Management of intra-abdominal vascular injury in trauma laparotomy: a South African experience

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Background: Intra-abdominal vascular injury (IAVI) is uncommon but continues to be associated with high mortality rates despite technological advances in the past decades. In light of these ongoing developments, we reviewed our contemporary experience with IAVI in an attempt to clarify and refine our management strategies and the outcome of these patients.

Methods: We retrospectively reviewed the charts of all patients admitted between January 2011 and December 2014 at a major trauma centre in South Africa who were found to have an IAVI during laparotomy for trauma. We collected demographic and clinical data including mechanism of injury, location and severity of the injury, concurrent injuries, physiologic parameters and clinical outcome.

Results: We identified 110 patients with IAVIs, of whom 98 had sustained penetrating injuries (55 gunshot wounds and 43 stab wounds). There were 84 arterial injuries (including 21 renal and 17 mesenteric) and 74 venous injuries (including 21 renal and 17 inferior vena caval). Combined venous and arterial injuries were found in almost one-third of patients (34 [30.9%]). Fifty-seven patients (51.8%) required intensive care admission. The overall mortality rate was 28.2% (31 patients); the rate was 62% for aortic injuries and 47% for inferior vena cava injuries. Liver injury, large bowel injury, splenic injury and elevated lactate level were all associated with a statistically significantly higher mortality rate.

Conclusion: The mortality rate for IAVI remains high despite decades of operative experience in high-volume centres. Open operative techniques alone are unlikely to achieve further reduction in mortality rates. Integration of endovascular techniques may provide an alternative strategy to improve outcomes.

Contexte : Les lésions vasculaires intraabdominales (LVIA) sont rares, mais elles sont toujours associées à un taux de mortalité élevé, malgré les progrès technologiques des dernières décennies. À la lumière de ces renseignements, nous avons passé en revue l'expérience récente en matière de LVIA afin de clarifier et de parfaire nos stratégies de prise en charge et d'améliorer les résultats des patients.

Méthodes : Nous avons examiné de manière rétrospective les dossiers de tous les patients admis entre janvier 2011 et décembre 2014 dans un grand centre de traumatologie d'Afrique du Sud chez qui une laparotomie a révélé la présence d'une LVIA. Nous avons recueilli des données démographiques et cliniques portant notamment sur le mécanisme lésionnel, la localisation et la gravité de la lésion, les blessures concomitantes, les paramètres physiologiques et l'issue clinique.

Résultats : Nous avons recensé 110 patients atteints de LVIA, dont 98 avaient subi des blessures par pénétration (55 causées par un projectile d'arme à feu et 43 par une arme blanche). Nous avons dénombré 84 lésions artérielles (dont 21 rénales et 17 mésentériques) et 74 lésions veineuses (dont 21 rénales et 17 touchant la veine cave inférieure). Dans l'ensemble, nous avons constaté des lésions veineuses et artérielles chez près du tiers des patients (34 patients, soit 30,9 %). Cinquante-sept patients (51,8 %) ont dû être admis à l'unité des soins intensifs. Le taux de mortalité global était de 28,2 % (31 patients); il était de 62 % pour les cas de lésions aortiques et de 47 % pour les lésions touchant la veine cave inférieure. Les lésions au foie, au gros intestin et à la rate ainsi que les taux élevés de lactate ont tous été associés à une hausse statistiquement significative du taux de mortalité.

Conclusion : Le taux de mortalité associé aux LVIA reste élevé malgré des décennies d'expérience chirurgicale dans des centres de traumatologie traitant un grand nombre de patients. Les techniques opératoires ouvertes seules sont peu susceptibles de donner lieu à une baisse de ce taux. L'intégration des techniques endovasculaires pourrait constituer une solution de rechange pour améliorer les résultats.

Much has been published about intra-abdominal vascular injury (IAVI) over the last 60 years. Most of these publications were retrospective; very few were documented large case series. The persistent theme throughout is that the management of IAVI is challenging and that mortality rates are high. Accessing the injured vessels may be difficult, and patients are often in a physiologically compromised state. In addition, competing priorities and concomitant intra-abdominal contamination restrict the options for vascular repair.[1]

The surgical response to these taxing injuries has been multifaceted. The initial approach was to perfect the surgical exposure and to debate the optimal operative techniques to manage these injuries.[2,3] Although standardizing these surgical lessons was important, it has become apparent that there is a natural limit to the extent to which improved operative techniques alone can further improve outcome. There has been much recent focus on imaging techniques, perioperative resuscitation, aggressive replacement of blood products and damage-control strategies. However, the mortality rate has not been substantially reduced over the last 2 decades (37% in 1975–1980 v. 33% in 2004–2009).[4–6] It is accepted that exsanguination eclipses coagulopathy as the primary cause of death in IAVI, with 1 study showing that only 24% of the deaths from uncontrollable hemorrhage were attributable to some form of coagulopathy.[6] Controlling exsanguination is therefore the single most important objective if one hopes to avoid death in these patients, yet controlling bleeding in these cases remains a challenge. The most recent military reports suggest that the next evolution in the management of these exsanguinating injuries will be a combination of surgical and endovascular-based modalities.[7,8]

In light of these ongoing developments, we reviewed our contemporary experience with IAVI to attempt to clarify and refine our management strategies and the outcome of these patients.

Methods

We retrospectively reviewed the charts of all patients admitted between January 2011 and December 2014 through the Pietermaritzburg Metropolitan Trauma Service, Pietermaritzburg, South Africa, who were found to have an IAVI during laparotomy for trauma. The data collected included sex, age, mechanism of injury, location and severity of the injury, and admission physiologic parameters, including lactate level. All abdominal vascular injuries were graded with the American Association for the Surgery of Trauma Organ Injury Scale (AAST-OIS) for abdominal vascular injury[9] (Table 1). Other data collected included any concomitant solid-organ injury, duration of hospital stay, admission to the intensive care unit (ICU) and end mortality. Ethics approval for this study and for maintenance of the register was obtained from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal.

Clinical setting

The Pietermaritzburg Metropolitan Trauma Service provides definitive trauma care to the city of Pietermaritzburg, the capital of KwaZulu-Natal province. It also serves as the trauma referral centre for 19 other provincial hospitals within the province. The service manages a high volume of trauma cases. It is pertinent to note the logistical challenges of prehospital medicine in this setting. Much of the catchment areas is rural, and the transfer time to hospital is often much greater than in the European or North American setting. Many patients whose condition is unstable die even before admission to hospital or access to prehospital medicine.

Injury management

The potential for an IAVI exists in all cases of penetrating torso trauma, and a systematic approach is required in this situation. Important clues to the presence of such an injury include the physiologic state of the patient on presentation and the path of the projectile. Patients with penetrating torso trauma whose condition is unstable are expedited to the operating room. In patients whose condition is stable, imaging may be used selectively, and treatment can be individualized according to the findings. At laparotomy a systematic approach is essential. Four-quadrant packing is used to control active bleeding, soiling is mopped up and the bowel eviscerated, and enteric leakage is controlled with packs. Damage-control techniques are implemented,

Table 1. American Association for the Surgery of Trauma Organ Injury Scale for abdominal vascular injury[9]*

Grade I	Unnamed superior mesenteric artery or superior mesenteric vein branches. Unnamed inferior mesenteric artery or inferior mesenteric vein branches. Phrenic artery/vein. Lumbar artery/vein. Gonadal artery/vein. Ovarian artery/vein. Other nonnamed small arterial or venous structures requiring ligation.
Grade II	Right, left or common hepatic artery. Splenic artery/vein. Right or left gastric arteries. Gastroduodenal artery. Inferior mesenteric artery, trunk, or inferior mesenteric vein, trunk. Primary named branches of the mesenteric artery (such as ileocolic artery) or mesenteric vein. Other named abdominal vessels requiring ligation/repair.
Grade III	Superior mesenteric vein, trunk. Renal artery/vein. Iliac artery/vein. Hypogastric artery/vein. Vena cava, infrarenal.
Grade IV	Superior mesenteric artery, trunk. Celiac axis proper. Vena cava, suprarenal and infrahepatic. Aorta, infrarenal.
Grade V	Portal vein. Extraparenchymal hepatic vein. Vena cava, retrohepatic or suprahepatic, aorta, suprarenal, subdiaphragmatic.

*Applicable for extraparenchymal vascular injuries. If the vessel injury is within 2 cm of the organ parenchyma, refer to the specific organ injury scale. Increase 1 grade for multiple grade III or IV injuries involving more than 50% vessel circumference. Downgrade 1 grade if less than 25% vessel circumference laceration for grade IV or V.

and there is no place in this cohort of patients for prolonged definitive management of enteric injuries.

The management of the IAVI follows standard guidelines. If a large central hematoma is recognized, proximal control of the aorta at the hiatus is recommended before the hematoma is explored. If a suprarenal injury is suspected, a combined left and right medial visceral rotation is required to expose this part of the aorta. If the injury is believed to be infrarenal, a right rotation usually suffices. Lateral hematomas are not explored unless there is active bleeding or rapid expansion. Pelvic hematomas are explored selectively. The path of the projectile is delineated to make sure it is away from any major vessels in the pelvis. All nonessential vessels are ligated. Simple venous injuries are repaired and complex ones ligated. Essential arterial injuries are managed with primary repair if possible; if this is not possible, more complex individual solutions are used, including temporary shunting and the use of interposition grafting or extra-anatomic bypass. The primary concern is always the physiologic status of the patient, and this dictates management.

Statistical analysis

Data are reported as mean or median values for continuous variables and proportions for categorical variables. We used the nonparametric Kruskal–Wallis test to assess differences in presenting heart rate, systolic blood pressure and lactate level dependent on AAST-OIS grade. We assessed categorical variables using the χ^2 test. We used a post hoc Dunn test to assess differences between groups.

We assessed concurrent organ injuries and examined their relation with mortality and ICU admission using χ^2 analysis. The 4 most common organ injuries and the single physiologic parameter most associated with death were included in a multiple logistic regression analysis. The dependent variable was death. The statistical significance level was accepted as 0.05 for all analyses. All statistical analysis was performed with the use of R 3.3.3 software (R Foundation).

Results

During the study period, 1283 patients underwent laparotomy for trauma, of whom 110 (8.6%) were found to have an IAVI. Ninety patients (81.8%) were male, and the mean age was 29 years (Table 2). Of the 110 injuries, 98 (89.1%) were penetrating trauma, and 12 (10.9%) were blunt. Of the 98 penetrating trauma cases, 55 were gunshot wounds and 43 were stab wounds. The mean admission physiologic parameters were heart rate 105 beats/min, systolic blood pressure 102 mm Hg and serum lactate level 5 mmol/L.

Arterial injuries

There were 84 arterial injuries in total: renal (21), mesenteric (17), aortic (8), external iliac (7), superior mesenteric (6), inferior mesenteric (6), common iliac (5), splenic (5), hepatic (2), internal iliac (2), sigmoid (2) and, in 1 case each, gonadal, omental and pancreaticoduodenal. Table 3 summarizes the patients' clinical characteristics by AAST-OIS grade. There was a significant difference in heart rate and systolic blood pressure across grade I–IV injuries. The post hoc Dunn analysis revealed this difference to be significant between grade I versus grade III ($p < 0.001$) and between grade III versus grade IV ($p = 0.006$) for systolic blood pressure, and between grade I versus grade IV ($p = 0.02$) for heart rate (Table 4).

The management strategies used in the patients with arterial injuries are summarized in Table 5. Aortic injury was associated with the highest mortality rate, 62%.

Venous injuries

Seventy-four venous injuries were identified: renal (21), inferior vena cava (17), common iliac (11), external iliac (6), internal iliac (4), superior mesenteric (4), inferior mesenteric (3), gonadal (3), portal (2), pelvic (2) and hepatic (1). Of the 17 inferior vena cava injuries, 9 were infrarenal. Table 6 summarizes the patients' outcome by AAST-OIS grade. There was no significant difference in rates of death or ICU admission across AAST-OIS grade for all venous injuries.

Table 2. Demographic and clinical characteristics of patients with intra-abdominal vascular injury

Characteristic	No. (%) of patients* n = 110
Age at presentation, yr; mean ± SD	29 ± 10
Male sex	90 (81.8)
Affected vessel†	
Artery	84 (76.4)
Vein	74 (67.3)
Wound type	
Penetrating	98 (89.1)
Gunshot wound	55 (50.0)
Stab wound	43 (39.1)
Blunt	12 (10.9)
Physiologic parameters on admission	
Heart rate, beats/min; mean ± SD	105 ± 22
Systolic blood pressure, mm Hg; mean ± SD	102 ± 27
Lactate level, mmol/L; mean ± SD	4.7 ± 3.6
Outcome	
Admitted to ICU	57 (51.8)
Died	31 (28.2)
Recovery without ICU admission	22 (20.0)

ICU = intensive care unit; SD = standard deviation.
*Except where specified otherwise.
†In 34 patients, both types of vessel were affected.

Table 3. Clinical characteristics of patients with arterial IAVIs, by AAST-OIS grade

Characteristic	AAST-OIS grade I n = 19	II n = 9	III n = 21	IV n = 19	p value*	Combined arterial injury n = 8	Total n = 68
Heart rate, beats/min; median ± SD	98 ± 27	112 ± 22	106 ± 14	115 ± 20	0.04†	93 ± 24	68
Systolic blood pressure, mm Hg; median ± SD	118 ± 25	96 ± 28	70 ± 22	99 ± 26	< 0.001†	113 ± 31	—
Lactate level, mmol/L; median ± SD	4.7 ± 3.1	3.5 ± 3.8	3.0 ± 1.7	4.4 ± 4.2	0.1†	5.1 ± 5.2	—
No. (%) died	4 (21)	3 (33)	4 (19)	4 (21)	0.8‡	4 (50)	—
No. (%) admitted to ICU	13 (68)	6 (67)	11 (52)	11 (58)	0.7‡	2 (25)	—
Total no. of arteries	19	18	21	26	—	16	84

AAST-OIS = American Association for the Surgery of Trauma Organ Injury Scale; IAVI = intra-abdominal vascular injury; ICU = intensive care unit; SD = standard deviation.

*Statistical tests were performed excluding combined injuries so as to fit the test assumption of nonoverlapping data.

†Kruskal–Wallis test.

‡χ^2 test.

Table 4. Post hoc Dunn analysis between all AAST-OIS groups for arterial IAVIs

Variable; AAST-OIS grade	AAST-OIS grade; p value I	II	III
Systolic blood pressure			
II	0.2	—	—
III	< 0.001	0.05	—
IV	0.12	0.9	0.006
Heart rate			
II	0.1	—	—
III	0.1	0.4	—
IV	0.02	0.9	0.2

AAST-OIS = American Association for the Surgery of Trauma Organ Injury Scale; IAVI = intra-abdominal vascular injury.

Table 5. Management of arterial injuries

Artery	Procedure; no. of injuries: Repaired	Ligated	PTFE graft	RSVG	Embolized	Packed	Total	Death (%)	Admission to ICU (%)
Renal	0	18	0	0	3	0	21	4 (19)	11 (52)
Mesenteric	0	17	0	0	0	0	17	4 (24)	12 (70)
Aorta	7	1	0	0	0	0	8	5 (62)	3 (38)
External iliac	5	1	0	1	0	0	7	2 (29)	3 (43)
Superior mesenteric	2	4	0	0	0	0	6	3 (50)	3 (50)
Inferior mesenteric	0	6	0	0	0	0	6	2 (33)	3 (50)
Common iliac	2	1	1	1	0	0	5	0 (0)	4 (80)
Splenic	0	5	0	0	0	0	5	2 (40)	3 (60)
Hepatic artery	0	1	0	0	0	1	2	1 (50)	1 (50)
Internal iliac	0	0	1	0	1	0	2	0 (0)	0 (0)
Sigmoid	0	2	0	0	0	0	2	0 (0)	1 (50)
Gonadal	0	1	0	0	0	0	1	0 (0)	0 (0)
Omental	0	1	0	0	0	0	1	0 (0)	0 (0)
Pancreaticoduodenal	0	1	0	0	0	0	1	0 (0)	0 (0)
Total	16	59	2	2	4	1	84	—	—

ICU = intensive care unit; PTFE = polytetrafluoroethylene; RSVG = reverse saphenous vein graft.

The management strategies used in the patients with venous injuries are summarized in Table 7. Inferior vena cava injuries had the highest mortality rate, 47%; in most cases (13) of inferior vena cava injury, the patient underwent primary repair.

Arterial and venous injury combined

Combined venous and arterial injuries were found in 34 patients, of whom 11 (32%) died and 21 (62%) were admitted to the ICU.

Concurrent injuries

Concurrent nonvascular injuries were as follows: small bowel (63), large bowel (33), liver (33), kidney (32), stomach (22), pancreas (19), diaphragm (12), duodenum (10), spleen (10), bladder (7) and ureter (4) (Table 8). The injuries associated with the highest mortality rates were of the spleen (60%, p = 0.02) stomach (50%, p = 0.01) duodenum (50%, p = 0.1) and liver (45%, p = 0.008); the lowest mortality rates were associated with ureteric (25%) and renal (25%) injuries. The 4 organ injuries most strongly suggestive of death on the χ^2 test and the physiologic parameter most associated with death (lactate level, Table 9) were included in a multiple logistic regression analysis. Liver injury, large bowel injury, splenic injury and elevated lactate level were all associated with a statistically significantly higher mortality rate (Table 10).

Clinical outcome

Fifty-seven patients (51.8%) required admission to the ICU. Thirty-one patients (28.2%) died; causes included renal dysfunction (25 patients), respiratory (6), intra-abdominal sepsis (4), wound sepsis (4), cardiac (3) and neurologic (3). The remaining patients did not require an ICU stay and had an uneventful postoperative recovery. All 4 patients who had vascular grafts had associated enteric injury. One of these patients, who had a destructive external iliac artery injury, had a prosthetic graft to restore continuity. Graft sepsis and graft failure developed, and the patient ultimately died due to hemorrhage from a septic false aneurysm.

Discussion

Numerous reports over the past half-century have reiterated that IAVIs are associated with a high mortality rate. Our findings suggest that this remains the case. Controlling exsanguination is key to achieving a reduction in death rates

Table 6. Outcome of patients with venous IAVIs, by AAST-OIS grade

Characteristic	AAST-OIS grade I, n = 3	II, n = 1	III, n = 26	IV, n = 31	V, n = 3	p value*	Combined venous injury, n = 5	Total, n = 69
No. (%) died	0 (0)	0 (0)	9 (35)	11 (35)	2 (67)	0.5	2 (40)	—
No. (%) admitted to ICU	2 (67)	1 (100)	15 (58)	4 (14)	1 (33)	0.6	3 (60)	
Total no. of veins	5	6	27	33	3	—	10	74

AAST-OIS = American Association for the Surgery of Trauma Organ Injury Scale; IAVI = intra-abdominal vascular injury; ICU = intensive care unit.
*Fisher exact test; performed excluding combined injuries so as to fit the test assumption of independent samples.

Table 7. Management of venous injuries

Vein	Procedure; no. of veins: Repaired	Ligated	PTFE graft	Packed	Total	Death (%)	Admission to ICU (%)
Renal	2	19	0	0	21	4 (19)	11 (52)
Inferior vena cava.	13	4	0	0	17	8 (47)	9 (53)
Common iliac	6	4	1	0	11	3 (27)	3 (27)
External iliac	2	4	0	0	6	1 (17)	5 (83)
Internal iliac	4	0	0	0	4	3 (75)	1 (25)
Superior mesenteric	0	4	0	0	4	0 (0)	2 (50)
Inferior mesenteric	0	3	0	0	3	0 (0)	2 (67)
Gonadal	0	3	0	0	3	0 (0)	2 (67)
Portal	1	0	0	1	2	2 (100)	0 (0)
Pelvic	0	2	0	0	2	1 (50)	1 (50)
Hepatic	0	0	0	1	1	0 (0)	0 (0)
Total	28	43	1	2	74	—	—

ICU = intensive care unit; PTFE = polytetrafluoroethylene.

following IAVIs, and this represents an ongoing surgical challenge. The methods of surgical ligation and repair, which were pioneered in the military conflicts of the mid to late 20th century, have remained largely unchanged.

Repair remains the only feasible option in aortic injuries; aortic ligation is almost universally fatal.[10] In this cohort of patients, after aortic injury, the highest mortality rate was found for the hepatic (50%), superior mesenteric (50%) and splenic (40%) arteries. All were managed by ligation apart from 1 injury to the mesenteric artery, which was repaired. Almost all cases of actively bleeding renal artery injuries were managed by nephrectomy. If there is a nonexpanding perirenal hematoma, this should be managed conservatively, as opening Gerota's fascia generally results in uncontrolled bleeding, which can be dealt with only by nephrectomy. If conservative management is embarked on, endovascular and endo-urological techniques can be used to salvage the situation once the initial operative management is complete.

Table 8. Distribution and outcome of nonvascular injuries

Injury	No. of patients	Rate of admission to ICU, %	*p* value*	Death rate, %	*p* value*
Small bowel	63	58	0.01	30	0.3
Large bowel	33	70	0.01	45	0.008
Liver	33	52	1.0	45	0.008
Kidney	32	60	0.4	25	0.6
Stomach	22	59	0.4	50	0.01
Pancreas	19	53	0.9	47	0.04
Diaphragm	12	58	0.6	33	0.7
Duodenum	10	70	0.2	50	0.1
Spleen	10	60	0.6	60	0.02
Bladder	7	43	0.6	29	1.0
Ureter	4	25	0.3	25	0.9

ICU = intensive care unit.
*χ^2 test.

Table 9. χ^2 analysis of physiologic parameters as predictors of death

	Outcome; median ± SD		
Parameter	Died $n = 31$	Survived $n = 79$	*p* value
Lactate level, mmol/L	7.5 ± 4.2	3.5 ± 2.6	< 0.001
Systolic blood pressure, mm Hg	89 ± 28	106 ± 25	0.002
Heart rate, beats/min	107 ± 23	104 ± 22	0.4

SD = standard deviation.

Table 10. Multiple logistic regression analysis of factors associated with death

Variable	OR (95% CI)
Elevated lactate level on admission	1.64 (1.34–2.12)
Large bowel injury	8.00 (2.32–32.54)
Liver injury	7.56 (1.98–36.06)
Spleen injury	12.04 (1.92–87.80)
Stomach injury	1.91 (0.51–7.10)

CI = confidence interval; OR = odds ratio.

Inferior vena cava injuries remain highly lethal, as evidenced by our mortality rate of 47%. Although primary repair was the most commonly used approach in our study, ligation is increasingly applied, especially for infrarenal caval injuries.[11,12] There were 17 inferior vena cava injuries in the current series, 4 of which (3 infrarenal and 1 suprarenal) were ligated. All 4 patients had associated enteric injuries, but all survived. Among the 13 cases of inferior vena cava repair, 8 patients (62%) died, all but 1 of whom had associated enteric injury.

The management of iliac artery injuries is extremely challenging, with most cases in the current series undergoing primary repair. One patient with an external iliac artery injury required a prosthetic interposition graft, and in 1 case a bleeding internal iliac artery injury was embolized. Interposition grafting is used in large-calibre vessels where flow must be preserved and has been reported in aortic, superior mesenteric artery, renal and iliac artery injuries.[13–15] Although complex injuries may require an interposition graft, the presence of intra-abdominal sepsis means that these repairs are at high risk for the development of graft sepsis. The consequences of graft failure in this setting are usually catastrophic. The 2 alternatives to an interposition graft are extra-anatomic bypass and a temporary intravascular shunt. However, creating an extra-anatomic bypass is usually not feasible in an injured patient whose condition is unstable. Although the use of temporary intravascular shunts as part of a damage-control strategy has been reported,[16] it has not found widespread use at our institution.

Although exsanguination eclipses coagulopathy as the primary cause of death in IAVI, failure to implement adequate resuscitative and damage-control strategies results in dismal outcomes. This was shown by our parent institution, King Edward VIII Hospital, in Durban, where the mortality rate for caval injuries increased from 35.7% to 88% over a 15-year period 2 decades ago. The increase was attributed to the lack of implementation of damage-control techniques in response to a massive increase in devastating gunshot wounds during a period of great political instability.[17] Since that period, damage-control approaches to IAVIs have gained widespread acceptance in our environment. Our current mortality rate is in keeping with the international and national literature, no doubt largely due to adoption of damage-control approaches.[6]

It is unlikely that we are going to achieve further reductions in mortality rates using exclusively open operative techniques. The most recent military reports suggest that the next evolution in the management of IAVIs will likely be endovascular-based modalities.[18] The advent of these techniques has expanded the scope for nonoperative approaches to IAVIs. Endovascular approaches can be used to arrest hemorrhage through balloon occlusion or embolization, or to repair an injured vessel with an endovascular graft. Embolization is an endovascular option for injuries to small and medium-sized nonessential vessels.[19] In our series, 4 patients underwent embolization (3 of the renal artery and 1 of the inferior internal iliac artery); all survived. Embolization of the internal iliac artery or its branches is generally well tolerated.[20] Although not performed in our analysis, successful embolization of superior mesenteric artery injuries has been reported.[21] The superior mesenteric artery territory is a particularly attractive area for endovascular intervention as it is difficult to surgically access this area. The development of hybrid operating rooms such as the so-called RAPTOR suite (resuscitation with angiography, percutaneous techniques and operative repair) may allow for more seamless integration of open and endovascular approaches in the management of IAVIs. Currently, there is great interest in resuscitative endovascular balloon occlusion of the aorta.[22] This innovation was prompted by the recent military experience, and reports on its use are limited.[23] This technique could be instrumental in facilitating proximal control while allowing endovascular intervention in vessels that are difficult to access without recourse to massive retroperitoneal dissections. The exact place of these techniques is yet to be defined.

Limitations

This was a single-centre experience. For a more thorough analysis, a larger study across multiple centres is required.

Conclusion

Despite the standardization of operative approaches and the implementation of damage-control surgery and resuscitation over the last 50 years, the mortality rate for IAVI remains high. Exsanguination remains the most common cause of death. It is hoped that the ongoing development of endovascular techniques and approaches in the management of these injuries may improve outcomes in the future.

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