Penetrating Injuries of The Abdominal Inferior Vena Cava – The Mayo Hospital Experience.

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This is a retrospective study of 16 patients with penetrating injuries of the abdominal inferior vena cava (IVC). 81% of the injuries were caused by gunshot and 19% by stabbing. 62.5% of these patients underwent lateral venorrhaphy, 18.75% underwent infrarenal ligation of the IVC and 18.75% died perioperatively before caval repair of any kind could be carried out. There was an overall mortality of 43.75%. Mortality seems to be directly related to the site of the IVC injury (higher for the suprarenal location and highest for the retrohepatic injuries), the presence of shock on admission, free bleeding and the lack of retroperitoneal tamponade at the time of surgery and also on the presence of additional vascular injuries.

Key Words.

The Inferior Vena Cava (IVC) is the most commonly injured intra-abdominal vessel and only half of the patients with this injury reach the hospital alive[1]. Abdominal IVC injuries associated with penetrating trauma are being seen with increasing frequency. Injuries of the abdominal IVC are associated with a high mortality and may be difficult to repair[2]. Despite advances in transport and resuscitation, mortality of abdominal IVC injuries remains unchanged in the west[3] and is even greater in developing countries like Pakistan. The increasing availability of both legal and illegal firearms in Pakistan and the general trend towards increasing civilian violence has resulted in an increase in penetrating IVC trauma presenting to our emergency room.

Mayo Hospital, Lahore, being the biggest and busiest trauma center in Pakistan, receives lots of patients with penetrating trauma to the abdomen. Abdominal vascular injuries in these cases are not uncommon. Among these, abdominal IVC injuries are associated with a high mortality. Prompt intervention and effective management could result in better survival ratios

Aims and Objects

The purpose of this study was :

1. To discuss effective diagnostic methods and appropriate surgical approaches for repair of the IVC below the diaphragm.
2. To identify subgroups with a higher mortality.
3. To review treatment principles, outcome variables and complications.

Patients And Methods

The complete medical records of 16 consecutive patients with penetrating injuries to the abdominal IVC , treated by our trauma team at Mayo Hospital Lahore from 1995 through 1998, were reviewed.

After arrival in our emergency, the initial resuscitation and diagnostic workup in all patients was conducted along Advanced Trauma Life Support (ATLS) principles. Large bore intravenous catheters were inserted into the upper extremities and standard crystalloid resuscitation was performed. Type specific blood was also infused if there was to be any delay until an operating room was available. If the patient's blood pressure stabilized, a chest x-ray and abdominal x-ray were rapidly performed.

All patients were operated upon on the basis of clinical assessment suggesting haemorrhagic shock and/or peritonitis.

After placing the patients supine on the operating table, skin preparation of the anterior and lateral torso in all our patients was done with Pyodine (Povidone Iodine) solution from the suprasternal area to the mid-thighs. This allowed us unimpeded access to enter either the thorax or the abdominal cavity through generous incisions and for the placement of drains and chest tubes as required. We explored all our patients iniatially with long midline abdominal incisions. In relatively more stable patients we preferred to open the abdomen only after type specific blood was available in the operating room. Once the abdomen was opened, the small bowel was delivered out of the incision and all the free blood and clot was rapidly evacuated either manually or with suction until the site of active bleeding became obvious and could be controlled with packing. This bought us some time for volume replacement and resuscitation. Temporary abdominal aortic clamping was also used in a few patients.

In most cases initial control of the IVC was accomplished by direct digital compression over the site of injury or compression with appropriately placed spongesticks above and below the IVC injury after mobilization of right colon and Kocherisation of duodenum. In some cases of infrahepatic IVC injuries one method of initial control was to get the assistants to apply direct compression with laparotomy pads over the IVC over the sacral promontory below and the immediately infrahepatic IVC above i.e., above and below the injury. This was followed by dissecting the area surrounding the

injury in order to apply definitive vascular control, which in most cases consisted of the use of vascular clamps (eg, satinski's).

Lateral venorrhaphy was the only form of repair used in most of the cases in our series. Ligation was performed in a few cases of infrarenal IVC injuries.

In cases of injury of the retrohepatic IVC, mobilisation and rotation of the appropriate liver lobe was employed or, failing which, the right chest was entered by converting it to a right thoracolaparotomy incision thus facilitating partial vascular exclusion (consisting of perihepatic packing, manual compression over the liver and a Pringle maneuver) or total vascular isolation using multiple occlusive vascular clamps.

All the patients in our series were given a peroperative antibiotic cover of Ampicillin, Genticyn and Metronidazole or a third generation cephalosporin combined with Metronidazole.

Results

There were a total of 16 patients of whom 14 were male and 2 females. The mean age was 27 years. 13 patients received firearm injuries and 3 sustained stabs. The location of IVC injuries was as shown in table 1.

Table 1. *Location Of IVC Injuries.*

Site Of IVC Injury	n= (%)
Retrohepatic	3 (18.91%)
Suprarenal/Renal	4 (22.9%)
Infrarenal/Bifurcation	9 (56.25%)
Total No. Of Patients	16

All patients arrived within 3 hours after having sustained the injury except one who arrived roughly 5 hours after the injury.

6 out of 13 patients with firearm injuries to the abdominal IVC had more than one gunshot wound to the abdomen or to other parts of the body. Out of the three who received stabs, only one patient had multiple ice pick injuries to the abdomen, while the other two had knife injuries.

Upon arrival in our emergency 11 patients were hypotensive (blood pressure < 90 mmHg), 3 had unrecordable blood pressure while 2 patients were relatively stable haemodynamically. Two of the three patients received with unrecordable blood pressure had cardiac arrest during surgery and subsequently died on table. Both these patients had massive thoracoabdominal injuries which included injuries to multiple organs including the abdominal IVC due to high velocity projectiles. These two patients underwent thoracolaparotomies. One of these patients had injuries to the abdominal IVC at two levels (retrohepatic and through-and-through infrarenal - only the infrarenal part could be effectively repaired before the patient died on table!). Efforts to resuscitate both these patients were offset by a lack of blood transfusions available for replacement during the operation

All patients were taken to theatre within one and a half hour of admission except the five who were grossly hypotensive or did not respond to resuscitation. These five patients were rushed to theatre within half an hour of admission (range 10 to 30 min.).

Although we explored all our patients iniatially with long midline abdominal incisions. Two of the patients subsequently required conversion to a right thoracoabdominal incision to gain control over retrohepatic IVC injuries.

Temporary abdominal aortic clamping was used in 2 patient. One of these patients had a combined firearm injury to the infrarenal IVC and abdominal aorta. The other had a near transection of the infrarenal IVC. Both these patients had become grossly hypotensive upon opening the abdomen.

Table 2. Type of repair of the abdominal IVC according to the site of injury

Site Of IVC Injury	Type Of Repair
Retrohepatic	Lateral Venorrhaphy-2
	No Repair-1*
Suprarenal/Renal	Lateral Venorrhaphy-3
	No Repair-1*
Infrarenal/Bifurcation	Lateral Venorrhaphy-5
	Ligation-3
	No Repair-1*

*Died before operative repair of any kind could be carried out.

As shown in table 2, Lateral venorrhaphy was used in 10 patients in our series. Ligation was performed in 3 cases of infrarenal IVC injury. A continuous 4.0 or 5.0 prolene stitch (depending upon availability) was used for venorrhaphy in all our cases. All through and through lacerations were repaired by rotation of the IVC to reach the posterior wall. In a few cases this required ligation of the lumbar veins to protect them from avulsion.

The mortality rates in our series, according to the different levels of IVC injury, are shown in table 3, i.e. 67% for retrohepatic IVC injuries, 53% for suprarenal/renal injuries and 33% for infrarenal injuries. The overall mortality was approximately 43.75%.

Table 3. Mortality

Site Of IVC Injury	Mortality N (%)
Retrohepatic	2(66.6%)
Suprarenal/Renal	2(52.94%)
Infrarenal/Bifurcation	3(33.3%)
Total	7(43.75%)

As shown in table 3, 7 of our 16 patients died including 2 of the 3 with retrohepatic and 5 of the 13 with infrahepatic caval injuries. All deaths in our series, except one patient who had sustained multiple stabs, were a consequence of multiple gunshot wounds involving multiple organs including the abdominal Vena Cava. All the patients in our series had at least one concomitant organ injury (Table 4).

Table 4.*Associated Injuries (Non-vascular).*

Intra-Abdominal Injuries	*n=*
Liver	7
Small Intestine	11
Large Intestine	5
Diaphragm	4
Duodenum	3
Stomach	2
Pancreas	2
Spleen	1
Kidney	2
Ureter	1
Urinary Bladder	1
Extra-abdominal injuries	
Chest	7
Head & Neck	1
Limbs	4

Of the 7 patients who died , 5 died on table from exanguination and secondary coagulopathy, one patient died 48 hours later as a consequence of shock and disseminated intravascular coagulopathy (DIC) and one patient died four weeks postoperatively due to overwhelming intra-abdominal sepsis which was a consequence of an associated intestinal injury .

70% of the patients who survived demonstrated significant postoperative complications (Table 5).The post-operative course of 3 patients was complicated by recurrent retroperitoneal bleeding within 24 hours of the operation, 5 patients showed evidence of lower extremity venous thrombosis, 1 patient had pulmonary embolism, 5 patients developed laparotomy wound infections, 3 patients had severe intra-abdominal sepsis secondary to intestinal injury, 3 patients had wound infections in relation to injuries of the limbs or head and neck, 4 patients suffered from severe chest infection and 1 patient had pancreatitis.

Table 5: *Postoperative Complications.*

Complications	*n=*
Recurrent retroperitoneal bleeding within 24 hours	3
Lower extremity venous thrombosis	5 (2 in the lateral venorrhaphy group and 3 in the infrarenal ligation group.)
Pulmonary embolism	1
Laparotomy wound infection	5
Intra-abdominal sepsis secondary to intestinal injury	3
Severe pulmonary infection	4
Wound sepsis in relation to injuries of limbs or head and neck	3
Pancreatitis	1

Follow-up in our patients was not very good. Only five of the survivors attended the follow up clinic for the first month after discharge from hospital and only two attended for the next six months. None of the patients (including the patients with in-hospital evidence of lower extremity thrombosis) had any venous sequel during their follow-up except one 45 year old gentleman who is still a regular visitor and complains of pain and swelling of the legs on prolonged standing .

Discussion

The majority of injuries of the abdominal IVC are due to penetrating trauma[2], although rarely, blunt trauma may also be involved. One in every fifty gunshot wounds and one in every 300 stab wounds of the abdomen will injure the IVC[4].

Immediate identification and resuscitation associated with a rapid surgical approach are the only factors that may improve survival of such devastating injuries[3].

The trauma surgeon must rapidly determine if the injured patient has life threatening intra-abdominal haemorrhage and promptly proceed with control of bleeding[5]. The surgeon must immediately perform three tasks during laparotomy to avert exanguinating haemorrhage within the abdomen [6],i.e. Location of the injured vessel is identified, surgical exposure of the injured vessel is achieved and haemostasis and restoration of critical blood flow are accomplished.

Operative control of the IVC can be accomplished by direct digital compression followed by proximal and distil control[2].

Venous repair versus venous ligation is an important issue. Any vein below the renal veins can be ligated[7]. In the presence of severe shock, difficult exposure and hypothermia, ligation is preferred. Up to one third of these patients develops significant symptoms of lower extremity venous hypertension, but the morbidity associated with this is often short-lived [2]. However , if the patient has suffered minimal blood loss and the vessel can be repaired by a lateral venorrhaphy technique that does not significantly constrict the lumen, repair of the IVC is recommended[5].

A number of factors were associated with an increased mortality. For IVC injuries, death is associated with free bleeding, the suprarenal location and the presence of shock on admission[3]. Patients who are haemodynamically stable have a better outcome than those who present in shock. Mortality is also directly related to the number of additional vascular injuries present. The major cause of death is haemorrhage from uncontrolled bleeding[8].

The mortality related to the site of injury . Retrohepatic IVC injuries caused the highest mortality. The concomitant hepatic injury was a major aggravating factor[9]. Of the three patients with retrohepatic vena caval injuries, vascular isolation was employed in two patients, only one of whom survived long enough to undergo definitive repair. The sole survivor in this group was the patient in whom a lateral venorrhaphy was carried out under direct digital control after mobilization of the

appropriate liver lobe. Of the four patients with suprarenal / renal injuries, three underwent a lateral venorrhaphy and one died before the IVC could be repaired. In the infrarenal injury group, lateral venorrhaphy was employed in five out of nine patients while three patients underwent infrarenal ligation and one patient died before any formal repair could be carried out. All three patients who underwent infrarenal ligation had complex transection / near-transection injuries of the infrarenal IVC and had suffered extensive blood loss from the IVC and concomitant injuries. However two of these patients survived.

The initial receiving blood pressure and the response to preoperative resuscitation also seem to have a direct bearing on mortality. 5 of the 7 patients who died were grossly hypotensive (blood pressure < 90mmHg) upon arrival in our emergency and did not respond to aggressive pre-operative resuscitation, while 9 of the 11 patients who responded to resuscitation , survived.

Table 6. Associated Injuries (Vascular).

Injuries	n=
Renal Vein	2
Renal Artery	1
Common Iliac Vein	1
Internal Iliac Vein	1
External Iliac Vein	2
External Iliac Artery	2
Abdominal Aorta	2
Inferior Mesenteric Vein	1
Splenic Artery	1

Mortality was also higher in patients who had vascular injuries in addition to the IVC injury (Table 6) and mortality increased as the number of additional vascular injuries increased. One patient who died on table had an injury to the retrohepatic IVC in addition to a through-and-through injury to the infrarenal vena cava. However one young man who had injuries to the pararenal IVC, the left renal vein and the inferior mesenteric vein (all repaired successfully) in addition to injuries to other intra-abdominal viscera, survived and recovered uneventfully ! He was discharged on the tenth postoperative day.

Finally, death seems to be associated with free retroperitoneal bleeding without tamponade. 6 of the 8 patients who had free bleeding at the time of operation, died.

Significant postoperative complications were seen in 70% of the patients who survived (Table 4).

Two of the patients who died postoperatively and one of the survivors had to be re-explored within 24 hours due to recurrent retroperitoneal bleeding.

Foremost, however, were the thromboembolic complications (no prophylaxis against thromboembolism was instituted in any of our patients.) There was a 20% overall incidence of thromboembolic complications after lateral venorrhaphy i.e. these patients demonstrated clinical and/or colour doppler/duplex scan (depending upon availability) evidence of lower extremity thrombosis. Only one of these patients exhibited clinical evidence of pulmonary embolism. All the three patients who underwent infrarenal ligation of the IVC had lower extremity thrombosis with gross edema at some stage postoperatively.

Among the nine survivors, five patients developed laparotomy wound infections, three had intra-abdominal septic complications secondary to injury of the abdominal viscera and four patients developed pulmonary septic complications postoperatively. Three of the survivors had septic complications related to injuries of the limbs or head and neck.

The postoperative course of one of the survivors who had sustained a pancreaticoduodenal injury in addition to the IVC injury was complicated by a severe pancreatitis.

Retrohepatic IVC injuries technically are the most challenging. These injuries present difficulties with exposure, since they are located behind the liver in an area of vessel which is difficult to mobilize. Techniques to allow vascular isolation of the region, without embarrassing venous return to the heart, have involved the placement of various shunts[2]. Most commonly, an atrio-caval shunt is fashioned from a perforated length of tubing and is secured with tourniquets placed above the diaphragm and above the renal veins. This necessitates a thoracotomy for placement[10]. Alternatively, a balloon-caval shunt may be introduced via the femoral vein in the groin[11]. More heroic techniques, such as mobilization of the liver by transecting the suprahepatic vena cava and rotating the liver anteromedially, have been proposed by some authors, but have not achieved clinical success to date[12]. Some authors have also recommended the insertion of intraluminal occlusion catheters into the injured IVC in order to control bleeding[13,14]. Some of these techniques, although tried by our trauma team in some patients previously, were not used in any of the patients in this series.

In conclusion, injuries of the abdominal IVC continue to provide taxing experiences for even the most experienced trauma surgeon. Injuries of this vessel indicate a profound level of injury[2]. Irrespective of the improvements in resuscitation and various operative methods available, penetrating trauma of the abdominal IVC remains a life threatening injury [13] and the mortality rate has remained largely unchanged since, with improved prehospital care and rapid transport, patients with very severe injuries who would otherwise have previously died before reaching hospital are now arriving in our emergency room[13,15]. Our mortality rate of 43.75% is comparable to the mortality rates of 30%to 53% quoted by authors in various other series[15-19].

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