We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

6,900
Open access books available

186,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Vascular Trauma

Krzysztof Szaniewski, Tomasz Byrczek and Tomasz Sikora

Abstract

Trauma is a leading cause of death and disability in young adults in developed countries with the high impact on future patient quality of life and productivity. The traumatic injury of the vessels is one of the most dangerous types of injury, requiring a fast and reliable diagnosis and, in vast majority of cases, immediate surgical treatment. In this chapter, the authors describe various types of vascular injuries according to injury types and locations. The prehospital care algorithms in patients with vascular trauma are proposed with the emphasis on bleeding control techniques and transportation technique to the nearest hospital. In the next subsection, the various peripheral vascular injuries of specific body areas are described. The truncal vessel trauma is discussed in the next subsection, focusing on fast diagnosis and decision on surgery. In the last subsection, a problem of iatrogenic vascular injury is described due to a rapid increase of minimally invasive techniques in which a vascular injury, as a complication of therapy, may occur.

Keywords: vascular trauma, vascular injury, peripheral vessels injury, truncal vessels injury, iatrogenic vascular trauma, aortic injury

1. Introduction

Trauma has become a leading cause of death among young adults in industrialized nations. In the United States in 2010, trauma was the cause of death in 63% of patients aged 1–24 years and 42% of the patients in the ages 25–44. Furthermore, trauma results with lowered patient's productivity with high economic impact. A vascular trauma incidence is estimated between 1.6 and 2% in adults during peace and between 6 and 12% during war. Most of the civilian casualties are injured by penetrating objects like firearm bullets, blades, or machine parts. In Europe, where access to firearms is limited, most of the penetrating vascular injuries result from criminal acts (e.g., knife stabbing), traffic, and labor accidents [1, 2].

2. Prehospital care in patients with vascular injury

2.1 On-site emergency procedures and medical transport

Fast initial diagnosis, patient's vital signs stabilization together with effective bleeding control, and quick transport to the hospital are crucial factors influencing future prognosis.

After the evaluation of the overall security condition on trauma site (traffic accident, disaster site, explosion area), it is important to predetermine a possible

trauma mechanism in order to predict possible vascular injury as well as collateral damage of the adjacent tissues [2].

The next step is the patient examination. After the initial evaluation of vital signs and recording the state of a victim's consciousness (GCS), a CABC rule should be applied (**Table 1**).

After CABC, a trauma extent assessment as well as medical examination are performed (SAMPLE) (**Table 2**). The medical examination should cover all body areas in direction from head to toe including the patient's back and extremities. The aim of that procedure is to find any eventual collateral damage which can be life-threatening. The additional information from other victims or witnesses should be gathered, if possible [3].

After the finishing of medical examination, the patient should be qualified to one of the following groups:

1. LOAD & GO—victim in extremely severe condition. Only a basic set of medical procedures is performed necessary to support life. The transport has a priority [4].

2. STAY & PLAY—all necessary procedures may be performed on-site. The transport follows the initial care.

During the transportation, especially with unstable patient in severe condition, the information to the admitting center (ATMIST scheme) should be sent (**Table 3**) [5].

The portable ultrasound devices are helpful in fast initial diagnosis of the injuries of large vessels of the chest or abdomen with the use of eFAST protocol (chest, pericardium, and abdomen) [6].

Below we propose a procedure of prehospital care in vascular trauma:

1. Initial examination, CABC, SAMPLE

2. Control of the visible external bleeding

3. Evaluation of possible internal bleeding(s)

4. Intravenous access (intramedullar), fluid supply, hypovolemic shock treatment

5. Bleeding control specific to the vascular injury area

6. Medical transport and ATMIST

2.2 Specific procedures of bleeding control according to area of the injury

Vascular injury of the extremities:

- Direct wound compression.

C	Control bleeding—the bleeding controls a visible and life-threatening hemorrhage
A	Airways—secure the airways and evaluate possible obturation causes
B	Breathe—ventilation rate, volume, and effectiveness
C	Circulation—central and peripheral circulation assessment, blood pressure, capillary flow, and skin perfusion

Table 1.
CABC rule in prehospital care of the patient.

S	Symptoms (bleeding, ischemia, shock, fractures, wounds, etc.)
A	Allergies (drugs, food, chemicals (e.g., disinfectants), materials (plaster dressing, etc.))
M	Medicines—recently used or prescribed medicines
P	Past—medical history and pregnancies
L	Lunch—last meal, time, and volume
E	Event—what has happened

Table 2.
SAMPLE rule in the examination of the victim of an accident.

A	Age
T	Time of the event
M	Mechanism
I	Injuries
S	Symptoms
T	Treatment (already performed)

Table 3.
ATMIST algorithm.

- Limb elevation.

  ○ Compression dressing.

- Tourniquet: usually applied on arm or thigh, less often in distal areas (forearm, below the knee) usually 8 cm above the suspected vascular lesion. An effective modification of that technique is to apply two tourniquets, one high on the limb and the second 8 cm above the wound. Then the first one is released, while the second stays closed [3, 7].

- Packing of the bottom of the wound with sterile gauze with continuous compression.

- Hemostatic dressings and substances: in the form of dressing, powder or foam—usually a 3–5 min time is needed to initiate coagulation between a dressing and injury site [3, 8].

Vascular injuries in the connection areas (armpits, groins):

- Direct compression.

- Compression dressing.

- Specific compression systems.

  ○ JETT (Junctional Emergency Treatment Tool).

  ○ SAM Junctional Tourniquet: the systems which are applied on inguinal or axillary regions where traditional compression system application is limited [9, 10].

Neck vasculature lesions:

- Direct compression.

- Compression with contralateral hand.

- Hemostatic media.

Vascular injuries of the head:

- Direct compression.

- Haemostatic suture of the skin vessels.

Vascular injury of the chest:

- Direct compression.

- Occlusive dressing.

- Emergency thoracotomy.

Vascular injury of the abdomen:

- Occlusive dressing.

- Hemostatic foams

  ○ Abdominal aortic and junctional tourniquet (AAJT)

  ○ Resuscitative endovascular balloon occlusion of the aorta (REBOA) [11, 12]

Vascular injury of the pelvis:

- Pelvic belt.

- Hemostatic foams.

2.3 Hypovolemic shock and fluid therapy

Patients in hypovolemic shock with controlled external bleeding should be administered with 500–1000 ml of crystalloids, with a constant blood pressure control. Blood pressure may be maintained near to normal values. In patients where there is no possibility to control the external or internal bleeding, crystalloids volume should allow to maintain the systolic blood pressure on the perfusion level (80–90 mmHg) to prevent anaerobic metabolism in supplied tissue. Exceptionally in patients with the traumatic lesion of the central nervous system, the systolic blood pressure should be maintained on higher levels of 100–110 mmHg, which secures cerebral perfusion pressure on the level of 60 mmHg [13].

3. Peripheral vascular injury

Isolated vascular injury of the extremities is the most common vascular injury type during the peace in high-volume trauma center in Europe. The incidence rises

in highly urbanized area due to traffic and labor accidents and varies between 1 and 2% of total number of traumatic patients admitted to the ER [14]. In our center, the incidence of the vascular trauma among all traumatic patients was 3% in a 5-year period (2014–2018). In the upper limbs, the regions of elevated risk are the armpit, the medial part of the arm, and the ulnar fossa due to a superficial position of the vascular structures. In the lower limb, attention should be focused on injuries of the groin, the medial thigh area, and the popliteal fossa. The ligation of the artery in vascular injury below the brachial bifurcation or knee trifurcation usually has no risk of the peripheral limb ischemia.

The vascular damage may be caused by penetrating object (like knife blade, a part of a machinery, steel rod, etc.) or may have been an effect of the blunt trauma with the force acting directly on the vessel wall or by the surrounding tissues like bone fragments or luxated joints. Penetrating injuries, mostly with low energy character, constitute 70–90% of cases [15]. Blunt vascular trauma may be the effect of the vessel contusion and secondary thrombosis, which is often a result of the knee joint or upper arm luxation and dislocation of the humerus/tibia causing the blunt trauma.

According to an extent of the wound, in penetrating vascular injury, various clinical manifestations may occur, from puncture wound with minimal bleeding and minute signs of the peripheral ischemia to a large laceration of the skin with life-threatening hemorrhage.

3.1 Diagnosis

The on-site evaluation and diagnosis was described earlier in this chapter; in hospital, the physician after gathering information from the medical emergency service team should also try to obtain information from the patient especially about the traumatic mechanism and possible time of eventual ischemia. The mechanism of injury has a prognostic value. High-energy injuries (penetrating or blunt) have elevated risk of vascular damage, and the risk of amputation is higher in high-energy blunt trauma. Collateral damage of surrounding tissues and adjacent structures may require separate intervention (e.g., orthopedic surgery), or in the case of extensive polytrauma, complex interdisciplinary approach with advanced life support techniques.

It is generally agreed that after 6 hours of the limb ischemia, irreversible changes occur in the nervous and musculatory systems, though it is important to precisely evaluate the onset time. The time may be counted from the injury time or if the ischemic process is iatrogenic (e.g., tourniquet, pressure dressing) from the time in which the blood flow was stopped.

Concomitant diseases and patient's medical history are also important (arteriosclerosis, cardiac diseases, diabetes), as well as medications are prescribed, especially ASA and VKA.

3.2 Medical examination

The decision of immediate surgery, especially when active bleeding is concerned, is crucial at the first minutes of examination, due to a high mortality rate in the case of misdiagnosis. A vast majority of victims presenting "hard signs" of vascular trauma require an immediate operation with sensitivity above 90%; on the other hand, if no "hard sign" is present (**Table 4**) (**Figures 1** and **2**), the vascular trauma probability is very low [16].

"Soft signs" are not so specific in the prediction of the vascular injuries, and immediate open repair usually is not necessary. A single soft sign increases a chance

Hard signs	Soft signs
Active pulsatile bleeding	Pulse deficit
Rapidly expanding hematoma	Neurological deficit
Pulselessness	Paleness of the extremity
Acute ischemia	Nonexpanding hematoma
Vascular thrill	—
Bruit	—

Table 4.
Hard and soft signs of vascular trauma.

of vascular injury in 10%, and two or more soft signs can have a vascular injury rate of 25% [17, 18] (**Figure 1**).

The pulse and extremity blood supply should be evaluated in the first place. A physical examination and the pulse palpation of **all extremities** should be performed.

The bleeding should be stopped as soon as possible by the use of compression dressing and tourniquet or if the situation allows temporary shunting of the damaged artery or vein. The vessel clamping or ligation can be done only in the last resort, when the patient's life is directly at risk. If the damaged vessel is clearly visible and ischaemic symptoms occur, the patient should be referred to vascular surgery in order to perform emergency revascularization. After the bleeding control, the focus should be directed on the chances of the limb salvage. The MESS score is the most popular tool in assessment of the extremity salvage chance [cite

Figure 1.
A typical "hard sign" of the blunt vascular injury of the groin.
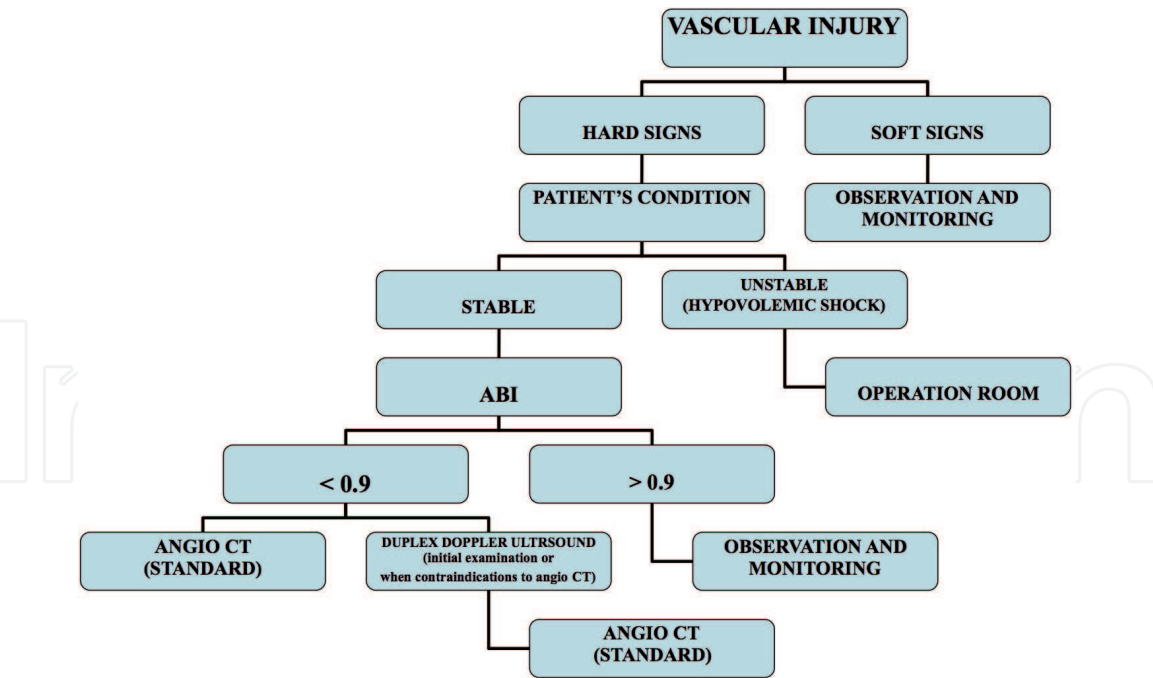
Figure 2.
The algorithm of the management of the peripheral vascular injury patient.

mess]. Afterwards, if ischaemic signs are present, the limb condition should be rated according to TASC II categorization. Quite often there is no sign of active bleeding, especially in young patients where even a total intersection of femoral or brachial artery does not end with massive hemorrhage due to a vessel end contraction and thrombosis [18–20].

Ankle-brachial index (ABI) or arterial pressure index (API) is a useful adjunct to physical examination. ABI value <0.9 has 87% sensitivity and 97% specificity in the assessment of vascular trauma, reaching 95% of sensitivity when focused on big arterial trunks. ABI value below 0.9 is an direct indication for further imaging as US, CT angiography, or MRI. On the other hand, ABI value >0.9 with no signs of the orthopedic injury allows to release the patient from ER, with the further referral to outpatient clinic in the next few days for reassessment of eventual delayed presentation of vascular injury [21].

3.3 Treatment

In the first option of treatment, especially in patients presenting with TASC II and III category , the treatment of choice is an open repair. Both stumps of the damaged vessels should be identified and clamped.

After the thrombectomy and vessel stump preparation, an anastomosis is performed. The best option is end-to-end anastomosis without any conduit; however that option is only possible in directly cut vessels where the surgeon is able to mobilize vessel stumps from the surrounding tissue very often soaked with the blood and tissue liquids. If there is any tension between arterial or venous stumps, the better option is to make a conduit, preferably from autologous vein. Reversed great saphenous vein (GSV) graft is the most popular choice; however, there are other possibilities like small saphenous vein and basilic or radio-cephalic vein. However, SSV and other peripheral veins are more difficult to harvest and may have insufficient diameter.

If the vein is not available, the surgeon faces a decision whether to use a homologous material (if available) like frozen bovine graft or frozen homograft

Surgical material
Autologous vein GSV, SSV, RCV, BV
Frozen bovine graft
Homograft
Silver-coated prosthesis (Braun, Intergard)
PTFE
Rifampin-soaked Dacron

Table 5.
Material for grafting in vascular injury.

or to use synthetic prosthesis. If the synthetic prosthesis has to be used as a conduit, the most infection-resistant option available on shelf should be utilized (**Table 5**).

The endovascular modality is limited only to cases with preserved continuity of the vessel, which can be visualized only in CT angiography, and we recommend that option to patients with TASC I category (viable limb). Usually endovascular approach is effective in arterial puncture with pseudoaneurysm formation or arterial thrombosis in cases of isolated blunt trauma mostly in popliteal and axial region or in cases of arm luxation (**Figures 3**–**5**).

Figure 3.
Blunt trauma of the popliteal fossa resolved by the endovascular approach. (a) thrombosis of the popliteal artery, (b) restored flow in the vessel
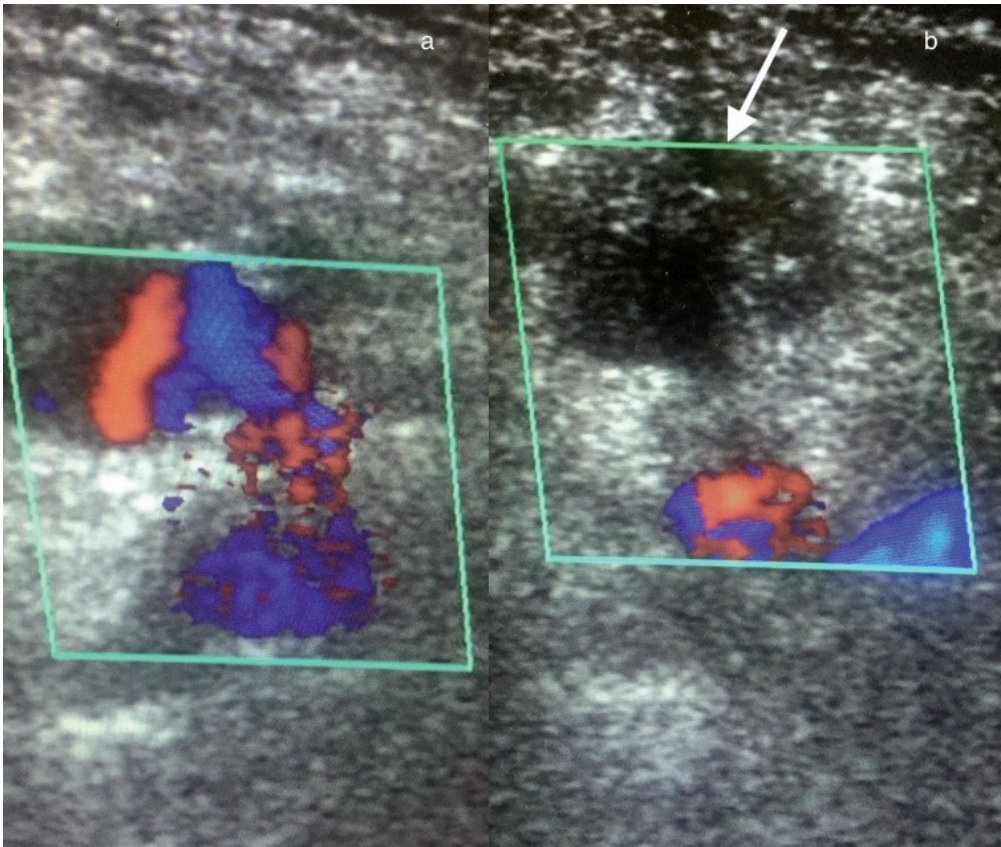
Figure 4.
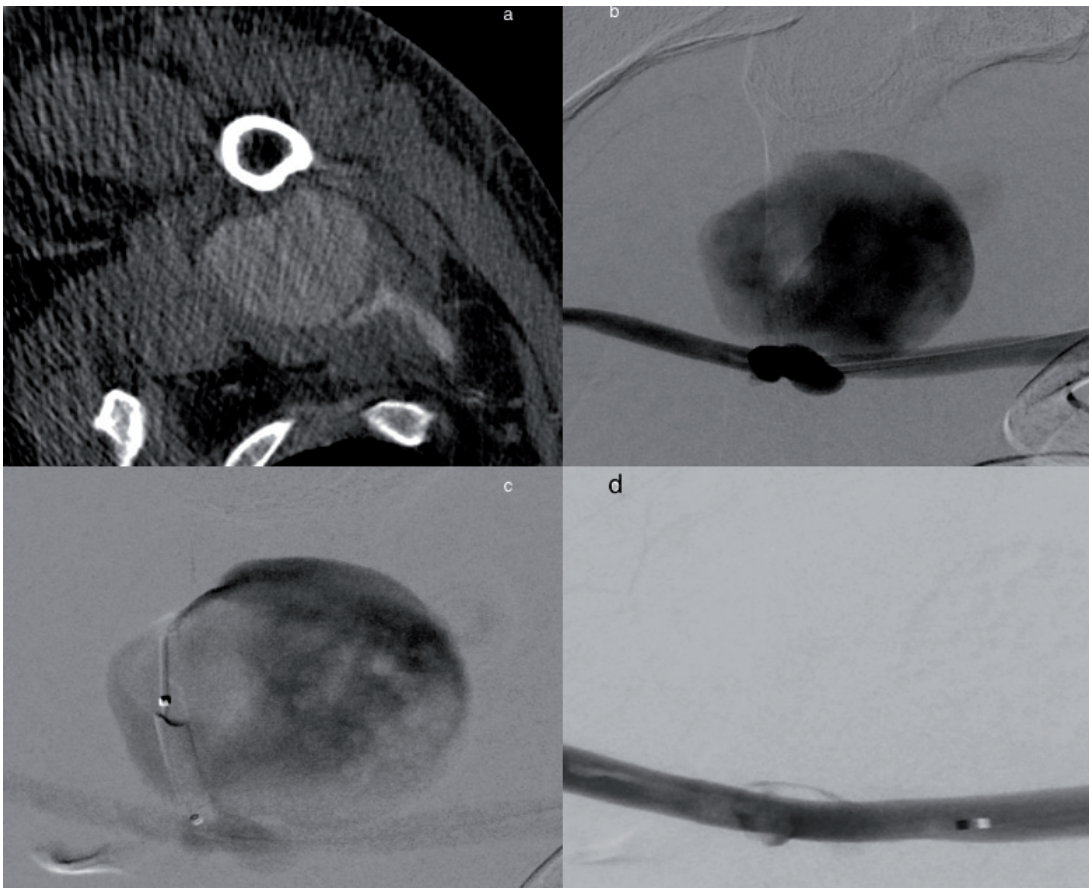*The pseudoaneurysm sac successfully closed by biothrombin injection (arrow) [22].*

Figure 5.
The pseudoaneurysm of the right axillary artery successfully resolved by trans-catheter thrombin injection.
(a) a CT scan of the lesion, (b) arteriography image of the lesion before the injection, (c) a balloon catheter
occluding the aneurysm "jet", (d) angiographic image of the axillary artery after the treatment [22].

4. Truncal large vessels trauma

4.1 Thoracic aorta injury

The traumatic damage of the thoracic aorta is usually an effect of traffic accidents or sudden fall resulting from acceleration-deceleration mechanisms. Less often it is a result of the penetrating injury like knife stabbing or gunshot. In that case the damage of the aortic wall is usually complete with massive hemorrhage into mediastinum or pleural cavity, which is in most cases fatal. In blunt trauma, the most common site of injury is the descending aorta left from subclavian artery ostium and below the aortic ligament. In most cases, the intimal tear occurs resulting in acute dissection progressing downwards to the visceral arteries and to the aortic bifurcation. Sometimes we can observe almost complete aortic wall tear, pseudoaneurysm formation in the chest and progressing dissection.

The computed angiotomography is a routine examination which allows to diagnose the thoracic aorta injury with high accuracy and has become a standard procedure in chest injuries. If there is no possibility of CT scanning, a transesophageal ultrasound can be used however in a very limited fashion.

From the beginning of the century, a thoracic endovascular stent-graft implantation (TEVAR) has become a routine procedure in salvaging patients with aortic injury, decreasing a perioperative mortality from 70% to 15–30%. If open surgical procedure has to be performed, a chance of survival drops dramatically to 15–20%. The open repair usually requires high aortic clamping, and the risk of the neurological deficit resulting from spinal cord ischemia is significantly higher than during the TEVAR. In TEVAR, however, the risk of spinal cord ischemia is also significant (23%), especially in cases when the graft fabric covers the ostium of the left subclavian artery (LSA) and suppresses the collateral circulation from internal mammary artery (LIMA) to the intercostals. If the patient is in stable condition, a surgeon can bypass the left subclavian ostium, by performing a carotid-subclavian conduit preserving the flow in LSA and LIMA. Another popular neuroprotective option is the drainage of the cerebrospinal fluid to reduce the pressure from eventual spine edema. In many centers that procedure is performed routinely during TEVAR or open repair when LSA closure is necessary [4, 23, 24].

4.2 Large veins of the chest

The rupture of the large veins in the chest is usually fatal, and patients do no reach the hospital. However, if the patient's condition allows for medial thoracotomy with sternotomy to expose superior vena cava, there is a chance to control the bleeding and after the patient stabilization to reconstruct the damaged vessel. There are some reports of successful endovascular treatment of vena cava injury [25–27]; however all concern iatrogenic injuries.

4.3 Abdominal aorta and iliac arteries

Abdominal aorta injuries result more often from penetrating mechanism than from blunt trauma. The location of the vessel makes it relatively resistant for blunt injury. If blunt aortic injury occurs, it is usually a part of extensive polytrauma with spine fracture and multiple adjacent organ damage. An exception may be an abdominal aortic rupture during blunt trauma of the abdomen without any collateral damage, which can occur during a car accident or a fall. More frequent are penetrating injures being a result of a criminal act or labor accident. The patient

usually presents symptoms of hypovolemic shock, and the first steps should be done to stabilize the vital signs and blood pressure and secure the adequate volume of blood and plasma. The CT scan is a standard procedure confirming an initial diagnosis with visible hematoma in retroperitoneal space. The REBOA procedure (**Figure 6**) is useful during patient stabilization and preparation to surgery or endovascular repair. In open repair a medial abdominal access is used to expose the aorta for clamping and vascular reconstruction usually by the use of polyester or PTFE graft [28]. Less often a simple suture of patch from polyester or autologous vein is used. If there is additional collateral damage like intestine tear, hepatic or renal injury or pelvic fracture, it can be done simultaneously. In cases of isolated aortic damage, usually resulting from penetrating mechanism, an endovascular stent-graft implantation (EVAR) is an effective option.

Blunt iliac artery injuries usually result in pelvic polytrauma with multiple fractures of the pelvis and possible damage of the bladder, uterus, intestines and ureter. In most cases an interdisciplinary approach of specialized trauma team is necessary, and a vascular surgeon's job is to restore the blood flow stopped by thrombosis of the iliac artery or to stop the bleeding and to perform the vascular reconstruction. In cases of hypogastric artery injury, the vessel ligation is the most common solution. In common iliac artery or external iliac artery injury, a reconstruction with the use of artificial bypass is the first choice. The venous grafting has a limited application due to not sufficient diameters of available veins. In cases in which an infection risk is elevated, silver knitted grafts are the most popular option. The isolated blunt external
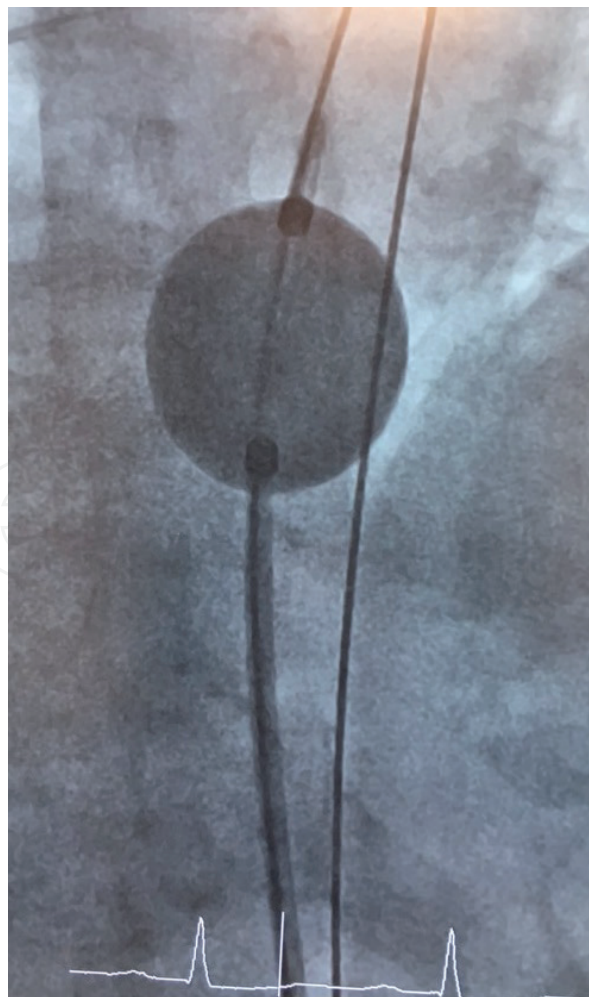

Figure 6.
REBOA technique in salvaging the patient with an aortic rupture.

iliac artery above the inguinal ligament resulting in its thrombosis and chronic limb ischemia in young patients resulting from a bike accident were reported [29].

Penetrating external iliac artery injuries especially in the region of inguinal ligament, known as death triangle injury, are challenging cases where fast decision of surgery is life-saving. The bleeding control in that region is difficult and possible only by direct compression or by modified REBOA procedure when the balloon is opened in the common iliac artery. The open repair is a gold standard because most of the injuries result from a knife stabbing or gunshot, and endovascular endografting has a limited application.

4.4 The injury of the inferior vena cava and iliac veins

A penetrating injury of the inferior vena cava usually produces a large retroperitoneal hematoma having a tendency to self-cease with the drop of the blood pressure and compression produced by the hematoma. That condition is however unstable, and the patient may die suddenly among the symptoms of irreversible hypovolemic shock. Urgent surgical exploration is necessary to seal the rupture in the vein wall. As much as possible the VCI should be exposed to find the rupture, and after the compression of the inflow and outflow site, suture it or reconstruct by the use of artificial graft (usually PTFE). Recently, there have been reports of successful treatment of the VCI ruptures by the use of covered stents or stent grafts however in majority concerning iatrogenic damage [14, 30–33].

The blunt injury of IVC is a very rare condition, with a prevalence of 1% of all blunt abdominal traumas resulting in dissection, pseudoaneurysm formation, or IVC thrombosis. In the literature there are single reports in the management of IVS blunt injuries usually catheter-directed techniques [16, 34, 35].

4.5 The injury of the carotid arteries and jugular vein

The penetrating injuries of the carotid arteries and jugular veins are mostly resulting in a stabbing effect or an effect of the gunshot. The bleeding control in the case of open wound of the neck is a crucial element of the further success. In the case of the venous injury, a direct compression on the ruptured vessel is usually sufficient to transport the patient to the operation room and to perform exploration and vessel reconstruction. The problem occurs in the case of arterial damage with high-volume blood outflow. Too much compression may lead to severe neurological deficits so pressure should be administered only to stop the bleeding. Additional wound packing may also be helpful. In our opinion every penetrating vascular injury of the neck should be surgically explored in order to prevent a secondary damage as uncontrolled hematoma expansion leading to neurological and respiratory deficits which is supported by the data from the literature [36, 37]. The unstable patients are qualified to immediate surgery, while the stable ones after fast-track imaging in order to localize the exact lesion location should also undergo surgical exploration (**Figure** 7).

Blunt injury of the cervical vessels is a relatively rare condition with prevalence <0.1% and however related to increased mortality and morbidity due to a cerebral infarction. The symptoms of the cerebral ischemia may occur up to 72 h after an accident due to an embolisation from the local vessel thrombosis or dissection. The CT angiography scans should be performed in all patients suffering the injury of the neck in stable condition without signs of rapidly developing hematoma in order to exclude a sub-intimal dissection or thrombosis which can be a source of embolic material. In these patients an endovascular option is a good solution for covering a damaged area with a closed cell stent or stent-graft.
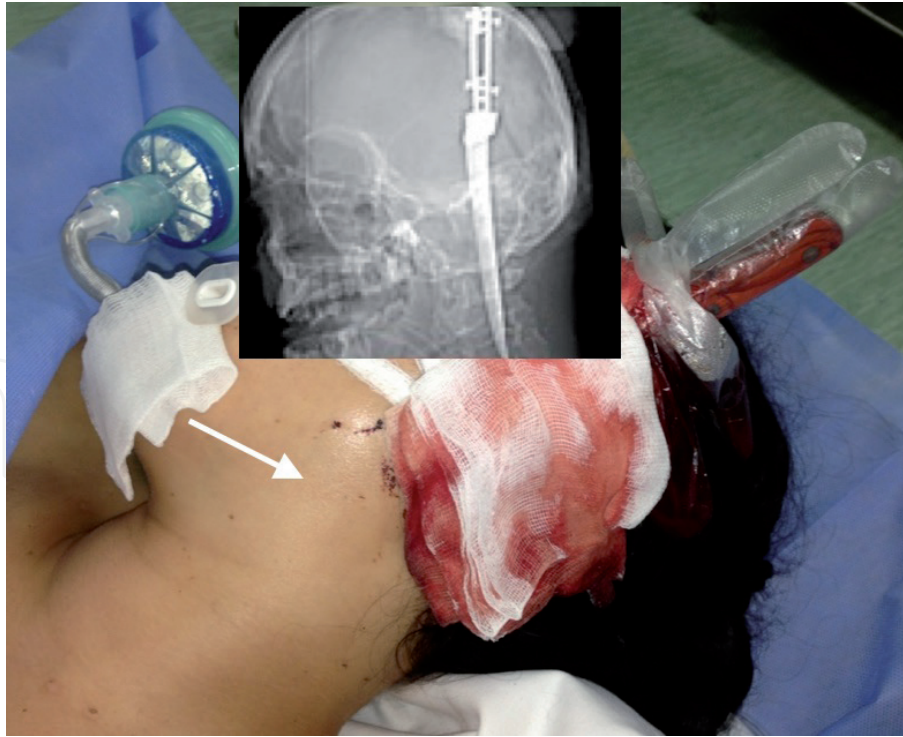
Figure 7.
Left carotid artery injury with the compressing hematoma (arrow).

5. Iatrogenic vascular injury

In the recent years, in the development of mini-invasive and endovascular techniques, an increase of iatrogenic vascular injuries is observed. A most common complication of the vascular access in endovascular approach is hematoma and pseudoaneurysm in the access site [22, 38]. The rate of these incidents varies between 0.5 and 1.0% and recently was decreased by the use of various vascular sealing systems. A perforation or tear of the arterial wall not in the access site is the second very frequent complication of the endovascular procedure. The typical location of the perforation is iliac arteries, when during the approach to the target lesion (coronary arteries, carotid arteries, abdominal aorta) a hydrophilic guidewire perforates the vessel typically in the location of arteriosclerotic plaque [5, 39]. If the guidewire perforation is noticed quickly, usually it has no consequences besides small extravasation which may require a low-pressure balloon inflation to seal the leak. Sometimes, however, the perforation is not noticed, and some larger bore devices (balloons, stent-graft parts) may be pushed outside the arteries producing a large diameter tear in the arterial wall. If there is no possibility to seal the leak by the use of stent-graft, the only solution is to open the low-pressure balloon inside the vessel and urgent laparotomy or thoracotomy.

In open repair, the iatrogenic traumatic vascular trauma has been observed mostly during orthopedic repositions, general surgery procedures, gynecology, and neurosurgery. After an introduction of the laparoscopic techniques at the beginning of the last decade of the XX century, an incidence of unintentional rupture of the large vessels in abdominal and pelvic region during the introduction of the trocars increased. That type of the injury may have very dramatic outcome, with massive and rapidly increasing hematoma especially when the abdominal part of vena cava or iliac veins are concerned. In that case only an instant conversion and pressure packing may stop the bleeding and save the patient. After a bleeding control is achieved, the vascular reconstruction may take place which is very often limited to pacing a vascular suture on the vein; less frequently the patch, bypass or ligation is needed [40–42].

When arterial vessels are damaged, a massive bleeding is not so often; in some cases, one can observe a pseudoaneurysm formation, vessel thrombosis, or retroperitoneal hematoma which also requires an urgent surgery; however, the symptoms are not so dramatic and chances are better. In that case, a vascular reconstruction usually ends with suturing the damaged artery. Sometimes, a thrombectomy is performed, with more extensive reconstructions with patches or bypasses. In the pelvic region, when hypogastric artery is damaged, very often a ligation of the vessel is one of the options.

Injuries of the hepatic arteries or vascular structures of hepatic ligament are less frequent and cause mostly by thermal mechanism during electrocoagulation [43].

Vascular injury during the orthopedic surgery is not a frequent complication with an incidence of 0.05–0.1%. However due to a large number of procedures performed, it concerns patients in almost every hospital in which total hip and knee arthroplasty is performed, as well as urgent repositions of the spine and long bones of the extremities with stabilization by the use of external or internal material [44, 45]. During the hip or knee replacement, the mechanism of injury is usually indirect, resulting from torsion and elongation forces resulting in intimal tear and vessel thrombosis. In rare cases the misplaced fixation screws of the acetabulum caused active bleeding or thrombosis of external iliac artery. During the open repositions, the mechanism is usually directly caused by a stabilization material and fixation screws resulting in arterial damage. In that case, the time of diagnosis is crucial, especially when iliac, femoral, or brachial arteries are involved. In some cases like popliteal artery thrombosis after a total knee replacement, an endovascular option is possible. However, in most cases, an arterial reconstruction is the only possible solution. Repositions of the bones of forearm and below the knee have a significantly lower risk of ischaemic complication due to the anatomic reasons, but an active bleeding or pseudoaneurysms may occur. In that area, however, a ligation of the single main arterial trunk like radial or tibial artery usually has no ischaemic consequences.

6. Conclusions

Vascular injuries are not a frequent condition; however, they are one of the most dangerous and challenging cases for medical personnel in the field of proper diagnostics and therapy. In the vast majority of cases, regardless of whether they concern civilian or warfare victims, there are penetrating injuries resulting in massive bleeding or limb-threatening ischemia. The implementation of proper treatment already at the prehospital stage is an essential factor for the patient survival and the limb salvage.

Fast initial assessment of the patient's condition based on the CABC algorithm, adopting an appropriate transport strategy (Load & Go or Stay & Play), application of bleeding control techniques adequate to the area of injury, and early prevention of hypovolemic shock are the key factors for prehospital treatment.

Due to the rapid development of minimally invasive techniques in various fields of medicine (cardiology, neurology, abdominal surgery, urology), the number of iatrogenic vascular injuries increased. Despite the low incidence of such events, iatrogenic injuries are quite common due to high volumes of minimally invasive procedures performed trand require the involvement of a vascular surgeon.

The vascular trauma is very often a part of polytrauma requiring the interdisciplinary trauma team of various specialists to perform a wide range of operations in one time such as vascular reconstructions together with reconstructive orthopedics or reconstruction of the urinary tract. The vascular trauma patients and especially patients with polytrauma should be transported to specialized trauma centers with the high reference level.

Author details

Krzysztof Szaniewski*, Tomasz Byrczek and Tomasz Sikora
Department of Vascular Surgery and Emergency Department, Trauma Center,
St. Barbara Hospital, Sosnowiec, Poland

*Address all correspondence to: kszaniewski@gmail.com

IntechOpen

References

[1] Sidawy AN, Perler BA. Rutherford's Vascular Surgery and Endovascular Therapy. 9th ed. Philadelphia, PA: Elsevier; 2019

[2] Hoff WS, Holevar M, Nagy KK, Patterson L, Young JS, Arrillaga A, et al. Practice management guidelines for the evaluation of blunt abdominal trauma: The East practice management guidelines work group. The Journal of Trauma. 2002;**53**(3):602-615

[3] Guła P, Machała W, Wydawnictwo Lekarskie PZWL. Postępowanie w obrażeniach ciała w praktyce SOR. Warszawa: Wydawnictwo Lekarskie PZWL; 2017

[4] Akhmerov A, DuBose J, Azizzadeh A. Blunt thoracic aortic injury: Current therapies, outcomes, and challenges. Annals of Vascular Diseases. 2019;**12**(1):1-5

[5] Mehta V, Pandit BN, Mehra P, Nigam A, Vyas A, Yusuf J, et al. Massive bleeding from guidewire perforation of an external iliac artery: Treatment with hand-made stent-graft placement. Cardiovascular and Interventional Radiology. 2016;**39**(1):106-110

[6] Sosada K, Żurawiński W, Wydawnictwo Lekarskie PZWL. Ostre stany zagrożenia życia w obrażeniach ciała. Warszawa: PZWL Wydawnictwo Lekarskie; 2018

[7] Davidovic LB, Cinara IS, Ille T, Kostic DM, Dragas MV, Markovic DM. Civil and war peripheral arterial trauma: review of risk factors associated with limb loss. Vascular. 2005;**13**(3):141-147

[8] Prichayudh S, Rassamee P, Sriussadaporn S, Pak-Art R, Sriussadaporn S, Kritayakirana K, et al. Abdominal vascular injuries: Blunt vs. penetrating. Injury. 2019;**50**(1):137-141

[9] Johnson JE, Sims RK, Hamilton DJ, Kragh JF. Safety and effectiveness evidence of SAM(r) junctional tourniquet to control inguinal hemorrhage in a perfused cadaver model. Journal of Special Operations Medicine: A Peer Reviewed Journal for SOF Medical Professionals. 2014;**14**(2):21-25

[10] Smith S, White J, Wanis KN, Beckett A, McAlister VC, Hilsden R. The effectiveness of junctional tourniquets: A systematic review and meta-analysis. Journal of Trauma and Acute Care Surgery. 2019;**86**(3):532-539

[11] Coleman JJ, Zarzaur BL. Surgical management of abdominal trauma. The Surgical Clinics of North America. 2017;**97**(5):1107-1117

[12] Trellopoulos G, Georgiadis GS, Aslanidou EA, Nikolopoulos ES, Pitta X, Papachristodoulou A, et al. Endovascular management of peripheral arterial trauma in patients presenting in hemorrhagic shock. The Journal of Cardiovascular Surgery. 2012;**53**(4):495-506

[13] Malgras B, Prunet B, Lesaffre X, Boddaert G, Travers S, Cungi P-J, et al. Damage control: Concept and implementation. Journal of Visceral Surgery. 2017;**154**(Suppl 1):S19-S29

[14] Branco BC, Musonza T, Long MA, Chung J, Todd SR, Wall MJ, et al. Survival trends after inferior vena cava and aortic injuries in the United States. Journal of Vascular Surgery. 2018;**68**(6):1880-1888

[15] Badole C, Patond K, Mk K. Salvage versus amputation: Utility of mangled extremity severity score in severely injured lower limbs. Indian Journal of Orthopaedics. 2007;**41**(3):183

[16] Cheaito A, Tillou A, Lewis C, Cryer H. Management of traumatic blunt IVC injury. International Journal of Surgery Case Reports. 2016;**28**:26-30

[17] Brunner MP, Cronin EM, Wazni O, Baranowski B, Saliba WI, Sabik JF, et al. Outcomes of patients requiring emergent surgical or endovascular intervention for catastrophic complications during transvenous lead extraction. Heart Rhythm. 2014;**11**(3):419-425

[18] Johansen K, Daines M, Howey T, Helfet D, Hansen ST. Objective criteria accurately predict amputation following lower extremity trauma. The Journal of Trauma. 1990;**30**(5):568-572-573

[19] Loja MN, Sammann A, DuBose J, Li C-S, Liu Y, Savage S, et al. The mangled extremity score and amputation: Time for a revision. Journal of Trauma and Acute Care Surgery. 2017;**82**(3):518-523

[20] Norgren L, Hiatt WR, Dormandy JA, Nehler MR, Harris KA, Fowkes FGR. Inter-society consensus for the management of peripheral arterial disease (TASC II). Journal of Vascular Surgery. 2007;**45**(1):S5-S67

[21] Feliciano DV. Management of peripheral arterial injury. Current Opinion in Critical Care. 2010;**16**(6):602-608

[22] Orawczyk T, Urbanek T, Biolik G, Ziaja D, Szaniewski K, Kuczmik W, et al. Thrombin injection in obliteration of femoral false aneurysms—Own experience. Chirurgia Polska. 2004;**6**(1):7-18

[23] Pang D, Hildebrand D, Bachoo P. Thoracic endovascular repair (TEVAR) versus open surgery for blunt traumatic thoracic aortic injury. In: Cochrane Vascular Group, editor. Cochrane Database Syst Rev. Hoboken, New Jersey, USA: John Wiley & Sons, Ltd; 2019. [cited 2019 Jun 15]; Available from: http://doi.wiley.

com/10.1002/14651858.CD006642.pub3. ISSN: 1465-1858

[24] Son S-A, Jung H, Cho JY, Oh T-H, Do YW, Lim KH, et al. Mid-term outcomes of endovascular repair for traumatic thoracic aortic injury: A single-center experience. European Journal of Trauma and Emergency Surgery. 2019. [cited 2019 June 15]; Available from: http://link.springer. com/10.1007/s00068-019-01166-6

[25] Altuwaijri T, Nouh T, Alburakan A, Altoijry A. Long-term follow-up of endovascular repair of iatrogenic superior vena cava injury: A case report. Medicine (Baltimore). 2018;**97**(50):e13610

[26] Azizzadeh A, Pham MT, Estrera AL, Coogan SM, Safi HJ. Endovascular repair of an iatrogenic superior vena caval injury: A case report. Journal of Vascular Surgery. 2007;**46**(3):569-571

[27] Mattox KL, Feliciano DV, Burch J, Beall AC, Jordan GL, De Bakey ME. Five thousand seven hundred sixty cardiovascular injuries in 4459 patients. Epidemiologic evolution 1958 to 1987. Annals of Surgery. 1989;**209**(6):698-705-707

[28] Weale R, Kong V, Manchev V, Bekker W, Oosthuizen G, Brysiewicz P, et al. Management of intra-abdominal vascular injury in trauma laparotomy: A South African experience. Canadian Journal of Surgery. 2018;**61**(3):158-164

[29] Kazibudzki M, Orawczyk T, Ludyga T, Krupowies A. Cyclist's injury—The cause of symptoms of chronic ischaemia of the lower limb young patients. Chirurgia Polska. 2005;**7**(4):292-295

[30] Matsumoto S, Jung K, Smith A, Coimbra R. Management of IVC injury: Repair or ligation? A propensity score matching analysis using the national trauma data bank. Journal

of the American College of Surgeons. 2018;**226**(5):752-759.e2

[31] Morishita H, Yamagami T, Matsumoto T, Takeuchi Y, Sato O, Nishimura T. Endovascular repair of a perforation of the vena caval wall caused by the retrieval of a gunther tulip filter after long-term implantation. Cardiovascular and Interventional Radiology. 2011;**34**(S2):321-323

[32] de Naeyer G, Degrieck I. Emergent infrahepatic vena cava stenting for life-threatening perforation. Journal of Vascular Surgery. 2005;**41**(3):552-554

[33] Starzl TE, Kaupp HA, Beheler EM, Freeark RJ. Penetrating injuries of the inferior vena cava. The Surgical Clinics of North America. 1963;**43**:387-400

[34] Kunkala M, Jenkins DH, McEachen J, Stockland A, Zielinski MD. Nonoperative management of traumatic suprahepatic inferior vena cava pseudoaneurysms. Journal of Vascular Surgery. 2011;**54**(6):80S-82S

[35] Sabat J, Hsu C-H, Chu Q, Tan T-W. The mortality for surgical repair is similar to ligation in patients with traumatic portal vein injury. Journal of Vascular Surgery. Venous and Lymphatic Disorders. 2019;**7**(3):399-404

[36] Nowicki J, Stew B, Ooi E. Penetrating neck injuries: A guide to evaluation and management. Annals of the Royal College of Surgeons of England. 2018;**100**(1):6-11

[37] Rutman AM, Vranic JE, Mossa-Basha M. Imaging and management of blunt cerebrovascular injury. Radiographics. 2018;**38**(2):542-563

[38] Eleshra A, Kim D, Park HS, Lee T. Access site pseudoaneurysms after endovascular intervention for peripheral arterial diseases. Annals of Surgical Treatment and Research. 2019;**96**(6):305-312

[39] Awan MU, Omar B, Qureshi G, Awan GM. Successful treatment of iatrogenic external iliac artery perforation with covered stent: Case report and review of the literature. Cardiology Research. 2017;**8**(5):246-253

[40] Guloglu R, Dilege S, Aksoy M, Alimoglu O, Yavuz N, Mihmanli M, et al. Major retroperitoneal vascular injuries during laparoscopic cholecystectomy and appendectomy. Journal of Laparoendoscopic & Advanced Surgical Techniques. 2004;**14**(2):73-76

[41] Hauser J, Lehnhardt M, Steinau H-U, Homann H-H. Trocar injury of the retroperitoneal vessels followed by life-threatening postischemic compartment syndrome of both lower extremities. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2008;**18**(2):222-224

[42] Li Z, Zhao L, Wang K, Cheng J, Zhao Y, Ren W. Characteristics and treatment of vascular injuries: a review of 387 cases at a Chinese center. International Journal of Clinical and Experimental Medicine. 2014;**7**(12):4710-4719

[43] Gupta V, Gupta V, Joshi P, Kumar S, Kulkarni R, Chopra N, et al. Management of post cholecystectomy vascular injuries. The Surgeon. 2018. [cited 2019 June 17]. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1479666X18301203

[44] Lopera JE, Restrepo CS, Gonzales A, Trimmer CK, Arko F. Aortoiliac vascular injuries after misplacement of fixation screws. Journal of Trauma—Injury, Infection and Critical Care. 2010;**69**(4):870-875

[45] Parvizi J, Pulido L, Slenker N, Macgibeny M, Purtill JJ, Rothman RH. Vascular injuries after total joint arthroplasty. The Journal of Arthroplasty. 2008;**23**(8):1115-1121