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Arterial Trauma of the Limbs and Pelvis: A 6-Year Experience of an Urban Trauma Centre

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Abstract

Aim-Background: Vascular trauma is followed by high morbidity, with iatrogenic injuries showing an increase in incidence during the last decade. The aim of this study is to present the 6-year experience of an urban trauma centre concerning the management of vascular trauma.

Methods: All major arterial injuries of the extremities treated during a 6-year period (08/2008- 08/2014) were retrospectively studied. Arterial injuries of the thorax/abdomen and major venous injuries were not included. All cases were classified into iatrogenic and non-iatrogenic injuries.

Results: Overall, 15 (22%) iatrogenic and 52 (78%) non-iatrogenic injuries were managed. Patients with iatrogenic injuries were older ($P = 0.001$) and mainly female ($P = 0.0002$) compared to those with non-iatrogenic injuries. Orthopedic surgery was responsible for the majority of iatrogenic cases, and motor vehicle accidents accounted for most of the non-iatrogenic cases. Popliteal (36%) and brachial (27%) arteries were the most commonly injured vessels. Almost 10% of patients needed primary/secondary amputation, with injury of a major nerve, bone fracture and extensive soft tissue loss being the major risk factors. Endovascular treatment was selected for the majority of iatrogenic injuries, although open repair was the primary management for non-iatrogenic cases. All grafts remain patent after a mean follow-up of 3.6 years.

Conclusions: Iatrogenic and non-iatrogenic arterial injuries of the extremities show different characteristics concerning epidemiology and management, which should be taken into consideration by the treating physician. Injury of major adjacent structures remains a major risk factor for amputation.

Key words: *Vascular trauma; extremities; iatrogenic injuries; non-iatrogenic injuries*

Introduction-Aim

Vascular trauma is observed in 0.2-4% of all trauma cases, with 64% to 82% resulting from penetration [1]. Moreover, during the last decade, the incidence of iatrogenic vascular injuries (IVIs) appears to be on the increase [2] with a reported incidence of up to one-third of all vascular trauma cases [3]. This could be ascribed to the increasing number of percutaneous arterial interventions [4]. However, not all fatalities after IVI are attributable to the injury itself, and almost half of the injuries have been considered avoidable [5].

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Vascular trauma in the geriatric population leads to higher mortality [6], with almost 50% of all cases located in the extremities [7]. Upper extremity arterial injuries are more common in civilian populations; lower extremity vascular injuries are more frequent among military personnel. Lower extremity artery injuries, in particular, may have a significant impact on the patient's outcome and can lead to limb loss or death if not properly managed [7].

Consequently, the aim of this study is to present the experience of a level I urban trauma centre as far as the management of major vascular injuries of the extremities is concerned. Furthermore, the different characteristics of iatrogenic and non-iatrogenic injuries are highlighted and discussed.

Methods

All data referring to patients with major arterial injuries of the extremities treated during a 6-year period (August 2008 – August 2014) at a level I urban trauma centre were retrospectively collected and analyzed. Patients were divided into two major groups based on the aetiology of the injury: *iatrogenic and non-iatrogenic arterial injuries*. The multidisciplinary team of surgeons included trauma surgeons responsible for the overall care of the patient, orthopedic surgeons who addressed bony and soft tissue injury, vascular surgeons who conducted vascular procedures, and plastic surgeons who managed tissue defects. Patients with major vascular trauma of the thorax, head or the abdomen were excluded from this study.

The type and mechanism of injury, location of injured vessel and therapeutic strategy were also evaluated. The presence of a concomitant osseous fracture, nerve or vein injury, or a significant soft tissue wound was also recorded. Other preoperative factors, such as early shock or metabolic acidosis, were not documented. Outcome data recorded for this analysis included major complications, in-hospital mortality (including deaths in the emergency department), and major primary or secondary amputation (in cases of revascularization failure) during the initial hospitalization. The mean follow-up of patients was 3.6 ± 1.5 years.

Comparisons between groups were performed using the *t test* for continuous variables and x^2 and *Fisher* exact tests for categorical variables as appropriate. Statistical significance was defined at a P value of <0.05. Multivariate logistic analysis between the two studied groups of patients was conducted to identify independent associations between various risk factors and limb loss (amputation). However, power analysis was not performed.

Results

Overall, 67 patients with major arterial injuries of the extremities were included in this study. Of these injuries, 15 (22%) were non-iatrogenic and 52 (78%) iatrogenic. The mean age of all patients was 45 years, with those suffering from iatrogenic injuries being older than those with non-iatrogenic injuries (67 vs. 41 years of age; P = 0.001). Overall, the majority of patients were male (63%). However, most of those with iatrogenic injuries were female (12/15) while those with non-iatrogenic injuries were mostly male (39/52) (P = 0.0002).

Iatrogenic injuries included trauma caused during orthopedic surgery procedures (11/15) and endovascular interventions (4/15). Non-iatrogenic injuries comprised trauma caused by different mechanisms: gunshot wound (5/52), motor vehicle/cycle accident (30/52), fall (5/52), and industrial accident (12/52). Most of the aforementioned injuries were located in the lower extremities (47%); injuries to the upper extremities (42%) and pelvis (11%) were reported in fewer patients. (Table 1)

Regarding the vessels injured, the popliteal artery (36%) and brachial artery (27%) were the most commonly injured arteries. In some cases, more than one artery was injured in the same extremity (e.g. tibial and peroneal artery), although no case was observed with combined upper and lower extremities vascular trauma. A great percentage of vascular injuries were accompanied by injury of adjacent structures such as major nerves (47%) and bones (40%). Adjacent structures were injured in patients with non-iatrogenic injuries more often than in those with iatrogenic injuries (P = 0.003).

Regarding the therapeutic strategy, primary or secondary amputation was necessary in seven patients (10%). Multivariate analysis showed that the co-existence of other injuries was associated with primary or secondary limb loss.

Table 1. *Distribution of vascular injuries and cause of injury (n = 67)*

Location	
- Upper extremities	28 (42%)
- Lower extremities	31 (47%)
- Upper + lower extremities	0
- Pelvis	8 (11%)
Type of vessel	
- Brachial artery	18 (27%)
- Radial artery	10 (15%)
- Common femoral artery	3 (4.5%)
- Profunda femoris artery	3 (4.5%)
- Superficial femoral artery	12 (18%)
- Popliteal artery	24 (36%)
- Anterior/posterior tibial artery	10 (15%)
- Peroneal artery	9 (14%)
- Branches of the iliac arteries	6 (9%)
Concomitant injuries	
- Major nerve injuries	31 (47%)
- Osseous fracture	27 (40%)
- Major nerve + osseous fracture	20 (30%)
Cause of injury	
Iatrogenic	15/67 (22%)
- Endovascular interventions	4
- Orthopedic surgery	11
Non-iatrogenic	52/67 (78%)
- Gunshot wound	5
- Motor vehicle/motor cycle accident	30
- Fall	5
- Industrial accident	12

Major nerve injury (RR = 17.34; 95% CI [1.03-291.96]; p = 0.048), bone fracture (RR = 21.96; 95% CI [1.31-369.28]; p = 0.03), and extensive soft tissue loss (RR = 24.87; 95% CI [1.78 – 398.34]; p = 0.018) were major risk factors for amputation.

Endovascular management was conducted in 80% of iatrogenic cases compared to 12% of non-iatrogenic injuries (P = 0.0001). In all cases of iatrogenic injuries treated with open surgery (3/3), a synthetic graft was used. However, a venous graft was applied in most of non-iatrogenic cases treated with open procedure (35/46) (P = 0.0063). The primary patency of all grafts used remains 100% during follow-up (mean follow-up period: 2.8 years). Regarding major complications, one patient died due to severe concomitant injuries (no difference between groups), and six patients (9%) presented reperfusion syndrome after graft placement and revascularization that was managed conservatively with success (iatrogenic: one, non-iatrogenic: five, p = 0.0016). Finally, two patients (both non-iatrogenic cases) suffered from post-revascularization compartment syndrome that was managed with early fasciotomy (no difference between groups). (Table 2)

Discussion

This study underlines the importance of multidisciplinary management of vascular trauma patients as the majority of our cases were also associated with injury of other adjacent structures. Additionally, our results highlight the differences between iatrogenic and non-iatrogenic arterial trauma as concerns characteristics and therapeutic management. Finally, specific risk factors for amputation are underlined, and the role of damage control is evaluated.

As shown in our study, patients with non-iatrogenic injuries represent the majority of cases managed for vascular trauma at an urban level I trauma centre. Arterial injuries are more common among young men and are caused mainly by blunt trauma associated with motor vehicle or motorcycle accidents [8]. In our series, popliteal and brachial artery injuries were the most frequent, although femoral vessels are among the most commonly reported injured vascular structures, comprising nearly 70% of all arterial injuries [9]. Regarding upper extremity trauma, equivalent demographics, mechanisms of injury, surgical management approaches and successful hospital outcomes have been demonstrated between penetrating and blunt injuries as well as between proximal and distal arterial injuries [10,11].

In our series, 22% of all patients presented with iatrogenic arterial injuries. Iatrogenic vascular injuries constitute about 10% of cases in most series [12]; however, the incidence shows an increasing trend given that more endovascular procedures, such as cardiac catheterization, are being performed routinely. In a similar retrospective study by De'Ath et al., 71% of patients presented with iatrogenic trauma [13]. Most of our iatrogenic cases were the result of orthopedic procedures, the majority of which did not require an amputation or open surgical management. In our study, injury of adjacent structures showed a significantly lower incidence after iatrogenic procedures which concurs with published data in the literature [14]. Endovascular treatment was the preferred choice with optimal outcome. Vascular trauma occurs relatively infrequently in association with general orthopedic trauma, but may be noted more often in injuries involving joint dislocations and areas in which vascular structures are tethered at the fracture site [15].

Regarding limb salvage, the rate of primary or secondary amputation in our series reached almost 10%, all of which cases were of non-iatrogenic origin. According to the literature, isolated lower extremity trauma with vascular injury carries a nearly 10% rate of mortality or limb loss [16]. Mortality is associated with penetrating mechanism and early shock, likely resulting from pre-hospital proximal arterial haemorrhage [17]. In this study, the presence of either major nerve or bone injury was strongly associated with limb loss. This concurs with other reports [18-20] in which the presence of these factors was also associated with eventual amputation. Absolute indications for primary amputation are documented ischaemia exceeding six hours with a non-viable limb and extensive nerve disruption [7]. However, in a study by Kauvar et al., the authors conclude that neither nerve nor soft tissue injury predict limb loss but may result in delayed amputation not captured in this

Table 2. *Type of treatment and outcome data (n = 67)*

Iatrogenic injuries (n = 15)	
- Endovascular treatment	12/15 (80%)
- Venous graft interposition	0
- Synthetic graft interposition	3/3 (20%)
Non-iatrogenic injuries (n = 52)	
- Endovascular treatment	6/52 (12%)
- Venous graft interposition	35/52 (67%)
- Synthetic graft interposition	6 /52(11%)
- Primary amputation	5/52 (9%)
Main outcomes	
Death	1/67 (1.5%)
Primary or secondary amputation	7/67 (10%)
Primary patency of grafts	44/44 (100%)
Reperfusion syndrome	6/67 (9%)
Compartment syndrome	2/67 (3%)

acute outcomes dataset [16]. In a multivariate analysis of 550 lower extremity arterial injuries, Hafez et al. [21] identified the following five independent risk factors for amputation: occluded graft, combined above-knee and below-knee injury, tense compartment at presentation, arterial transection, and associated compound fracture. There are several mangled extremity severity score (MESS) systems available to help make a decision about amputation, but none has 100% sensitivity [22].

Regarding damage control, 90% of our cases were managed with successful primary arterial reconstruction. However, intraluminal shunting and aggressive treatment of haemodynamic instability, among other factors, seem to be beneficial in achieving reasonable outcomes in trauma centres with limited resources or no vascular surgeons [23]. In a stable patient, primary arterial repair is preferred, although temporary shunting should be selected for unstable patients in order to save both the life and limb of the patient [24]. Additionally, other factors such as concomitant vein and nerve injury, associated long bone trauma, soft tissue loss, and fasciotomy site management greatly influence the outcome [22]. Although damage control has proved its value for injuries during wartime or in the battlefield and is supported by many authors [24], recent data also show promising results in urban trauma centres [26].

The majority of non-iatrogenic arterial trauma was managed at our centre using open surgery and venous graft placement. Patients with non-occlusive injuries may be managed non-operatively, although surgery is warranted when lesions persist or worsen [22]. End-to-end anastomosis is preferred if it can be performed without undue tension; however, typically, this is not possible if more than 2 cm of vessel is lost [27]. The conduit of choice is usually the reversed autogenous saphenous vein from the contralateral leg [7,27]. When osseous structures are injured, temporary shunting or permanent artery repair typically precedes orthopedic stabilization to restore limb circulation, as minimizing ischaemia duration is critical to overall outcome [7]. At our centre, revascularization always preceded orthopedic surgery too.

Endovascular repair should be used selectively and should not replace open repair, which remains the gold standard of management for extremity traumatic arterial injuries, especially for mixed type injuries of higher severity. However, endovascular treatment was selected for most of the iatrogenic vascular injuries in our series. Other authors support the utilization of endovascular techniques for iatrogenic trauma [28,29], and especially after elective orthopedic surgery [30,31]. It is also the gold standard for the treatment of pelvic arterial haemorrhage associated with pelvic fractures as it provides direct identification of sources of bleeding [32,33]. Although endovascular surgery involving the extremities is extremely challenging from a technical standpoint, the appropriate choice of access site, careful technique, and selective use of closure devices may reduce the incidence of such complications after endovascular procedures [34].

As concerns postoperative complications, reperfusion syndrome was observed in 9% of cases, although death and compartment syndrome were less common. Hafez et al. consider that it is more relevant to identify signs of severe ischaemia such as compartmental hypertension or loss of sensation or function than to rely on the absolute ischaemia time for predicting outcome [21]. The sequelae of compartment syndrome are thought to be due to impairment of the microcirculation within the compartment leading to ischaemia and irreversible tissue damage [35]. Therefore, early fasciotomy should be performed without hesitation in patients with long ischaemic periods and in those with combined arterial/venous injury [36]. Compartment syndrome has itself been linked to delay in the restoration of blood flow, presence of associated venous injuries, lower extremity fractures, intra-operative blood loss, multiple arterial injury, and preoperative pulse deficit [35].

In conclusion, non-iatrogenic injuries of the extremities should be managed by a multidisciplinary team in an urban level I trauma centre in order to achieve optimal outcomes, with temporary or permanent vascular management always preceding reconstruction of other injured structures. Major nerve, bone or soft tissue damage are primary risk factors for amputation. The majority of iatrogenic injuries can be successfully managed using endovascular techniques, while open surgery is preserved for non-iatrogenic mixed type injuries yielding satisfying results.

Ethical Approval - Informed Consent

The authors declare that the study has been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Also all patients gave their written informed consent prior to their inclusion in the study.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. Caps MT. The epidemiology of vascular trauma. Semin Vasc Surg 1998;11:227-31.

2. Rudström H, Bergqvist D, Ogren M, Björck M. Iatrogenic vascular injuries in Sweden. A nationwide study 1987-2005. Eur J Vasc Endovasc Surg 2008;35:131-8.
3. Giswold ME, Landry GJ, Taylor LM, Moneta GL. Iatrogenic arterial injury is an increasingly important cause of arterial trauma. Am J Surg 2004;187:590-2.
4. Lazarides MK, Tsoupanos S, Georgopoulos S, Chronopoulos A, Arvanitis DP, Doundoulakis NJ. Incidence and patterns of Iatrogenic arterial injuries. A decade's experience. J Cardiovasc Surg 1998;39:281–5.
5. Rudström H, Bergqvist D, Björck M. Iatrogenic vascular injuries with lethal outcome. World J Surg 2013;37:1981-7.
6. Konstantinidis A, Inaba K, Dubose J, et al. Vascular trauma in geriatric patients: a national trauma databank review. J Trauma 2011;71:909-16.
7. Franz RW, Shah KJ, Halaharvi D, Franz ET, Hartman JF, Wright ML. A 5-year review of management of lower extremity arterial injuries at an urban level I trauma center. J Vasc Surg 2011;53:1604-10.
8. Nemati M, Nosratinia H, Goldust M, Raghifar R. Arterial injuries in extremities trauma, angiographic findings. Pak J Biol Sci 2013;16:145-7.
9. Carrillo EH, Spain DA, Miller FB, Richardson JD. Femoral vessel injuries Surg Clin North Am 2002;82:49–65.
10. Franz RW, Goodwin RB, Hartman JF, Wright ML. Management of upper extremity arterial injuries at an urban level I trauma center. Ann Vasc Surg 2009;23:8-16.
11. Franz RW, Skytta CK, Shah KJ, Hartman JF, Wright ML. A five-year review of management of upper-extremity arterial injuries at an urban level I trauma center. Ann Vasc Surg 2012;26:655-64.
12. Wani ML, Ahangar AG, Ganie FA, Wani SN, Wani NU. Vascular injuries: trends in management. Trauma Mon 2012;17:266-9.
13. De'Ath HD, Galland RB. Iatrogenic and non-iatrogenic vascular trauma in a district general hospital: a 21-year review. World J Surg 2010;34:2363-7.
14. Brown GD, Swanson EA, Nercessian OA. Neurologic injuries after total hip arthroplasty. Am J Orthop (Belle Mead NJ) 2008;37:191-7.
15. Winkelaar GB, Taylor DC. Vascular trauma associated with fractures and dislocations. Semin Vasc Surg 1998;11:261-73.
16. Kauvar DS, Sarfati MR, Kraiss LW. National trauma databank analysis of mortality and limb loss in isolated lower extremity vascular trauma. J Vasc Surg 2011;53:1598-603.
17. Trellopoulos G, Georgiadis GS, Aslanidou EA, et al. Endovascular management of peripheral arterial trauma in patients presenting in hemorrhagic shock. J Cardiovasc Surg (Torino) 2012;53:495-506.
18. Heis HA, Bani-Hani KE, Elheis MA. Overview of extremity arterial trauma in Jordan. Int Angiol 2008;27:522-8.
19. Moniz MP, Ombrellaro MP, Stevens SL, Freeman MB, Diamond DL, Goldman MH. Concomitant orthopedic and vascular injuries as predictors for limb loss in blunt lower extremity trauma. Am Surg 1997;63:24-8.
20. Fowler J, Macintyre N, Rehman S, Gaughan JP, Leslie S. The importance of surgical sequence in the treatment of lower extremity injuries with concomitant vascular injury: A meta-analysis. Injury 2009;40:72-6.
21. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. J Vasc Surg 2001;33:1212-9.
22. Dua A, Desai SS, Shah JO, et al. Outcome predictors of limb salvage in traumatic popliteal artery injury. Ann Vasc Surg 2014;28:108-14.
23. Ratnayake A, Samarasinghe B, Bala M. Outcomes of popliteal vascular injuries at Sri Lankan war-front military hospital: case series of 44 cases. Injury 2014;45:879-84.
24. Oliver JC, Bekker W, Edu S, Nicol AJ, Navsaria PH. A ten year review of civilian iliac vessel injuries from a single trauma centre. Eur J Vasc Endovasc Surg 2012;44:199-202.
25. Rasmussen TE, Clouse WD, Jenkins DH, Peck MA, Eliason JL, Smith DL. The use of temporary vascular shunts as a damage control adjunct in the management of wartime vascular injury. J Trauma 2006;61:8-12; discussion 12-5.
26. Oliver JC, Gill H, Nicol AJ, Edu S, Navsaria PH. Temporary vascular shunting in vascular trauma: a 10-year review from a civilian trauma centre. S Afr J Surg 2013;51:6-10.
27. Frykberg ER. Popliteal vascular injuries. Surg Clin North Am 2002;82:67–89.
28. Xiong J, Liu M, Guo W, et al. A retrospective study on endovascular management of iatrogenic vascular injuries. Vascular 2012;20:65-71.
29. Simmons JD, Walker WB, Gunter Iii JW, Ahmed N. Role of endovascular grafts in combined vascular and skeletal injuries of the lower extremity: a preliminary report. Arch Trauma Res 2013;2:40-5.
30. Rossi G, Mavrogenis A, Angelini A, Rimondi E, Battaglia M, Ruggieri P. Vascular complications in orthopaedic surgery. J Long Term Eff Med Implants 2011;21:127-37.
31. Mavrogenis AF, Rossi G, Rimondi E, Ruggieri P, Mercuri M. Embolisation for vascular injuries complicating elective orthopaedic surgery. Eur J Vasc Endovasc Surg 2011;42:676-83.
32. Niola R, Pinto A, Sparano A, Ignarra R, Romano L, Maglione F. Arterial bleeding in pelvic trauma: priorities in angiographic embolization. Curr Probl Diagn Radiol 2012;41:93-101.
33. Hauschild O, Aghayev E, von Heyden J, et al. Angioembolization for pelvic hemorrhage control: results from the German pelvic injury register. J Trauma Acute Care Surg 2012;73:679-84.
34. Tonnessen BH. Iatrogenic injury from vascular access and endovascular procedures. Perspect Vasc Surg Endovasc Ther 2011;23:128-35.
35. Topal AE, Eren MN, Celik Y. Lower extremity arterial injuries over a six-year period: outcomes, risk factors, and management. Vasc Health Risk Manag 2010;6:1103-10.
36. Aydın H, Okçu O, Dural K, Sakıncı U. Management of community-based shotgun injuries of the extremities: impact of emergent vascular repair without angiography. Ulus Travma Acil Cerrahi Derg 2011;17:152-8.