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Penetrating injuries of the abdominal inferior vena cava

E Degiannis MD FRCS
Senior Consultant and Senior Lecturer

G C Velmahos MD
Medical Officer and Lecturer

R D Levy MD FCS(SA)
Senior Consultant and Senior Lecturer

I Souter MD
Medical Officer

C A Benn MD
Registrar

R Saadia MD FRCS
Chief Surgeon and Professor of Surgery

Department of Surgery, Baragwanath Hospital, University of the Witwatersrand Medical School, Johannesburg, Republic of South Africa

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This is a retrospective study of 74 patients with penetrating injuries of the abdominal inferior vena cava; the cause of injury was gunshot in 91% and stabbing in 9%. Of the patients, 77% underwent lateral venorrhaphy, 5% underwent infrarenal ligation of the inferior vena cava (IVC), and 18% died perioperatively before any caval repair could be carried out. There was an overall perioperative mortality of 39%. Persistent shock, the site of the venous injury, particularly in the retrohepatic position, and the number of associated vascular injuries were directly related to mortality. Irrespective of the improvements in resuscitation and the various operative methods available, penetrating trauma of the abdominal IVC remains a life-threatening injury.

There has been an enormous increase in civilian violence, especially involving firearms, in South Africa during the last 5 years. In 1992 alone, more than 3000 cases with gunshot wounds were admitted through the emergency department. As a result of the escalation in violence over this period our hospital has admitted an increasing number of arterial injuries *(1–4)*, many of which involve the inferior vena cava (IVC). The purpose of this study is to evaluate our management policy in penetrating injuries of the abdominal IVC following our recent experience.

Correspondence to: Mr E Degiannis, Department of Surgery, Medical School, 7 York Road, Parktown 2193, Johannesburg, Republic of South Africa

Materials and methods

Baragwanath Hospital, situated in Soweto, has 3000 beds and is the largest teaching hospital attached to the University of the Witwatersrand, Johannesburg. From January 1990 to December 1994, a retrospective study was undertaken of all patients operated on with penetrating injury to the abdominal IVC. There was a total of 74 patients of whom 69 were men and five women. The mean age was 31 years (range 20–52 years). In all, 67 patients (91%) sustained bullet injuries, 17 of which were confirmed to be caused by high-velocity missiles and the majority of the remainder to low-velocity missiles. Seven patients (9%) sustained knife injuries.

The mean time between injury and arrival at hospital was 75 min. All patients, apart from one with stab wounds, arrived less than 150 min after the injury. These time intervals are approximate and have been calculated from recorded information given by the ambulance personnel.

The initial resuscitation and diagnostic work was conducted along Advanced Trauma Life Support (ATLS) principles. Of the 67 patients, 26 had more than one gunshot wound to the abdomen or to other anatomical sites. All seven patients with stab injury of the IVC had only one entrance wound. Sixty-three patients (85%) were hypotensive on arrival in the emergency department (BP $\leqslant$ 90 mmHg). Of these patients, 21 had unrecordable blood pressure, six of whom had a cardiac arrest within 20 min of arrival at hospital and underwent successful emergency department thoracotomy *(5)*. The mean time between admission and arrival in the operating

room was 115 min. The time depended on the patients' response to resuscitation. There were 31 patients who did not respond to resuscitative measures and were taken to theatre in a mean time of 53 min (range 12–93 min). The 43 patients who were not hypotensive on admission or responded to resuscitation had a mean hospital preoperative time of 168 min (range 75–205 min).

All patients were operated on on the basis of findings suggesting haemorrhagic shock or peritonitis *(6,7)*. All laparotomies were performed via a long midline incision. The first priority was to control any source of major bleeding. Free and clotted blood was rapidly evacuated so that the site of active haemorrhage could be identified and controlled with packing. When it became evident that IVC injury was more likely, adequate time was given for resuscitation by the anaesthetist when the haemorrhage could be controlled. However, in most cases control could not be obtained easily. Temporary aortic clamping was used in the majority of patients who came to theatre hypotensive, who became hypotensive because of haemorrhage on opening the abdominal cavity or who had associated arterial injuries. Initial control of the IVC injury was usually accomplished by manually compressing the site of the bleeding while dissecting the area surrounding the injury in order to apply definitive vascular control. This was accomplished in most patients by mobilisation of the ascending colon and Kocherisation of the duodenum. Mobilisation and rotation of the appropriate liver lobe was employed in cases of injury of the retrohepatic vena cava. In a few cases, vascular isolation of this area with median sternotomy and application of multiple vascular clamps was also employed *(8)*.

Vascular clamps were used in the majority of cases during the repair of the IVC injuries. We tried to avoid blind clamping if at all possible and special attention was paid to its application and handling so that further injury of the thin-walled vein was avoided. Through-and-through lacerations were usually repaired by rotation of the IVC to reach the posterior wall. In a few cases because of danger of avulsion of the lumbar veins the anterior laceration was extended after proximal and distal control was achieved and the repair of the posterior wall was performed through the lumen of the cava. In one patient with combined aortocaval injury at the bifurcation, the right common iliac artery was divided and the aorta rotated to expose its posterior wall as well as the iliocaval venous confluence.

When lateral venorrhaphy was employed, a continuous 4.0 nylon or 4.0 prolene stitch was used. Infrarenal ligation of the IVC was also performed; this was not accompanied by fasciotomies. Table I shows the site of the IVC injury. Table II shows the non-vascular and Table III the vascular associated injuries in the whole series. All patients in the study had at least one concomitant organ injury.

Table IV shows the type of repair applied according to the site of injury. Of the 14 patients with retrohepatic injuries, it was possible to employ vascular isolation in nine; only six of these survived long enough to undergo definitive repair. All six injuries were treated by lateral venorrhaphy. Of the 17 patients with suprarenal/renal injuries, 15 underwent lateral venorrhaphy. In the infrarenal IVC segment, 32 injuries (84%) were amenable to lateral venorrhaphy. One patient with injury at the bifurcation required patch venoplasty with autogenous

Table I. Site of inferior vena cava injury and associated perioperative mortality*

Site	*Patients (n)*	*Mortality n (%)*
Retrohepatic	14	10 (71)
Suprarenal/renal	17	9 (53)
Infrarenal	38	8 (21)
Bifurcation	5	2 (40)
Total	74	29 (39)

*Deaths caused by exsanguination or secondary coagulopathy

Table II. Non-vascular associated organ injuries (70/74 patients)

Organ	*No (%) of patients*
Intra-abdominal	
Small bowel	38 (51)
Liver	21 (28)
Diaphragm	11 (15)
Duodenum	11 (15)
Stomach	7 (9.5)
Large bowel	7 (9.5)
Pancreas	7 (9.5)
Spleen	3 (4)
Ureter	3 (4)
Bladder	1 (1.3)
Extra-abdominal	
Chest	12 (16)
Limbs	7 (9.5)
Head and neck	4 (5.5)
Spine	1 (1.3)
Total	133

Table III. Associated vascular injuries (31/74 patients)

Vessel	*No (%)*
Renal vein	10 (13.5)
Common iliac artery	5 (7)
Renal artery	4 (5.5)
Lumbar artery	4 (5.5)
Common iliac vein	4 (5.5)
External iliac vein	4 (5.5)
Portal vein	3 (4)
Aorta	2 (3)
Hepatic artery	2 (3)
Left gastric artery	2 (3)
External iliac artery	2 (3)
Internal iliac vein	2 (3)
Superior mesenteric vein	1 (1.5)
Splenic artery	1 (1.5)
Splenic vein	1 (1.5)
Total	47

Table IV. Type of repair of the abdominal IVC according to the site of injury and associated hospital mortality*

Site		*Repair n*	*Mortality n*
Retrohepatic	(14)		
Lateral venorrhaphy		6	2
No repair †		8	8
Suprarenal/renal	(17)		
Lateral venorrhaphy		15	9
No repair †		2	2
Infrarenal	(38)		
Lateral venorrhaphy		32	5
Ligation		4	2
No repair †		2	2
Bifurcation	(5)		
Lateral repair		4	2
Saphenous patch		1	0
Total		74	32

* All patients except three died perioperatively of exsanguination or secondary coagulopathy
† Patients died before operative repair could be carried out

saphenous vein. Ligation of the IVC was applied in four patients with infrarenal injuries, in whom the IVC was completely or almost completely transected. The complex nature of the injury and the extensive blood loss from the IVC, as well as from concomitant injuries, rendered the ligation of the vena cava more imperative than a time-consuming reconstruction of this IVC injury in a physiologically unstable patient. Only two of these patients survived.

All patients with vascular injuries alone were given a perioperative antibiotic course of cefazolin, which was administered over a period of 48 h. In the patients with associated gastrointestinal tract injury, as was most often the case, the antibiotic regimen consisted of penicillin, amikacin and metronidazole.

Results

Of the 74 patients, 29 (39%) died from exsanguination or secondary coagulopathy. Of these, 23 died in the operating theatre, including five of the six patients who had undergone successful emergency department thoracotomy. The remaining six patients died within the next 2 days in the intensive care unit from irreversible shock because of disseminated intravascular coagulopathy (DIC). Only one of the 29 patients who succumbed sustained stab injury, the remainder sustained gunshot injuries.

Many factors were associated with increased mortality. The mortality related to the site of the injury, and the associated type of repair is shown in Tables I and IV. The retrohepatic location of the injury carried the highest mortality (71%) and eight of the 14 patients with this injury succumbed before any type of operative repair was employed. The concomitant hepatic injury was a major aggravating factor *(8)*.

Table V. Effect of number of additional vascular injuries on survival

Number of additional injuries	*Number of patients*	*Mortality**
0	43	13 (30%)
1	20	9 (45%)
2	7	3 (43%)
3	3	3 (100%)
4	1	1 (100%)
Total	74	29

* Another three patients died from causes unrelated to vascular injuries

Virtually all the risk factors reflected the duration and depth of shock.

Mortality was influenced by the initial blood pressure and the response to preoperative resuscitation. All 29 patients who died intraoperatively or in the immediate postoperative period were hypotensive on admission, including 15 of the 21 patients who were admitted with unrecordable blood pressure. It is noteworthy that of the 17 high-velocity injuries there were 10 deaths. Of the 31 patients who did not respond to resuscitative measures on admission 26 died, while only three of the 32 hypotensive patients who responded died. There was no mortality in the group of 11 patients who were non-hypotensive on arrival at the emergency department.

The presence of additional vascular injury significantly increased the risk of death (Table V). All four patients with more than two vascular injuries in addition to the caval injury died from exsanguination or secondary coagulopathy in the immediate perioperative period. A combination of IVC injury with iliac artery injury was particularly ominous as five out of seven patients died, although in all five patients there were less than a total of three vascular injuries present *(9)*.

There were another three postoperative deaths. One was attributed to pulmonary embolism and two to intra-abdominal sepsis from associated organ injuries, and occurred between the 3rd and 5th postoperative weeks.

Of the 42 survivors, 25 (59%) developed significant postoperative complications. Thromboembolic complications developed in a significant number of patients. No prophylactic treatment against thromboembolism was given owing to our reluctance to institute heparin therapy in patients with a recent major bleed. Of the 39 survivors who were treated by lateral venorrhaphy, 4 (10%) developed lower extremity thrombosis (the clinical diagnosis was confirmed by venography), and one (2.5%) pulmonary embolism. Taking into consideration that the one patient who succumbed to pulmonary embolism had also undergone lateral venorrhaphy, there was a 15% incidence of thromboembolic complications after lateral venorrhaphy. The postoperative course of the two patients who survived the infrarenal ligation of the IVC was complicated by lower extremity thrombosis with massive oedema. The patient who required the saphenous vein patch at the bifurcation of the IVC did not develop any venous complications.

There were 35 further significant postoperative complications among the survivors; 18 had pulmonary and eight intra-abdominal septic complications secondary to injury of the abdominal viscera. There was also one paraplegic patient from injury to the spinal cord, three patients with septic complications related to the injury of the limbs and head and neck, and five with laparotomy wound infections.

Our follow-up was unsatisfactory as only 26 patients (62%) came back for review 1 month after discharge and only 12 (28%) after 2 months. All six patients who were discharged with evidence of lower extremity thrombosis attended the follow-up clinics and had no apparent venous sequelae 6 months after discharge. During the 5 years of the study, no patient returned to this hospital with late thromboembolic complications after IVC repair. The possibility that a patient who developed complications after treatment for this injury may have attended another hospital cannot be excluded.

Discussion

Penetrating injury of the abdominal IVC continues to pose a taxing problem for the trauma surgeon. Its frequency is estimated to be as high as 10% for gunshot wounds and 3% for stab wounds *(10)*. The mortality of those patients reaching the hospital alive is between 30% and 53% *(10–14)*. The survival rate has increased because of improvements in resuscitation and increased experience in the management of these patients. But this increase is marginal since, with improved prehospital care and transport, patients with very severe IVC injuries who would have previously died are arriving at the emergency centres. As a result of this the mortality from civilian injuries has always been >30% *(13)*. At present, the experience with this injury originates chiefly from the North American Trauma Centres. The increasing availability of legal and illegal firearms worldwide will result in an increase of penetrating IVC trauma even in traditionally less violent societies *(15–17)*.

We agree with the conclusions reached by several authors that the presence of shock on arrival, the site of IVC injury and the presence of associated vascular injuries are predictors of poor perioperative mortality *(10,12–14,17)*. In our study, mortality affected only the group of patients who were hypotensive on admission. There was a four times higher mortality rate in those hypotensive patients who were admitted with unrecordable than those admitted with recordable blood pressure. The mortality rate was six times higher in those patients who did not respond to preoperative fluid resuscitation than in those who responded. In the patients with retrohepatic injury, the mortality rate was three times higher than those with infrarenal injury. Finally, there was an increase of the mortality rate directly related to the presence and the number of additional vascular injuries. A combination of IVC injury with three or four additional vascular injuries was particularly ominous, as all these patients died.

The majority of civilian IVC injuries can be managed by lateral venorrhaphy. This was the case with 92% of our patients who underwent repair. Primary repair of the IVC injury is recommended, even if the luminal diameter is compromised *(10)*. The fear of pulmonary emboli originating from a partially stenosed vein has not been confirmed by clinical experience *(18)*. In our study there was a 5% incidence of pulmonary emboli and 10% incidence of thrombosis alone in those patients who underwent lateral venorrhaphy.

The insertion of intraluminal occlusion catheters in order to control bleeding has been recommended by some authors, but we have not used them in our patients *(19)*.

Ligation of the infrarenal part of the IVC is usually well tolerated and there is regression of symptomatology with time *(20)*. This was the case with the two patients in our study who survived the initial operation after infrarenal IVC ligation. On the other hand, suprarenal ligation of a previously normal IVC is followed by immediate haemodynamic consequences, which include a significant fall in cardiac output owing to venous pooling and reduction in venous return to the heart *(10,21)*. Renal function is further compromised by renal hypertension; however, there have been several reports of patients surviving suprarenal IVC ligation in trauma situations *(10)*. Inferior vena cava interposition grafts, even when using autogenous vein, have been condemned because of a very high occlusion rate *(22)*. However, there are some authors who would still recommend PTFE grafts in this situation *(23)*. A number of alternatives to interposition grafting have been proposed, such as portocaval shunts *(21)*, splenorenal anastomosis *(22)*, and vena caval transposition *(24)*.

Retrohepatic IVC injuries are characterised by difficulty in accessibility and high mortality, irrespective of the method of operative management employed. As Dr Walt said in his address before the Society for Surgery of the Alimentary Tract: "Too much has been written on the topic of hepatic venous injuries and there are possibly more authors on the subject than survivors of the procedures described" *(25)*. Vascular isolation and internal shunting have both been practised with limited success, with continuing controversy over which is the optimal approach.

Heaney *et al. (26)* first described the vascular isolation of the liver and demonstrated the efficacy of this technique in elective hepatic resections.

Pachter *et al. (27)* described an alternative procedure to vascular isolation. Initially, they apply compression at the site of injury and Pringle's manoeuvre, and then resuscitate the patient. The compresssion is then released, they inspect the site of the injury and make an early diagnosis of juxtahepatic IVC injury as indicated by the failure of the Pringle's manoeuvre to adequately control the haemorrhage. This is followed by prolonged portal triad occlusion with hepatocyte protection by means of large doses of steroids and topical hypothermia. Access to the vascular injury site for primary repair or ligation is achieved by extensive finger fracture of the liver *(27)*.

Buechter *et al. (28)* described another technique of managing retrohepatic vena cava injury. After initial mobilisation of the liver, Pringle's manoeuvre and clamping of the suprarenal vena cava, a clamp is placed across the suprahepatic, infradiaphragmatic vena cava. The suprahepatic vena cava is transected and the liver is retracted forwards to allow a posterior approach to the retrohepatic veins and retrohepatic vena cava *(28)*.

There is, perhaps, no more drastic procedure in trauma surgery than that of inserting a shunt *(29–33)*. Insertion of an atrial caval shunt requires practice and co-ordinated teamwork in a crisis situation *(29)*. For a surgeon inexperienced in atrial caval shunt use, its insertion can be a disaster.

In conclusion, penetrating trauma to the abdominal IVC continues to be a challenging injury. The persistence of shock, the high location of the venous injury and the number of associated vascular injuries are predictors of poor prognosis. Despite the improvements in prehospital and hospital resuscitation and the variety of available methods of operative management it continues to be burdened with a depressingly high mortality.

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