Journal of Acute Disease

Original Article

doi: 10.4103/2221-6189.330741 jadweb.org

Endovascular management of traumatic arterial emergencies: A single center retrospective study

Erdem Birgi[1]✉, Hasanali Durmaz[1], Kürşat Güreşci[2], Onur Ergun[1], Gülşen Çığsar[3], Burhan Kurtuluş[4], Baki Hekimoğlu[1]

[1]*Department of Radiology, Diskapi Yildirim Beyazit Training and Research Hospital, University of Health Sciences, Ankara, Turkey*

[2]*Department of Radiology, Ömer Halisdemir University Training and Research Hospital, Niğde, Turkey*

[3]*Department of Emergency Medicine, Diskapi Yildirim Beyazit Training and Research Hospital, University of Health Sciences, Ankara, Turkey*

[4]*Department of Orthopaedic Surgery, Diskapi Yildirim Beyazit Training and Research Hospital, University of Health Sciences, Ankara, Turkey*

ABSTRACT

Objectives: To present our experience in delivering endovascular therapies for emergent vascular traumas with various vascular structures.

Methods: Between September 2013 and February 2018, patients who underwent endovascular intervention due to penetrating, blunt and iatrogenic arterial traumas were analyzed, retrospectively. Demographic data, trauma site, mechanism of injury, angiographic findings or arterial injury patterns, treatment methods, and outcomes were recorded.

Results: A total of 30 patients were included. The mean age of patients was 39 years (range: 15-87 years). Arterial trauma locations were in the compressible area with a rate of 43% (n=13) and in the noncompressed area with a rate of 57% (n=17). Mechanisms of injuries were blunt [53% (n=16)], penetrating [17% (n=5)], and iatrogenic [30% (n=9)]. The most common indication for endovascular treatment was blunt noncompressible injury (n=12). Methods used for treatment were stent-graft (46%, n=14) and coil embolization (54%, n=16). Immediate success was obtained in all procedures. The mean follow-up duration was 5 months (range: 1-12 months).

Conclusions: Endovascular treatments performed in traumatic arterial emergencies are effective and minimally invasive with very low complication rates even in hemodynamically unstable patients.

KEYWORDS: Arteries; Emergencies; Endovascular procedures; Trauma

1. Introduction

In the last two decades, endovascular techniques play an important role in the management of elective or emergent vascular injuries. Diagnostic angiography of vascular injuries are used with an increasing frequency in the evaluation of trauma patients, such as embolization in pelvic trauma, while covered stent is used in current endovascular treatments for blunt aortic injuries. With the evolution of new guide wires, catheters, stents, and increased experience, catheter-based treatment modalities have been developed[1].

Significance

Endovascular techniques play an important role in the management of elective or emergent vascular injuries. Our study shows that endovascular interventional treatment methods can be performed with low complication rates and high technical success in various traumatic arterial emergencies, even in hemodynamically unstable patients.

✉To whom correspondence may be addressed. E-mail: ebirgi@gmail.com

How to cite this article: Birgi E, Durmaz H, Güreşci K, Ergun O, Çığsar G, Kurtuluş B, et al. Endovascular management of traumatic arterial emergencies: A single center retrospective study. J Acute Dis 2021; 10(6): 233-241.

Article history: Received 19 June 2021; Revision 9 November 2021; Accepted 16 November 2021; Available online 30 November 2021

According to National Trauma Data Bank, Reuben *et al.* reported that endovascular management of emergent vascular injuries increased from 2% to 8% from 1994 to 2003[2]. Noncompressible torso hemorrhage (NCTH) is the second most common cause of death in traumas, even the most common cause of preventable deaths[3]. Endovascular treatments are becoming popular in the control of hemorrhage due to their minimally invasive nature. Endovascular interventions in pelvic arterial trauma and thoracic aortic injuries have become the main treatment and are used with an increasing frequency for other vascular injuries[4].

In this study, applications and effectivity of covered stent and coil embolization treatments of various vascular traumatic emergencies were evaluated.

2. Patients and methods

2.1. Patients

The patients with clinical and radiological proven vascular injuries and hemorrhage or with proven vascular pathology after diagnostic angiography, who needed immediate treatment and admitted to our Interventional Radiology Unit between September 2013 and February 2018 were included in this study.

2.2. Ethical consideration

Ethics committee approval was obtained from our institution (Decision date and number: 02.04.2018-48/17). Patients were

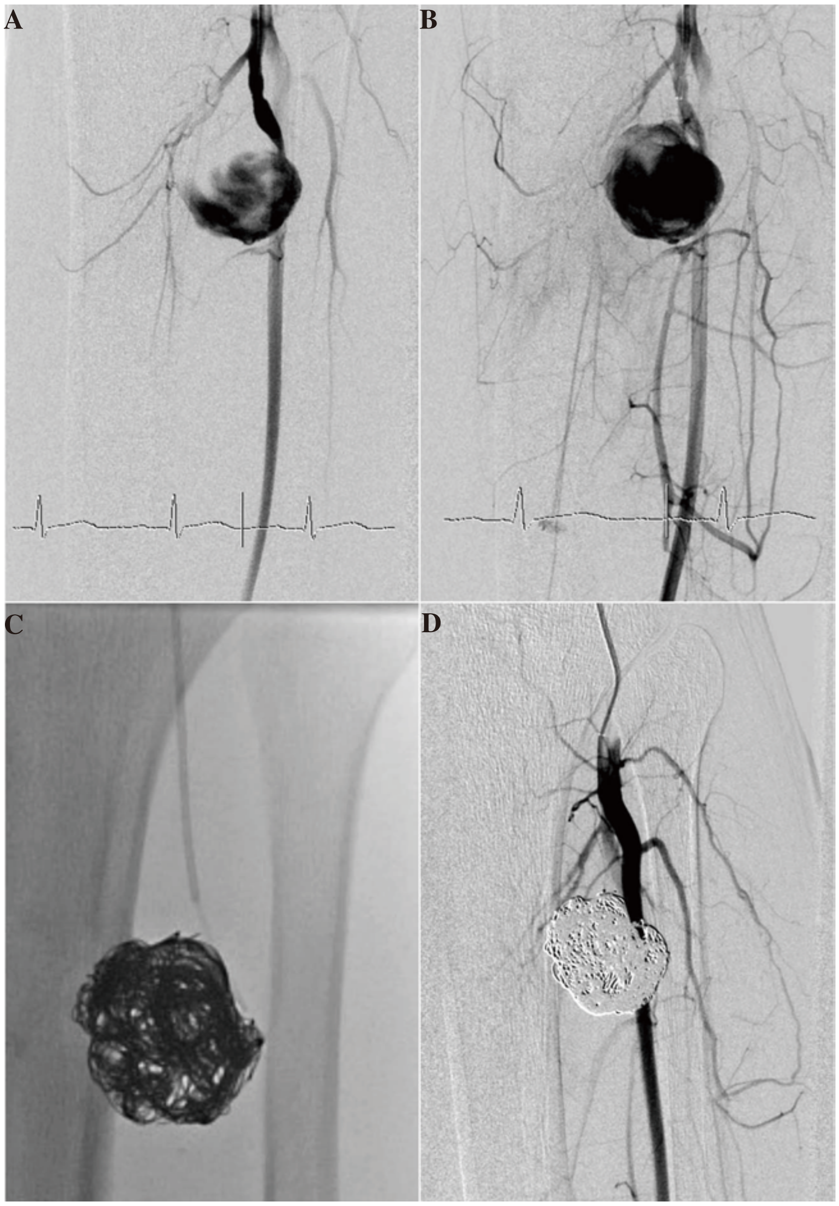

Figure 1. A 33-year-old male patient had a pseudoaneurysm with a diameter of 3 cm in the tibioperoneal trunk secondary to gunshot wound injury (A, B). The pseudoaneurysm was evaluated by Doppler US and there was no proper access for percutaneous thrombin injection. The pseudoaneurysm was selectively catheterized and embolized with coils (C, D).

informed about the treatment and the post-treatment process. Written consent was obtained from patients. The study was conducted in accordance with the Declaration of Helsinki.

2.3. Data collection

Demographic data of patients, traumas site (compressible or noncompressible areas), mechanism of the injury (blunt, penetrating, iatrogenic), angiographic findings or arterial injury patterns (extravasation, pseudoaneurysm, transection, dissection, rupture, arteriovenous fistula), treatment methods (stent-graft or coil embolization), and outcomes were retrospectively recorded.

2.4. Perioperative management

All patients were hemodynamically stable, and there was no additional trauma that required any intervention. Clinical findings, Doppler ultrasonography, contrast-enhanced computed tomography, or computed tomography angiography (CTA) were used in the diagnosis of the injury. Definite diagnosis was obtained through digital subtraction angiography. Imaging methods and laboratory tests were used to test the level and pattern of the arterial

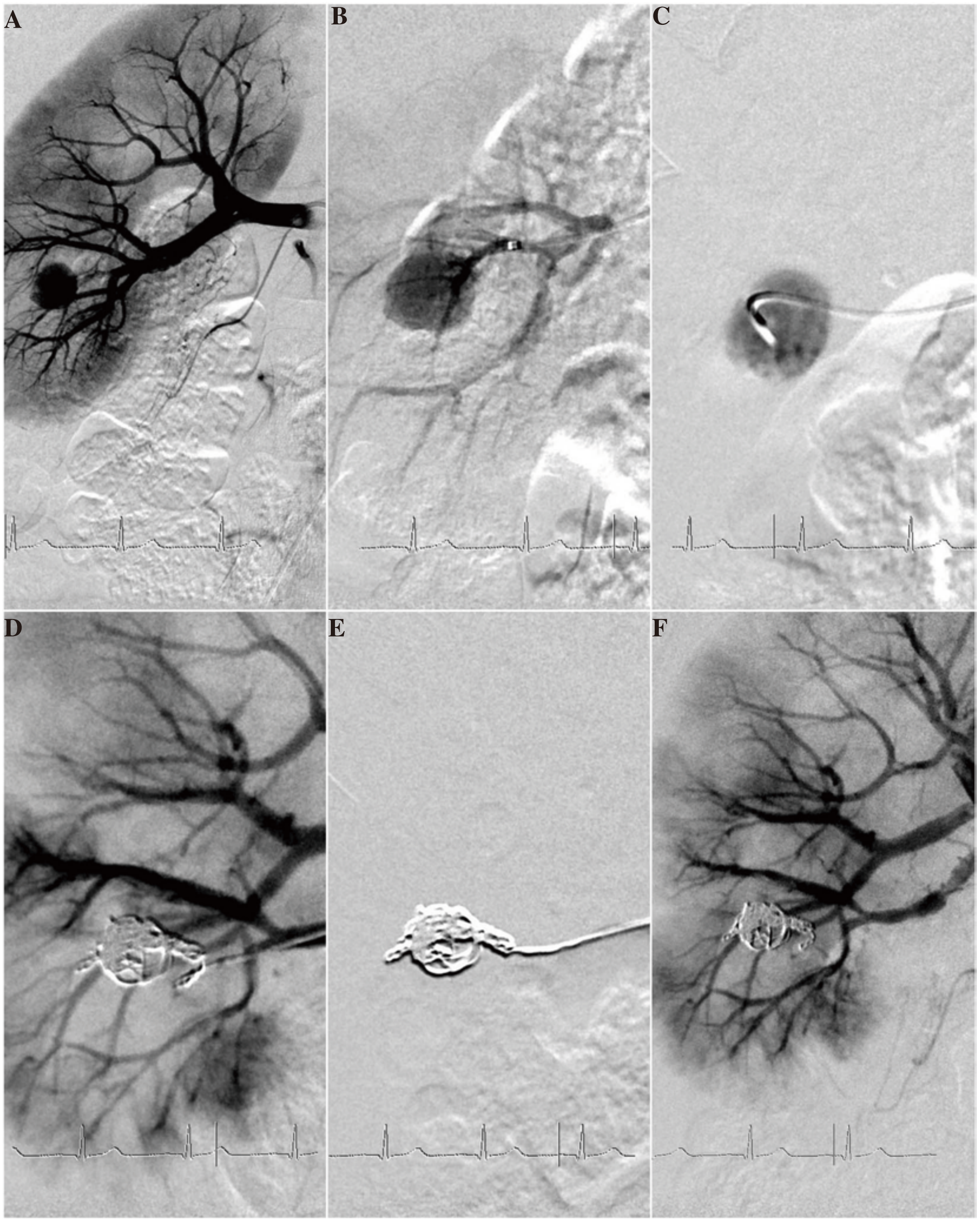

Figure 2. A 54-year-old male patient with renal pseudoaneurysm following blunt trauma was admitted for embolization. Pseudoaneurysm formation sized in 12 mm×9 mm was observed in the localization of the arcuate arteries (A, B). After advancing the microcatheter (C), coils were used for embolization and the pseudoaneurysm was excluded from the circulation. Control angiography shows no filling of the aneurysm (D-F).

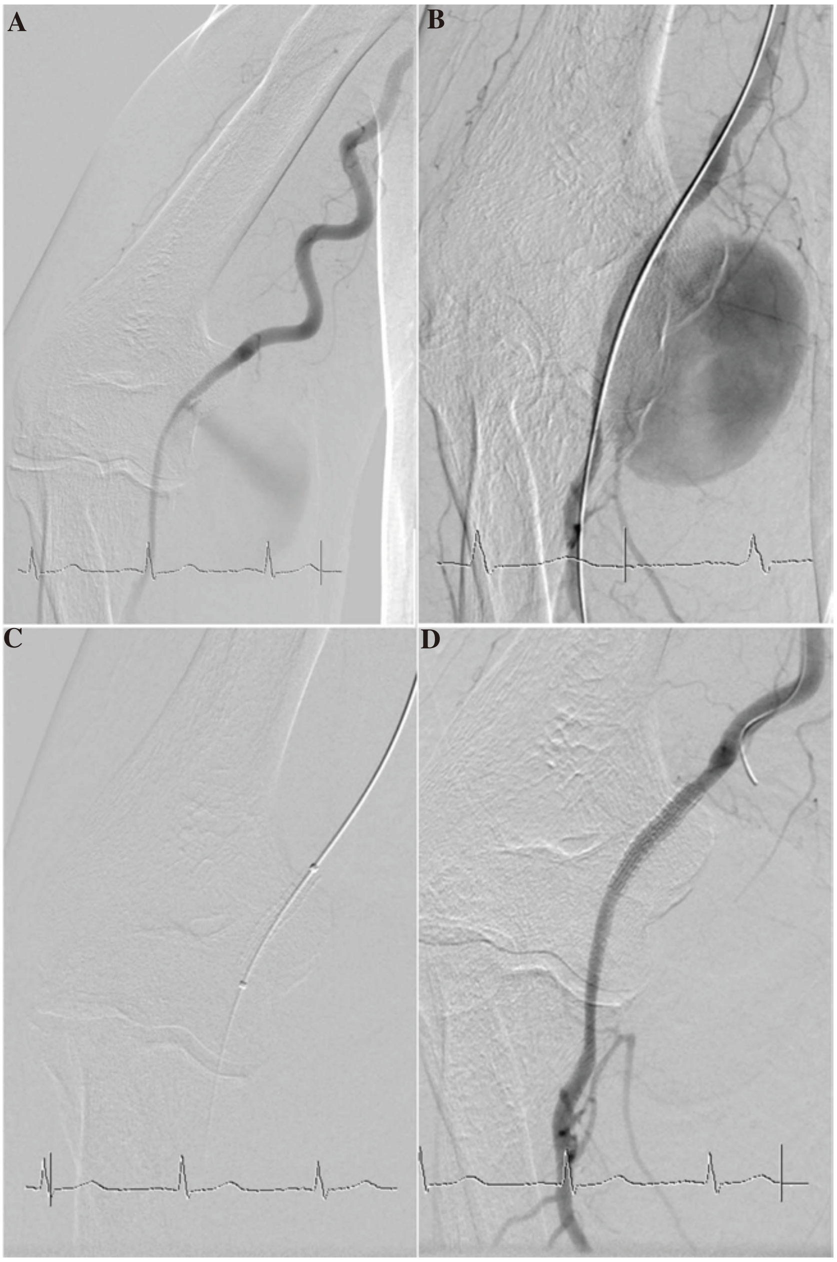

Figure 3. Digital subtraction angiography was performed in a 74-year-old male patient after iatrogenic trauma during the vascular intervention. Pseudoaneurysm with a size of 60 mm×50 mm was observed in the distal segment of the right brachial artery (A). The pseudoaneurysm was passed by catheter and guidewire manipulations (B). A 25 mm×5 mm sized stent-graft was placed into the brachial artery lumen to exclude the pseudoaneurysm (C). Control angiograms reveal the patency of the lumen and exclusion of the aneurysm (D).

lesion before the procedure. Attention was paid to patients with international normalized ratio<1.5 and platelet value>50.000/mm^3. All procedures were performed in the angiography unit with a road mapping feature. During each procedure, 70 IU/kg of heparin was administered to achieve the optimal activated clotting time and patients were anticoagulated with heparin for 24 h. After the procedure, patients with stent-grafts were prescribed daily 75 mg clopidogrel for at least 6 months and daily 100 mg acetylsalicylic acid lifelong to prevent stent thrombosis and thromboembolism. Patients were sent to the intensive care unit for hemodynamic monitoring and followed up with clinical findings and Doppler US or CTA if necessary. There was no need to perform angiography in the follow-up.

2.5. Endovascular interventions

Arterial access was provided by the seldinger technique under local anesthesia based on US guidance from the right or left common femoral artery. A 4-6 French (Fr) introducer sheath was placed and 4-5 Fr diagnostic catheters (Cordis Corp., Zug, Switzerland) were advanced to obtain a non-selective arteriogram. Micro-catheter was used for super-selective embolization (Progreat 2.7 Fr; Terumo

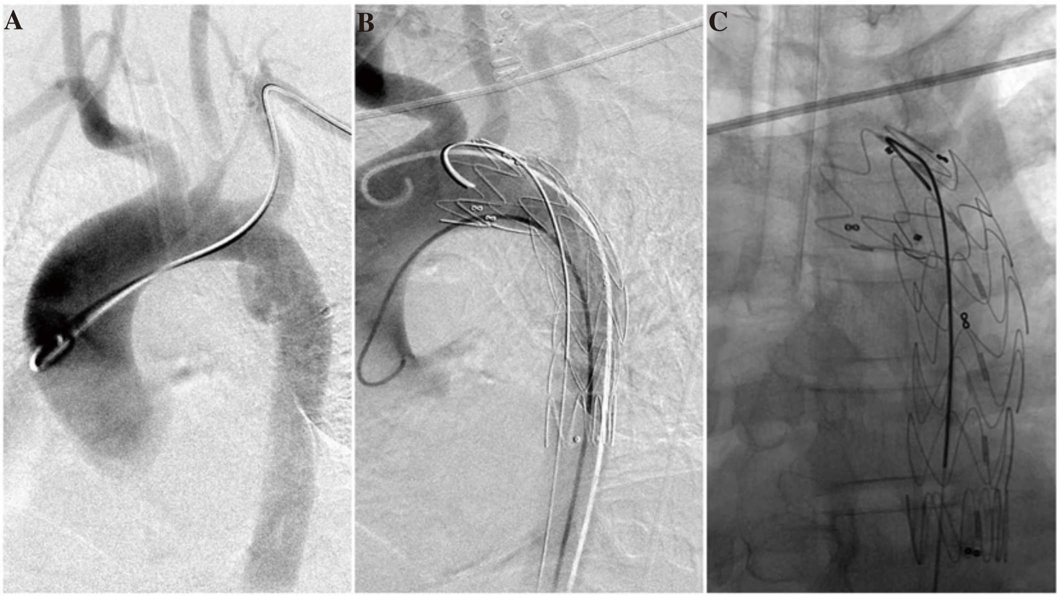

Figure 4. A 43-year-old male patient with a transection in the proximal descending aorta after a motor vehicle accident, arterial access was provided by femoral cut-down under general anesthesia. Arcus aortogram *via* brachial artery revealed a pseudoaneurysm at the proximal thoracic aorta (A). Aneurysm was excluded from the circulation after the aortic stent-graft deployment (B, C).

Medical Corp., Somerset, NJ, USA). The lesions were embolized with metallic detachable coils. Control angiograms were used to exclude the lesion from the circulation (Figure 1 and Figure 2).

Arterial access for the treatment of thoracic and abdominal aortic pathologies with stent-grafts was provided by right-sided femoral cut-down under general anesthesia. The contralateral femoral artery was performed for the pelvic or extremity lesions. A 6-10 Fr short or long introducer sheath was placed in the femoral artery. 4-5 Fr diagnostic catheters (Cordis Corp., Zug, Switzerland) were advanced into the aorta to obtain non-selective arteriograms. Covered stent-graft (Viabahn VBX, W.L. Gore ass., Flagstaff, AZ, USA) or self-expandable Wallgraft (Boston Scientific, San Francisco CA, USA) was placed in appropriate size for the region of the pathology. In the control images, the proper placement of the stent-graft was verified, and the lesion was excluded from the circulation (Figure 3 and Figure 4).

2.6. Statistical analysis

Statistical analyses were performed using SPSS 25.0 software (IBM Corp.). Mean and minimum and maximum values were used as descriptive statistics for numerical data whereas numbers and percentages were used for categorical data.

3. Results

A total of 30 patients were included. The mean age of the patients included in the study was 39 years (range: 15-87 years). Mechanisms of injury were blunt 53% (*n*=16), penetrating 17% (*n*=5) and iatrogenic 30% (*n*=9). The etiology in all blunt traumas was motor vehicle accidents. Penetrating traumas were caused by gunshot wounds, and iatrogenic traumas were developed after an interventional procedure or surgery. The vascular traumas depending on the location of the lesion were 43% (*n*=13) in the compressible areas and 47% (*n*=17) in the noncompressed areas.

Among patients with trauma in uncompressed areas, one patient had a dissection in the intrathoracic common carotid artery (CCA) after blunt trauma and was treated by endovascular stent-graft. A covered stent was preferred in a patient after inadvertent subclavian

Table 1. Demographic data, type of trauma, trauma site, arterial injury patterns, and treatment.

Items	Number	%
Gender		
Female	8	27
Male	22	73
Trauma site		
Compressible	13	43
Noncompressible	17	57
Injury type		
Blunt	16	53
Penetrating	5	17
Iatrogenic	9	30
Arterial injury pattern		
Transection	3	8
Dissection	3	8
Extravasation	12	33
Pseudoaneurysm	12	33
Rupture	4	11
AVF	2	5
Perforation	1	2
Treatment type		
Stent-graft	14	47
Coil embolization	16	53

AVF: Arteriovenous fistula.

arterial insertion of a central venous catheter. Three patients had transection in descending thoracic aorta (DTA) due to blunt trauma, and then endovascular aortic stent placement was performed. One patient had a rupture of abdominal aortic aneurysm after blunt trauma, and the aneurysm was excluded from the circulation with stent-grafts, but the patient died owing to multiorgan failure in the first month. One patient underwent iatrogenic dissection in the common iliac artery and was treated with stent-graft immediately. Pseudoaneurysm (PA), arteriovenous fistula, and extravasation in the branches of the internal iliac artery developed in three patients after blunt or penetrating trauma. These patients were treated with hydrocoils through super-selective catheterization. In five patients, PA and extravasation developed after blunt or iatrogenic trauma in the renal artery branches and were treated with coil embolization. Two patients had extravasation of hepatic arteries after blunt trauma and were treated with coil embolization.

Among patients with traumas in the compressible areas, one patient had dissection and PA in the internal carotid artery (ICA) after blunt trauma and was treated with a covered stent-graft. In one patient, extravasation in the costal cervical artery was detected iatrogenically after surgery, and leakage was treated with coil embolization. In one patient, ischemia was developed due to iatrogenic PA in the brachial artery and treated with coil embolization. Graft rupture was detected in a patient who had brachial graft after blunt trauma and the covered stent was placed urgently. One patient had PA in the superficial femoral artery (SFA) after blunt trauma and was treated with coil embolization. Two patients had extravasation in the SFA due to iatrogenic and penetrating trauma and were treated with stent-graft. Two patients had PA and extravasation after penetrating trauma in the deep

Table 2. Trauma site, injury type, pattern, and preferred endovascular treatment.

Trauma site	Number	Age, years	Injury type	Injury pattern	Treatment
Compressible					
Neck					
ICA	1	43	Blunt	Dissection/PA	Stent-graft
ECA	1	75	Iatrogenic	Extravasation	Coil emb
Upper Limb					
Brachial	1	74	Iatrogenic	PA/ischemia	Coil emb
Brachial graft	1	24	Blunt	Graft rupture/extravasation	Stent-graft
Lower Limb					
SFA	3	22	Blunt	PA	Coil emb
		73	Iatrogenic	Extravasation	Stent-graft
		27	Penetrating	Extravasation	Stent-graft
DFA	2	41	Penetrating	PA	Coil emb
		16	Penetrating	Extravasation	Coil emb
CFA	2	77	Blunt	Extravasation	Stent-graft
		72	Iatrogenic	PA/ischemia	Stent-graft
Crural	1	33	Penetrating	PA	Coil emb
Femoral graft	1	36	Iatrogenic	Graft rupture	Stent-graft
Non compressible					
Thoracic outlet					
Intrathoracic CCA	1	43	Blunt	Dissection	Stent-graft
Subclavian	1	55	Iatrogenic	Perforation	Stent-graft
Thorax					
DTA	3	55	Blunt	Transection	Stent-graft
		43	Blunt	Transection	Stent-graft
		48	Blunt	Transection	Stent-graft
Abdominal, major					
AAA	1	87	Blunt	Aneurysm rupture	Stent-graft
CIA	1	57	Iatrogenic	Dissection	Stent-graft
IIA	3	15	Blunt	PA	Coil emb
		37	Penetrating	Extravasation	Coil emb
		79	Blunt	PA/AVF	Coil emb
Abdominal, branch					
Renal	5	23	Blunt	PA/AVF/extravasation	Coil emb
		44	Blunt	Rupture	Coil emb
		38	Iatrogenic	PA/extravasation	Coil emb
		47	Iatrogenic	PA/extravasation	Coil emb
		54	Blunt	PA	Coil emb
Hepatic	2	62	Blunt	Extravasation	Coil emb
		48	Blunt	Subcapsular extravasation	Coil emb

PA: pseudoaneurysm; AVF: arteriovenous fistula; CCA: common carotid artery; ICA: internal carotid artery; ECA: external carotid artery; SFA: superficial femoral artery; DFA: deep femoral artery; CFA: common femoral artery; AAA: abdominal aortic artery; DTA: descending thoracic artery; CIA: common iliac artery; IIA: internal iliac artery; Emb: embolization.

femoral artery (DFA) and were treated with coil embolization. One patient had extravasation in the common femoral artery after blunt trauma and stent-graft was placed. In one patient, a giant PA developed due to high cannulation above the inguinal ligament and resulted in distal ischemia, upon this emergent stent-graft was performed. In one patient, PA in the crural arteries due to penetrating trauma was treated with endovascular coil embolization. In one patient, iatrogenic femoral graft rupture was excluded from the circulation with a covered stent.

Arterial injury patterns or angiographic findings were extravasation (33%), pseudoaneurysm (33%), rupture (11%), transection (8%), dissection (8%), arteriovenous fistula (5%) and perforation (2%). The most common indication for endovascular treatment was blunt noncompressible injury (n=12). Treatment types were stent-graft (47%, n=14) and coil embolization (53%, n=16). Immediate success was obtained in all procedures (100%). All patients were hemodynamically stable, and there was no additional traumas that require intervention. Mean follow-up time 5 months (range: 1-12 months). There was no procedure-related complication. Patients' demographic data, type of trauma, regions of trauma, arterial injury patterns, and treatments are shown in Table 1 and Table 2.

4. Discussion

In this study, arterial vascular traumas in various compressible or noncompressible areas in 30 patients due to blunt, penetrating, and iatrogenic etiology treated with endovascular methods were evaluated retrospectively. Since the last decades, there has been an increase in the use of endovascular techniques in approach to vascular trauma, especially in noncompressible torso hemorrhage. Branco *et al.* using National Trauma Data Bank data reported the increase in the use of endovascular techniques and lower mortality rates in blunt and penetrating traumas with the comparison of the open surgery and endovascular cohort groups between 2002 and 2010[5]. Faulconer *et al.* used the American Association for the Surgery of Trauma Prospective Observational Vascular Injury Trial database in their study and demonstrated high utilization of endovascular therapies, associated with the decreased need for blood transfusion and improved survival rates[6]. In our study, immediate success was obtained with no need for blood transfusion post-processing.

The definitions and management of NCTH were published by Morrison in 2012. In their definitions of NCTH is a trauma that is in one of four anatomic regions (thoracic, solid organ, axial vessel, pelvic fracture), including hemorrhagic shock, and needs immediate surgery for bleeding control. Hemorrhagic shock was not present in patients included in the study, but there was an indication of immediate surgical intervention[4].

In this study, compressible areas were also included. Vascular traumas were 43% (n=13) in the compressible areas, 57% (n=17) in the non-compressed areas, and mechanisms of the injuries were blunt 53% (n=16), penetrating 17% (n=5) and iatrogenic 30% (n=9). Faulconer *et al.* reported the type of injury as 49% of blunt, 40% of penetrating, and 11% of mixed. As in our study, the most common traumas in the cohort group were blunt traumas[6]. The reason for the low penetrating trauma in this group may be the choice of traditional surgery in penetrating trauma. Arterial injury patterns or angiographic findings were extravasation (33%), pseudoaneurysm (33%), rupture (11%), transection (8%), dissection (8%), arteriovenous fistula (5%) and perforation (2%). In the study of Faulconer *et al.*, arterial injury patterns were transection (36.7%), partial transection or flow-limiting defect (24.8%), pseudoaneurysm (11.8%), and occlusion (10.1%).

Covered stents in smaller diameters are commercially available and can be used in pseudoaneurysms or dissections in both blunt and penetrating traumas. Du Toit *et al.* examined the series of penetrating carotid injuries in zone Ⅰ and zone Ⅲ treated with a stent graft for ten years. The technical success rate in 19 patients was 100% within 30 d after the procedure[7]. In our study, one patient had a dissection in the zone Ⅰ CCA segment, and one patient had dissection and PA in zone Ⅲ ICA due to blunt trauma and was treated with self-expandable covered stent-grafts.

Surgical treatment of the external carotid artery (ECA) injuries is relatively simple and the internal maxillary artery embolization is a well-known treatment method in nasal bleeding. Post-traumatic ECA embolization is well defined in the literature, and transcatheter embolization is an attractive treatment option in these patients[8].

Implantation of the percutaneous central venous catheter into the brachiocephalic artery inadvertently is particularly suitable for endovascular treatment. Catheter withdrawal and external compression have a high complication rate. Guilbert *et al.* reported a case series and literature review about inadvertent catheterization of the arteries. Fifteen of 24 (62.5%) and 7 of 7 (100%) patients with carotid and subclavian artery cannulation showed complication rates of 7.1% in patients treated with surgical exploration and 0% with endovascular management. Injuries in zone Ⅰ of the neck, intrathoracic arteries, and the subclavian arteries are preferentially managed percutaneously when large-bore catheters are inadvertently placed[9]. In our study stent-graft was preferred in the management of the inadvertent catheterization of the subclavian artery.

Recently, endovascular repair became a first-line treatment option for blunt descending thoracic aortic injury (BTAI). In multiple series with short- and mid-term follow-up, thoracic endovascular aortic repair shows a favorable alternative to open repair for traumatic aortic injuries, and many studies have shown that mortality and paraplegia rates are reduced with endovascular repair of BTAI. Therefore, the latest clinical practice guidelines published by the Society for Vascular Surgery have reported that endovascular repair of traumatic thoracic aortic injuries should be preferred instead of open surgical repair or non-operative treatment[10-12]. In our study, three patients had transection in DTA after blunt trauma, and implantation of endoprostheses was performed.

Mortality rates of the patients with hemodynamically unstable pelvic fractures are high. In the absence of life-threatening hemodynamic instability and no arterial lesion, transient nonselective embolization of both internal iliac arteries can be performed. The success rate in arterial embolization of pelvic fractures is 80%-100%. Pelvic angiography and embolization are recommended in the event of arterial contrast extravasation, regardless of the patient's hemodynamic status[13]. In the series of Cherian *et al.*, the internal iliac artery was the second most common artery to embolize. All patients were treated with embolization and did not require a second embolization[14]. In our series, PA, AVF, and extravasation in IIA were developed in 3 patients after blunt or penetrating trauma. These patients were treated with hydrocoils through super-selective catheterization.

More than 80% of patients with blunt liver damage can be treated nonoperatively. Arterial embolization is the preferred procedure in hemodynamically stable patients with markedly active bleeding on CT. Although haemodynamic instability shows the need for operative treatment, recent studies have shown that arterial embolization can be performed effectively in hemodynamically unstable patients with a success rate of 93%[15]. In the study of Cherian *et al.*, hepatic injuries accounted for 42% of all injuries and in all cases, super-selective embolization of the hepatic artery was performed with success and none of them required surgical intervention[14]. In our study, two patients had extravasation of hepatic arteries after blunt trauma and were treated with super-selective coil embolization.

Arterial embolization of the renal artery is increasingly accepted for the treatment of active bleeding without surgical exploration, and surgical intervention is needed only 5% to 10% of the patients. Hemodynamically unstable patients with active extravasation of intravenous contrast material require urgent intervention; however, the guidelines are still controversial about the treatment method, whether surgical exploration or angioembolization[16]. Shoobridge *et al.* reported that these injuries could now be managed with embolization[17]. In a series of hemodynamically unstable patients with grade Ⅴ injuries; 100% technical and clinical success were reported without further intervention[18]. In our study, 5 patients with PA and extravasation developed after blunt or iatrogenic trauma in the renal artery branches treated with coil embolization, and there were no complication and need of additional intervention. Common iliac and external iliac artery dissections, lacerations, and pseudoaneurysms can be easily treated with covered stents. Iliac and femoral vessel injuries often require abdominal examination depending on the degree of hematoma[19-20]. White *et al.* performed a prospective multi-institutional trial to evaluate covered stents in vascular traumas. Compared with historical managements, endovascular treatments had a high technical success rate (94%), benefit in early mortality, and reduction in adverse events[19]. The majority of vascular traumas in the extremities can be controlled by tamponade and the limbs tolerate longer ischemia times of 4 to 6 h, thus giving time to address other life-threatening injuries. Complete tears in proximal vessels can be treated with open surgery while vessel thrombosis, intimal deterioration, and partial lacerations might be treated with endovascular techniques[21]. Both penetrating and blunt traumatic lesions were successfully treated with covered stents in common, superficial femoral arteries and brachial artery[19,22,23]. The injuries in the tibial and peroneal vessels can be embolized if they are associated with active bleeding, pseudoaneurysms, or arteriovenous fistulas. In the presence of superficial pseudoaneurysms, ultrasound-guided thrombin injection can be performed[19]. In our study, a covered stent was preferred in rupture and extravasation due to proximal brachial and superficial femoral artery injuries, whereas PA in the brachial artery and superficial artery, coil embolization was preferred. Two patients had PA and extravasation at DFA, and coil embolization was performed to exclude multiple feeders. One patient had PA in the crural arteries after penetrating trauma, and PA was excluded with coil embolization.

The major limitation of our study is its retrospective nature. Furthermore, the follow-up was limited. Multicenter larger prospective series with long-term follow-up are needed.

In conclusion, endovascular treatments performed in arterial traumatic emergencies are effective and minimally invasive with lower complication risks even in hemodynamically unstable patients.

Conflict of interest statement

The authors report no conflict of interest.

Authors' contributions

All authors contributed equally to this article.

References

[1] Oyeniyi BT, Fox EE, Scerbo M, Tomasek JS, Wade CE, Holcomb JB. Trends in 1029 trauma deaths at a level 1 trauma center: Impact of a bleeding control bundle of care. *Injury* 2017; **48**(1): 5-12.

[2] Reuben BC, Whitten MG, Sarfati M, Kraiss LW. Increasing use of endovascular therapy in acute arterial injuries: analysis of the National Trauma Data Bank. *J Vasc Surg* 2007; **46**(6): 1222-1226.

[3] Kauvar DS, Wade CE. The epidemiology and modern management of traumatic hemorrhage: US and international perspectives. *Crit Care* 2005; **9**(5): 1-9.

[4] Morrison JJ, Rasmussen TE. Noncompressible torso hemorrhage: a review with contemporary definitions and management strategies. *Surg Clin North Am* 2012; **92**(4): 843-858.

[5] Branco BC, DuBose JJ, Zhan LX, Hughes JD, Goshima KR, Rhee P, et al. Trends and outcomes of endovascular therapy in the management of

civilian vascular injuries. *J Vasc Surg* 2014; **60**(5): 1297-1307.

[6] Faulconer ER, Branco BC, Loja MN, Grayson K, Sampson J, Fabian TC, et al. Use of open and endovascular surgical techniques to manage vascular injuries in the trauma setting: A review of the American Association for the Surgery of Trauma Prospective Observational Vascular Injury Trial registry. *J Trauma Acute Care Surg* 2018; **84**(3): 411-417.

[7] du Toit DF, Coolen D, Lambrechts A, Odendaal JV, Warren BL. The endovascular manage ment of penetrating carotid artery injuries: Long-term follow-up. *Eur J Vasc Endovasc Surg* 2009; **38**(3): 267-272.

[8] Sclafani A, Sclafani S. Angiography and transcatheter arterial embolization of vascular injuries of the face and neck. *Laryngoscope* 1996; **106**(2 Pt 1): 168-173.

[9] Guilbert MC, Elkouri S, Bracco D, Corriveau MM, Beaudoin N, Dubois MJ, et al. Arterial trauma during central venous catheter insertion: Case series, review and proposed algorithm. *J Vasc Surg* 2008; **48**(4): 918-925.

[10] Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair or endo vascular stent graft in blunt traumatic thoracic aortic injuries: Results of an American Association for the Surgery of Trauma Multicenter Study. *J Trauma* 2008; **64**(3): 561-570.

[11] Tang GL, Tehrani HY, Usman A, Katariye K, Otero C, Perez E, et al. Reduced mortality, paraplegia, and stroke with stent graft repair of blunt aortic transections: a modern meta-analysis. *J Vasc Surg* 2008; **47**(3): 671-675.

[12] Lee WA, Matsumura JS, Mitchell RS, Farber MA, Greenberg RK, Azizzadeh A, et al. Endovascular repair of trau matic thoracic aortic injury: clinical practice guidelines of the Society for Vascular Surgery. *J Vasc Surg* 2011; **53**(1): 187-192.

[13] Cullinane DC, Schiller HJ, Zielinski MD, Bilaniuk JW, Collier BR, Como J, et al. Eastern Association for the Surgery of Trauma practice management guidelines for hemorrhage in pelvic fracture-update and systematic review. *J Trauma* 2011; **71**(6): 1850-1868.

[14] Cherian M, Kalyanpur T, Murali KS, Garg A, Munde Y, Yadav A, et al. Safety and effectiveness of transarterial embolization for blunt abdominal injuries: A multicenter study with review of literature. *J Clin Interv Radiol* 2016; **1**(1): 13-19.

[15] Monnin V, Sengel C, Thony F, Bricault I, Voirin D, Letoublon C, et al. Place of arterial embolization in severe blunt hepatic trauma: A multidisciplinary approach. *Cardiovasc Intervent Radiol* 2008; **31**(5): 875-882.

[16] McGuire J, Bultitude MF, Davis P, Koukounaras J, Royce PL, Corcoran NM. Predictors of outcome for blunt high grade renal injury treated with conservative intent. *J Urol* 2011; **185**(1): 187-191.

[17] Shoobridge JJ, Corcoran NM, Martin KA, Koukounaras J, Royce PL, Bultitude MF. Contemporary management of renal trauma. *Rev Urol* 2011; **13**(2): 65-72.

[18] Saour M, Charbit J, Millet I, Monnin V, Taourel P, Klouche K. Effect of renal angioembolization on posttraumatic acute kidney injury after high-grade renal trauma: A comparative study of 52 consecutive cases. *Injury* 2014; **45**(5): 894-901.

[19] White R, Krajcer Z, Johnson M, Williams D, Bacharach M, O'Malley E. Results of a multicenter trial for the treatment of traumatic vascular injury with a covered stent. *J Trauma* 2006; **60**(6): 1189-1195.

[20] Tsai FC, Wang CC, Fang JF, Lin PJ, Kao CL, Hsieh HC, et al. Isolated common iliac artery occlusion secondary to atherosclerotic plaque rupture from blunt abdominal trauma: Case report and review of the literature. *J Trauma* 1997; **42**(1): 133-136.

[21] Wolma FJ, Larrieu AJ, Alsop GC. Arterial injuries of the legs associated with fractures and dislocations. *Am J Surg* 1980; **140**(6): 806-809.

[22] Risberg B, Lonn L. Management of vascular injuries using endovascular techniques. *Eur J Surg* 2000; **166**(3): 196-201.

[23] Lonn L, Delle M, Karlstrom L, Risberg B. Should blunt arterial trauma to the extremities be treated with endovascular techniques? *J Trauma* 2005; **59**(5): 1224-1227.