Endovascular Treatment of Traumatic Injuries of the Subclavian, Carotid and Axillary Arteries

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Abstract

**Objective:** Injury to the subclavian, carotid or axillary arteries is uncommon. Exposure of these vessels is associated with significant morbidity, and mortality ranges from 5% to 30%. Endovascular methods may offer an alternative approach to these technically challenging injuries.

**Methods:** From March 2011 and February 2013, eight consecutive patients with traumatic subclavian, carotid and axillary artery injuries were treated endoluminally with covered stent. Treated vessels were subclavian (n=7), carotid (n=1) and axillary (n=1) and as one patient had carotid subclavian communication. The target lesion was accessed antegrade via the femoral artery (n=5), retrograde through the brachial artery (n=1), combined antegrade and retrograde via femoral and brachial artery (n=1) and triple access via both femoral and brachial access (n=1).

**Results:** Mean age was 34.5 years with 7 male and 1 female and all patients were symptomatic with palpable mass (n=5), palpable thrill (n=3) and rest pain (n=1). We had 7 cases of traumatic pseudoaneurysm and 1 cases of traumatic subclavian contusion; history of trauma was present in 8 cases with bullet injury 5/8 cases (62.5%), RTA 2/8 cases (25%) and one case of iatrogenic injury (12.5%). Ballon mounted covered stent were used to exclude arterial injury with two cases of endoleak managed successfully. Techniqal success occurred in 100% and 1 year survival rate were 100% with no endoleak.

**Conclusion:** Covered stents are a feasible alternative to open repair in properly selected patients with subclavian, carotid or axillary artery injury, resulting in shorter procedure time and less blood loss.

**Key Words:** Endovascular – Covered stent – Pseudoaneurysm.

Introduction

MOST subclavian, carotid and axillary injuries occur as a result of penetrating trauma [1]. Proximal and distal control of the injured vessel is not always easy, and involves extensive dissection including a combination of supraclavicular or infraclavicular incision, median sternotomy, and thoracotomy. As a result, postoperative morbidity and risk for further injury to surrounding structures is significant [2]. Endovascular techniques offer an alternative by averting direct dissection in the zone of injury. Case reports have indicated successful treatment of subclavian pseudoaneurysm with balloon-expandable and self-expandable stents [3]. Sullivan et al., reported use of covered Palmaz stents for endovascular exclusion of axillary and subclavian pseudoaneurysm in 3 patients [4]. Du Toit et al., used the Hemobahn endovascular prosthesis in 10 patients with penetrating injuries of the subclavian, carotid, and axillary arteries [5]. This type of therapy is appealing in a patient population that frequently has multiple traumatic injuries or medical comorbid conditions. We report a retrospective review of our experience with endovascular repair of subclavian, carotid or axillary injuries in which all patients who underwent endovascular repair received balloon expandible covered stent.

The reduced morbidity and mortality in endovascular interventions, as well as faster convalescence following percutaneous therapy when compared to traditional operations encourage more and more development in angioplasty techniques which sometimes nowadays considered the standard management of traumatic injuries of the great vessels of the aortic arch [6].

Patients and Methods

This is a retrorespective study discussing minimally invasive endovascular techniques in patients with traumatic subclavian, carotid and axillary pseudoaneurysm. It was conducted at Kasr Al-Ainy Teaching Hospital during the period from March 2011 and February 2013.
Patient gender, demographics, presence of co-morbidities, indication for intervention, the procedure, possible complications, benefits, risks and other alternative interventions were all explained to the patients and an informed consent was obtained.

I- Clinical assessment:
• History was taken from all patients including: Epidemiological features (age, gender), comorbidities (diabetes, hypertension, cardiac disease, renal impairment), symptomatology (palpable mass, TIAs and stroke exercise pain, rest pain, tissue loss,) and history of trauma.
• Clinical examination was done for all patients including: Bilateral upper limb pressure measurements, assessment of both upper limbs and carotid pulsations, neurological assessment, color changes, temperature, tissue loss (ulcer or gangrene) assessment of motor power, supraclavicular palpation for pulsating mass or thrill and auscultation for audible bruit.

II- Pre-procedural investigations:
• Routine laboratory tests: Complete blood picture, kidney and liver function tests, coagulation profile and blood glucose level.
• Duplex scanning and CT angiography: Before intervention with the The following information were gathered:
  - Different aortic arch configuration and anomalies.
  - Lesions as regard to site, type, pathology, extension and relation to vital branches.
  - Proximal and distal landing zone.
  - Tortuosity of the vessels.
  - The suitability of the iliac and femoral and brachial arteries for vascular access site.

III- Selection criteria for our study:
Inclusion criteria:
All patient with traumatic subclavian, carotid or axillary artery injury with or without pseudoaneurysm.

Exclusion criteria:
• Non traumatic degenerative aneurysm.
• Unstable patient.
• Active bleeding.
• Infected aneurysm.
• Known intolerance to study medications or contrast agents as severe renal impairment or allergy.
• Non consented patients.

IV- Procedural data:
1- Preprocedure preparations:
All endovascular procedures were done in our angiosuite under local anesthesia with a loading dose of clopidogrel 300mg was given the night of the procedure and well hydrated with. Cerebral activity was monitored by verbal and motor response.

2- Size of sheath:
In all cases 6 French (6F) sheath was used for diagnostic angiography and changed according to each case with 9F long sheath in 1 case, 10F long sheath in 6 case and 11F long sheath in 1 case.

3- Access:
• Single access through right femoral artery was used in 5 cases and Lt brachial artery in 1 case.
• Double access through right femoral and left brachial artery was used in 1 case.
• Triple access through both femoral and left brachial artery was used in 1 case.

4- Wire used: 0.035” hydrophilic wire (Terumo) was used in 8 patient and stiff 0.035” wire in 8 patient.

5- Catheter used: Selective catheters were used; vertebral (n=4), Bernstein (n=2) and Simmons II (n=1).

6- Balloon angioplasty:
Post stent dilatation was done in all case.

7- Stenting:
• Covered stent were used to exclude arterial injury in 7 patient (8 lesions) with pseudoaneurysm and in one patient with traumatic contusion of subclavian artery.
• All covered stent were balloon mounted with stent size range between 6-12mm and length between 40-80mm.

V- Procedural outcome:
Initial procedural success was considered to have occurred when angiographic success was obtained with complete exclusion of aneurysm with no endoleak, no dissection or extravasation of the contrast.

VI- Procedural complications:
Complications were divided into major and minor. Major complications included death, need for emergency surgery, major bleeding or acute
thrombotic occlusion. TIAs or stroke Minor complications included hematoma, treated dissection, or peripheral emboli.

VII- Post-procedural management:

The arterial sheath was routinely removed 2-4 hours after the procedure and mobilization was delayed for 6-12 hours. Digital compression was held proximal to the skin puncture site for 15-20 minutes. Most patients were discharged on the 2nd or 3rd day following the procedure after receiving instructions on risk factors control and treatment including Aspirin 150mg/day for life, Clopidogrel 75mg/day for at least 3 months.

VIII- Follow-up:

All patients were managed in hospital for 2 to 3 days before discharge and follow-up in all patients by clinically and or duplex ultrasonography at 1 week, 3, 6 and 12 months.

Results

The age of the patients ranged from 14 to 50 years with a mean age of 34.5 years, they included 7 male (87.5%) and one female (12.5%), 4 cases (50%) were smoker with free medical history. History of trauma was present in all cases (100%) with bullet injury 5/8 (6.25%) cases Fig. (1), RTA 2/8 (25%) cases and iatrogenic injury for axillary artery (12.5%) was present in one case after puncture of axillary artery in patient with CRF on regular dialysis Fig. (2).

All patients were symptomatic with palpable mass (n=5), palpable thrill (n=3) rest pain (n=1). There were different aortic arch configuration and anomalies. Bovine arch was present in 1 patient (n=1). Right Subclavian (n=6), left subclavian (n=1), left axillary (n=1), and right carotid artery (n=1), was involved in one case with subclavian carotid arterial connection. According to Morphological description of the lesions; We had 7 cases of traumatic pseudoaneurysm in 8 patient as one patient had both carotid subclavian connection and 1 cases of traumatic subclavian contusion. Covered stent were used to exclude arterial injuries and pseudoaneurysm with adequate proximal and distal landing zone. Post stent dilatation were done in all cases Figs. (3,4).

Completer exclusion of arterial injury and pseudoaneurysm with no endoleak occurred in 6 patients Figs. (5-7).
that stent in-place, and then we deployed another covered stent to open the occluded lesion, and a 3rd covered stent to exclude the aneurysm thereafter Fig. (10).

Single access through right femoral artery was used in 5 cases and Lt brachial artery in 1 case. Double access was used in 1 case with Iliac tortuosity reduced the ability to steer the equipment through the femoral access. Although the wire crossed the artery at the aneurysm site, passage by different catheters failed repeatedly due to mild ostial subclavian stenosis, acute bent of the subclavian artery after the innominate bifurcation followed by marked tortuosity of the artery Figs. (8,9). An open brachial access was used to provide a relatively stable wire support. The axillary chronic lesion hindered the smooth passage of the balloon-expandable covered stent, which opened prematurely in the upper brachial artery. We deployed
• Triple access: Through both femoral and left brachial artery in 1 case with floosing technique as angiography from femoral access fail to show the origin of the subclavian artery; brachial access was used and angiography showed bovin trunk with occlusion of 2\textsuperscript{nd} part of subclavian Fig. (11). Wire was passed from brachial access to femoral access (flossing technique and other femoral sheath was used for angiography). Covered stent were inserted with balloon dilatation of the distal part Fig. (12) completion arteriography was done showing patency of arterial tree Fig. (13).

**Fig. (11): Angiography showing occlusion of 2\textsuperscript{nd} part of subclavian artery with triple access.**

**Fig. (12): Angiography showing balloon dilatation of distal part of the stent.**

**Fig. (13): Angiography after deployment of the stent.**

Two cases of endoleak occurred after deployment of the stent; one case following stenting of the right subclavian artery aneurysm and it was managed by balloon angioplasty Fig. (14). Endoleak disappeared completely after 2 weeks as evident with angiography Fig. (15).

**Fig. (14): Angiography with balloon dilatation.**

**Fig. (15): Angiography showing stent with no endoleak.**

Another case after subclavian artery stenting a type 1 endoleak where Balloon dilatation failed to reduce the endoleak. Selective angiogram from the CCA revealed that the aneurysm is connected to CCA as well and forms an arterio-arterial fistula rather than an aneurysm Fig. (16). A second covered stent was inserted in the CCA to exclude the aneurysm starting after the innominate bifurcation Fig. (17). Another angiogram was done and revealed decrease endoleak. Angiography 2 weeks later showed persistence of endoleak. Another covered stent was inserted in the subclavian artery with complete disappearence of the endoleak Fig. (18).
Technical success was achieved in 8/8 cases (100%). Mean length of hospital stay was 2 to 3 day. We had no related mortalities. Follow-up was up to 1 year in all patients with 30 day and 1 year survival rate were 100% and 1ry patency rate was 100% with no endoleak.

Discussion

This study was designed to assess the role and outcome of endovascular management of traumatic subclavian, carotid and axillary artery injury. This study was done on 8 patients; all were managed using covered stent for excluding arterial injury.

The advantages of minimally invasive technique are obvious with lower initial morbidity and mortality, no need for general anesthesia, shorter hospital stay, and less trauma. It has an excellent functional outcome, safety, and midterm results. Increasingly, outpatient angioplasty is now feasible [7].

Subclavian, carotid and axillary artery injuries constitute 5% to 10% of arterial trauma in civilians. The most frequent cause is penetrating trauma, and structures concomitantly involved include the brachial plexus, aerodigestive tract, sympathetic chain, and spinal cord [8]. Surgical stress, frequently combined with concomitant injuries, results in significant morbidity [8].

Conventional open surgical approaches have included thoracotomy or sternotomy [9]. Although long-term durability for these procedures is excellent, open surgical reconstruction is associated with significant cardiac, pulmonary, infectious, and neurologic operative morbidity [7]. Kalakunla et al., reported a postoperative complication rate of 24% [10]. Mortality ranges from 5% to 30% in various studies [8].

The remote access avoids major operative dissection in this anatomic area and avoid sternotomy or thoracotomy especially in case of trauma. By eliminating the dissection, the risk of significant hemorrhage from arteriovenous fistulas or vascular injuries is minimized. The possibility of injury to important surrounding structures, such as the subclavian vein or brachial plexus, which may be difficult to identify because of hemorrhage or involvement in the original injury, is therefore eliminated [11]. Patients with decreased life expectancy when long term patency is not a primary concern might benefit from this less invasive procedure. Also, patients who are poor candidates for general anesthesia can undergo an endovascular approach with intravenous sedation and local anaesthesia [11].

Widespread use of endovascular stent treatment of vascular injuries has become an acceptable and less invasive alternative to surgical repair in subclavian, carotid and axillary artery injury [11].

The present study included 7 male (87.5%) and 1 female (12.5%) with male to female ratio 7/1.
showing the predominance of male in SATs aneurysmal diseases. This differs than with Marcelo et al., who had 74 case of aneurysmal disease with male to female ratio 3/1 in which most aneurysm were degenerative [12] this may be because all cases in our study are due to trauma which are more common in males.

The patients age ranged from 14-50 with mean age of 34.5 ys. This comparable to Marcelo et al., in which most patients presenting with degenerative aneurysms seems to fall in the 60 year-old age group while traumatic and iatrogenic aneurysm fall in age group between 40-60 years [12].

In our study; treated vessels were right subclavian (n=6), left subclavian (n=1) left axillary (n=1) right common carotid (n=1) was involved in one case with subclavian carotid communication.

This is comparable to the distribution in Marcelo et al., in which the subclavian artery was most commonly affected (n=37), followed by the common carotid (n=27), internal carotid (n=8) innominate (n=2), and vertebral (n=1) [12].

SATs injuries and pseudoaneurysm are rare and subclavian injury occur in 3% of penetrating injuries to the neck. Blunt injuries account for 2% to 3% of all reported subclavian artery injuries [13].

In our study we had 5 cases of subclavian artery pseudo aneurysm, one case of carotid pseudoaneurysm secondary to penetrating injury, one case of iatrogenic axillary pseudo aneurysm, one case of contusion thrombosis of subclavian artery and one case of pseudo aneurysm of subclavian artery due to blunt injury and no cases of innominate artery aneurysm and this is comparable to Kieffer et al., who had no cases of innominate artery aneurysm [14] and against Bower who had 6 cases this is may be due the long period of his retrospective survey over 40 years [15].

In our study, all cases with traumatic and aneurysmal disease were symptomatic with 6 case presenting with palpable mass (75%) 3 cases with Palpable thrill (37.5%) and one case with rest pain (12.5%). This is different from Marcelo et al., in which 52 of 74 patients were asymptomatic at the time of diagnosis (70%) and 15 patients (20%) had suffered embolization (9 strokes or TIA and 6 upper-limb embolization) [12].

Chan et al., who studied the aneurysms of the supra-aortic vessels had been reported to be symptomatic in up to 50% of patients. They are more commonly discovered following screening or follow-up exams such as CT, X-rays, or US for asymptomatic patients. Once diagnosed, any supra-aortic vessel aneurysm should be considered a clinically significant lesion as it has the potential of significant complications if left untreated [16].

Mean length of hospital stay was 2 to 3 day. There were no deaths, myocardial infarctions, or strokes. This comparable to Briani et al., in which Mean length of hospital stay was 1.2 days. There were no perioperative procedure-related complications and at 30-day follow-up, no deaths, myocardial infarctions, or strokes [17].

Endovascular treatment is expected to reduce operative morbidity and mortality rates. In our study 30 days and 1 year mortality rates were 0% this is compares to Elias et al., who have 30-day and 1 year mortality rate of 0% [18].

The choice of the access site depends on many factors, such as location of the pathology, access route, arch tortuosity, device size, and the need for additional treatments. The ipsilateral axillary or brachial approach, while allowing a more direct route, increases the risk of hematoma or pseudo aneurysm and resultant neuropathy. To reduce the risk, a cut-down may be required to introduce the device [19].

Adjunctive techniques to facilitate crossing complex stenotic and total occlusive disease include favoring a retrograde approach for innominate and subclavian lesions. A retrograde approach provides a shorter, more direct course to support wires and catheters used to cross the occlusion. Snares of the wire after it has transversed the occlusion and entered the aortic arch to establish femoral-brachial access has been described by several authors (flossing technique). This approach establishes a stable access through-and-through wire, allowing precise stent deployment for Innominate or subclavian lesions. Endovascular recanalization of occlusive lesions involving the aortic arch vessels can be facilitated through the placement of through-and-through wire access [19].

In our study we used single femoral access in 5 cases (62.5%) brachial access in one case (12.5%), combined access (right femoral and left brachial were used in 1 patient (12.5%) and triple access (both femoral and left brachial were used in 1 patient. (12.5%) using flossing technique with wire entering in brachial access and passed to femoral sheath with 3 rd sheath in contralateral femoral artery for angiography. This is comparative to Hilfiker et al., who use the femoral approach in
In the last decade, stent graft technology has evolved remarkably and has now been applied as an alternative way of treatment for supra-aortic aneurysms and arterial injury [21]. Over the past several years, many case reports have been published describing the treatment of traumatic SATs aneurysms with endovascular techniques and devices. Initially, individuals described obtaining proximal control with the placement of an occlusion balloon in the proximal vessel under fluoroscopic guidance prior to open repair. However, multiple reports now describe placement of an endovascular stent-graft across the site of extraluminal extravasation. Unlike an atherosclerotic aneurysm, the focal nature of these injuries allows for excellent sealing of endoluminal grafts around the site of injury. Endovascular treatment avoids the morbidity and mortality associated with an open operation and its technical application is simplified by deployment of devices in arteries free of atherosclerosis [21].

In our study we used 12 stent in 8 patient one patient had 3 covered stent to cover both carotid and subclavian pseudo aneurysm, in another patient we used 3 covered stent as one stent was deployed in brachial artery due to tortuosity of the artery, one stent to exclude subclavian pseudo aneurysm and 3 rd stent for axillary artery occlusion near the joint.

While endovascular repair is an attractive option, several anatomical limitations exist. It is unusual for aneurysms of the subclavian or innominate to have adequate proximal and distal landing zones. Also, coverage of branch vessels such as the right carotid, vertebral arteries, and left internal mammary when it has been used for coronary bypass could have dire consequences. Stent grafts crossing the first rib may be subject to extrinsic compression. Long-term results are poor because of stent compression and fracture [22].

The overall technical success rate for endovascular stenting for repair of arterial injuries was 93.6% [12] which is comparable to our study with technical success in 9/9 (100%) lesions in patient with traumatic and aneurysmal diseases.

Unsuccessful stent placement, which occurred infrequently, was attributed to a variety of reasons, including the inability to traverse the lesion with a guidewire, persistent contrast extravasation after stent placement, or graft migration requiring either placement of coils or conversion to open repair [12].

8 lesions with traumatic pseudo aneurysm were managed with 100% technical success with no perioperative and long term morbidity and no mortality; one case with contusion thrombosis with suspected injury was managed with 100% technical success and 100% patency rate at 1 year with no perioperative and long term morbidity and no mortality.

Our result was comparable to the literature with technical success ranging between 85.7-100% in traumatic and aneurysmal diseases (Table 1).

Table (1): Shows technical success and mortality rate with endovascular exclusion of SAT s aneurysms.

<table>
<thead>
<tr>
<th>Study</th>
<th>Technical success</th>
<th>30 day Mortality</th>
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<tbody>
<tr>
<td>Lyden et al., 2001</td>
<td>96%</td>
<td>2.2% mortality</td>
</tr>
<tr>
<td>du Toit et al., 2003</td>
<td>96.7%</td>
<td>3.3% mortality</td>
</tr>
<tr>
<td>Zoffoli et al., 2006</td>
<td>85.7%</td>
<td>0% mortality</td>
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<tr>
<td>Piffaretti et al., 2007</td>
<td>100%</td>
<td>0% mortality</td>
</tr>
<tr>
<td>Marcelo et al., 2009</td>
<td>93.6%</td>
<td>0% mortality</td>
</tr>
<tr>
<td>Mark et al., 2011</td>
<td>100%</td>
<td>2.3% mortality</td>
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</tbody>
</table>

In our study 30 day survival rate was 100% and 1 year survival rate was 100% this is comparable to Marcelo et al., with Survival at 30 days was 100%. Five-and 10-year survival rates were 87% and 43%, [13].

Conclusion:

Aneurysms arising from the supra-aortic trunks pose a surgical challenge, because of the difficulties that may be encountered in proximal control. Endovascular exclusion with covered stent has become a first choice of treatment in many centers in many selected patients with an excellent functional outcome and midterm results. Double access have to be considered and may be flossing technique to give more accessibility and stability to the system. Open surgical bypasses should be considered for cases in which surgical intervention is indicated for another reason or in lesions after failed angioplasty or in which angioplasty is contraindicated.

References


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