Changing Profiles of Diagnostic and Treatment Options in Subclavian Artery Aneurysms

B.P. Vierhout a,*, C.J. Zeebregts b, J.J.A.M. van den Dungen b, M.M.P.J. Reijnen c

a Department of Surgery, Wilhelmina Hospital Assen, Assen, The Netherlands
b Department of Surgery, Division of Vascular Surgery, University Medical Center Groningen, Groningen, The Netherlands
c Department of Surgery, Alsyszorgoep, Location Rijnstate, The Netherlands

Submitted 3 December 2009; accepted 9 March 2010
Available online 15 April 2010

Abstract

Background: Subclavian artery aneurysms (SAAs) are rare and may cause life- and limb-threatening complications. Therapeutic options greatly differ as do access alternatives. The aim of the study was to assess its clinical presentation, diagnostics and therapeutic options as reported in the literature.

Method: A literature search was performed of the Medline, Cochrane and EMBASE databases. All articles, published until September 2009, describing treatment of an SAA were included.

Results: A total of 191 reports, of which 126 met the inclusion criteria, were identified and were published from June 1915 until September 2009. Of these, 394 SAAs were described in 381 patients, with a mean age of 52 \( \pm \) 16 years. The median diameter was 40 mm (range: 10–180 mm). The aetiology appeared to change in time towards more exogenous causes. Fifty-one percent of the SAAs presented with a pulsating mass, shoulder pain and/or non-specific chest pain. Embolisation, rupture and thrombosis were present in 16%, 9% and 6% of patients, respectively, and their incidence was related to the anatomical localisation of the SAA. Open surgery and endovascular repair had a complication rate of 26% and 28%, respectively (\( p = 0.49 \)). Cardio-pulmonary complications were restricted to open repair. Mortality rates for open and endovascular techniques were similar (5%). The mortality rates for conventional elective and emergency procedures were 3% and 13%, respectively, and for endovascular repair 4% and 8%, respectively.

Conclusion: The profiles of diagnostic and treatment options of SAAs are changing. Although guidelines considering timing of intervention may not be conducted from available literature, intervention appears to be indicated, especially in distal SAAs, due to the risk of thrombo-embolic complications. Endovascular repair and hybrid procedures appear to be the preferred treatment modalities, due to a lower rate of cardiopulmonary complications.

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The incidence of subclavian artery aneurysms (SAAs) has been repeatedly reported to be rare. Dent et al. identified only two SAAs in their series of 1488 aneurysms. In that study, however, all false, postoperative, dissecting and mycotic aneurysms were excluded. According to Wickham and Martin, only 57 cases had been described until 1963. Since then the frequency of reports in literature has increased. The SA consists of an intrathoracic and an extra-thoracic part, while anatomically it may be divided into four parts. From a surgical point of view, a more practical categorisation into three parts has been suggested: a proximal, a middle and a distal part. The proximal part extends from its origin, the innominate artery on the right and the aorta on the left side, to the medial border of the scalene muscles. The middle portion of the SA is located dorsal to the scalene muscles. The distal part of the SA extends from the lateral border of the anterior scalene muscle to the lateral border of the first rib.

The aetiology of an SAA in early publications was frequently of mycotic, syphilitic or tuberculotic origin. In 1916, the thoracic outlet syndrome (TOS), also called costoclavicular compression syndrome, was recognised as an evoking mechanism of SAA formation. Due to limb- or even life-threatening complications treatment is usually indicated. The current study was performed in order to summarise available data on all aspects related to SAA, including aetiology, clinical presentation, diagnostics, treatment modalities and complications.

Materials and methods

A search was conducted to identify reports in which treatment of a non-anomalous SAA was described, using the MEDLINE, EMBASE and Cochrane databases. Papers were included from the start of the databases until September 2009. Earlier publications were tracked using manual cross-referencing with the earliest article published in June 1915. The following MeSH search terms were used: aneurysm, subclavian artery and therapy. These terms were applied in various combinations in addition to the use of the ‘related articles’ function. Full-text articles were studied without restriction of language of publication and manual cross-referencing was performed. Demographic data, aneurysm characteristics, treatment modalities, complication and survival data were extracted using standardised criteria. Included reports had to contain above-mentioned data. When two or more studies from the same institution were identified, the study of larger size or better quality was included, unless the reported outcomes were mutually exclusive. Reports were excluded from further analysis if they did not clearly describe diagnostics and treatment, or if treatment of an aberrant right subclavian aneurysm (ARSA) was reported. Reports published before 1980 were compared to those published afterwards. This arbitrary cut-off point at 1980 was chosen since in that decade the first reports were published on endovascular repair.

Results

A total of 191 reports on SAAs were identified of which 126 met the inclusion criteria. A total of 49 reports presented patients with an aberrant right SAA, 15 reports only described the existence or incidence of a SAA and one study was a duplicate publication. The 126 reports included could be categorised into 10 single-centre series and 116 case reports. Three-hundred and eighty-one patients were diagnosed with 394 SAAs. Two-hundred and eleven patients were described in single-centre series and 170 in case reports. The mean age of patients was 52 ± 16 years, with a male–female ratio of 59:41. The median diameter of the SAA was 40 mm (range: 10–180 mm) and 57% were right-sided.

Aetiology and localisation

The aetiology of SAAs has been summarised in Table 1. Until 1980, most SAAs were related to TOS, infection or atherosclerosis. Afterwards, traumatic and iatrogenic causes were more frequently described, while atherosclerosis and collagen disorders remained important.

The majority (39%) of SAAs were located in the proximal segment of the SA. The middle segment accounted for 25%, and 24% was located in the distal segment. In the remaining 11% of cases, localisation of the SAA was not described. The evoking mechanisms of SAA formation seemed to differ between each region of the SA. Proximal aneurysms were mostly caused by atherosclerosis (19%), collagen disorders (18%), trauma (15%), infection (13%) and in-hospital procedures (12%). The middle segment SAAs were mainly caused by collagen disorders (23%), trauma (15%), in-hospital procedures (10%), infection (10%) and TOS (15%). A distal SAA was mostly described in relation to TOS (46%) or as a consequence of blunt or penetrating trauma (23%).

Clinical presentation

Fifty-one percent of patients presented with a pulsating mass, shoulder pain and/or non-specific chest pain. Other symptoms included local compression, embolisation, thrombosis and rupture (Table 2). Brachial plexopathy was the most frequently described sign of local compression. Symptoms of local compression were atypical in many cases. In this context, compression of the stellate ganglion induced Horner syndrome, while recurrent laryngeal nerve compression caused hoarseness. Dysphagia and dyspnoea, due to compression of the oesophagus and trachea, respectively, have also been reported. Subclavian vein compression, causing venous congestion, was described once and another report described compression of the mammalian artery after coronary artery bypass surgery.

Embolisation, often related to TOS, was described in 16% (n = 56) of cases both to the upper extremity (n = 44) and the cerebrum (n = 12). Cerebrovascular accidents were also reported in a patient with fibromuscular dysplasia, in a patient 18 months after a motor vehicle accident and in a patient with an atherosclerotic aneurysm. Limb-loss due to embolisation has never been reported, but embolisation was fatal in one patient.

Thrombosis occurred in 21, mostly female, patients with TOS, in the age range of 17–57 years. These were all true
aneurysms with a relatively small diameter of 12–25 mm.9,17,50,51 Thrombosis never appeared to have a fatal outcome, but two patients50,51 lost their hand because of gangrenous complications.

Rupture was reported in 32 patients (9%) and was fatal in six of them. In another patient, rupture resulted in amputation.52 Most survivors presented with an episode of hemoptysis, which may be considered as an early sign of rupture (n = 9).18,37,38,53 A suspicion of an SAA was often confirmed by angiography, which used to be the gold standard. Nowadays, the investigation of choice for initial diagnosis is duplex ultrasound scanning.69 Angiography was performed in 50% of the reports before surgical exclusion. Computed tomography angiography (CTA; 14%) and magnetic resonance angiography (MRA; 3%) are increasingly being used (Fig. 1).

### Table 1: Aetiology of SAA.

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Before 1980</th>
<th>After 1981</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of cases (%)</td>
<td>Number of cases (%)</td>
<td>Number of cases (%)</td>
</tr>
<tr>
<td>Trauma</td>
<td>5 (10%)</td>
<td>123 (37%)</td>
<td>128 (33%)</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>12 (24%)</td>
<td>60 (18%)</td>
<td>72 (19%)</td>
</tr>
<tr>
<td>T.O.S.</td>
<td>12 (24%)</td>
<td>59 (18%)</td>
<td>71 (18%)</td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>0 (0%)</td>
<td>32 (10%)</td>
<td>32 (8%)</td>
</tr>
<tr>
<td>Collagen disorders</td>
<td>5 (10%)</td>
<td>24 (7%)</td>
<td>29 (7%)</td>
</tr>
<tr>
<td>Myotic</td>
<td>8 (16%)</td>
<td>13 (4%)</td>
<td>21 (5%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>3 (6%)</td>
<td>4 (1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>Coarctation aortae</td>
<td>2 (4%)</td>
<td>5 (1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>Congenital</td>
<td>1 (2%)</td>
<td>4 (1%)</td>
<td>5 (1%)</td>
</tr>
<tr>
<td>Post-radiotherapy</td>
<td>0 (0%)</td>
<td>5 (1%)</td>
<td>5 (1%)</td>
</tr>
<tr>
<td>H.I.V.</td>
<td>0 (0%)</td>
<td>3 (1%)</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>Not defined</td>
<td>3 (6%)</td>
<td>4 (1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td>336</td>
<td>387</td>
</tr>
</tbody>
</table>

### Table 2: Incidence of reported symptoms of a SAA.

<table>
<thead>
<tr>
<th>Type</th>
<th>Symptoms</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local signs</td>
<td>Pulsating mass, shoulder pain, non-specific chest pain</td>
<td>51%</td>
</tr>
<tr>
<td>Rupture</td>
<td>Hemoptysis, hematotherax, open rupture, hemorrhage</td>
<td>9%</td>
</tr>
<tr>
<td>Compression</td>
<td>Dysphagia, dyspnoe, brachial plexopathy, Homer’s syndrome, hoarseness</td>
<td>36%</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>Ischemic arm</td>
<td>6%</td>
</tr>
<tr>
<td>Embolization</td>
<td>Numb or cyanotic fingers, cerebral infarction</td>
<td>16%</td>
</tr>
</tbody>
</table>

### Diagnostic tools

Diagnosis of an SAA is strongly related to its symptoms and localisation. SAAs, located in the middle and distal segment, are regularly diagnosed at physical examination (48% and 59%, respectively). Aneurysms of the proximal part of the SA are mostly diagnosed on a routine chest X-ray (41%) and less frequently at physical examination (13%).

A suspicion of an SAA was often confirmed by angiography, which used to be the gold standard. Nowadays, the investigation of choice for initial diagnosis is duplex ultrasound scanning.69 Angiography was performed in 50% of the reports before surgical exclusion. Computed tomography angiography (CTA; 14%) and magnetic resonance angiography (MRA; 3%) are increasingly being used (Fig. 1).

### Treatment modalities

The indication for exclusion of an SAA is usually based on prevention of upper limb thrombosis, embolisation and rupture. The risk of development of these complications may depend on various aneurysm-related characteristics, including its aetiology and localisation. Treatment modalities include conservative management, open surgical repair, endovascular exclusion and various hybrid techniques.

### Conservative management

Conservative management, consisting of best medical treatment and observation, was described in seven patients. Four patients, having an underlying disease that withheld them from surgery, eventually died of rupture.39,41,63 Three of these patients had a mycotic SAA and one suffered from severe pulmonary insufficiency. The remaining three patients refused surgery and showed no aneurysm growth within a follow-up duration of 1 year.2,6,70 The aetiology of the SAA in these patients was associated with coarctation of the aorta, atherosclerosis and idiopathic.

![Figure 1](attachment:image.png) CT-angiography of a 36-year old female patient with a middle segment SAA related to TOS. Arrow pointing at the SAA.
Conventional surgical repair

Three-hundred and twenty-nine patients underwent conventional surgical repair. Access options for the proximal SA greatly differed and included right and left thoracotomy, sternotomy with and without supraclavicular or transclavicular access, axillary access and anterior thoracotomy in combination with mini-sternotomy and supraclavicular access. The mid-segment of the SA appeared usually easier to reach using a supraclavicular access. This approach may be combined with an infraclavicular incision, clavicular division and (partial) clavicular resection. In cases of a SAA due to TOS, aneurysm repair was often combined with first-rib resection.71,72

Various surgical procedures have been described for the exclusion of a SAA. The first described treatment option was ligation only15,18,20–22,35,38,42,52,55,58,68,73–76 and later in combination with a carotid–subclavian (n = 5)77–81 or femoro-axillary bypass (n = 1).66 Ligation of the SAA was fatal in two early reports; both patients died of exsanguination on the day of surgery and the 76th postoperative day, respectively.11,42 Aneurysmorraphy was mainly used for smaller and false aneurysms.19,29,45,50,61,68,75,82,83 Aneurysm resection combined with vein- or polyester-graft reconstruction provided a useful alternative and was performed in 51% of cases prior to 1980. Only one procedure was reported with fatal outcome, due to a ruptured Stanford type-A aortic dissection during surgery in a patient with Ehlers–Danlos syndrome.47 In the single-centre series, the mortality rate of open repair was 8%, while the overall mortality in the surgically treated group was 5%. Seventy-eight percent of treatments were performed in an elective setting with a mortality rate of 3%, while 18% was carried out in an emergency setting, with a mortality rate of 13%. In the remaining patients, it was unclear whether the procedure was performed in an elective or emergency setting.

A variety of postoperative complications have been described following surgical repair (Table 3). Postoperative recurrent laryngeal nerve injury was described in 3%.35,43,64 In 1%, an abscess had to be drained11,42 and seven patients (2%) developed an ischemic arm, of which four needed a (partial) amputation.16,50,51 The overall complication rate was 26%. Systemic complications, such as massive coagulopathy, acute tubular necrosis and cerebrovascular accidents, were all reported once.18,36,59 Pulmonary complications, including a chylothorax35 and an oesphago-pleural fistula38 occurred in 5% of patients and was often related to trauma. Paraplegia due to a brachial cord lesion (3%) may be temporary17,19,86 or persistent.29,84,87 In 2% of cases, the presence or absence of complications was not mentioned.

Endovascular and hybrid repair

To date, 63 cases of endovascular SAA repair have been published (Fig. 2a and b). In the mid-1990s, the first endovascular subclavian aneurysm repair (EVSAR) procedures were published. After a follow-up period of 6 months, no complications were observed.88–92 In 1996, a patient died 6 days after an EVSAR, presumably due to pre-existent cardiac insufficiency.44 Beregi et al. have published a series of 19 patients with peripheral aneurysms, including five SAAs. All SAAs were successfully excluded using various stent-grafts, but, at the 1-year follow-up, two stent-grafts had occluded. It was concluded that treatment of peripheral aneurysms with stent-grafts not only had a high rate of immediate success, but also had a high incidence of thrombosis.93 Schoder et al. described 10 patients that were electively treated with a stent-graft to repair an SAA due to trauma or a misplaced central venous catheter. The primary patency at the 1-year follow-up was 100%. Strut dislocation without stenosis was observed in one patient and a 50% stenosis, due to compression between the clavicle and the first rib, occurred in another.94 Other published procedure-related complications include in-stent stenosis,62,96 stent-fracture,96,97 pseudo-aneurysm formation,93,98 early thrombosis92 and wound infection after surgical closure of the groin.98 The overall complication rate for EVSAR was 28% with a mortality rate of 5%. Eighty percent of patients were operated upon in an elective setting, with a mortality rate of 4%. The remaining 20% were emergency procedures and had a mortality rate of 8%.

Case-series with endovascular treatment have not been published to date. Fourteen percent of EVSAR procedures were performed in combination with open techniques,67,99–101 including the re-implantation of the SA or vertebral artery in the common carotid artery46,102,103 and first-rib resection in case of TOS.104

Complications were allocated in the endovascular group.

Table 3  Incidence of complications following SAA repair.

<table>
<thead>
<tr>
<th></th>
<th>Open repair</th>
<th>Endovascular</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases (%)</td>
<td>Number of cases (%)</td>
<td>Number of cases (%)</td>
<td></td>
</tr>
<tr>
<td>No complications</td>
<td>239 (73%)</td>
<td>36 (75%)</td>
<td>8 (80%)</td>
</tr>
<tr>
<td>Early thrombosis</td>
<td>4 (1%)</td>
<td>1 (2%)</td>
<td>1 (10%)</td>
</tr>
<tr>
<td>Late thrombosis</td>
<td>4 (1%)</td>
<td>3 (6%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Stenosis</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>False aneurysm</td>
<td>0 (0%)</td>
<td>4 (8%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Disintegrating nitinol wire</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Abscess</td>
<td>3 (1%)</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Gift infection</td>
<td>2 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Ischemic arm</td>
<td>6 (2%)</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Recurrent laryngeal nerve injury</td>
<td>9 (3%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Injury of the brachial cords</td>
<td>7 (2%)</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Rebleeding</td>
<td>4 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Unsuccessful ligation</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Disarticulation</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Shoulder instability</td>
<td>8 (3%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Cardiac complications</td>
<td>4 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Pulmonary complications</td>
<td>15 (5%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Massive coagulopathy</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>2 (1%)</td>
<td>0 (0%)</td>
<td>1 (10%)</td>
</tr>
<tr>
<td>Acute tubular necrosis</td>
<td>1 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>
Discussion

In the present study, we have shown that a SAA is a rare entity with <400 published reports in world literature. The true prevalence, however, may well be higher because common presentations and adverse outcomes are likely to be under-reported. This review of the historical literature was based entirely on case reports and small series and, therefore, the level of evidence presented is low, as is the nature of evidence related to other rare conditions. The profile of diagnostic and treatment options of SAAs is changing. While a mycotic cause is less common nowadays, traumatic and iatrogenic causes are reported more frequently.

The occurrence of life- and limb-threatening complications, such as rupture, embolisation and thrombosis, seemed to depend on the anatomical localisation of the aneurysm. Proximal and mid-clavicular aneurysms had a higher incidence of rupture, when compared to distal aneurysms. We could not deduct a diameter at which an SAA should be excluded. Whether other parameters may be better predictors for rupture remain to be elucidated. Thrombo-embolic complications were mainly related to distally located aneurysms. Nevertheless, 9% of thrombo-embolic complications occurred in proximal SAAs. The risk of thrombo-embolic complications was unrelated to the diameter of the SAA and did also occur in small aneurysms of only 12—25 mm, emphasising that early intervention may be indicated, especially in distal SAAs.

As a result of the complication risk, prompt diagnosis and treatment are indicated. In recent years, the number of reported asymptomatic SAAs has increased, due to routine chest X-rays. The non-invasive nature of duplex ultrasound scanning may facilitate early diagnosis. Nonetheless, nowadays, CTA and MRA are being used more frequently and are likely to become the new gold standard, because of their ability to image the relation of the SAA with its surrounding tissues.

Morbidity and mortality rates of open and endovascular repair were within the same range. Mortality rates may be underestimated since the publication of cases may have been partly restricted to successfully treated patients. In the single-centre series, the mortality of open repair was 3% higher, but these included trauma patients that may have increased mortality rates. Complications following EVSAR and hybrid procedures seem to be less severe when compared to those following open repair. Systemic complications were strictly reserved to open surgery as were plexopathy of the brachial cord and injury of the recurrent laryngeal nerve. Endovascular options mainly depend on anatomical characteristics of the aneurysm and access. Especially in trauma and iatrogenic SAAs, EVSAR has proven to be of value. It seems reasonable to assume that emergency repair is associated with an increased mortality. In the present study, 18% of conventional and 20% of endovascular procedures were performed in an emergency setting, with a mortality rate of 13% and 8%, respectively. The great diversity of symptoms and treatment modalities of these patients made a reliable comparison between groups impossible.

The SA is extremely mobile and exposed to rotationary forces during abduction and ante-flexion of the arm. Therefore, a stent-graft, used for EVSAR, has to be flexible and resistant to kinking and fracture. To date, a variety of stent-grafts have been used. In-stent stenosis and thrombosis were seen in early series; however, in recent studies, patency seems to have increased. Patency results of endovascular treatment may further increase with the development of better stent-grafts and improved post-procedural pharmacotherapy.

In conclusion, we have shown that the SAA is a rare vascular entity with life- and limb-threatening complications. Diagnostic and treatment options are evolving. Although guidelines considering the timing of intervention may not be conducted from available literature, early intervention appears to be indicated, especially in distal SAAs, due to the risk of thrombo-embolic complications. Endovascular repair and hybrid procedures appear to be the preferred treatment modalities, due to a lower rate of cardiopulmonary complications.

Conflict of Interest

None declared.
Acknowledgements

The authors thank Romel Zamudio, M.D., of the Almenara Hospital in Lima, Peru, for his help in the retrieval of Hispanic reports.

References


Subclavian Artery Aneurysms


