Traumatic arterial injuries: endovascular management

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Objective
The purpose of this study is to evaluate the efficacy of endovascular management of traumatic arterial injuries.
Patients and methods
We conducted our prospective study at Vascular Surgery Department and Radiology Department, Zagazig University Hospitals, Egypt, and intervention Radiology Department, Alnoor Specialist Hospital, Makkah, Saudi Arabia, from January 2015 to March 2019. Seventeen interventions were performed. The mean age was 39±3.6 years (range, 27–49 years), and 13 (76.5%) patients were males. The site of arterial injuries included superficial femoral artery in seven (41.2%) patients, deep femoral artery in one (5.9%) patient, one of the branches of internal iliac artery in five (29.4%) patients, anterior division of right hepatic artery in one (5.9%) patient, and subclavian artery in three (17.6%) patients. The injuries were extravasation in seven (41.2%) patients, pseudoaneurysm in five (29.4%) patients, and arteriovenous fistula in five (29.4%) patients.
Results
Initial success was achieved in 15 (88.2%) patients. We failed in two (11.8%) patients who were converted to open surgery. Nine covered stents were deployed, gelfoam embolization in one patient, microparticles embolization in two patients (successful in one patient and failed in the other in whom vascular plug was used), and coil embolization in three patients. Early complications occurred in four patients (extravasation in one patient, puncture site hematoma in two patients, and partially occlusive thrombus/spasm of deep femoral artery in one patient). Late complications occurred in two patients in the form of stent graft occlusion who underwent short bypass. The median follow-up time was 15 months (range, 5–24 months). Mean intervention-free period was 6.5 months.
Conclusion
Endovascular management of arterial injuries in hemodynamically stable patients can be a good alternative to open surgery in anatomic regions that are difficult to access and unfit patients for major surgery with possibility of massive blood loss.

Keywords:
arterial, endovascular, injuries

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Introduction

Arterial injuries mostly result from penetrating injuries, which include gunshot wounds and stab wounds, or iatrogenic injury, and they are in the form of transection, pseudoaneurysm, arteriovenous fistula (AVF), or bleeding. In addition; blunt trauma, which includes motor vehicle collisions and pedestrians hit by motor vehicles, may lead to pelvic fracture and active bleeding [1].

Open surgical management of such injuries may be very difficult owing to inaccessibility of these arterial lesions especially when injuries occur in major arteries; moreover, pseudoaneurysms and AVFs distort the local anatomy, thereby increasing the difficulty of open surgical management. Hemodynamically stablized patients can be treated by endovascular techniques [2].

The continuous advancement in the field of endovascular intervention allowed it to be recognized as an effective tool for such patients. In acute trauma with active arterial bleeding, the mainstay of endovascular intervention is to stop bleeding. Regarding the injury type and site, there are many endovascular options. For end arteries, selective embolization can stop bleeding with minimal tissue loss [3]. Embolic agents are temporary or permanent. Gelfoam is the commonest temporary agent used in acute trauma. Permanent agents include microparticles, coils, and vascular plugs. In nonend arteries, endovascular options also include front and

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back door arterial embolization in relatively small arteries or deployment of a covered stent to seal the site of injury while keeping patency in larger arteries. Early exclusion of pseudoaneurysm and closure of AVF is recommended because arterial rupture and venous hypertension carry high risk of morbidity and mortality. The principal line of treatment is deployment of a covered stent across the origin of the pseudoaneurysm or AVF [4].

Patients and methods

After taking approval of local institutional review board. We conducted our prospective study at Vascular Surgery Department and Radiology Department, Zagazig University Hospitals, Egypt, and Intervention Radiology Department, Alnoor Specialist Hospital, Makkah, Saudi Arabia, from January 2015 to March 2019. Our patients underwent history taking, physical examination, laboratory investigations, and computed tomographic angiography.

Inclusion criteria

Stabilized and resuscitated patients with inaccessible injuries, distorted anatomy of the injured area, contaminated wounds, AVFs, pseudoaneurysms with neck diameter more than 3 mm, or major medical comorbidities were included.

Exclusion criteria

The following were the exclusion criteria:

(1) Patients with venous injuries.
(2) Patients with major arterial injuries and greater hemodynamic instability.
(3) Associated injuries endangering the patient life.

All patients provided informed consent for undergoing the procedure and agreed to the use of the contrast material. Some cases were performed in angio suite and some in the operating theater, with the patients prepared for surgical management if needed.

Endovascular technique

Computed tomographic angiography was reviewed to determine the site and type of injury and to prepare necessary materials, for example, sheath, catheters, the suitable embolic agent, or covered stent. Right common femoral artery was mostly used as the access except if near to the lesion. Arterial puncture was done under US guidance to ensure proper location and avoid injured segment. Sheath length and diameter was decided based on the location of the injured artery and embolic material that would be used. Diagnostic catheters, for example, pigtail, cobra or vertebral, were used depending on the anatomy of the traumatized artery. This is followed by selective angiography.

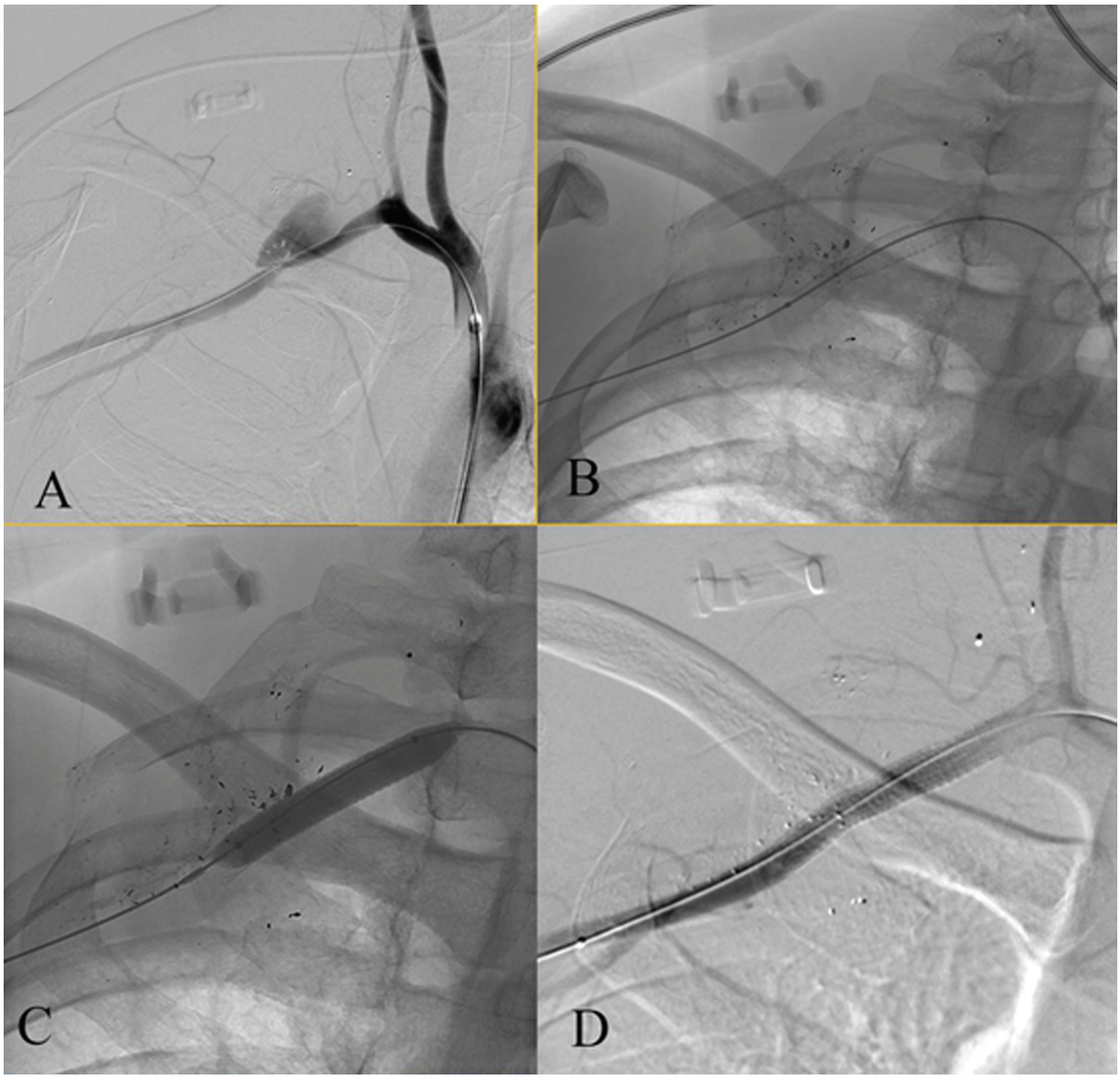
In medium-sized and large arteries, covered stents were used to seal the site of injury, for example, subclavian artery (SCA) (Fig. 1) and superficial femoral artery (SFA) (Fig. 2). Viabahn stent graft (W.L. Gore & Associates Inc., Flagstaff, Arizona, USA) was used because of its low profile. Stent graft diameter usually exceeded the artery's diameter by 1–2 mm, whereas the length was the shortest possible length that can do the job. Temporary occlusion of a bleeding arterial branch of internal iliac artery (IIA) was done by injection of gelfoam (Curaspon) (Curamedical, Assendelft, the Netherlands) (Fig. 3).

Permanent occlusion of a bleeding end artery was done by injection of polyvinyl alcohol (PVA) microparticles (Boston Scientific, Cork, Ireland), for example, internal pudendal artery (Fig. 4). The size of microparticles (range, 250–1000 μm) was selected based on the size of bleeding artery. Coils were another option especially for pseudoaneurysms, for example. pseudoaneurysm of a branch of the anterior division of IIA (Fig. 5) and pseudoaneurysm of anterior division of the right hepatic artery (Fig. 6). The size and shape of coils were selected according to the vessel's size and morphology. Oversizing by 10–20% was used. We used detachable coils (Interlock-18 fibered IDC; Boston Scientific) or fibered pushable coils (Multi-Loop-18, Complex Helical-18, and Vortex Diamond-18; Boston Scientific and Azur-35; MicroVention Inc., Tustin, California, USA). Microparticles and coils were delivered with microcatheters, for example, Renegade Hi-Flo, Direxion (Boston Scientific), Repar-18 (ev3, Irvine, California, USA), or Maestro (Merit Medical Systems Inc., South Jordan, Utah, USA).

Vascular plugs were used in bleeding end-arteries. Plugs provided rapid closure of the arteries and were used to rapidly occlude the bleeding artery, especially in less hemodynamically stable patients, or in conjunction with microparticles for one of the branches of IIA (Fig. 7). Amplatzer-Vascular plug 4 (AGA Medical Corporation, Plymouth, Massachusetts, USA) was used with 10–20% oversizing. In each case, a completion angiography was done to ensure complete exclusion of the injured artery and to exclude other complications, for example, thrombosis or occlusion of the parent artery.

Technical success was considered when the intervention was finished with completion angiography showing

Figure 1



A 25-year-old man exposed to a gunshot wound in the right shoulder region. (a) Right brachiocephalic angiography shows an active contrast extravasation from the right subclavian artery. (b, c) A 7 mm×5 cm VIABHAN (W.L. Gore & Associates Inc.) self-expandable covered stent was deployed across the ruptured segment followed by 7-mm balloon inflation. Fracture of the second rib (arrow) and the opaque bullet fragment are noted. (d) Completion angiography shows complete sealing without extravasation from the injured segment with preservation of the right vertebral artery.

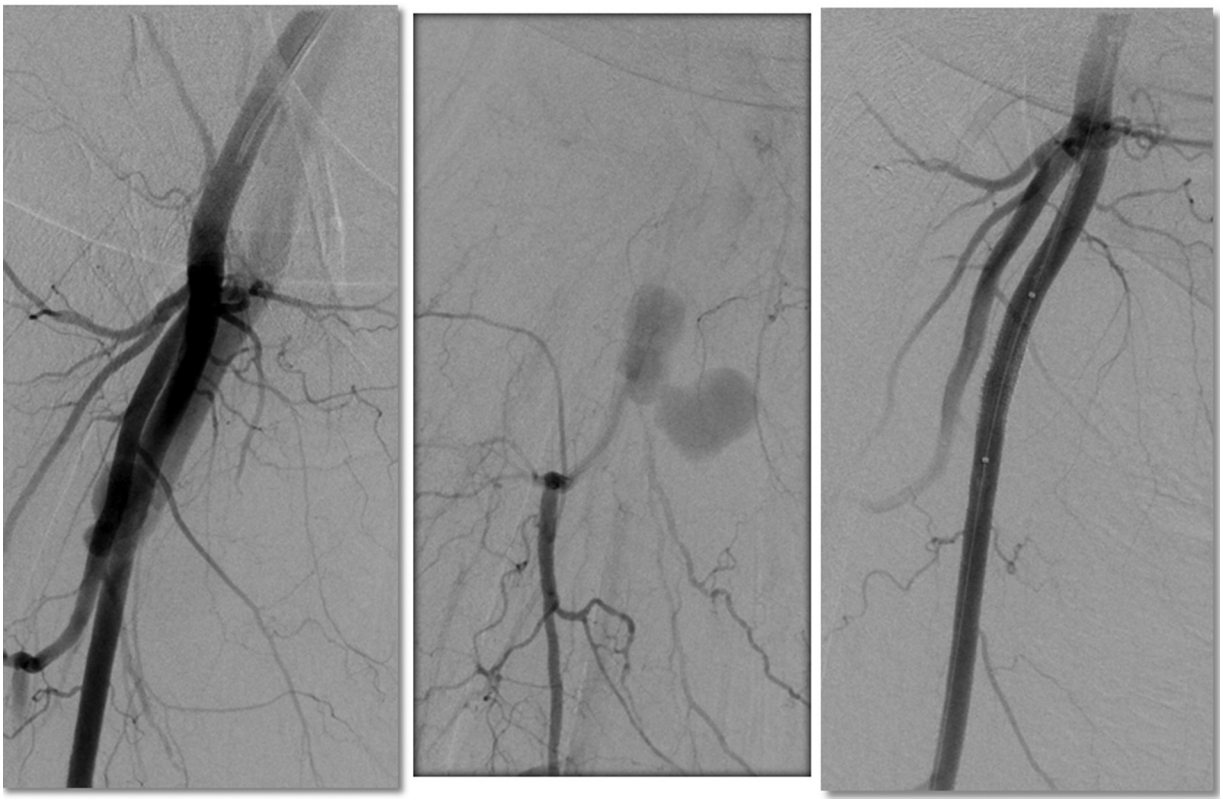
continuation of arterial tree without significant residual stenosis, occlusion causing vascular compromise, or residual bleeding with extravasation. Technical failure was considered if we could not cross the lesion, significant residual stenosis (>30%), occlusion causing vascular compromise, or residual bleeding. The patients were followed up for hemodynamic stability and arterial patency.

Results

The mean age of the patients was 39±3.6 years (range, 27–49 years). Overall, 13 (76.5%) patients were males and four (23.5%) patients were females (Table 1). A total of 17 interventions were performed in 17 patients with traumatic arterial injuries. The cause was penetrating injuries in five patients (owing to stab wound in four patients and gunshot in one patient), blunt trauma in six patients (leading to fracture femur in one patient and fracture pelvis in five patients), and iatrogenic injury in six patients (owing to temporary dialysis catheter insertion in two patients, after percutaneous coronary intervention in three patients, and laparoscopic cholecystectomy in one patient) (Table 2).

The SFA was the most commonly injured vessel (seven patients) (41.2%) owing to stab wound in three patients, blunt trauma causing fracture femur in one

Figure 2



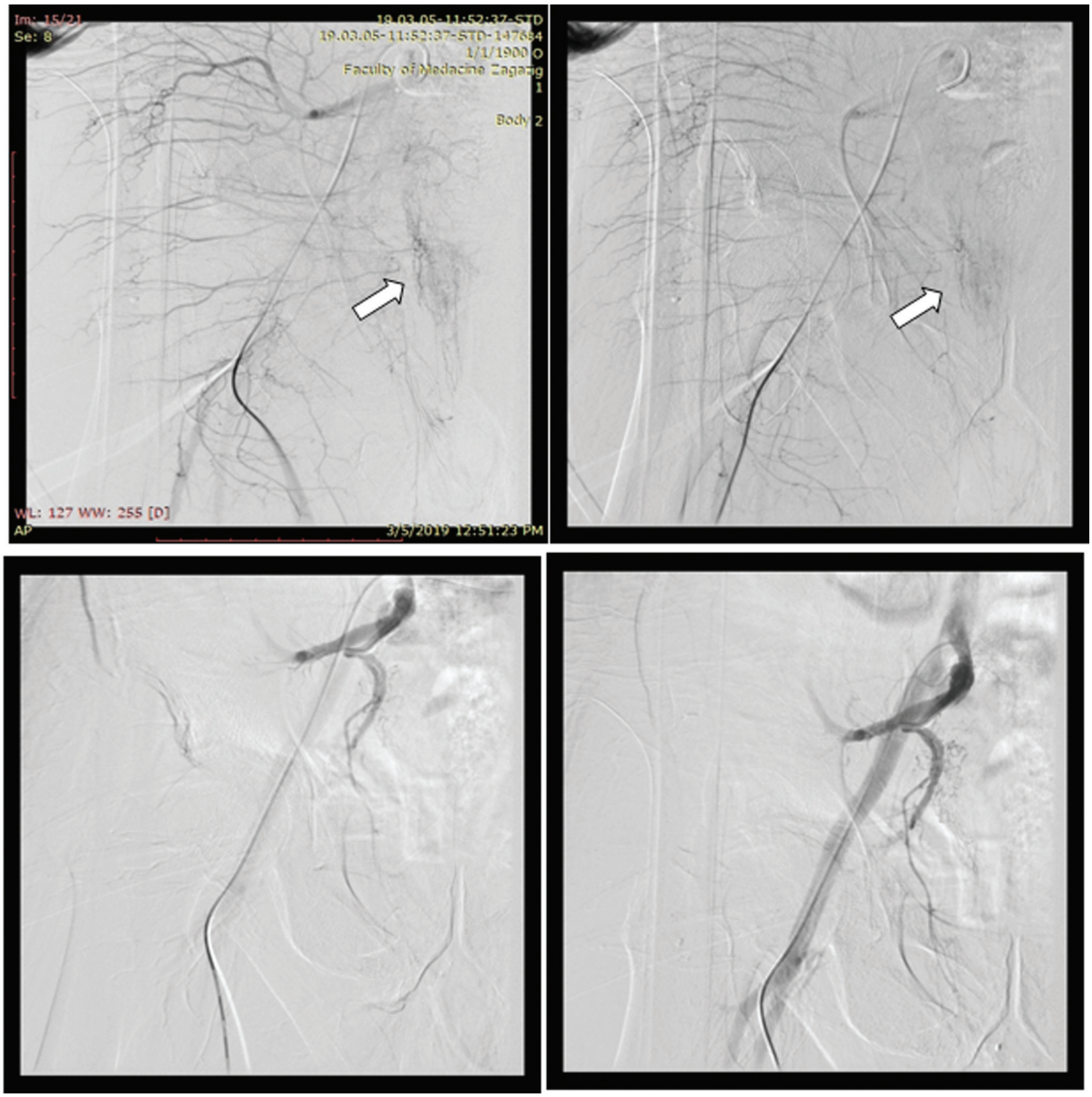
A 55-year-old female, developed arteriovenous fistula after transfemoral percutaneous coronary intervention. (a) Right common femoral angiography shows a fistula between superficial femoral artery and superficial femoral vein. (b) Delayed image shows the associated pseudoaneurysm with lobulated outline. (c) Completion angiography after placement of 8×25 mm Viabahn stent (W.L. Gore & Associates Inc.) shows disappearance of arteriovenous fistula while preserving arterial continuity.

patient, and iatrogenic injury after percutaneous coronary intervention in three patients. The injuries were in the form of AVF with the femoral vein in four patients, pseudoaneurysm in one patient, and near-complete injury and extravasation in two patients. Injury to deep femoral artery (DFA) was in the form of AVF in one (5.9%) patient owing to stab wound. Injuries to the ILA branch in five (29.4%) patients, owing to blunt trauma causing fracture pelvis, included extravasation in four patients and pseudoaneurysm in one patient. Injury to the anterior division of right hepatic artery owing to iatrogenic injury during laparoscopic cholecystectomy was in the form of pseudoaneurysm in one (5.9%) patient. Injuries to the SCA, in three (17.6%) patients, included extravasation in one patient owing to gunshot and pseudoaneurysm in two patients owing to temporary dialysis catheter insertion (Table 3).

Nine covered stents were deployed in nine patients, gelfoam embolization of the bleeding vessel was done in one patient, microparticles embolization of the bleeding vessel was done in two patients (was successful in one patient and failed in the other patient in whom vascular plug was used), and coil embolization of the bleeding vessel was done in three patients. Follow-up at 3, 6, 12, and 24 months after the intervention was done, and the median follow-up was 15 months (range, 5–24 months) (Table 4).

Initial success with continuation of the arterial tree and no extravasation was achieved in 15 (88.2%) of 17 patients. We failed in two (11.8%) patients with near-complete SFA injury (were converted to open surgery). Early complications (Table 5) occurred in four patients in the form of contrast extravasation in one patient (was successfully treated by embolization of a branch of the posterior division of IIA by vascular plug), puncture site hematoma in two patients (were managed conservatively), and partially occlusive thrombus/spasm of DFA after stent graft placement, which occurred in one patient (was managed conservatively without additional interventional procedures). Late complications occurred in two patients in the form of stent graft occlusion after 5 and 8 months, respectively; these patients were treated by open bypass. Mean intervention-free period was 6.5

Figure 3



A 49-year-old male, road traffic accident victim. (a, b) Selective right internal iliac artery digital subtraction angiography showed contrast extravasation from the internal pudendal branch of the anterior division of the internal iliac artery. (c, d) After nonselective gelfoam (Curaspon) (Curamedical) embolization of the right internal iliac artery with occlusion of the feeding vessel.

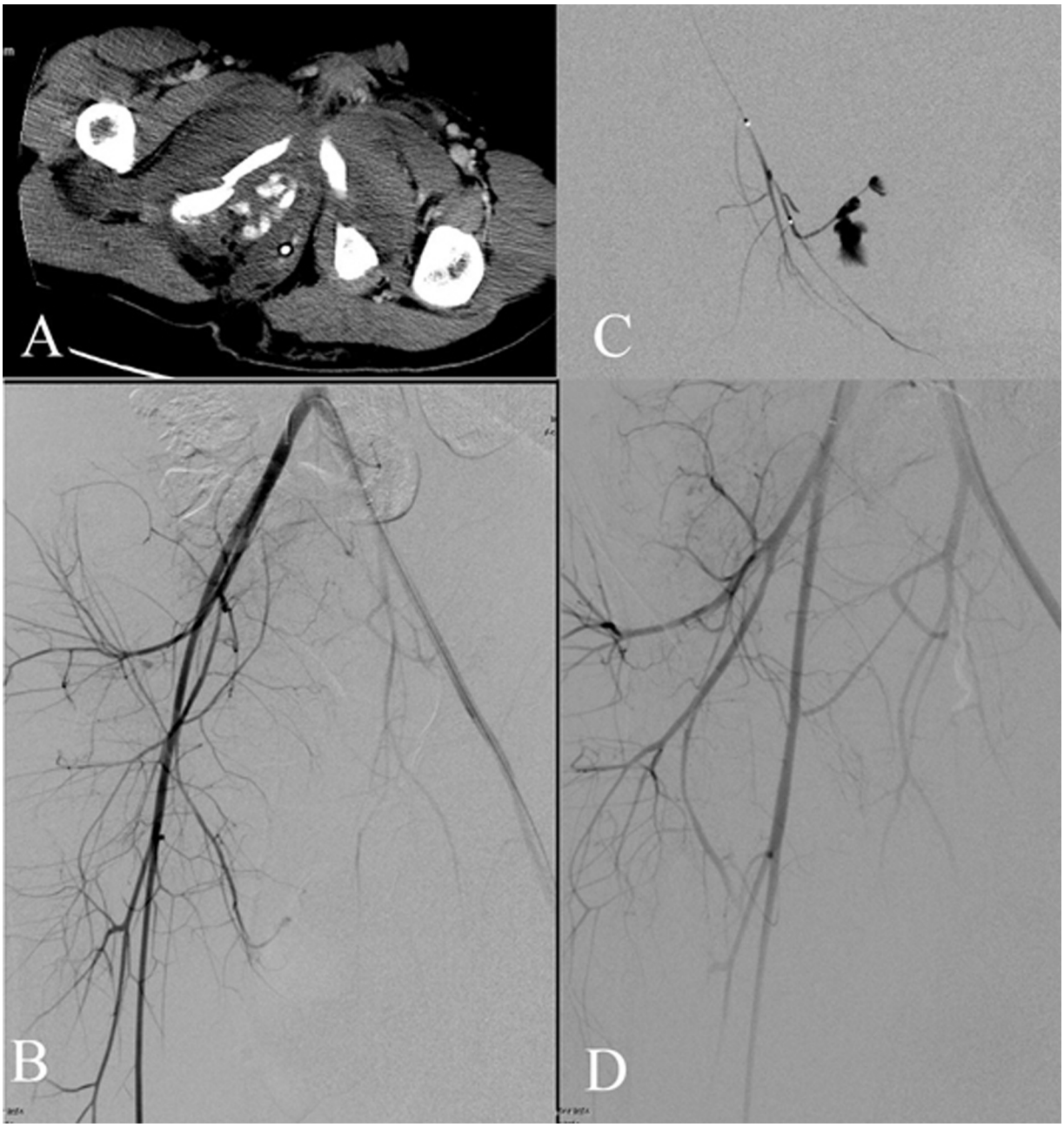
months. Three patients died, where one patient died 11 days after gelfoam embolization owing to pulmonary embolism and two patients died because of myocardial infarction and neglected uremia after 7 and 11 months, respectively.

Five patients were lost to follow-up (two patients with near-complete SFA injury who was transformed to open surgical treatment; one patient died 11 days after gelfoam embolization, owing to pulmonary embolism; and two patients died owing to myocardial infarction and neglected uremia after 7 and 11 months, respectively). Twelve patients were followed up with a median follow-up of 15 months (range, 5–24 months). Two patients needed short bypass owing to stent graft occlusion after 5- and 8-month follow-up. Mean intervention-free period was 6.5 months.

Discussion

Despite the potential disadvantages of endovascular intervention like intimal hyperplasia induced by stent grafts, endovascular procedures have the advantages of avoiding the traditional open surgery in challenging occasions such as difficult anatomic regions (as in subclavian and pelvic arterial injuries that can be difficult and require major operations for exposure,

Figure 4

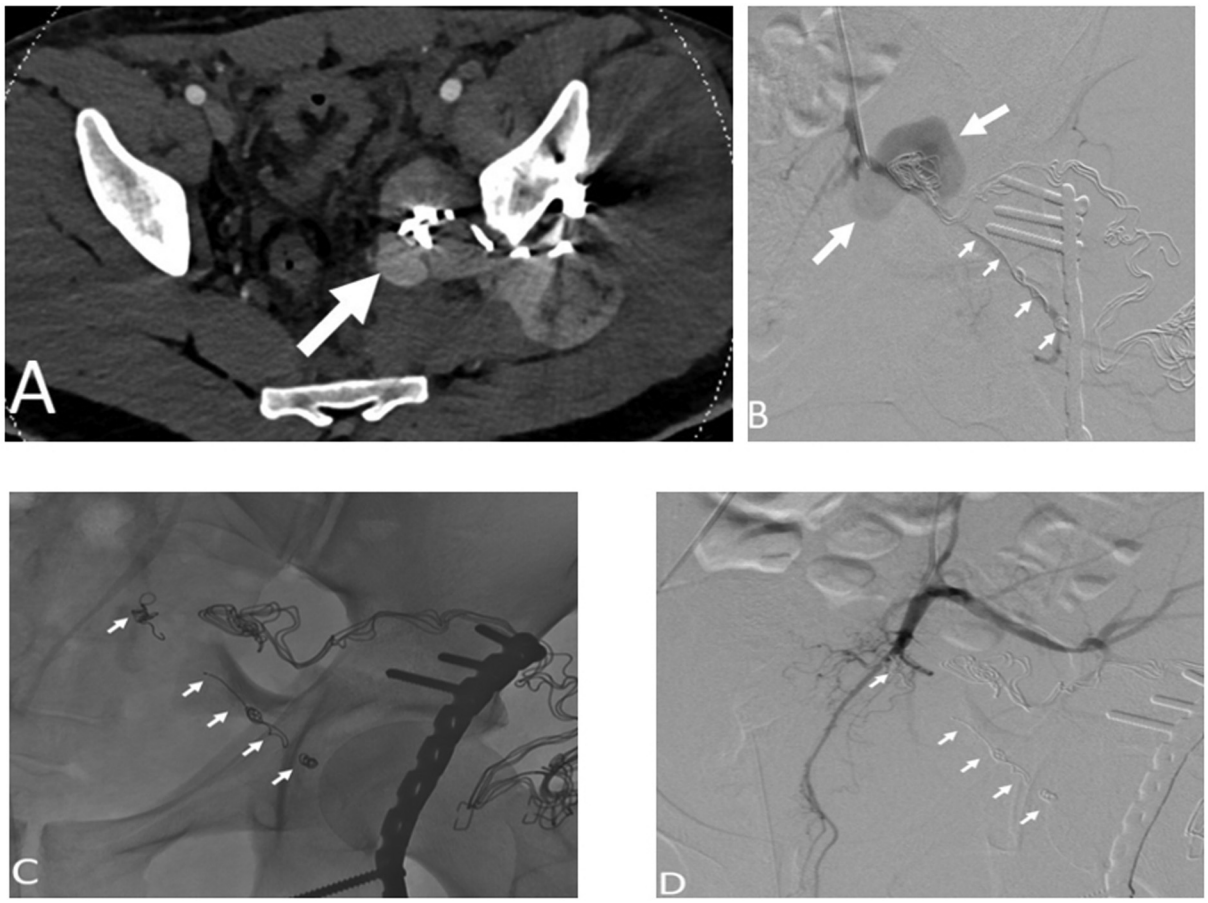


A 14-year-old boy road traffic accident victim. (a)Axial computed tomographic angiography image in the arterial phase shows contrast extravasation in the right perineum causing big hematoma in addition to fracture right inferior pubic ramus. (b) Selective arteriogram of the right common iliac artery showed extravasation of contrast through the right internal pudendal artery (arrow). (c) Superselective catheterization of the artery with microcatheter confirms contrast extravasation. (d) Completion angiogram following injection of 250 μm polyvinyl alcohol microparticles (Boston Scientific) confirms successful embolization of the bleeding artery.

proximal and distal control, and repair), distorted anatomy especially in cases of AVF and pseudoaneurysm, contaminated areas or unfit patients for major surgery, and possibility of huge blood loss. In these occasions, endovascular intervention has many advantages over surgical management [5–7].

Some studies have assessed the efficacy of endovascular procedures in the treatment of arterial injuries. In a study done by Reuben *et al.* [8] in which 281 endovascular procedures were done for the treatment of arterial injuries, the mean age of the patients was 34 years (range, 28–50), 52 patients were females and 229 patients were males, and 154 arterial injuries occurred owing to blunt trauma, whereas 127 owing to penetrating injuries. However, in a study done by Garrick *et al.* [9] in which 15 endovascular procedures were done for traumatic arterial lesions, 93% of the patients were

Figure 5



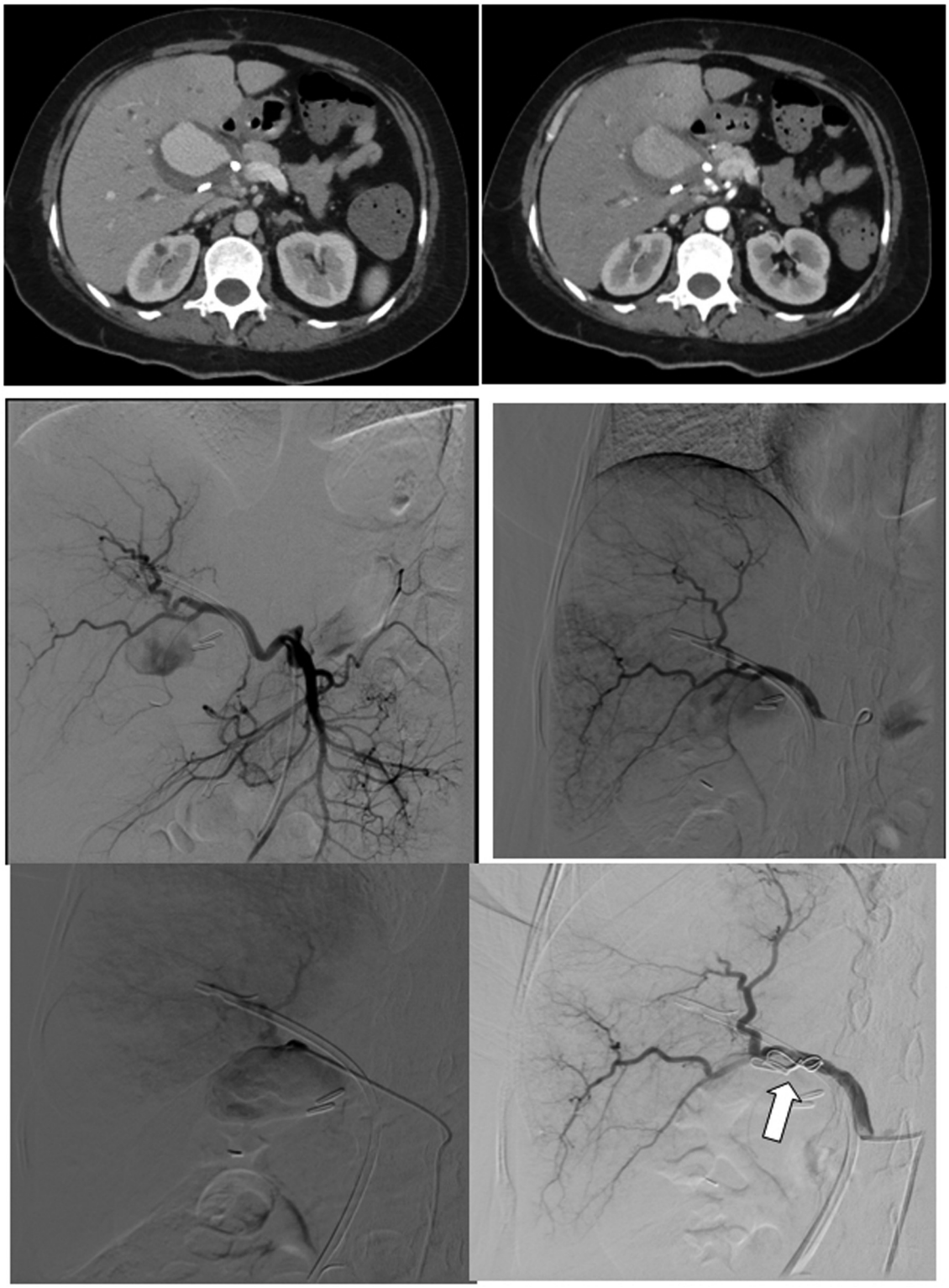
A 25-year-old male, road traffic accident victim. After fixation of pelvic fracture patient became less hemodynamically stable, packing was done to control bleeding. (a) Axial computed tomographic angiography shows bleeding and a pseudoaneurysm (arrow) related to one of the branches of anterior division of left internal iliac artery. (b) Superselective angiography after placement of coils (complex Helical-18) (Boston Scientific) (small arrows) distal to the pseudoaneurysm (large arrows). (c) Fluoroscopic image shows coils deployed distal and proximal to the aneurysm (arrows). Completion angiography (d) confirmed exclusion of the bleeding artery (arrows).

males and 7% were females, the mean age of the patients was 31.7 years, and 80% of the lesions occurred owing to penetrating injuries, whereas 20% of the lesions owing to blunt injuries. In our study, 17 endovascular procedures were done for 17 patients, with mean age of 39±3.6 years (range, 27–49 years); 13 (76.5%) patients were males, whereas four (23.5%) patients were females; and five (29.4%) lesions where to penetrating injuries and six (35.3%) lesions owing to blunt injuries, whereas six (35.3%) lesions were due to iatrogenic injury.

In our study, SFA was the most commonly injured artery [seven (41.2%) of 17 arterial lesions] followed by one of the IIA branches [five (29.4%)]. The injury was in the form of extravasation in seven (41.2%) patients, pseudoaneurysm in five (29.4%) patients, and AVF in five (29.4%) patients. However, in a study done by Branco *et al.* [10], which included 1388 patients over 9 years from 2002 to 2010, the most commonly injured artery was the thoracic aorta (40.7%) followed by the external iliac artery (19.2%). However, in a study done by Desai *et al.* [11] which included 28 patients, the most commonly injured artery was the popliteal artery in eight (29%) followed by the SCA in seven (25%), whereas isolated arterial tear with extravasation in nine (35%) and pseudoaneurysm in nine (35%) were considered the most common types of lesions.

In the present study, stent graft was used in nine (52.9%) lesions (five at SFA, three at SCA, and one at DFA) whereas embolization was done in six (35.3%) lesions. Initial success and continuation of the arterial tree with no extravasation was achieved in 15 (88.2%) patients. However, in a study done by Marin *et al.* [5], which included seven patients, stent graft was used in all seven (100%) patients, most of them at SFA, with initial success and continuation of the arterial tree being achieved in all patients (100%). In contrast, in a study done by Desai *et al.* [11], which included 28 patients, stent graft was used in 23 (82%) patients,

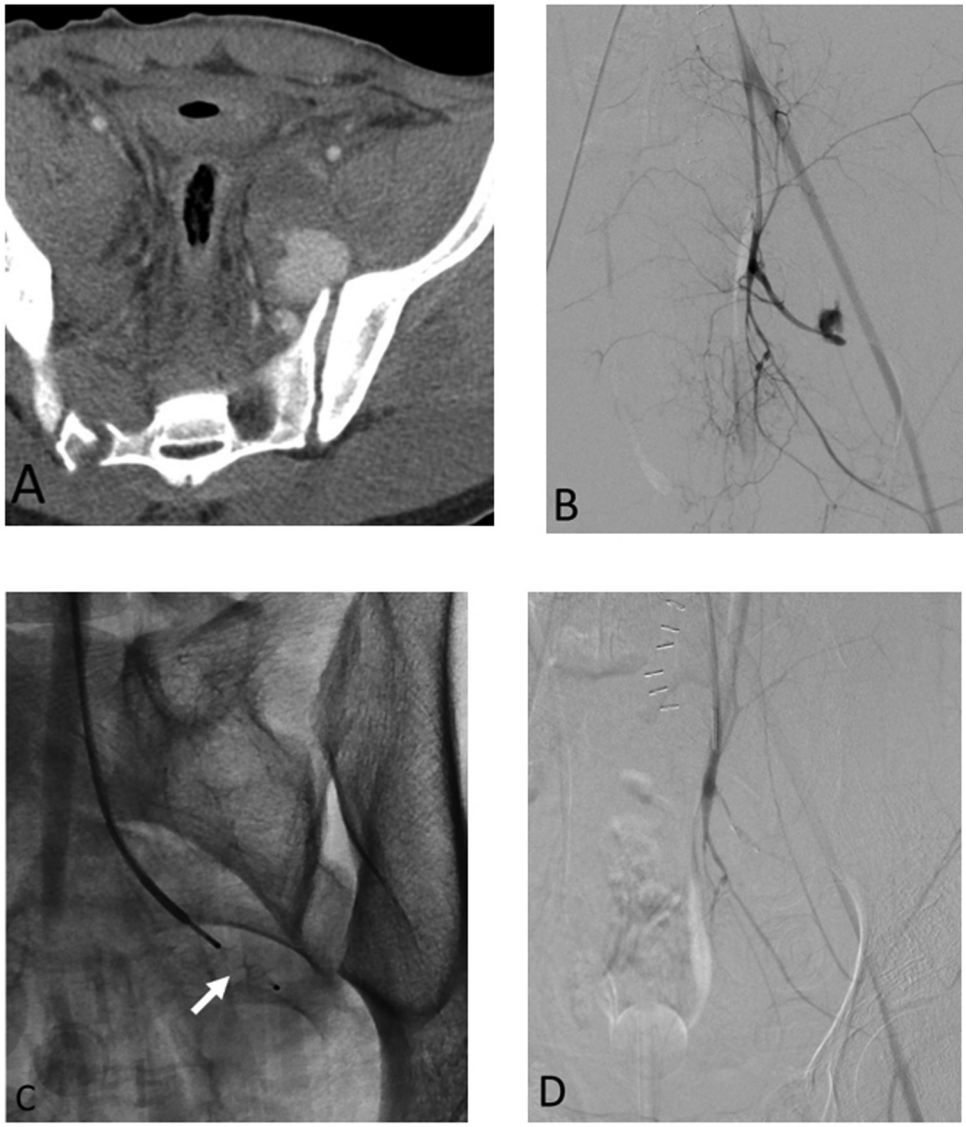
Figure 6



A 29-year-old female patient after laparoscopic cholecystectomy. (a) Axial computed tomography image during the arterial phase and (b) portovenous phase shows a pseudoaneurysm at the porta hepatis with progressive contrast filling starting at the arterial phase. (c) Selective superior mesenteric artery (SMA) digital subtraction angiography showed right hepatic artery arising from the SMA. (d) Pseudoaneurysm with a narrow neck from the anterior division of the right hepatic artery. (e) The tip of the catheter advanced till the neck of the aneurysm. (f) After successful coiling (Azur-35 Pushable coil) (MicroVention Inc.) (arrow) of the neck of the pseudoaneurysm with no more contrast flow inside preserving the parent artery.

whereas embolization was done in five (18%) patients, with initial success in all 28 (100%) patients.In our study, five patients were lost to follow-up (two patients with near-complete SFA injury who transformed to open surgical treatment, one patient died 11 days after gelfoam embolization, owing to pulmonary embolism,

Figure 7



A 24-year-old male, road traffic accident victim, still less hemodynamically stable after laparotomy. (a) Axial computed tomographic angiography image and (b) selective left internal iliac angiography show contrast extravasation from a branch of the posterior division of left internal iliac artery. (c) Because of failed control with 700–1000 μm microparticles (Boston Scientific), a 4-mm vascular plug 4 (AGA Medical Corporation) was deployed (arrow). (d) Completion angiography confirms complete occlusion of the bleeding artery.

Table 1 Demographic data and risk factors

Variables	*n* (%) (*N*=17)
Age (mean±SD)	39±3.6
Age range	27–49
Sex	
Male	13 (76.5)
Female	4 (23.5)
Smoking	4 (23.5)
Hypertension	3 (17.6)
Diabetes	4 (23.5)
Coronary artery disease	3 (17.6)
Chronic renal failure	2 (11.8)

Table 2 Mechanism of injury

Mechanism and type of injury	*n* (%) (*N*=17 patients)
Mechanism of injury	
Penetrating injury	5 (29.4)
Blunt injury	6 (35.3)
Iatrogenic injury	6 (35.3)
Penetrating injury	5 (29.4)
Stab	4 (23.5)
Gunshot	1 (5.9)
Blunt injury	6 (35.3)
Fracture femur	1 (5.9)
Fracture pelvis	5 (29.4)
Iatrogenic injury	6 (35.3)
After dialysis catheter	2 (11.8)
After PCI	3 (17.6)
Laparoscopic cholecystectomy	1 (5.9)

PCI, percutaneous coronary intervention.

and (two patients died owing to myocardial infarction and neglected uremia after 7 and 11 months, correspondingly). Twelve patients were followed up

Table 3 Type of the lesion

Type of the lesion	*n* (%) (*N*=17 lesions)
Partial injury with extravasation	7 (41.2)
AVF	5 (29.4)
Pseudoaneurysm	5 (29.4)

AVF, Arteriovenous fistula.

Table 4 Endovascular management of arterial injury based on anatomic location

Endovascular procedure Anatomical location	Stent graft (*N*=9 lesions)	Embolization (*N*=6 lesions)
SFA	5	–
DFA	1	–
IIA branch	–	5
SCA	3	–
RHA anterior division	–	1

DFA, deep femoral artery; IIA, internal iliac artery; RHA, right hepatic artery; SCA, subclavian artery; SFA, superficial femoral artery.

Table 5 Complications of the procedure

Types	*n* (%)
Early complications	4 (23.5)
Extravasation	1 (5.9)
Puncture site hematoma	2 (11.8)
Spasm	1 (5.9)
Late complications	2 (11.8)
Stent graft occlusion	2 (11.8)

with a median follow-up of 15 months (range, 5–24 months). Two patients needed short bypass owing to stent graft occlusion after 5 and 8 months of follow-up. However, in a study done by Desai *et al.* [11], seven patients were lost to follow-up (five died before the first visit to the clinic and two underwent amputation). Fourteen (50%) patients were followed. The median follow-up was 13 months (range, 1–60 months). Four (14%) patients required a second intervention within follow-up because of stent graft occlusion, where three of them underwent bypass within 1 month, and one patient needed bypass at 50 days.

Conclusion

Endovascular management of arterial injuries in hemodynamically stable patients can be a good alternative to open surgery in anatomic regions that are difficult to access and unfit patients for major surgery with possibility of massive blood loss.

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Nil.

Conflicts of interest

There are no conflict of interest.

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