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SCIENTIFIC REVIEW

Despite Major Therapeutic Advances, Vena Caval Trauma Remains Associated with Significant Morbidity and Mortality

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Abstract

Background Penetrating inferior vena caval injuries remain a challenging operative entity. This study reviews our local experience with the injury over a nine-year period and attempts to contextualize it within the published literature that emanates from South Africa on the topic.

Methods A single-centre retrospective review of prospectively collected data was performed of all patients who underwent a laparotomy for a penetrating IVC injury. Descriptive statistics were calculated for demographics, clinical and biochemical parameters, intraoperative data, ICU admission and outcomes.

Results During the nine-year period, thirty-five patients sustained penetrating injuries to the IVC. Mechanism of injury included 25 low velocity gunshots (71%) and 10 stab wounds (29%). The anatomical location included two (6%) supra-renal, six (17%) juxta-renal and 27 (77%) infra-renal injuries. Venorrhaphy was performed in 22 cases (63%) and ligation in 13 (37%). Average ICU stay was 5.4 days. Thirteen patients died (37%), of which six (46%) died within 24 h of arrival.

Conclusion Despite dramatic improvements in surgical trauma care over the last four decades, penetrating injury to the IVC carries a high mortality rate ranging from 31 to 37%. It is unlikely that further improvements can be achieved by refining operative techniques and approaches to resuscitation. Future endeavours must focus on applying the burgeoning understanding of endovascular surgery to these injuries.

Introduction

The management of the injuries to the inferior vena cava (IVC) is particularly challenging as the caval system is a high flow low pressure system and the wall of the cava itself is not robust [1, 2]. The surgical approaches and techniques of handling the cava itself have been well described and universally taught since the nineteen-sixties and seventies [3–7]. Since these initial operative descriptions there have been dramatic improvements in clinical practice. These include the overall improvement associated the development of trauma systems, as well as with the ubiquitous availability of CT scan, major advances in resuscitation and ICU, damage control surgery and resuscitation, endovascular surgery the development of

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Retrograde Balloon Occlusion of the aorta (REBOA). A significant body of literature on the topic of IVC trauma has emanated from South Africa over the last four decades [8–12]. These reports reflect the continual changes, refinements and improvements in clinical practice over that time period. This current review of the topic aims to interrogate our contemporary experience with trauma to the IVC, to contextualize this experience within the existing literature from South Africa, and to highlight potential areas where ongoing advances may allow for improved outcomes.

Clinical setting

Pietermaritzburg is the capital city of the coastal province of Kwa Zulu Natal in South Africa. Grey's Hospital provides tertiary surgical care to the city of Pietermaritzburg and the western third of the province, covering a population of over three million people. The Pietermaritzburg Metropolitan Trauma Service maintains an electronic database of all trauma cases called the Hybrid Electronic Medical Registry (HEMR). Ethics approval for the maintenance of the registry and for this study has been formally approved and maintained by the Biomedical Research Ethics Committee of the University of Kwa Zulu Natal (BCA 221/13).

Methodology and statistics

All patients who sustained penetrating abdominal trauma with an associated IVC injury were identified using a word search of the data base. Patient demographics, mechanism of injury, admission vital signs, clinical laboratory data, operative technique, blood loss and autotransfusion usage, associated injuries, admission to ICU and duration of stay, mortality rate, death within 24 h and cause of death were extracted. Patients with blunt trauma as well as patients whose injuries were managed conservatively were excluded. Iatrogenic vena cava injuries were also excluded. Descriptive statistics were calculated for age, demographics, clinical and biochemical parameters, intraoperative data, ICU admission and outcomes. Central tendency was expressed as medians and inter-quartile ratios. Mortalities were divided into acute (within 24 h of arrival to hospital) and non-acute (beyond 24 h of admission) and compared. The following criteria were used to diagnose the presence of shock, a MAP < 65 mmHg a SBP < 90 mm Hg as well as clinical evidence of decreased cerebral and peripheral perfusion. Damage Control Surgery and its indications were defined based on the criteria described In the Definitive Surgical Trauma Care (DSTC) Guidelines and included complex intra-abdominal injuries as well as the presence of acidosis, hypothermia and hypotension [5].

Results

During the period, July 2012 to June 2021, a total of 13,952 trauma patients were admitted and a total of 1712 trauma laparotomies were performed over the same period. In this group of this cohort of 1712 trauma laparotomies a total of 35 IVC injuries were identified. Twenty-five of these were secondary to a low velocity gunshot (GSW) (71%) with stab wound (SW) injuries being responsible for the remaining 10 (29%) cases. The mean age of patients was 29.1 years with 30 patients (86%) being male and 5 (14%) being female. A total of 11 patients (31.4%) presented to the emergency department with features of shock. The median vital parameters included a pulse of 95 bpm, systolic blood pressure of 102 mmHg, diastolic blood pressure 64 mmHg, mean arterial pressure of 76 mmHg, respiratory rate of 18 breaths per minute, SpO2 of 94% and body temperature of 35.8 °C. Biochemical and metabolic parameters revealed a mean haemoglobin of 13.2 g/dL, a pH of 7.32, base deficit of 5.1 and a lactate of 5.2 mmol/L. The interquartile range for base deficit was 9–1,3 (25–75%) with a mean of 3.1. The interquartile range for lactate was 2–7.6 mmol/L (25–75%) with a mean of 3.7 mmol/L. The average injury severity score (ISS) was 21 with the mean Abbreviated injury score Abdominal parameter (AIS) being 4.3 out of 5.

Intra-operative details

An attending surgeon was present at 33 (94%) of laparotomies and an attending anesthesiologist was present at 6 (17%). Most often trauma occurs at night when the attending anaesthesiologist is on call from home and mostly this means that they will only come to the hospital for prolonged cases, many of these trauma cases being limited in time. The in-house anaesthesiologist is usually a senior trainee. Damage control surgery was utilized in 18 (51%) of cases, whilst definitive surgery was performed in the remaining 17 cases (49%). The average operating time was 2 h and 26 min. No statistical difference was noted in the average operating times between the damage control and non-damage control groups. The average intraoperative blood loss was 1711 ml with an autotransfusion system being used in 18 (51%) of cases. The location of injury included two (6%) supra-renal, six (17%) juxta-renal and 27 (77%) infra-renal injuries. Supra-renal injuries carried a mortality rate of 100% compared to the overall average of 34%. Juxta-renal injuries did not infer a higher mortality risk with a rate of 33.3%.

Intra-operative techniques used to control haemorrhage included venorrhaphy with or complete ligation of the inferior vena cava. Venorrhaphy was performed in 22 cases

(63%) with ligation being used in 13 (37%). Ligation alone did not infer a mortality risk with 5 of the 13 cases of ligation (38%) demising. Associated intra-abdominal injuries were present in all cases, the commonest being a small bowel perforation in 16 cases (46%) followed by duodenal injury in 14 cases (40%) and gastric injury in 12 cases (34%). Associated extra-abdominal injuries were present in 12 patients (34%) with penetrating thoracic trauma being the commonest in seven (58%), followed by maxillo-facial trauma in 3 (25%). Three patients underwent operative access to a second body cavity with two thoracotomies and one pericardial window being performed. These were for associated penetrating thoracic trauma. One of these cases was found to have an associated gunshot injury to the right atrium with a supra-renal inferior vena cava injury, underwent simultaneous laparotomy and thoracotomy with two consultant-led operative teams but demised on table from exsanguination. Primary abdominal closure was performed in 11 cases (31%) with a temporary abdominal closure technique being used in 24 (69%). The commonest temporary closure method was Bogota bag in 19 cases (79%) followed by opsite sandwich in the remaining 5 (21%).

Outcomes

All patients who survived the initial operation were admitted to the ICU with an average stay of 5.4 days. An average hospital stay of 10.3 days was noted. A total of 13 Patients died (37%) with six patients (46%) dying within 24 h of arrival to the emergency department. These six acute deaths occurred on the operating table or shortly after arrival to the ICU as a consequence of haemorrhage, acidosis and coagulopathy. The remaining seven deaths occurred beyond 24 h and occurred in the ICU. The commonest cause of death in the non-acute deaths was renal failure in 5 cases (71%) followed by single cases of ventilator associated pneumonia and intra-abdominal sepsis accordingly. Haemodynamic parameters on arrival such as pulse and mean arterial pressure did not strongly correlate with a higher mortality risk, with non-survivors having an average pulse of 96 bpm, mean blood pressure of 65 mmHg. Systolic blood pressure was noted to be lower in the non-survivor group at 101 mmHg versus 105 mmHg. Mechanism of injury was found to have a small difference in mortality. The total number of non-survivors in the gunshot group was ten out of 25 (40%) versus three out of ten (33%) in the stab group. Non-survivors were found to have a higher lactate of 8.1 mmol/L and a higher base deficit of 9 when compared to survivors. Patients who died had a higher average intra-operative blood loss of 2300 ml. Suprarenal injuries carried a 100% mortality rate and infer a mortality risk. Ligation of the inferior vena cava did not appear to infer an increased risk of death.

Discussion

The management of IVC trauma is difficult. The vena-cava is a high flow low pressure system and large volumes of blood can be lost rapidly. In addition, the wall of the vena cava is not muscular like the aorta. It is thin and tears easily. This means that inappropriate instrumentation and poor handling may exacerbate the injury. There have been a total of five series of vena caval trauma published in South Africa since 1983. These are summarized in Table 1. Over the four decades, there have been a number of dramatic advances and changes. These include improvements in technology, imaging, trauma systems and our understanding of and approach to resuscitation and damage control surgery. Figure 1 attempts to highlight and contextualize these changes and to juxtapose them against the published data from South Africa. The most striking observation is that the mortality rate for his injury remains stubbornly in the range of 31–43%. Penetrating injury to the IVC remains a devastating injury. In addition, approximately half of all mortalities occur on the operating table or within the first 24 h. This suggests that death is related to blood loss.

The technical aspects of managing trauma to the IVC have received much attention. Standard texts advise proximal and distal control either by direct digital compression or by swabs on an atraumatic instrument. The posterior defect in the cava cannot be accessed by rotating the vessel but only by extending the wound in the anterior aspect. Suture repair must be effected with a fine vascular suture. Ligation of IVC injuries has been shown to be effective with acceptable morbidity rates. Our current experience supports the utility of ligation in the appropriate setting. It is unlikely that further improvements in the outcome will be achieved through ongoing refinements in operative technique.

There are some other areas where further quality improvement may produce some benefit. Early retrieval and prompt delivery to an appropriate trauma centre are important in patients with a vena-cava injury. Our current retrieval system has developed considerably over the last decade. Modern communication allows for direct contact between retrieval teams and hospital-based clinicians. This allows us to triage and direct patients in real time and almost certainly has improved our system. Rural patients with a cava injury are unlikely to survive road transfer to our centre and the use of our aero-medical retrieval system may improve outcomes in this group. The lack of an attending anaesthesiologist at operation is a system

Table 1 Comparison of 6 IVC injury Series [8–12]

Location	Durban	Johannesburg	Durban	Cape Town	Pretoria	Pietermaritzburg
Period	1980–1983	1990–1994	1990–1995	1999–2003	1993–2005	2012–2021
Patients	28	74	26	48	26	35
Age	30	31	29	27	31	29
Anatomic location (%)						
°Retrohepatic	7 (25)	14 (9)	3 (11)	1 (2)	3 (12)	0
°Supra-renal	13 (46)	17 (22)	8 (30)	6 (13)	9 (36)	2 (6)
°Juxta-renal	0	0	0	0	0	6 (17)
°Infrarenal	8 (28)	43 (59)	15 (55)	41 (85)	15 (56)	27 (77)
Mechanism						
°Gunshot	7 (33)	67 (91)	17 (65)	45 (94)	27 (100)	25 (71)
°Stab	15 (53)	7 (9)	5 (19)	1 (2)	0	10 (29)
°Blunt	4 (14)	0	4 (16)	2 (4)	0	-
Mortality (%)	10 (36%)	32 (43%)	23 (88%)	15 (31%)	10 (37%)	13 (37%)

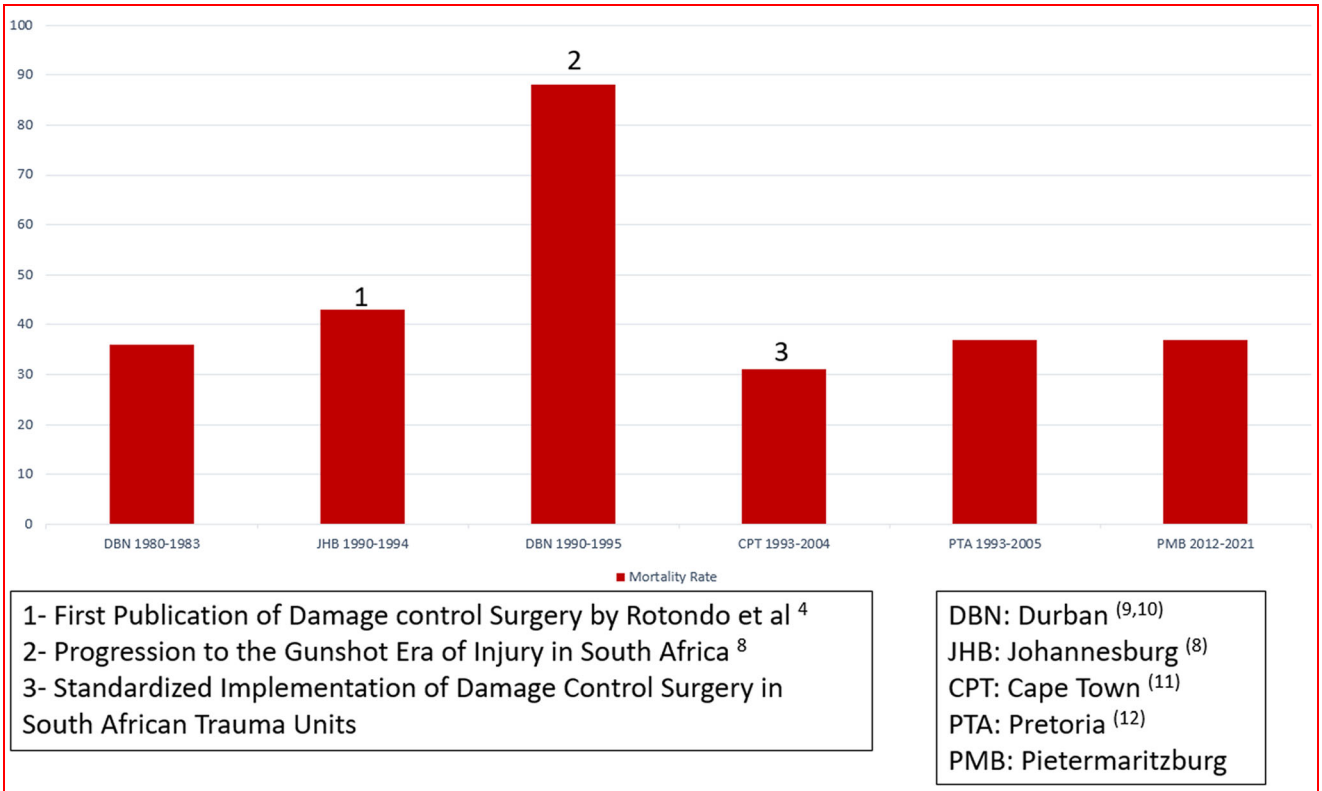

Fig. 1 IVC injury mortality rate in South Africa: 1980–2021 [8–12]

weakness which we are in the process of addressing. However, even with ongoing attempts to refine our system, it appears that any potential improvements in outcome will be dependent on developments in endovascular approaches.

The approach of a modern hybrid operating theatre with advanced imaging and endovascular capacity, as well as open surgical capacity, may improve outcomes for IVC trauma. Retrograde balloon endovascular occlusion of the aorta (REBOA) may be able to improve outcome for intra-abdominal vascular injuries [13]. REBOA allows for

inflow control of an aortic injury and facilitates control and repair of an aortic injury. This has been extended, to the development of retrograde balloon endovascular occlusion of the vena cava (REBOVC) [14–19]. REBOVC involves fluoroscopic guided placement of an inflatable balloon into the inferior vena cava via the femoral vein. Balloon inflation caudal to the site of injury arrests haemorrhage temporarily until open surgery and exposure can occur and allow for operative control and repair. There have been several reports on the use of REBOVC over the past five years as well as two recent experimental porcine trials [20, 21]. This may hold out the possibility of improved outcomes.

Conclusion

Despite dramatic improvements in surgical trauma care over the last four decades penetrating injury to the IVC carries a high mortality rate ranging from 31 to 37%. It is unlikely that further improvements can be achieved by refining operative techniques and approaches to resuscitation. Future endeavours must focus on applying the burgeoning understanding of endovascular surgery to these injuries.

Declarations

Conflict of interest The authors do not have any relevant disclosures or conflicts of interest for this work and no funding was utilized either.

References

1. Weale R, Kong V et al (2018) Management of Intra-abdominal vascular injury in trauma laparotomy: a South African Experience. Can J Surg 61(3):158–164
2. Hansen CJ, Bermadas C et al (2000) Abdominal vena cava injuries: outcomes remain dismal. Surgery 128(4):572–578
3. Paul JS, Webb TP et al (2010) Intraabdominal vascular injury: Are we getting any better? J Trauma Inj Infect Crit Care 69(6):1393–1397
4. Rotondo MF, Schwab CW et al (1993) Damage control: an approach for improved surivial in exanguinating penetrating abdominal trauma. J Trauma 35(3):375–382
5. Boffard KD et al (2019) Management of definitive surgical trauma care, 5th ed. CRC Press, United States
6. Mattox KL (2004) Top knife: the art & craft of trauma surgery, 1st ed. Castle Hill Barns, Shrewsbury, U.K.
7. Advanced Trauma Life Support, 10th ed (2018) American College of Surgeons
8. Robbs JV, Costa M et al (1984) Injuries to the great veins of the abdomen. SAJS 22(4):223–228
9. Degiannis E, Velmahos C et al (1996) Penetrating injuries of the inferior vena cava. Ann R Coll Surg Engl 78:485–489
10. Clarke DL, Madiba TE et al (1999) Inferior vena caval injury in the firearm era. SAJS 37(4):107–109
11. Navsaria P, de Bruyn P et al (2005) Penetrating abdominal vena cava injuries. Eur J Vasc Endovasc Surg 30:499–503
12. Van Rooyen PL, Karusseit VOL et al (2014) Inferior vena cava injuries: a case series and review of the South African experience. JINJ-5784
13. Khan MZ, Bruce J et al (2019) Hybrid use of REBOA in a South African tertiary trauma unit for penetrating torso trauma. BMJ Case Rep 12:e229538
14. Angeles AP, Agarwal N et al (2004) Repair of a juxta-hepatic inferior vena cava injury using a simple endovascular technique. J Trauma Inj Infect Crit Care 56(4):918–921
15. Castelli P, Caronno R et al (2005) Emergency endovascular repair for traumatic injury of the inferior vena cava. Eur J Cardiothorac Surg 28(6):906–908
16. Tillman BW, Vaccaro PS et al (2006) Use of an endovascular occlusion balloon for control of unremitting venous hemorrhage. J Vasc Surg 43:399–400
17. Bui TD, Mills JL et al (2009) Control of inferior vena cava injury using percutaneous balloon catheter occlusion. J Vasc Endovasc Surg 43(5):490–493
18. Bisulli M, Emiliano G et al (2017) Resuscitative endovascular balloon occlusion of vena cava: an option in managing traumatic vena cava injuries. J Trauma Acute Care Surg 84(1):211–213
19. Herrero A, Souche R et al (2020) Endovascular balloon occlusion during reconstruction of portal vein injury. Langenbecks Arch Surg 405:391–395
20. Reynolds CL, Celio AC et al (2017) REBOA for the IVC? Resuscitative balloon occlusion of the inferior vena cava (REBOVC) to abate massive hemorrhage in retrohepatic vena cava injuries. J Trauma Acute Care Surg 83(6):1041–1046
21. Wikström MB, Krantz J et al (2019) Resuscitative Endovascular balloon occlusion of the inferior vena cava is made haemosynamically possible by concomitant endovascular balloon occlusion of the aorta—a porcine study. J Trauma Acute care 88:3

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