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THE TREATMENT OF PENETRATING WOUNDS OF THE INFERIOR VENA CAVA

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The treatment of penetrating wounds of the inferior vena cava has received little attention in the surgical literature. To date, only 18 patients with this type of injury have been known to survive after operation. In only 1 report[28] has the successful treatment of more than a single patient been described.

The purpose of the present study is to present experience with 12 injuries of the inferior vena cava, caused by bullet perforation in 10 cases and knife laceration in the other 2. Eleven of the patients survived and 1 died. Although the wounds were incurred in different anatomic locations, with a variety of weapons, and with differing associated injuries, the natural behavior of the perforated vessel exhibited a common pattern in every case. Furthermore, the problems encountered during surgical repair were so similar that definite recommendations have evolved concerning the operative treatment of this type of injury.

OBSERVATIONS

Incidence. The victims were all young, ranging from 13 to 38 years (Table I) and averaging 27 years. There were 10 men and 2 women; 9 Negroes and 3 Caucasians. Incidence of venal caval injury in relation to

total number of patients with penetrating abdominal injuries admitted between 1955 and 1960 was determined for the patients from Cook County Hospital (Cases 5 through 12). There were 6 injuries of the inferior vena cava in a group of 260 missile injuries treated by laparotomy for an incidence of 2.3 per cent. Two caval knife wounds represented 0.34 per cent of the 585 penetrating stab wounds treated at Cook County Hospital during the same period.

Table I

Weapon of injury. Most of the gunshot wounds were incurred from pistols, from .22 to .38 caliber (Table II), generally at close range. In Case 9, a .38 caliber pistol was discharged with the muzzle in direct contact with the skin of the abdominal wall. The stab wounds were inflicted with a pocket knife and a large butcher knife (Cases 6 and 7).

Location of vena caval injury. The injury was above the renal veins in 4 patients and below in 8 (Fig. 1). The most superior wound, located just below the liver, caused the only death (Case 10). The 2 knife wounds (Cases 6 and 7) lacerated only the anterior wall of the vena cava (Fig. 1). Damaged by bullets either caused lateral avulsion of the wall (Cases 1, 2, 8, and 9) or double perforations of both anterior and posterior walls (Cases 3 through 5 and 10 through 12). With double perforations the posterior rent was sometimes not directly

Table I

Case No.	Date	Age and sex	Blood pressure and pulse	Caval bleeding at operation	Retroperitoneal hematoma	Hemoperito- neum (quantity)	Other visceral injuries	Blood or plasma (ml.)	Complications
1*	Sept. 8, 1956	27, M	90/60, 120	None	Large	Minimal	Duodenum, pancreas	5,000	None
2*	Oct. 19, 1956	38, M	50/20, 130	None	Large	Moderate	Stomach, duodenum, aorta	4,000	None
3*	Jan. 4, 1957	25, M	110/80, 86	None	Moderate	Minimal	Duodenum, jejunum	5,000	Iliofemoral thrombosis
4	Nov. 2, 1956	27, M	120/80, 100	None	Large	1,000 ml.	Ileum, colon	3,500	Wound infection
5	Oct. 21, 1956	26, M	90/60, 124	None	Large	Large	Liver, duodenum	3,500	Temporary leg edema
6	Dec. 26, 1958	36, M	84/60, 84	None	Large	Minimal	Liver, pancreas	5,000	Pneumonia, pancreatic fistula
7	Jan. 28, 1959	36, M	140/60, 72	None	Moderate	Minimal	Duodenum, jejunum, ileum	3,500	None
8	March 20, 1960	23, M	80/40, 130	None	Large	2,000 ml.	Liver, duodenum, portal vein	8,200	Wound infection
9	Feb. 11, 1960	20, F	Not in shock	None	Moderate	?	Pancreas, small bowel, colon, superior mesenteric vein	?	Subphrenic abscess, empyema
10	March 29, 1960	27, F	140/90, 96	None	Small	1,500 ml.	Liver	14,000	Transfusion mismatch, died P.O. of hemorrhage
11	Sept. 10, 1960	13, M	100/60, 80	None	Small	750 ml.	Duodenum, jejunum	1,000	None
12	Sept. 23, 1960	28, M	Unobtainable	None	Large	1,500 ml.	Liver, gall bladder, pancreas	5,500	Renal failure, biliary fistula, temporary paraplegia

*Previously described in detail.[28]

opposite the anterior tear (Cases 10 through 12). In Case 10 inability to locate the posterior laceration caused massive blood loss, necessitating 14,000 ml. transfusion.

Clinical condition. All patients had peritonitis. In 6 cases there was evidence of shock which ranged from collapse to a mild reduction in blood pressure (Table I). The other 6 had no evidence of cardiovascular instability (Table I).

Hemoperitoneum. At operation, there was considerable variation in the amount of free blood in the peritoneal cavity (Table I). In 6 cases the quantity was minimal. In the other 6 the quantity was considered large. In no case was active hemorrhage encountered from the vena caval injury at the onset of exploration.

Diagnosis of inferior vena caval injury at operation. At operation a retroperitoneal hematoma was noted in all cases. The hematoma was large in 7 cases but in the other 5 it was of moderate or small size. In the only patient who died (Case 10) the hematoma was thought to contain less than 5 ml. of blood. In half the cases, the diagnosis was first suggested when massive and unexpected hemorrhage occurred upon opening of the retroperitoneal space for repair of other retroperitoneal injuries. In all patients, the diagnosis ultimately was made by direct inspection of the injured vessel.

Control of hemorrhage. In half the cases, vena caval injury was suspected prior to opening of the retroperitoneal space and in half it was not. When the venous injury was unexpectedly encountered during dissection, the field was suddenly flooded with blood. Pressure at the site of perforation with packs, stick sponges, and fingers, or insertion of a tamponading finger into the rent, were all used. Vascular clamps, when available, were invaluable (Fig. 2). Even when vena caval injury was suspected and proximal and distal control obtained before opening the retroperitoneal space, hemorrhage was often exsanguinating (Case 4) and required additional control at the site of injury by pressure (Fig. 3) or vascular clamps.

Blood loss. Total transfusions of blood and plasma ranged from 1,000 ml. (Case 11) to 14,000 ml. (Case 10), and averaged 5,200 ml. In all cases, the major losses occurred during exposure and control of the inferior vena caval perforation.

Concomitant injuries. Other major visceral injuries were found in every case (Table I); to the liver, pancreas, stomach, duodenum, jejunum, ileum, colon, gall bladder, aorta, portal vein, and superior mesenteric vein. In all cases except 1 (Case 10), retroperitoneal exploration was thought at operation to be obligatory for the diagnosis and treatment of other retroperitoneal injuries.

Treatment of injured vena cava. Suture repair, generally with continuous No. 5-0 silk sutures, was performed in all but Case 5 in which ligation was carried out. With several of the bullet wounds with tissue loss, this necessitated a reduction in the lumen. The nature of the concomitant injuries dictated the use of drains in all but 2 cases.

Mortality rate and morbidity. One patient died (Case 10) 18 hours after operation of diffuse hemorrhage (Table II). Four survivors had no complication (Table I). There were 2 wound infections. One patient (Case 3) had ileofemoral thrombosis with a good final result. The patient treated with vena caval ligation (Case 5) had temporary edema of the legs. Three patients (Cases 6, 9, and 12) had life-threatening complications—one a pancreatic fistula and pneumonia; another subphrenic abscess and empyema; and a third with renal failure, temporary paraplegia, and a biliary fistula (Table I).

The following case reports selected from our series of 12 emphasize some of the recurrent problems encountered with vena caval injuries.

CASE REPORTS

Case 4. A 27-year-old Negro man was admitted on Nov. 2, 1956, to the Veterans Administration Research Hospital, 3 hours after having been shot in the abdomen. The patient could not or would not provide a history, either upon admission or later. He had been admitted to another
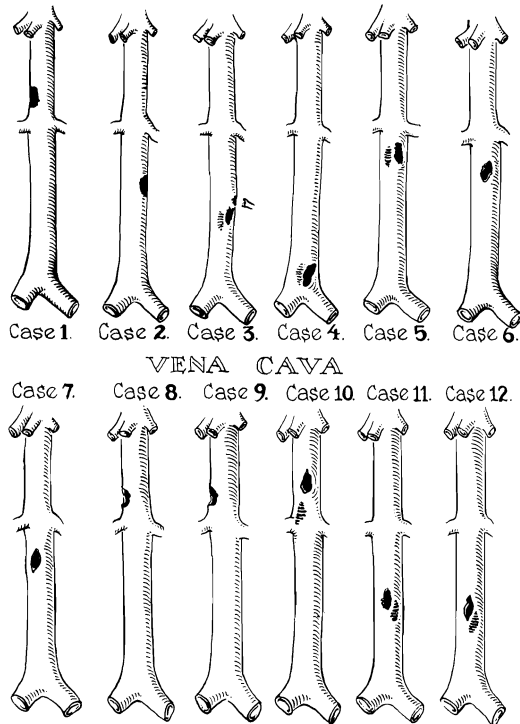
Case 1.   Case 2.   Case 3.   Case 4.   Case 5.   Case 6.
VENA CAVA
Case 7.   Case 8.   Case 9.   Case 10.   Case 11.   Case 12.

Fig. 1. The location and extent of the injuries to the inferior vena cava. The diagrams are in the same order as the case reports.

hospital 1 hour after injury and transferred without treatment. He did not appear to be gravely wounded. Blood pressure was 120/80 and pulse 100. There was a wound of entry in the midline, 1 cm. above the umbilicus, with no powder burns. There was no wound of exit. The patient had generalized peritonitis. No blood was found with gastric aspiration, urinary catheterization, or rectal examination. Hematocrit was 49, white blood cell count was 9,550, with 80 polymorphonuclear leukocytes. Abdominal roentgenograms showed a .38 caliber bullet in the right ilopsoas muscle, just superior to the sacroiliac joint.

Operation was performed through a long right paramedian incision 4½ hours after the injury. Spinal anesthesia supplemented with Pentothal was used. Approximately 1,000 ml. free blood was in the peritoneal cavity. The bullet had passed through the transverse colon and 2 loops of small bowel and then entered the retroperitoneal space near the bifurcation of the inferior vena cava (Fig. 3, *A*). A large hematoma occupied the right lower quadrant and extended up the right gutter (Fig. 3, *A*). All active bleeding had ceased.

Tapes were placed around the iliac veins and tightened (Fig. 3, *B*). The retroperitoneal space was entered by excision of the peritoneum lateral to the colon with extension around the inferior

portion of the cecum, and by medial mobilization of the colon (Fig. 3, *A*). Upon entry of the hematoma, massive hemorrhage occurred which was only partly controlled by quick passage and tightening of a tape around the vena cava above the site of bleeding (Fig. 3, *B*). Despite the fact that both iliac veins below and the vena cava above were occluded, venous return from the intervening lumbar veins allowed serious bleeding to continue from the lacerated cava. This was eventually controlled by pressure and packing on each side of the injured vessel (Fig. 3, *C*). The caval penetration was just above the bifurcation. The bullet had passed through the center of the vessel causing a 1 cm. tear in the anterior and posterior walls without loss of vessel tissue(Fig. 1). The anterior laceration was closed with No. 5-0 arterial silk (Fig. 3, *C*), and the posterior wall rolled over and closed in a similar manner (Fig. 3, *D*). The colon and small bowel lacerations were closed in 2 layers, and the abdomen closed without drainage. Transfusions totaled 3,500 ml.

Convalescence was complicated only by a superficial wound infection which responded to antibiotics and drainage. The patient was discharged on Oct. 29, 1956, 26 days after operation. He did not return for further examination.

Case 8. A 23-year-old Negro man was admitted on March 20, 1960, 5 hours after sustaining an accidental gunshot wound of the abdomen at close range with a .32 caliber pistol. Three hours after injury, he had been seen at a private hospital where no blood pressure could be detected. He was given 750 ml. plasma and transferred to Cook County Hospital. On arrival, blood pressure was 80/40, pulse 130, and respirations 30. There was a wound of entry just below the right costal margin at the lateral margin of the rectus and no wound of exit. He had generalized peritonitis with some localization to the right upper quadrant. Bright red blood was found in the gastric aspirate and in the rectum. Urinalysis gave normal results and the hematocrit was 33.

Transfusion under pressure was started through a large-bore needle in the arm, and the patient was removed to the operating room for further resuscitation. When the blood pressure had returned to 110/80, he was anesthetized with Pentothal-ether-cyclopropane and exploration was carried out through a long right paramedian incision. Approximately 2,000 ml. of blood was removed, and the trajectory of the missile studied (Fig. 2, *B*). The bullet had passed through the right lobe of the liver and through the second part of the duodenum just below the entrance of the common duct into the retropancreatic tissues. The head of the pancreas was elevated by a large retroperitoneal hematoma (subsequently shown to

be caused by caval and portal lacerations) which had dissected laterally around the upper half of the right kidney (Fig. 2, *A*). There was bleeding from the liver perforations, but free hemorrhage from the caval and portal lacerations had ceased.

Bleeding from the liver wounds was controlled with Gelfoam packs. The retroperitoneal space was exposed by medial mobilization of duodenum and pancreas (Kocher maneuver) and by mobilization of the right colon (Fig. 2, *A*). When the plane of the hematoma was entered, massive hemorrhage occurred with the sudden loss of 1,500 ml. of blood. This was rapidly controlled with pressure and with the tangential application of several straight and curved Potts clamps to the general focus of bleeding. Manipulation was temporarily discontinued while transfusions were given rapidly. The tissue trapped by the Potts clamps was then inspected. An 1.5 cm. avulsing wound of the right side of the inferior vena cava, just above the right renal vein, was identified (Fig. 2, *C*). This was repaired with continuous No. 5-0 arterial silk sutures (Fig. 2, *D*). In addition, a 1.5 cm. avulsing wound was found just where the splenic joins the superior mesenteric to form the portal vein (Fig. 2, *B*). This tear was also closed with No. 5-0 arterial silk. The distal end of the splenic vein, which was still bleeding, was then identified and ligated (Fig. 2, *C*). Although both the portal vein and inferior vena cava were narrowed by the repair, flow appeared to be satisfactory.

The 2 duodenal perforations were closed in 2 layers. Profuse lymphatic leak was noted in the region of the pancreas, but the source of this could not be found. A chaffin tube and 6 Penrose drains were placed in the subhepatic and retroperitoneal spaces. During the preoperative, operative, and immediate postoperative periods, the patient received 750 ml. of plasma, and 7,500 ml. of blood.

During the early postoperative period, oral temperatures were elevated to 102° F. with gradual lysis in 14 days under antibiotic therapy. Discharge from the drain sites ceased by the seventeenth day. The patient was discharged on May 3, 1960, 6 weeks after operation. On June 18, 1960, he was asymptomatic, without evidence of caval or portal thrombosis, and had returned to work.

DISCUSSION

Including the 12 cases in the present study, there have been 22 documented instances of gunshot injury of the inferior vena cava with 18 survivals and 10 stab wounds with 8 survivals (Table II). This type of injury, is, however, probably more common than the small numbers of reports

indicate. In the present study, lacerations of the inferior vena cava occurred in 2.3 per cent of all gunshot wounds of the abdomen treated by laparotomy during a 5-year interval at Cook County Hospital. With stab wounds treated during the same period the incidence was only 0.34 per cent. Tabulations in other large series also suggest that the vena cava is perforated in 1 to 3 per cent of gunshot wounds[11, 21, 32] but much less often in abdominal stab wounds.

All of the patients described here and

Table II

| Author and year	Type of weapon	Treatment	Outcome
Taylor, 1916	Shell fragment	None	Died
Taylor, 1916	Bomb fragment	Clamped	Survived
Sheppe, 1922	.38 caliber pistol	Not described	Died
Condict, 1924	Scissors	Suture	Survived
Sala, 1924	Knife	Suture	Survived
Wurzel, 1931	Gunshot	Suture	Survived
Barnes, 1938	? stab	Ligation	Survived
Stor, 1939	Gunshot	Suture	Survived
Hartzell, 1940	Pocket knife	Suture	Survived
Escobar, 1942	? stab	Suture	Survived
Escobar, 1942	? stab	Suture	Died
Kidd, 1945	Bomb splinter	Suture	Survived
Frazer, 1946	Shell fragment	Ligation	Survived
Rack, 1950	Gunshot	Suture	Survived
Mauro, 1953	Knife	Suture	Died
Chachava, 1954	Gunshot	Suture	Survived
Angerer, 1955	Gunshot	None	Died
Angerer, 1955	Gunshot	Suture	Survived
Bolot et al., 1955	Gunshot	Ligation	Survived
Paula et al., 1956	Knife	Suture	Survived
Starzl et al.			
1*	.22 caliber pistol	Suture	Survived
2*	.32 caliber pistol	Suture	Survived
3*	.357 Magnum pistol	Suture	Survived
4	.38 caliber pistol	Suture	Survived
5	.32 caliber pistol	Ligation	Survived
6	Butcher knife	Suture	Survived
7	Knife	Suture	Survived
8	.32 caliber pistol	Suture	Survived
9	.38 caliber pistol	Suture	Survived
10	.38 caliber pistol	Suture	Died
11	.22 caliber rifle	Suture	Survived
12	.32 caliber pistol	Suture	Survived

*Previously reported in detail.[28]
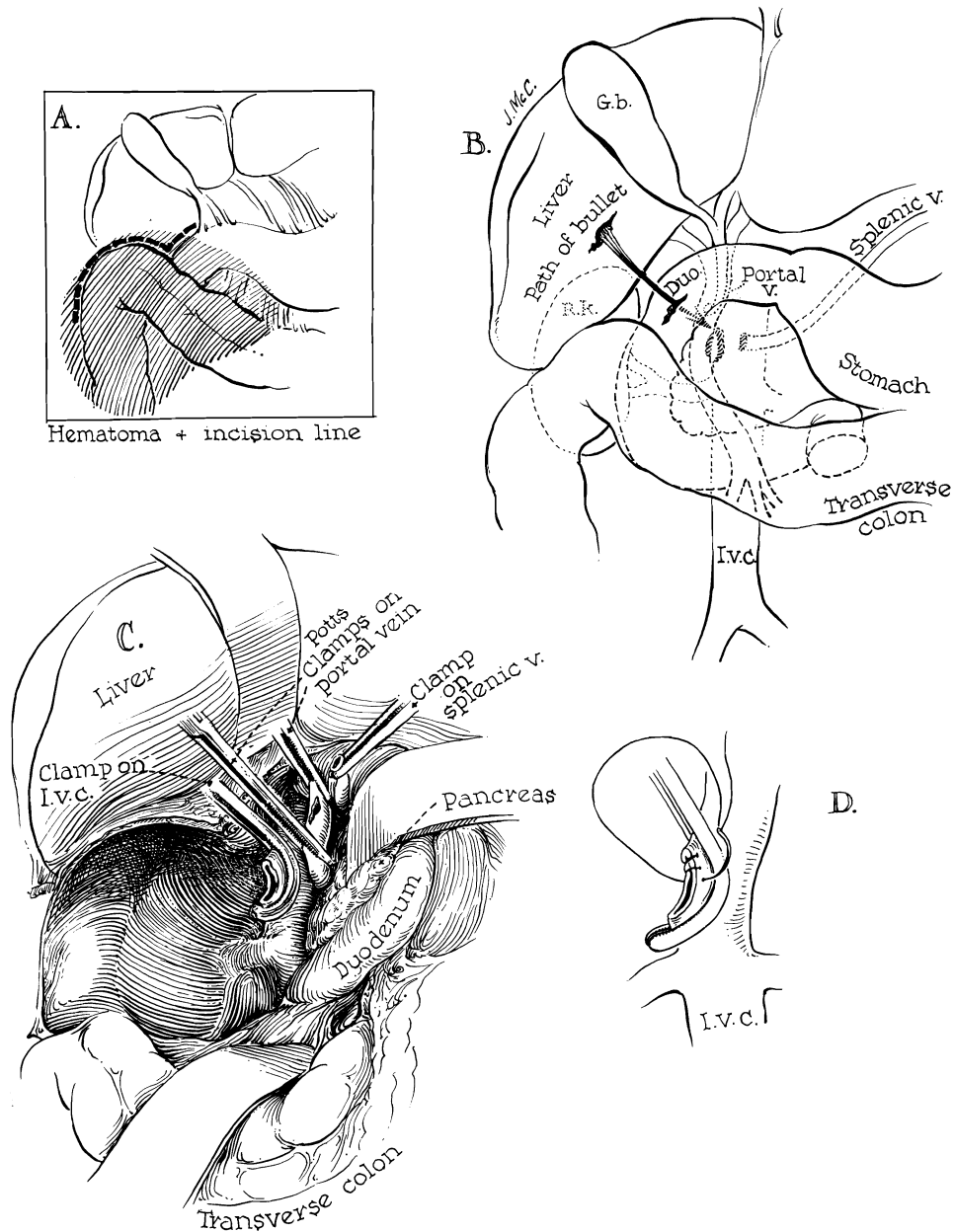
Fig. 2. Case 8. Steps in management of caval and portal injuries. Similar method was used in Case 1. *A,* Extent of hematoma and peritoneal incision. *B,* Trajectory of bullet. *C,* Operative exposure. *D,* Repair of caval laceration.

those in most previously reported cases had other visceral injuries which were usually multiple. Some of the patients in the present series, however, did not appear gravely injured and the presence of a major vascular injury was not even remotely suspected preoperatively.

In all cases, a retroperitoneal hematoma was found, but its significance was often not realized. The hematoma was usually quite large, but in some instances it was deceptively small. In every patient and in those in most previously reported cases, active intraperitoneal bleeding from the caval injury
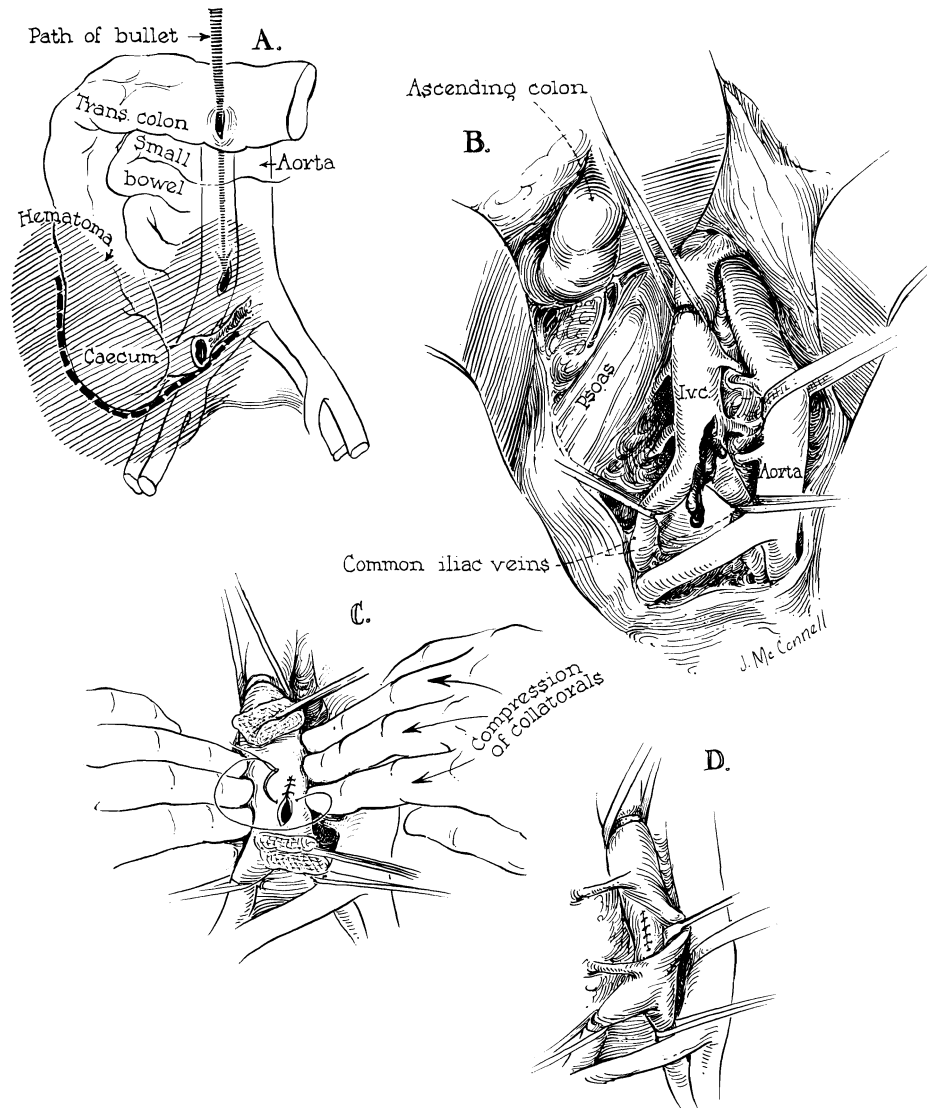
Fig. 3. Case 4. Management of inferior vena caval injury. *A,* Extent of hematoma and peritoneal incision. *B,* Colon reflected and tapes tightened around cava and both iliac veins. Bleeding continued. *C,* Compression of lumbar veins and application of stick sponges close to the laceration. Anterior rent being closed. *D,* Vessel rolled and posterior laceration repaired.

had ceased by the time of laparotomy. Serious bleeding did not occur until the retroperitoneal space and the hematoma were entered, usually for the purpose of ruling out or treating retroperitoneal visceral injuries. At this time, exsanguinating hemorrhage announced a major vascular injury in all current and most previously recorded cases, often to the surprise of the surgeon.

The most effective means for immediate control of hemorrhage proved to be pressure or the application of vasular clamps on or immediately above and below the injury, insertion of a finger through the hole into the lumen of the vessel, or application of curved vascular clamps across the rent in the vessel. When occlusion with tapes or vascular clamps was performed at any signifi-
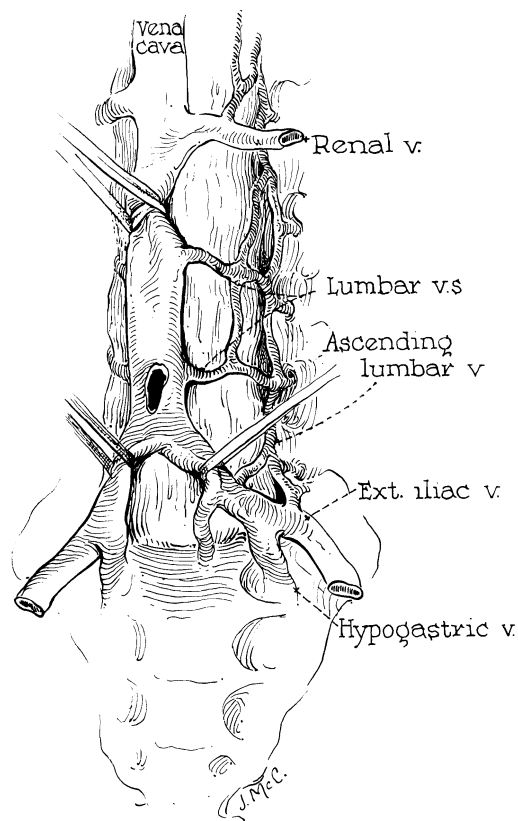
Fig. 4. Latticework of large collateral vessels which connect different segments of inferior vena cava. Note that clamps placed at a distance from vascular injury fail to control hemorrhage because of collateral inflow (Anatomic study from B. J. Anson, *Atlas of Human Anatomy,* Philadelphia, 1950, W. B. Saunders Company).

cant distance above and below the injury (Cases 3, 4, and 10), collateral influx through the lumbar veins resulted in hemorrhage almost as severe as with the cava open. This is explicable on the basis of the anatomic studies of Davis and associates,[8] who demonstrated that a collateral system consisting of the ascending lumbar vein and the lumbar vessels connects all levels of the abdominal vena cava by a latticework of large caliber veins (Fig. 4). Such studies also explain the limited value of preliminary occlusion of the vena cava above and below the hematoma in minimizing hemorrhage.

In view of the difficulties in controlling hemorrhage, the advisability of exploring retroperitoneal hematomas might be questioned since undoubtedly many caval injuries would heal spontaneously if the clot were not disturbed. Such speculation would be for the most part fruitless if applied to the type of injury described in the present series, since retroperitoneal exploration was mandatory in 11 of the 12 cases for the diagnosis and treatment of other visceral injuries. Moreover, the assumption that retroperitoneal bleeding will not resume may not be warranted. In Taylor's case,[30] a small hematoma was undisturbed at operation, and the patient bled to death into the retroperitoneal space within 6 hours. Finally, it has become clear that in some instances both the inferior vena cava and aorta are injured (Case 2), with possible development of an aortocaval fistula. Nine such cases have been described which have required repair from months to years after the original injury.[4, 9, 10, 14, 15, 20, 23, 26, 34]

When a hematoma is discovered near the great vessel, certain precautions can be easily observed before manipulation of the hematoma or opening of the retroperitoneal space since bleeding is almost invariably not a problem at this time. The skin incision can be extended if necessary. The posterior peritoneal incisions can be planned for provision of maximum exposure of the desired area. If the injury is above the renal veins, as it was in 4 cases of the present series, some modification of the Kocher maneuver has been effective. If the laceration is below the renal veins, as occurred in 6 cases, good exposure is obtained by medial mobilization of the right colon, by incision at the base of the small bowel mesentery, or by a combination of these maneuvers.

A considerable quantity of blood should be ready for use in the operating room. Adjustments for maximum illumination of the depth of the wound should be requested. Vascular clamps and suitable arterial sutures should be brought to the operating table. Finally, at least 1 functional cut-down or large-bore needle should be in the arm for blood administration, since forced trans-

fusions in the legs may only aggravate the bleeding. When at last the retroperitoneal space is entered, the dissection should proceed rapidly in order to control the hemorrhage quickly.

The treatment of choice of the caval laceration is suture repair. This was carried out in 11 of the 12 patients in the present series. In 1 case, and in several reported by other authors (Table II), ligation of the vessel was carried out, usually with resultant temporary pain and edema in the legs. With penetration above the renal veins, ligation would usually result in death,[33] although ligation above the renal veins was successfully used in 1 reported case[5] in which postoperative venograms suggested the presence of a double vena cava. Most wounds will need drainage of the retroperitoneal space.

Eleven of the 12 patients in the present series survived, although serious complications included iliofemoral thrombosis, renal failure, pancreatic fistula, biliary fistula, subphrenic abscess, pneumonia, wound infection, empyema, and temporary paraplegia. In the single death, it was thought that a bleeding diathesis was provoked by excessive transfusion at the time of operation. Likewise, patients in most of the other reported cases have survived repair or ligation (Table II). In no case has thrombosis of the repaired vena cava been known to occur. A bizarre complication in a patient who was not operated upon[16, 31] was the passage of the bullet up the cava into the heart. In another case, the missile slipped from the grasp of the surgeon and was carried into the right ventricle.[27]

SUMMARY

During the last 5 years, 10 gunshot and 2 stab wounds of the inferior vena cava have been treated, with 11 survivals and 1 death. The lacerations were above the renal veins in 4 cases and below in the others. All patients had other serious visceral injuries. Treatment consisted of suture repair in 11 cases and ligation in the twelfth.

Upon exploration, free intraperitoneal bleeding from the caval wound had ceased in every case. The signal finding was a retroperitoneal hematoma which was often deceptively small. Commonly, the surgeon explored the retroperitoneal space in order to treat other visceral injuries, only to be confronted with unexpected massive hemorrhage when the hematoma was entered. Difficulties in controlling the bleeding are often related to the well-developed collateral system by which different segments of the inferior vena cava are freely connected.

When a hematoma is found in the vicinity of the great vessels and the retroperitoneal space is to be explored, certain precautions should be observed. These include provision for adequate exposure, procurement of blood, and adjustment of lighting. Additional help can be summoned and vascular instruments should be brought to the operating table. A large-bore needle or cutdown should be placed in an arm vein. The posterior peritoneal incision should be planned for maximum and rapid exposure, so that hemorrhage can be quickly controlled when the plane of the hematoma is entered.

The patients in Cases 1 through 3 (previously reported) were treated at the Jackson Memorial Hospital, Miami. The patient in Case 4 was operated upon by Dr. Charles J. Staley at the Veterans Administration Research Hospital, Chicago. The patients in Cases 5 through 12 were operated upon by the resident staff at Cook County Hospital with the exception of the one in Case 9 who was transferred to Cook County Hospital after receiving primary surgical care from Dr. Anthony Nicosia of Chicago. Dr. Paul Nora, who operated on the patient in Case 7, assisted in the translation of some of the foreign journals.

ADDENDUM

After this report had been submitted, Drs. Ochsner, Crawford, and De Bakey (Surgery 49: 397, 1961) published an account of a large number of vena caval injuries treated in Houston, Texas.

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