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# Functional Results of Cervical Rib Resection for Thoracic Outlet Syndrome: Impact on Professional Activity

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1 Functional results of cervical rib resection for thoracic outlet syndrome: impact on  
2 professional activity.

3

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14

15 Declarations of interest: none

16

17 Abstract

18 Objective: The aim of this study is to report long-term functional results following cervical rib  
19 (CR) resection for thoracic outlet syndrome (TOS).

20 Methods: This monocentric study included all cases of resection of CR for TOS performed  
21 between January 2004 and December 2016. Data were retrospectively collected from the  
22 hospital electronic database including pre-operative symptoms and the evaluation of  
23 occupational well-being, intraoperative data, and early clinical evaluation and occupational  
24 well-being during the post-operative period. Patients were categorized as neurogenic TOS  
25 (NTOS), arterial TOS (ATOS), arterial and neurogenic (ANTOS), venous TOS (VTOS) or  
26 asymptomatic according to preoperative evaluation. We evaluated the improvement in work  
27 life between the preoperative and the post-operative period. Further assessment was a  
28 negative Roos or elevated arm stress test (EAST) during the post-operative period.

29 Results: Thirty-three patients with a median age of 38.5 years (30-46) were included. Thirty-  
30 six procedures were performed: 33 % to treat ATOS (12/36), 39% for NTOS (14/36), 19% for  
31 ANTOS (7/36), 3% for VTOS (1/36) and 6% (2/36) for asymptomatic lesions. There were 9  
32 cases of subclavian artery aneurysms leading to additional arterial repair. Due to distal  
33 embolization, a cervical sympathectomy was associated in 5 procedures. First rib resection  
34 (FRR) was associated in 4 procedures (11%) and C7 transverse process resection was  
35 performed in 15 procedures (42%). The technical success rate was 100% and intra-operative  
36 complications were observed in 4 patients (11%) with favorable postoperative outcomes.  
37 During the early postoperative period, 3 Claude Bernard Horner's syndrome and 1  
38 asymptomatic subclavian dissection were detected. Late complications included 2 bypass  
39 thromboses (6%) at 6 weeks and 16 months. Post-operative EAST improved in 16 limbs  
40 (44%).

41 Prior to the procedure, only 27% (9/33) patients had normal work lives. After the procedure,  
42 64% (21/33) of patients were able to return to their normal work activity.

43 Conclusion: Cervical rib resection for TOS seems to be a safe procedure leading to good  
44 short and long-term clinical results with a favorable impact on recovering a normal work life  
45 in these young patients.

46

47 Keywords: thoracic outlet syndrome – cervical rib

48

49	Abbreviations
50	
51	ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome
52	ATOS: Arterial Thoracic Outlet Syndrome
53	CBH: Claude Bernard Horner
54	CTA: Computed Tomography Angiography
55	CR: Cervical Rib
56	CS: Cervical Sympathectomy
57	EAST: Elevated Arm Stress Test
58	EMG: Eletromyogram
59	FRR: First Rib Resection
60	FRRS: First Rib Resection and Scaleneotomy
61	NTOS: Neurogenic Thoracic Outlet Syndrome
62	TOS: Thoracic Outlet Syndrome
63	VTOS: Venous Thoracic Outlet Syndrome

64 1. Introduction

65 Cervical rib (CR) is an abnormal bone originating from the seventh vertebra [1]. CR is  
66 observed in 0.2 to 1% of the general population [2,3]. Only 10 % of CR are responsible of  
67 thoracic outlet syndrome (TOS). TOS is secondary to the compression of the neurovascular  
68 bundle. CR is associated with an increased rate of arterial compression in TOS [4,5]. Arterial  
69 injuries are frequently associated to stage 3 or 4 of Grüber's classification [6].

70 Different subtypes of TOS are described according to the compressed anatomical structure:  
71 vascular TOS (arterial or venous) or neurogenic TOS [7]. Surgical decompression in TOS  
72 without anatomical abnormality is indicated when physiotherapy fails. While physiotherapy is  
73 associated with favorable results in NTOS, conservative treatment is rare in vascular TOS.  
74 Where CR is associated with TOS, it must be surgically corrected. No conservative treatment  
75 was performed in case of symptomatic CR. CR resection was first described by Coote in 1861  
76 [8]. Many studies report short and long-term results of surgical decompression for TOS [9].  
77 First rib resection and scalenectomy (FRRS) associated with CR resection when present is the  
78 surgical treatment of TOS. The association of FRRS and CR resection is controversial. Most  
79 studies report results of combined FRRS and CR resection. CR resection without FRRS for  
80 TOS is rarely studied in the literature. Nevertheless, the presence of CR can be responsible for  
81 specific vascular complications like subclavian aneurysms that require appropriate treatment.  
82 In this study, we reported the monocentric experience of CR resection in TOS over 12 years.  
83 We evaluated long term functional results following cervical rib resection for TOS and the  
84 occupational impact of the surgery.

85

86 2. Material and Methods

87 *2.1 Study population:*

88 From 2004 to 2016, all patients who underwent CR resection were selected from the hospital  
89 electronic database. Research was made with keywords “rib resection” and “thoracic outlet  
90 syndrome” and all operative reports were reviewed. In this analysis, we included all patients  
91 with FFRS who required complementary CR resection. We excluded from this study cases of  
92 FFRS without CR resection.

93 Demographic and clinical data such as gender, age at the time of surgery, medical history,  
94 active smoking, pre-operative symptoms, and the orthopedic history of the upper limb,  
95 medical therapy, professional activity and occupational disability were collected. The Roos or  
96 elevated arm stress test (EAST) was performed as part of the clinical examination before the  
97 procedure and 1 month after the procedure [10].

98 Patients were classified according to reporting standards [7]. Preoperative symptoms could be  
99 arterial (ATOS) (arm claudication, the absence of radial pulse, finger ulcer or necrosis, upper  
100 limb ischemia with or without neurologic impairment), neurogenic (NTOS) (paresthesia,  
101 weakness, muscle atrophy of the upper limb), both arterial and neurogenic (ANTOS) or  
102 venous (VTOS) (edema, deep vein thrombosis). Clinical exam classified subtype of TOS  
103 (ATOS, NTOS, ANTOS and VTOS).

104 All patients were explored by Chest X Ray, dynamic ultrasound and CTA. A chest X Ray  
105 depicted a cervical rib. Patients were retrospectively categorized using Grüber’s classification.  
106 Grüber’s classification of cervical rib was described in 1968 and differentiated 4 anatomical  
107 presentations [11] : 1: a rudimentary rib that does not penetrate into the transverse process; 2:  
108 a small cervical rib that extends beyond the transverse process of the seventh cervical vertebra  
109 with a free distal end; 3: a cervical rib continued by a fibrous or fibromuscular band ending at  
110 the first thoracic rib and 4: a cervical rib connected to the first thoracic rib by true cartilage.  
111 Dynamic Doppler ultrasound was systematically performed to explore vascular TOS and  
112 diagnose potential associated arterial injuries. Doppler ultrasound was performed by a trained

113 physician. Both venous and arterial vessels are explored. Blood flow cessation during  
114 dynamic maneuver (45° abduction above the shoulder) while normal at rest confirmed the  
115 diagnosis. Computed tomography angiography (CTA) both at rest and during dynamic  
116 maneuver was systematically performed. Anatomical abnormality, vessel compression  
117 location and the arterial run off was analyzed and helped surgical planning. An angiogram  
118 was performed pre-operatively if distal emboli were depicted on CTA or in cases of distal  
119 ulcers, lack of radial or ulnar pulses. Electromyogram (EMG) with nerve conduction was  
120 performed in patients with symptoms suggesting NTOS. The decrease of distal nerve  
121 conduction and low velocity (50 m/s) suggested a brachial plexus impairment.

## 122 *2.2 Surgical technique:*

123 All surgeries were performed under general anesthesia as described by Shein in 1971 [12].  
124 The phrenic nerve was systematically assessed by external monitoring at the beginning and at  
125 the end of the procedure. Access was supraclavicular. CR was systematically performed. FRR  
126 and/or C7 transverse process resection were performed if dynamic maneuvers depicted a  
127 stress compression of vessels or of neurologic bundles after CR resection. Bone resection was  
128 performed with a Kerisson clamp. Adjunctive cervical sympathectomy (CS) was performed  
129 prior to 2015 in patients presenting with aneurysms and distal emboli. Data on intra-operative  
130 complications and on additional arterial subclavian repair (aneurysmorrhaphy, aneurysm  
131 resection, bypass, embolectomy) were collected. At the end of the procedure, dynamic  
132 maneuvers were systematically performed to confirm the release of the neurovascular bundle  
133 during upper limb abduction. When confirmed, the procedure was considered as a technical  
134 success. All patients except those with isolated NTOS received antiplatelet therapy following  
135 surgery. A postoperative Doppler ultrasound was systematically performed in ATOS and  
136 ANTOS at one month.



137 For the purpose of this study, we updated the follow-up of each patient either using the report  
138 of their last medical visit in the year (general practitioner, neurologist or Doppler ultrasound)  
139 or by phone.

140 We evaluated each patient's quality of work life pre-and post-operatively. Preoperative EAST  
141 and professional activity was systematically evaluated preoperatively and collected  
142 retrospectively. We also evaluated the EAST during the post-operative period. Post-operative  
143 EAST was collected retrospectively from the report of surgical visit at one month. The post-  
144 operative ability of work was evaluated on November 2017 using standardized telephone  
145 questionnaire to evaluate professional occupation and compare it to preoperative status.

146 Early outcomes were those within the first 30 days of follow up. Short term outcomes are the  
147 outcomes after the 30 first postoperative days up to the first year and long-term outcomes  
148 were those after the 1<sup>st</sup> postoperative year.

### 149 *2.3 Statistical analysis:*

150 Categorical variables were presented as percentages and continuous variables were expressed  
151 as median with interquartile ranges (Q1-Q3).

152

## 153 3. Results:

### 154 *3.1 Demographic data*

155 From January 2004 to December 2016, 36 cervical ribs were resected in 33 patients at our  
156 institution. Three patients (9%) required bilateral CR resection.

157 The population consisted in 27 women and 6 men with a median age of 38.5 year old (30-46)  
158 at the time of surgery. The youngest patient was 13 years old and the oldest 58 years old. One  
159 patient had a history of ipsilateral collarbone fracture, and 7 were followed for upper limb  
160 orthopedic disease. Details of demographic data are summarized in Table I. Among the 36  
161 cervical resections, 22 were on the right side. The most common Grüber's category for the

162 resected cervical rib side treated was the fourth (22/36, 61%). Contralateral CR was present in  
163 27 patients (27/33, 82%) mostly of category 3 in Grüber's classification.

164 Most frequently, patients were treated for NTOS (14/36, 39%). VTOS was only depicted in  
165 one patient (3%) (Table II). There were 2 asymptomatic patients (6%). The youngest patient  
166 of this study was a 13-year-old girl who presented with a severe scoliosis treated with a back  
167 brace. A unilateral CR was discovered on the X Ray of the spine. The CR was removed after  
168 multidisciplinary discussion including orthopedic and vascular surgeons. The second one was  
169 a 28-year-old female who presented with a left cervical rib complicated of a voluminous  
170 subclavian aneurysm. It was decided to remove the contralateral CR preventively.

171 EAST was positive for 64% (23 limbs) as detailed in Table Iva.

172 On preoperative exams, 9 subclavian aneurysms, 6 subclavian stenosis and 6 subclavian post-  
173 stenotic dilations (3 aneurysms and 3 ectasia) were depicted. EMG was performed in 23 limbs  
174 and reported suffering of the brachial plexus in 49% limbs (11/23).

175 *3.2 Procedure results* (Table III).

176 Among patients with upper limb ischemia (19%, 7/36), two (6%, 2/36) required CR resection  
177 associated with urgent revascularization. The last required anticoagulation therapy before CR  
178 resection.

179 The resection of CR was complete in 94% (34/36) of procedures. CR resection was left  
180 incomplete when the release of the neurovascular bundle was obtained and the whole CR  
181 could not be accessed without risking neurologic or vascular damage.

182 Additional arterial procedures were required during 9 procedures (25%) with arterial  
183 aneurysms: 1 aneurysmorrhaphy, 5 aneurysm resections with direct reconstruction and 3  
184 prosthetic bypasses. Three subclavian ectasias were left untreated.

185 The technical success rate was 100%.

186 Intraoperative complications were observed in 11% of procedures: 4 pleural breach treated by  
187 adjunctive chest tube. All pleural breach resolved favorably at 48h. No brachial plexus or  
188 phrenic nerve injury was described.

### 189 *3.3 Early outcomes*

190 The median length of hospitalization was 3.5 days (3-4).

191 Postoperative complications were detected in 11% of the cases studied: 3 (8%) Claude  
192 Bernard Horner's (CBH) syndrome, spontaneously resolved and an asymptomatic subclavian  
193 dissection (3%) was depicted on a systematic postoperative Doppler ultrasound. This  
194 dissection was treated only by antiplatelet therapy with favorable outcomes. No access  
195 complication were diagnosed.

196 On clinical exam at 1 month, 7 limbs (19%) were EAST positive: 4 NTOS (29%) and 3  
197 ATOS (25%) (Table IVa). All patients treated with adjunctive CS had a radial pulse  
198 postoperatively.

### 199 *3.4 Short and long-term outcomes:*

200 The median follow-up was 91 months (39-123). The last procedure performed had a follow-  
201 up of eleven months and the earliest 165 months. Two patients were lost to follow up because  
202 they could not be reached by phone. They were both considered as unable to have a normal  
203 professional activity. One of them had no clinical evaluation during the postoperative period  
204 and was considered worsened (EAST positive on follow-up).

205 Late complications were two bypass thromboses (6%) at 6 weeks and 16 months. One  
206 required a secondary procedure. The embolectomy performed in emergency was not  
207 successful and a thoracic sympathectomy by videothoracoscopy was required at one year to  
208 treat upper limb claudication with a good clinical outcome. The last bypass occlusion was  
209 asymptomatic and detected at 16 months on standard follow up Doppler ultrasound.

210 During follow-up, patients with ATOS, ANTOS or VTOS were followed up with Doppler  
211 ultrasound or CTA. The patency rate was 75 % at 1 year, 67% at two years, 67% at 5 years.  
212 Three patients presented with a reoccurrence of symptoms at 6 weeks, at 4 years and at 10  
213 years after the surgery. The first patient was the patient who presented a bypass thrombosis.  
214 The two others were NTOS.

### 215 *3.5 Professional activity:*

216 During the pre-operative period, 9 patients (27%) had a normal work life and 24 (73%) were  
217 unable to work. On latest follow up, 64% (21/33) had a normal work life: 14 (42%) were  
218 improved and seven (21%) patients showed no improvement. Patients were unable to work  
219 after the surgery in 36% of cases (12/33). Ten patients (30%) showed no modification and  
220 two patients (6%) worsened: one patient suffering from fibromyalgia who required a  
221 reorganization of activity and one lost to follow-up considered as worsened. There were no  
222 missing data for pre and post-operative EAST and professional activity evaluation. Details  
223 according to symptoms are summarized in Table IVb.

224

## 225 4. Discussion

226 We described outcomes of our surgical approach of CR resection for TOS with a  
227 supraclavicular access associated with FRR only when neurovascular entrapment was  
228 persistent during intraoperative dynamic maneuvers testing. CR resection was most often  
229 studied when performed with FRRS. Our postoperative outcomes are acceptable considering  
230 both clinical and functional evaluation. Functional results and quality of life after surgery of  
231 TOS in the literature were previously analyzed [9]. We focused on the occupational ability in  
232 our evaluation of postoperative functional outcome in this young population [3]. Divi et al in  
233 2005 reported similarly results on ability to work in patients presenting with venous and  
234 neurogenic TOS [13].

235

236 TOS was difficult to diagnose. Many symptoms may be related to TOS while not specific  
237 [15]. We reported eleven cases (31%) associated with rheumatologic disease (shoulder of  
238 neck). Diagnostic tools were limited. In our study, all patients benefitted of clinical exam,  
239 Doppler ultrasound and CTA. We performed systematically both imaging in order to confirm  
240 TOS, plan surgery and explore vascular complications. TOS may associate vascular and  
241 neurogenic subtypes. In our population, 19.4% presented with ANTOS. Diagnostic tools of  
242 NTOS appeared less reliable. While EAST was majorly positive in NTOS and ANTOS (86%  
243 and 87% respectively), only 49% were confirmed by nerve conduction velocities decrease.  
244 The reliability of EMG in NTOS diagnosis may be questioned. EAST evaluation could be  
245 more effective for NTOS diagnosis as previously advocated [10,14].

246

247 Our technique was to prioritize CR resection. FRR was only removed when the neurovascular  
248 bundle was found intraoperatively compressed after CR resection. This technique was  
249 previously described by Davies et al, Desai and Robbs and Ambrad-Chalela et al [15–17].  
250 Little evidence is available when considering CR resection alone [6,18–20]. Whether CR  
251 resection must be associated with FRRS remains controversial. Where applicable, CR  
252 resection for TOS is mandatory [21]. Many studies described removing CR along with the  
253 first rib to prevent a late recurrence [6,18,21]. However, the FRR may increase postoperative  
254 morbidity because of a deeper dissection [18]. Interestingly, FRR resection was only required  
255 in our population in NTOS patients and is preformed partially in half of them. One did not  
256 improve after surgery. C7 transverse process resection was also performed in 42% of  
257 procedures when a large apophysis was depicted. Cormier et al [23] also described a C7  
258 process resection in their study in 1989. No result considering the association with C7 process  
259 resection was available to our knowledge. Two CR resections were not complete. Both

260 procedures were technical success One was the only VTOS of this series. The second one was  
261 an ANTOS with a negative EAST. He was able to return at work post-operatively.

262 Our results suggested a safety and efficiency of CR resection alone. On follow-up, a low rate  
263 of recurrence of TOS was depicted (9%, 3/36). All were treated by CR resection only. This  
264 rate was similar to the 11.5% recurrence of TOS described after exclusive FRRS [24]. No  
265 recurrence of symptoms was observed on follow-up after CR was partially removed.  
266 Recently, Gelabert et al [25] advocated the necessity to withdraw completely the CR bone or  
267 the first rib bone to avoid the recurrence of symptoms. Recurrent TOS after CR resection  
268 exclusively was not studied to our knowledge.

269

270 Where additional arterial procedures were required, long term functional results were  
271 favorable. Aneurysm resection and direct anastomosis of subclavian artery seemed to provide  
272 good results as described previously [23]. As opposed to direct anastomosis, use of Dacron  
273 graft was associated to a risk of postoperative occlusion during the first year. Prosthetic use  
274 should be avoided for arterial repair during TOS surgery, as previously described [5,26] .  
275 Subclavian ectasia left untreated did not evolve into aneurysm when CR resection was  
276 performed as reported elsewhere [26,27]. Association between CR and ATOS [5] and severity  
277 of ATOS could justify the preventive resection of a complete CR in case of contralateral  
278 arterial injury [6,28]. In this study, one patient was treated preventively after ATOS as  
279 described above.

280

281 Our study was one of the largest on CR resection in TOS to our knowledge. However, limits  
282 may be discussed. The study was a retrospective and monocentric study of a small population.  
283 Different subtypes of TOS were analyzed as the surgical strategy did not differ. Nevertheless,  
284 results may be biased by the heterogeneity of the TOS symptoms. Furthermore, we did not

285 use validated questionnaires of quality of life because of numerous symptoms presented by  
286 our population. We favored the evaluation of the professional activity to evaluate functional  
287 results as this pathology concerned young active patients.

288

## 289 5. Conclusion

290 CR resection itself seems to be a safe and efficient treatment of TOS. FRRS may be required  
291 depending on intraoperative dynamic maneuvers. Favorable long term outcomes in terms of  
292 occupation are associated to this technique. A larger population is required to confirm these  
293 results.

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Table I: Pre-operative demographics data (N=33)

Median age	38.5 [30;46]	
		N (%)
Male	6	(18)
Female	27	(82)
Cardiovascular risk		
Smoking	18	(55)
Obesity	3	(9)
Dyslipidemia	1	(3)
Associated orthopedic issues		
Collarbone fracture	1	(3)
Rheumatoid polyarthritis	2	(6)
Scoliosis	3	(9)
Cervical discopathy	3	(9)
Cervical osteosynthesis	1	(3)
Shoulder tendinopathy	1	(3)
Shoulder capsulitis	1	(3)
Carpal tunnel	3	(9)
Ipsilateral	1	(3)
Bilateral	2	(6)

Table II: Pre-operative symptoms N = 36

	N	(%)
NTOS <sup>*</sup>	14	(39)
Paresthesia	8	(22)
Weakness	13	(36)
Muscle's atrophy	4	(11)
ATOS <sup>†</sup>	12	(33)
Upper limb Ischemia	7	(19)
Claudication of arm	8	(22)
Finger ulcer or necrosis	5	(14)
Radial pulselessness	7	(19)
ANTOS <sup>‡</sup>	7	(19)
Claudication	6	(17)
Paresthesia	4	(11)
Muscle weakness	6	(17)
Muscle's atrophy	1	(3)
VTOS <sup>§</sup>	1	(3)
Deep venous thrombosis	1	(3)
Asymptomatic	2	(6)

<sup>\*</sup>NTOS Neurogenic Thoracic Outlet Syndrome. <sup>†</sup>ATOS: Arterial Thoracic Outlet Syndrome

<sup>‡</sup>ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. <sup>§</sup>VTOS: Venous Thoracic Outlet Syndrome.

361

362

Table III: Procedure data and complications N = 36

	N	(%)
Supraclavicular access	36	(100)
<hr/>		
Bones resection		
Cervical rib resection	36	(100)
Total	34	(94)
Partial	2	(6)
First rib resection	4	(11)
Total	2	(6)
Anterior bow	1	(3)
Posterior bow	1	(3)
C7 transverse process resection	15	(42)
<hr/>		
Muscle resection		
Anterior scalene		
Section during access	35	(97)
Distal resection on first rib	19	(53)
Posterior scalene	1	(3)
<hr/>		
Additional arterial procedure	9	(25)
Aneurysmorrhaphy	1	(3)
Aneurysm resection- anastomosis	5	(14)
Bypass	3	(8)
Proximal embolectomy	0	(0)
Distal embolectomy	2	(6)
<hr/>		
Additional cervical sympathectomy	5	(14)
<hr/>		
Technical success	36	(100)
<hr/>		
Intraoperative complications		
Pleural breach	4	(11)

Table IVa: Clinical evaluation: Positive EAST\* (N=36)

	ATOS <sup>†</sup> (n=12)	NTOS <sup>‡</sup> (n=14)	ANTOS <sup>§</sup> (n=7)	VTOS (n=1)	Asymptomatic (n=2)	Total (n=36)
Pre-operative	5 (42)	12 (86)	6 (87)	0 (0)	0 (0)	23 (64)
Post-operative	3 (25)	4 (29)	0 (0)	0 (0)	0 (0)	7 (19)

Table IVb: Clinical evaluation: Professional ability (N=33)

	ATOS <sup>†</sup> (n=12)	NTOS <sup>‡</sup> (n=12)	ANTOS <sup>§</sup> (n=7)	VTOS (n=1)	Asymptomatic (n=1)	Total (n=33)
Improvement	3 (25)	6 (50)	5 (71)	0 (0)	0 (0)	14 (42)
Stabilization	9 (75)	4 (33)	2 (29)	1 (100)	1 (100)	17 (52)
Worsening	0 (0)	2 (17)	0 (0)	0 (0)	0 (0)	2 (6)

\* EAST: Elevated Arm Stressed Test. <sup>†</sup> ATOS: Arterial Thoracic Outlet Syndrome. <sup>‡</sup> NTOS: Neurogenic Thoracic Outlet Syndrome. <sup>§</sup> ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. VTOS: Venous Thoracic Outlet Syndrome.

Table 1: Pre-operative demographics data (N=33)

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Median age	38.5 [30;46]	
		N (%)
Male	6	(18)
Female	27	(82)
Cardiovascular risk		
Smoking	18	(55)
Obesity	3	(9)
Dyslipidemia	1	(3)
Associated orthopedic issues		
Collarbone fracture	1	(3)
Rheumatoid polyarthritis	2	(6)
Scoliosis	3	(9)
Cervical discopathy	3	(9)
Cervical osteosynthesis	1	(3)
Shoulder tendinopathy	1	(3)
Shoulder capsulitis	1	(3)
Carpal tunnel	3	(9)
Ipsilateral	1	(3)
Bilateral	2	(6)

Table 2: Pre-operative symptoms N = 36

	N	(%)
NTOS <sup>*</sup>	14	(39)
Paresthesia	8	(22)
Weakness	13	(36)
Muscle's atrophy	4	(11)
ATOS <sup>†</sup>	12	(33)
Upper limb Ischemia	7	(19)
Claudication of arm	8	(22)
Finger ulcer or necrosis	5	(14)
Radial pulselessness	7	(19)
ANTOS <sup>‡</sup>	7	(19)
Claudication	6	(17)
Paresthesia	4	(11)
Muscle weakness	6	(17)
Muscle's atrophy	1	(3)
VTOS <sup>§</sup>	1	(3)
Deep venous thrombosis	1	(3)
Asymptomatic	2	(6)

<sup>\*</sup>NTOS Neurogenic Thoracic Outlet Syndrome. <sup>†</sup>ATOS: Arterial Thoracic Outlet Syndrome

<sup>‡</sup>ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. <sup>§</sup>VTOS: Venous Thoracic Outlet Syndrome.



Table 3: Procedure data and complications N = 36

	N	(%)
Sub clavicular access	36	(100)
<hr/>		
Bones resection		
Cervical rib resection	36	(100)
Total	34	(94)
Partial	2	(6)
First rib resection	4	(11)
Total	2	(6)
Anterior bow	1	(3)
Posterior bow	1	(3)
C7 transverse process resection	15	(42)
<hr/>		
Muscle resection		
Anterior scalene		
Section during access	35	(97)
Distal resection on first rib	19	(53)
Posterior scalene	1	(3)
<hr/>		
Additional arterial procedure	9	(25)
Aneurysmorrhaphy	1	(3)
Aneurysm resection- anastomosis	5	(14)
Bypass	3	(8)
Proximal embolectomy	0	(0)
Distal embolectomy	2	(6)
<hr/>		
Additional cervical sympathectomy	5	(14)
<hr/>		
Technical success	36	(100)
<hr/>		
Intraoperative complications		
Pleural breach	4	(11)

Table 4a: Clinical evaluation: Positive EAST\* (N=36)

	ATOS <sup>†</sup> (n=12)	NTOS <sup>‡</sup> (n=14)	ANTOS <sup>§</sup> (n=7)	VTOS (n=1)	Asymptomatic (n=2)	Total (n=36)
Pre-operative	5 (42)	12 (86)	6 (87)	0 (0)	0 (0)	23 (64)
Post-operative	3 (25)	4 (29)	0 (0)	0 (0)	0 (0)	7 (19)

Table 4b: Clinical evaluation: Professional ability (N=33)

	ATOS <sup>†</sup> (n=12)	NTOS <sup>‡</sup> (n=12)	ANTOS <sup>§</sup> (n=7)	VTOS (n=1)	Asymptomatic (n=1)	Total (n=33)
Improvement	3 (25)	6 (50)	5 (71)	0 (0)	0 (0)	14 (42)
Stabilization	9 (75)	4 (33)	2 (29)	1 (100)	1 (100)	17 (52)
Worsening	0 (0)	2 (17)	0 (0)	0 (0)	0 (0)	2 (6)

\* EAST: Elevated Arm Stressed Test. <sup>†</sup> ATOS: Arterial Thoracic Outlet Syndrome. <sup>‡</sup> NTOS: Neurogenic Thoracic Outlet Syndrome. <sup>§</sup> ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. VTOS: Venous Thoracic Outlet Syndrome.