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The effect of early endovascular intervention on the outcome of traumatic vascular injuries

Erken dönem endovasküler girişimin travmatik vasküler yaralanmaların sonucuna etkisi

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Background: In this study, we reported mid-term results of early endovascular treatment modalities for traumatic vascular injuries confirmed by angiography.

Methods: Between January 2007 and December 2010, patients who were admitted to our clinic with gunshot injury or suspected penetrating/blunt injuries and suspected vascular injury were examined. After angiographic examination, 10 patients underwent endovascular treatment due to vascular injury. Vascular injuries were due to penetrating injury in three patients, gunshot injury in six patients and blunt trauma in one patient. Six patients presented with a pseudoaneurysm (two of which associated with arteriovenous fistula), three with rupture and one with axillary artery-to-bronchial fistula.

Results: Coil embolization was performed in patients with arterial rupture. Stent graft implantation was performed in patients with pseudoaneurysm formation, arteriovenous or artery-to-bronchial fistula. All procedures were performed under local anesthesia. Symptoms related to vascular injury disappeared within postoperative three days and they were discharged on the postoperative fifth day. All patients were re-examined by color Doppler ultrasonography at three and 12 months. No findings of related extravasation, stenosis or ischemia were detected in the follow-up.

Conclusion: Unnoticed vascular, traumatic or gunshot injuries may lead to limb dysfunction in the long-term. Angiographic evaluation of the vascular injury in suspected patients allows early treatment of vascular injuries. Endovascular treatment of vascular injuries in the same procedure is associated with less blood transfusion, shorter intensive care and in-hospital stay and lower mortality in patients with angiographically vascular injury.

Key words: Endovascular procedure; trauma; vascular injury.

Amaç: Bu çalışmada erken dönemde anjiyografik olarak tanı konulan travmatik vasküler yaralanmaların endovasküler yöntemlerle tedavisine ilişkin orta dönem sonuçlarımız bildirildi.

Çalışma planı: Ocak 2007 - Aralık 2010 tarihleri arasında ateşli silah yaralanması ya da şüpheli penetran/künt travma nedeni ile kliniğimize başvuran ve vasküler yaralanma şüphesi bulunan hastalar erken dönemde incelendi. Anjiyografik değerlendirme sonrası 10 hastada vasküler yaralanma nedeni ile endovasküler tedavi uygulandı. Vasküler yaralanmaların nedeni üç hastada penetran yaralanma, altı hastada ateşli silah yaralanması, bir bir hastada ise künt travma idi. Hastaların altısında yalancı anevrizma (ikisinde arteriyovenöz fistül eşlik ediyordu), üçünde rüptür ve birinde aksiller arter-bronşiyal fistül mevcuttu.

Bulgular: Arteriyel rüptür bulunan olgularda koil embolizasyonu uygulandı. Yalancı anevrizma ve arteriyovenöz ya da arteriyobronşiyal fistül bulunan olgularda stent greft implantasyonu uygulandı. Bütün işlemler lokal anestezi altında gerçekleştirildi. Vasküler yaralanmaya bağlı semptomlar ameliyat sonrası üçüncü günde kayboldu ve hastalar 5. günde taburcu edildi. Bütün hastalar ameliyat sonrası 3. ve 12. ayda renkli Doppler ultrasonografi ile incelendi. Takiplerinde ekstravazasyon, stenoz ve iskemi bulgusuna rastlanmadı.

Sonuç: Travma ya da ateşli silah yaralanması sonrası gözden kaçan vasküler yaralanmalar, uzun dönemde ekstremite disfonksiyonuna yol açabilir. Vasküler yaralanma şüphesi bulunan hastaların anjiyografik olarak değerlendirilmesi erken dönemde tedavi şansı sağlar. Anjiyografik değerlendirmede vasküler yaralanma tespit edilen hastaların aynı işlem esnasında endovasküler yöntemlerle tedavisi; daha az kan transfüzyonu, daha kısa yoğun bakım kalış süresi ve düşük mortalite ile ilişkilidir.

Anahtar sözcükler: Endovasküler işlem; travma; vasküler hasar.

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Trauma-induced vascular injuries may be complicated by hemorrhage, thrombosis, sepsis, erosion, dissection, or occlusion.[1] Moreover, pseudoaneurysm formation commonly occurs in the four-seven days of trauma due to diagnostic failures in the first examination. However, visualization of vascular structures avoids late complications after the trauma. Angiography is necessary for the evalution of the intimal disruption or dissection after gunshot injuries, and early diagnosis of vascular injury allows for early treatment. In this way, a minimally invasive approach to the vessels can be performed with minimal mortality and morbidity rates.

Emergency surgery must be performed when extravasation occurs, and it is accomplished via a large incision which may lead to increased blood loss and transfusions. Endovascular procedures are alternative treatment options to the surgery, especially for hemorrhage with surgical inaccessibility, arteriovenous fistula (AVF), or pseudoaneurysms.[2] This report includes the midterm results of early endovascular treatment in patients with traumatic vascular injury.

PATIENTS AND METHODS

Endovascular treatment of vascular injuries was performed on 10 male patients at our facility between January 2007 and December 2010. All patient injuries were caused by responsible mechanisms. Penetration was seen in three patients, gunshot wounds were present in six patients, and blunt trauma occurred in one patient. Because of these traumas, three patients suffered from hemorrhage, six had pseudoaneurysms, two had AVF associated with pseudoaneurysms, and one had an axillary arteriobronchial fistula (Table 1).

After the diagnosis was established, all patients were transferred to the hybrid operating room, which belongs to the cardiovascular surgery department and was designed specifically for endovascular procedures and minimally invasive surgery. The Arcadis® Avantic C-arm (Siemens AG, Erlangen, Germany) was used for the angiographic examinations of all patients.

RESULTS

After preparing the hybrid operating room, the 10 patients were treated via endovascular procedures. Table 1 summarizes the diagnoses, injured vessels, traumatic causes, and treatment methods. Nine of the 10 patients were in the army, and they were between 20 and 22 years old. The other patient was 59-years-old and had retired from the army.

Three patients were admitted to the hospital with hemorrhage after a gunshot injury. Two of them had bleeding originating from the anterior tibial artery (ATA), and one had an associated tibial fracture. Angiography revealed the disconnection of the ATA laminar flow; hence, coil embolization of the ATA was performed with the guidance of a microcatheter and under local anesthesia (Figure 1). The patient with the bone fracture was then transferred to the orthopedics department. Another patient was hemorrhaging from the peroneal artery, and coil embolization was performed on this artery using the same procedure. The endovascular procedures for hemorrhage were ended after control angiography.

Mass expansion in the thigh, pulsatile mass, thrill, and heart murmur occurred for four-seven days of the trauma in four patients (Table 1). Doppler ultrasonography (USG) revealed pseudoaneurysms of the superficial femoral artery (SFA) in these patients, who were then transferred to our department. One of them had foot drop due to a peroneal nerve injury, and another had an AVF accompanying by a pseudoaneurysm. In addition, AVF could not be ruled out in one other patient. All four of these patients were transferred to the hybrid operating room after receiving 300 mg clopidogrel perorally. Antegrade diagnostic arteriography was performed after obtaining access to the SFA with an 8-French sheath. Angiography

Table 1. Vascular injuries treated by endovascular procedures

Injured vessels	Type of trauma	Vascular injury	Accompanying lesion	Treatment	n
SFA	Penetrating	Pseudoaneurysm	–	Covered stent	2
SFA	Gun shot injury	Pseudoaneurysm	–	Covered stent	2
SFA-SFV	Penetrating	Pseudoaneurysm	Arteriovenous fistula	Covered stent	1
SFA-SFV	Gun shot injury	Pseudoaneurysm	Arteriovenous fistula	Covered stent	1
Axillary artery	Blunt	Bronchial fistula	–	Covered stent	1
Anterior tibial artery	Gun shot injury	Rupture	Tibial fracture	Coil	1
Anterior tibial artery	Gun shot injury	Rupture	None	Coil	1
Peroneal artery	Gun shot injury	Rupture	None	Coil	1

SFA: Superficial femoral artery; SFV: Superficial femoral vein.

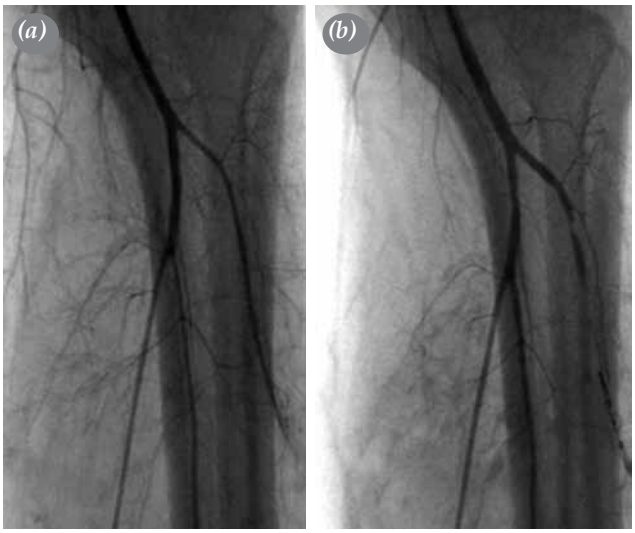

Figure 1. (a) Discontinuity of the anterior tibial artery after trauma. **(b)** Control angiography after coil embolization.

Figure 2. (a) Preoperative angiography of the pseudoaneurysm and arteriovenous fistula of the superficial femoral artery. **(b)** Postoperative control angiography after stent graft implantation.

revealed pseudoaneurysms in all four cases along with an additional AVF in two of the four. Heparin 5000 U was administered via the sheath, and the patients were then treated through the use a self-expanding stent graft (Viabahn®, W.L.Gore & Associates, Flagstaff, Arizona, USA). After examining the stent graft with control angiography, the patients were transferred to the intensive care unit (ICU) (Figure 2).

One patient was admitted to the hospital with hemoptysis five days after blunt trauma of his shoulder. The origin of the bleeding was not revealed in the computed tomography (CT) or bronchoscopy. However, magnetic resonance angiography revealed an axillary arteriobronchial fistula, and the patient was moved to the hybrid operating room where angiography revealed an axillary arteriobronchial fistula originating from the proximal one-third of the axillary artery. After performing a standard antiaggregant regimen, a 9x50 mm Viabahn® self-expanding stent graft was implanted into the axillary artery (Figure 3).

All patients with stent graft implants received 100 mg aspirin perorally after being transferred to the ICU, and 1000 units/hour heparin perfusion was given intravenously for six hours. Next, dual antiplatelet treatment (aspirin and clopidogrel) and enoxaparin (for 3 days) were started.

There was no need for blood or blood product transfusion in the perioperative period. The patients who underwent coil embolization were examined for ischemic signs, but none appeared in the postoperative period.

The pulsatile mass, thrill, and heart murmur disappeared at the end of the procedure, and in the patients with pseudoaneurysms, the diameter of the

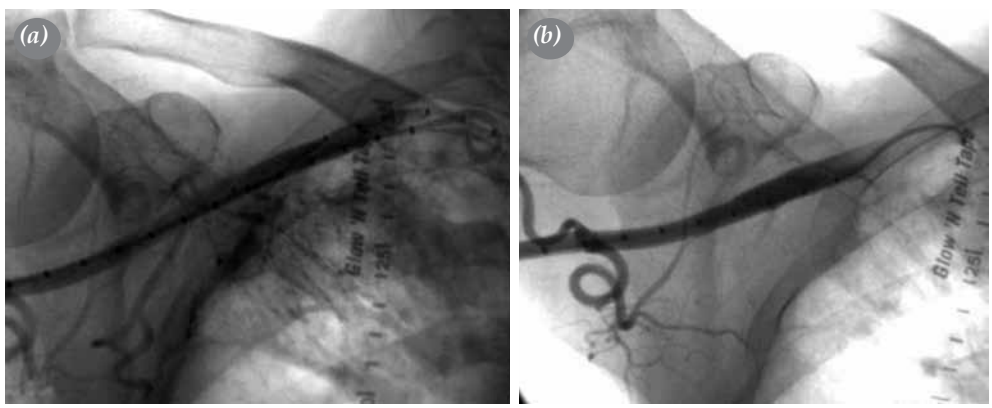

Figure 3. (a) Axillary arteriobronchial fistula in the preoperative angiography. **(b)** Control angiography after stent graft implantation.

thigh returned to normal size with elevation after three days. In the axillary arteriobronchial fistula patient, hemoptysis disapperaed gradually after two days.

We performed endovascular treatment of vasculary injuries due to trauma on a total of 10 patients, and eight of these were discharged from the hospital on the postoperative fifth day. The patient with hemorrhage associated with a tibial fracture was operated on by orthopedic surgeons after vascular repair and was followed up in the orthopedics department. Meanwhile, the patient with foot drop was transferred to the neurosurgery department after one week.

All cases were examined by color Doppler USG in the third and 12th months, and no signs of extravasation or stenosis were seen in the follow-up period.

DISCUSSION

Traumatic vascular injuries, particularly those that are caused by penetrating or gunshot traumas, can result in different pathologies ranging from simple intimal disruption to the complete rupture of the vessel. Extravasation may cause active hemorrhage or a pseudoaneurysm due to the limitations of neighboring structures.[3] Dissection or ischemic signs of extremity can occur as a result of intimal disruption. Furthermore, surgical exploration is necessary after the development of pulsatile hematoma, hemorrhage, thrill, or ischemia.[4]

Traumatic vascular injuries can result in serious delayed complications, and these may occur even years later if they are not identified. Patients with traumatic injuries must be closely monitored, and arteriography is recommended to evaluate their condition with regard to a potential vascular injury, even if overt clinical signs or symptoms of vascular injury are absent.[1] The placement of occluding balloons to control bleeding, the initial treatment method for vascular surgery, has been widely reported.[4] Additionally, the recent development and application of endovascular technology and therapy has led to the use of stent grafts in the management of arterial injuries.[5] Currently, stent graft implantation or coil embolization are considered to be the optimal methods of treatment for pseudoaneurysms or uncontrollable bleeding.[5-10]

Arterial occlusion, AVF, and pseuoaneurysms are the late complications of gunshot injury, and these occur at rates of 12.5%, 35%, and 52.5%, respectively. Pseudoaneurysms are diagnosed in the early period of penetrating injuries, but this happens in the late period of blunt traumas. Unfortunately, psuedoaneurysm rarely stay asymptomatic over a long period of time,[7] and they become symptomatic related to their size.[11] The initial symptoms are pain, edema, mass expansion, and distal ischemia, and AVF may be seen concomitantly with any of these symptoms.[5] They usually become symptomatic four-seven days after the penetrating or gunshot injury.[11] In 50% of our patients, the pseudoaneurysms were associated with AVF, and the patients were transferred to our hospital with mass expansion during this time period. We moved the patients suspected of having vascular injuries to the hybrid operating theater as soon as consultation had occurred and performed the endovascular procedure under local anesthesia. White et al.[12] reported a 94% success rate in the endovascular treatment of 62 arterial injures that included the femoral, iliac, and subclavian arteries. We treated anterior tibial, subclavian, femoral, and peroneal arterial injuries with stent graft implantation or coil embolization without any complications or additional surgical exploration.

Direct arterial repair, open ligation, coil embolization, and direct thrombin injection are sometimes preferred for the treatment of pseudoaneurysms.[6] Unexpected life-threatening complications might develop in the conventional repair of pseudoaneurysms or while exploring the edematous, fibrotic, and fragile traumatic tissues.[6,9] This could cause blood loss necessitating a blood transfusion. Wide skin incisions are sometimes required to control bleeding, and these might result in cosmetic problems after the recovery period. As a treatment alternative to pseudoaneurysm repair, stent graft implantation or coil embolization have reported decreased risks due to the use of general anesthesia and the longer operating time.[5-7] This enables faster recovery along with early mobilization and decreases the length of time spent in the ICU and the hospital.

Late-term complications due to traumatic vascular injury may increase postoperative morbidity. The mean blood use in the open surgical group was six units of packed red cells per patient, and none of the stent graft group required blood transfusions for the patients' innominate arterial injuries.[10] Stent graft deployment can be performed with mild anticoagulation; therefore, the major bleeding complications observed with heparinization and blood transfusions can theoretically be avoided.[13] We performed our endovascular procedures with local anesthesia, and the mean operation time was 32.5 minutes. No blood transfusion was required in any of our patients repaired with this procedure, and there were no early or late-term complications related to this.

Endovascular therapy is becoming more popular in the management of cervicomediastinal arterial injuries.[7,10,14] In addition to the cervicomediastinal region, intracranial carotid and vertebral artery circulations are difficult to reach surgically, thus

the endovascular technique might be a life-saving procedure.[3] Surgical repair of traumatic subclavian artery injuries is technically demanding because of the anatomic position and standard surgical exposure techniques, including median sternotomies, posterolateral and anterolateral thoracotomies, often with extrathoracic extension, and "book" incisions.[15] In the endovascular treatment of cervicomediastinal vascular injuries, vascular access at a location far from the primary injury obviates the need for a wide dissection in the region of interest.[15] We treated one patient with an axillary arteriobronchial fistula using the endovascular approach. Conventional surgery might have necessitated an excessive incision that would have included the thorax and neck, but we performed the endovascular stent graft implantation successfully with brachial access and under local anesthesia (Figure 3).

The second most common cause of mortality after trauma is an acute aortic tear. Aortic pseudoaneurysms occur weeks or years after penetrating injuries and have high rupture and mortality rates.[2] Patients with a trauma-related aortic tear have a 90% risk of mortality while those who undergo open surgery have only an 8-33% risk along with a 2-26% risk of paraplegia.[16] Endovascular repair of descending aortic injuries excludes thoracotomies, single lung ventilation, and aortic cross-clamping. Comparative studies have reported that while there was no mortality or paraplegia in the endovascular treatment groups, there was a 16-17% mortality risk and a 16% paraplegia risk in the surgery groups.[17,18] Although the endovascular procedure has proven to be a straightforward, safe, and effective alternative, the long-term results are not complete, and the number of patients that have been treated endovascularly is quite small in international series. However, positive results have been seen, and this has encouraged surgeons to select endovascular procedures as the first choice for traumatic aortic disease.[13]

Bone fractures associated with vascular injuries increase the operation time. The direct exploration of a wound in the presence of a fracture and active bleeding can be challenging and is more likely to cause collateral damage to the neighboring structures.[9] The repaired vessels might also be reinjured in the orthopedic surgical period. Stent grafts are associated with rapid recovery and help to reduce the length of surgery through the use of early revascularization. We performed coil embolization of the ATA in the patient with a tibial fracture, and the orthopedic surgeons then performed external fixation of this fracture.

Like conventional surgery, stent graft manipulation can cause complications such as fracture of the stent, kinking, migration, and occlusion during bone surgery.[9] The Viabahn® stent graft consists of thin, expanded polytetrafluoroethylene (PTFE) grafts supported by a self-expanding nitinol stent, making it not only strong, but also flexible enough to be used in vascular injuries with low complication rates.[9] We performed implantations with the Viabahn® stent graft in seven pseudoaneurysm patients without any complications.

Bacterial colonization may be present in the edematous tissue of pseudoaneurysms, and it has been hypothesized that graft infection can evolve after stent graft replacement in the traumatic vascular injury site that was contaminated. Although it is accepted as a contaminated wound, the use of a synthetic vascular prosthesis is common in cases with low infection rates. Endovascular surgical stent graft implantation might be preferable to a synthetic vascular prosthesis with conventional surgery. It has been reported that there was no sign of infection in the one-year follow-up after endovascular stent graft implantation into the abdominal aorta, although the retroperitoneal region was infected.[2] In addition, successful repair of an infected internal carotid artery pseudoaneurysm has been reported.[8] As a consequence, endovascular procedures can be performed with broad-spectrum antibiotic prophylaxis in traumatic arterial procedures. We performed dual antibiotic prophylaxis with first-generation cephalosporin and gentamicin in our patients, and there were no signs of infection in the follow-up period.

Stent graft stenosis and DVT were reported after implantation of the Viabahn® stent graft in patients with polytrauma.[9] Arterial stenosis accompanied by venous thrombosis (VT) might be a sign of insufficient antiaggregant therapy. However, different regimes of antiplatelet therapy can be started following control angiography.[7] Even though a patient may have polytrauma, we suggest the use of heparin for six hours following the procedure, low-molecular-weight heparin (LMWH) following the heparin therapy, and dual antiplatelet (aspirin, clopidogrel) regimes. In our experience, no hemorrhagic complications and no signs of arterial stenosis or VT have been seen in the control Doppler examinations.

In conclusion, early angiography should be performed on all patients with gunshot injuries and potential vascular injuries after trauma. This could be performed in a hybrid operating theater as these injuries should be repaired simultaneously.

Undiagnosed vascular traumatic or gunshot injuries may lead to more complex vascular pathologies and extremity dysfunction in the long-term. When performed in the early period, diagnosis and repair using the endovascular technique can be accomplished with less blood transfusions, shorter stays in the ICU and hospital, and low mortality.

Declaration of conflicting interests

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