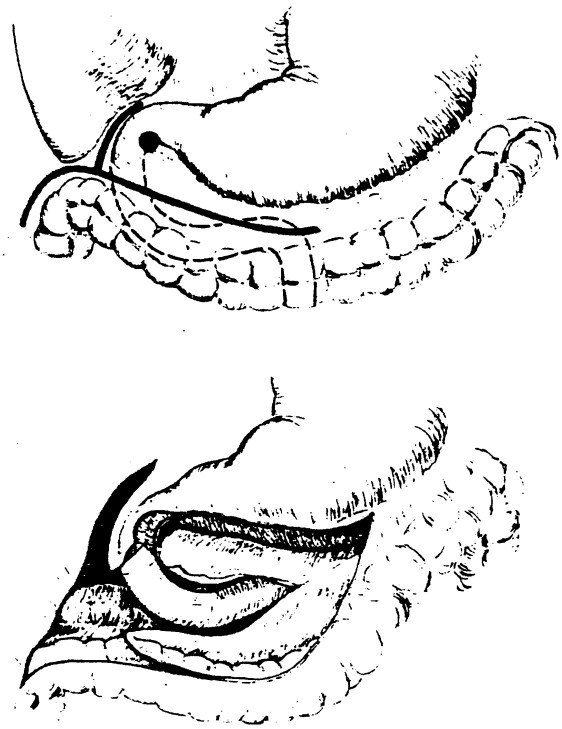

FIG. 1. (After Russell Drake). Peritoneal incisions (upper) and reflections (lower) for exploration of the inferior vena cava, above the level of the renal veins. The location of the bullet tract in Case 1 is indicated by a solid circle.

84. He was anesthetized with cyclopropane and exploration was carried out through a midline incision, from the xiphoid to the umbilicus. On entering the abdominal cavity, a large quantity of blood and bile-stained free fluid welled up into the wound. A perforating wound of the first part of the duodenum was immediately identified (see figure 1). This was on the inner aspect of the second portion of the duodenum and passed through the head of the pancreas. The pancreas was elevated by a large hematoma which had dissected laterally into the retroperitoneal space above the right kidney. There was no active intraperitoneal bleeding.

Because it was feared that laceration of the portal vein or inferior vena cava had occurred, it was elected to perform retroperitoneal exploration before doing any more intraperitoneal manipulation. The midline incision was extended along the right side of the xiphoid process superiorly and below the umbilicus inferiorly. The hepatic flexure of the colon was mobilized inferiorly, and the pyloric aspect of the gastrocolic ligament divided. The superior leaf of the transverse mesocolon was divided and the mesocolon swept inferiorly. Finally, the right lateral peritoneal reflection of the first and second portions of the duodenum was divided as in the Kocher maneuver. This gave wide access to the entire duodenum (fig. 1). Before elevating the duodenum, final preparations were carried out. The cutdown was checked in the leg, as well as an 18 gauge needle in the arm. Curved and straight Potts ductus and bulldog clamps were brought to the operating table. Two thousand ml. of blood were readied for use.

The duodenum was then elevated and the retroperitoneal space quickly entered. At this time a massive hemorrhage occurred with an estimated blood loss of 1000 ml. in a few

seconds. Digital exploration of the inferior vena cava disclosed the presence of a bullet hole which just admitted the full tip of the middle finger. With the finger in place, the hemorrhage ceased and henceforth was not a difficult problem. During the massive bleeding, the blood pressure became unobtainable. With the tamponading finger in place, further operative manipulation was discontinued for 10 minutes while 1500 ml. of blood were given. His blood pressure returned to 120/80 and he remained in good condition for the balance of the procedure.

With the finger in place, the cava was then mobilized and rubber tapes placed proximal and distal to the injury. At the inferior extent of this dissection, the entrance of the renal veins was identified. The wound in the cava was found to be in the right lateral side, with loss of $\frac{1}{4}$ to $\frac{1}{3}$ of the vessel substance. The rent was closed with continuous no. 00000 arterial silk. When tested, the site of repair had a constriction of approximately 40 per cent of the diameter.

Next, the first portion of the duodenum was mobilized from the head of the pancreas. Anterior and posterior perforations were identified and closed with two layers of interrupted silk. A choledochostomy was then performed, and it was found by probing that one of the sutures in the anterior duodenal closure had obstructed the common duct. The offending suture was removed and, after demonstrating a patent common duct, a short-arm T tube was left in place. Four Penrose drains were brought through stab wounds; 2 from Morrison's pouch and 2 from the head of the pancreas. During the entire preoperative and operative period, the patient received 4000 ml. of blood and 1000 ml. of plasma.

Convalescence was remarkably benign. The drains erupted large quantities of bile-stained fluid for the first few days but this had ceased at the end of a week and the drains were all removed. He had an ileus for 5 days which was treated by gastric suction. Serum amylase levels were elevated (highest 327 units) for the first week but then declined to normal values (less than 200 units in our laboratory). The wound healed cleanly and all sutures were removed on the seventh day. A T tube cholangiogram on the tenth postoperative day was normal. He was discharged on the seventeenth postoperative day with the T tube in place and clamped off. At no time was there evidence of venous stasis in the lower extremities.

The patient was followed in the outpatient clinic. Five weeks, after another normal cholangiogram, the T tube was removed. He did not return to the clinic and was last seen in the emergency room on Oct. 27, 1956 with multiple lacerations of the head, arms and face, presumably incurred in a knife fight.

Case 2. This 38 year old white man was brought in to the emergency room at 4:27 p.m. on Oct. 19, 1956 a few minutes after having been shot in the abdomen with a .32 caliber pistol. His blood pressure was 50/20 and his pulse was 130. Immediately, a cutdown was placed in each leg and pressure transfusion started with plasma. He was taken at once to the operating room and further resuscitative measures carried out on the operating table.

The patient was intoxicated. There was a wound of entry at the midpoint between the xiphoid and umbilicus, just to the right of the midline. In the left flank was an area of ecchymosis just above the ileum, which was thought to be near the bullet. He had peritonitis.

By 5 p.m., after 1500 ml. of plasma and 100–200 ml. of blood, the blood pressure was 140/80. He was anesthetized with cyclopropane and explored through a long midline incision from the xiphoid nearly to the pubis. On entering the peritoneal cavity, approximately 500 ml. of free blood was removed. A large retroperitoneal hematoma was immediately noted near the midline, below the transverse mesocolon centered midway between the renal arteries and bifurcation and extending both laterally and into the mesentery of the small bowel. It was feared that an aortic or inferior vena caval injury had occurred, despite the fact that serious bleeding had ceased. Two thousand ml. of blood were brought into the operating room and vascular clamps prepared. The entire small bowel was eviscerated to the right. The left lateral leaf of the small bowel mesentery was incised widely at its base. At this point acute fresh bleeding occurred, but this was easily controlled with stick sponge pressure on the widely exposed cava. It was found that the bullet had passed between the

aorta and vena cava. There was a 5 mm. tear in the left side of the vena cava. In addition, there was an injury at the right side of the contiguous aorta with a greatly thinned out bulging acute aneurysm. The 1 cm. acute aortic aneurysm was watched with considerable fascination for the next few minutes, while several surgeons were asked in to view the operative findings. While this was being done, the aorta ruptured with a sudden loss of approximately 500 ml. of blood. The hemorrhage was immediately controlled with finger and stick sponge pressure, and the aortic tear was repaired with 4 or 5 interrupted no. 0000 arterial silk sutures. The laceration of the inferior cava was repaired with a similar technic.

Further examination of the abdomen revealed through-and-through bullet wounds of the stomach and third portion of the duodenum. The 4 perforations were closed with 2 layers of no. 0000 silk. A Penrose drain was led from the retroperitoneal space on the left from near the inferior pole of the kidney out through a stab wound. During the entire preoperative and operative period, the patient received 1500 ml. of plasma and 2500 ml. of blood.

Both cutdowns were removed immediately after surgery. Convalescence was uncomplicated. He was never febrile. An ileus responded to gastric suction by the third postoperative day. Streptomycin and penicillin were discontinued on the fifth postoperative day and he was discharged on the sixth postoperative day. The wound healed per primum and retention sutures were removed in the clinic on the fifteenth postoperative day. He was last seen on Jan. 2, 1957. There has been no evidence of venous stasis in the legs.

Case 3. This 25 year old intoxicated Puerto Rican was brought to the emergency room at 3 p.m. on Jan. 4, 1957 a short time after having been shot twice with a .357 magnum police pistol. He did not appear to be critically injured. His blood pressure was 110/80 and pulse 86. On examination he was found to have 2 wounds of entry. There was a penetrating wound of the right shoulder (which subsequently was shown to be a trivial injury). In addition, there was a bullet wound of the right flank posteriorly. Roentgenograms of the abdomen demonstrated a bullet in the left upper quadrant posteriorly. He had the physical findings of peritonitis with absent bowel sounds. There was no blood in the urine and gastric aspiration did not yield blood. Hemoglobin was 16.1 grams.

Five hundred ml. of plasma were started and he was admitted to the ward. There, evidence of peritonitis became more florid, with intense abdominal pain. He was taken to the operating room at 5:45 p.m. and explored through a midline incision from the xiphoid to 2 inches below the umbilicus. On entering the abdomen, there was less than 200 ml. of free blood present. Bleeding had ceased. Almost immediately, the bullet was encountered in the greater omentum. The transverse colon was next elevated superiorly and a retroperitoneal hematoma noted behind the third portion of the duodenum just proximal to the ligament of Treitz. The peritoneum was incised transversely over the hematoma, the third portion of the duodenum elevated, and a through-and-through duodenal perforation demonstrated.

Until this moment the hematoma had not been manipulated. An exploring finger was then placed into the hematoma and an attempt made to follow the bullet tract. When the finger was withdrawn, it was followed by a massive hemorrhage. The finger was immediately replaced with control of the bleeding.

An incision was then made in the peritoneum lateral to the right colon and the entire right colon swept medially. Good exposure of the cava was obtained and it was possible to apply a curved Potts ductus clamp to the proximal cava, but in doing so one of the lumbar veins was torn from the side of the parent vessel creating another small linear caval tear. A tape was passed around the right iliac vein and a straight Potts ductus clamp applied to the left iliac vein. Despite these maneuvers, finger pressure was still necessary at the site of the bullet injury due to the efflux of blood through the intervening lumbar and middle sacral veins.

The caval injuries were assessed at this time and were found to be about 2 inches above the bifurcation. There were lacerations on both the anterior and posterior surfaces of the vessel, each about 1.5 cm. long, indicating a through-and-through bullet injury. In addition there was a 1 cm. laceration superior to this where the lumbar vein had been torn off. These

were repaired with continuous no. 00000 arterial silk. Just as repair of the third laceration was completed, hemorrhage was noted in the pelvis. Investigation showed that the Potts clamp on the left iliac vein had cut through the vessel wall, creating a 4 mm. transverse laceration. This was sutured with no. 00000 arterial silk.

The two previously demonstrated perforations of the third part of the duodenum were then closed with 2 layers of no. 0000 silk. Further examination disclosed a through-and-through perforation of the proximal jejunum and this was closed in a similar manner. Prior to surgery the patient had received 500 ml. of plasma. During the operation he received 4000 ml. of whole blood and 500 ml. of plasma expander.

Postoperatively, the patient had an adynamic ileus. Bowel sounds returned on the fourth postoperative day. On the seventh day, he developed evidence of thrombosis of the left ileo-femoral system, presumably at the site of the Potts clamp injury to the femoral vein. There was no swelling of the right lower extremity at any time. He was treated with anticoagulants with subsequent disappearance of the signs of thrombosis. He was discharged on the twentieth postoperative day in good condition. He was last seen on 25 March 1957 at which time there was no evidence of venous stasis in either leg.

DISCUSSION

In all cases of caval injury reported previously, and in the present series as well, serious hemorrhage had ceased by the time celiotomy was performed and the only evidence of a serious venous injury frequently was a disarmingly small retroperitoneal hematoma. It is quite possible that, with this spontaneous tamponade, no further venous hemorrhage would occur if the retroperitoneal space were not explored. It is, however, not possible for the surgeon to be certain of this. In addition, it is frequently necessary (as in the present series) to carry out such exploration for the detection and management of other retroperitoneal injuries which, if left untreated, would lead to almost certain mortality. Therefore, when the trajectory of a missile projects to or near the great vessels, we believe that a planned program designed to give exposure of the potentially injured vessel should be instituted. There is no need for haste, since recurrence of hemorrhage need not be anticipated until the retroperitoneal dissection is begun. Lighting can be adjusted, necessary vascular instruments obtained, additional assistants summoned, and additional blood crossmatched. During this period of preparation, manipulation of the hematoma should be carefully avoided.

For injuries at or below the level of the transverse mesocolon, the inferior cava can be explored either by evisceration to the right followed by incision in the left leaf of the small bowel mesentery at its base (Case 2, fig. 2) or by evisceration to the left followed by reflection of the right colon to the left (Case 3). The former approach is superior if concomitant aortic injury is suspected, while the latter approach is superior if evidence is present of a right renal injury. Dissections on cadavers have demonstrated that a combination of the above two dissections leads to an extraordinarily broad exposure of both the aorta and the inferior cava. In this maneuver, the entire small bowel, right colon, and related mesenteries are reflected in a cephalad direction.

For injuries above the level of the transverse mesocolon, the approach used in Case 1 (fig. 1) is probably the best, consisting of mobilization of the hepatic flexure, transverse colon and transverse mesocolon inferiorly combined with a Kocher maneuver. By any approach, the dissection can be carried out with lei-

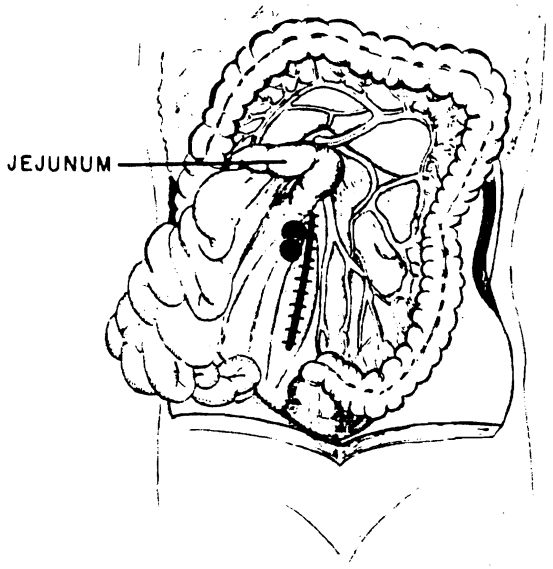

FIG. 2. (After Kay Hyde). Peritoneal incision through the left leaf of the small bowe mesentery, at its base, for exposure of the inferior vena cava below the transverse meso-colon. The upper and lower solid circles indicate the levels of caval injury in Cases 2 and 3 respectively.

sure until the plane of the hematoma is reached, but from this point on the dissection is done rapidly.

After bleeding is controlled by pressure, repair may be possible (Case 2) or proximal and distal isolation of the lacerated vessel may be necessary before suture is feasible. It is our opinion that suture repair is almost always more desirable than caval ligation.

In one of the present patients, it is probable that thrombosis of the iliac vein occurred. This is the only such complication recorded in the small series of caval injuries to date. The patient in question had 4 suture lines; 3 in the cava and 1 in the iliac vein. We believe that anticoagulant therapy should be considered in such a patient with multiple venous injuries.

SUMMARY

Three consecutive gunshot wounds of the inferior vena cava successfully treated with suture repair are presented. These represent the eighth, ninth, and tenth cases of missile injury to the inferior cava, with survival, in the literature. Recovery in one patient was complicated with external iliac thrombosis.

One of the patients had an associated aortic laceration, also sutured. All the patients had additional multiple serious visceral injuries.

One of the caval injuries was above the level of the renal veins; the second such case, to our knowledge, in the literature.

In these 3 patients, as well as almost all others in the literature, massive bleeding had ceased by the time of celiotomy. The signal finding was the presence

of a retroperitoneal hematoma. By probing or manipulating the hematoma, the surgeon may precipitate a massive hemorrhage at a time when he is ill-prepared to deal with it.

When such a retroperitoneal hematoma is found in the vicinity of the great vessels, a methodical program for exploring the retroperitoneal space should be instituted before any manipulation is done. This should include procurement of a large quantity of blood, adjustment of lighting, preparation of necessary vascular instruments, and planned wide exposure.

For caval injuries at or below the transverse mesocolon, one may approach the retroperitoneal space by reflection of the small bowel and its mesentery to the right (Case 2, fig. 2) or by reflection of the right side of the colon to the left (Case 3). The ultimate in exposure is gained by a combination of these maneuvers, reflecting the small bowel, right colon and related mesenteries in a cephalad direction. For injuries above the transverse mesocolon, the hepatic and transverse colon as well as the transverse mesocolon are swept inferiorly. The retropancreatic area can then be entered with wide exposure with the Kocher maneuver (Case 1, fig. 1).

It is our opinion that postoperative anticoagulation therapy is not routinely necessary but should be considered in multiple or unusually severe caval injuries.

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