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

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Declarations of interest: none

Abstract

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

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

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

1. Introduction

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

Different subtypes of TOS are described according to the compressed anatomical structure: vascular TOS (arterial or venous) or neurogenic TOS [7]. Surgical decompression in TOS without anatomical abnormality is indicated when physiotherapy fails. While physiotherapy is associated with favorable results in NTOS, conservative treatment is rare in vascular TOS. Where CR is associated with TOS, it must be surgically corrected. No conservative treatment was performed in case of symptomatic CR. CR resection was first described by Coote in 1861 [8]. Many studies report short and long-term results of surgical decompression for TOS [9]. First rib resection and scalenectomy (FRRS) associated with CR resection when present is the surgical treatment of TOS. The association of FRRS and CR resection is controversial. Most studies report results of combined FRRS and CR resection. CR resection without FRRS for TOS is rarely studied in the literature. Nevertheless, the presence of CR can be responsible for specific vascular complications like subclavian aneurysms that require appropriate treatment.

In this study, we reported the monocentric experience of CR resection in TOS over 12 years. We evaluated long term functional results following cervical rib resection for TOS and the occupational impact of the surgery.

2. Material and Methods

2.1 Study population:

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

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

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

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

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

2.2 Surgical technique:

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

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

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

Early outcomes were those within the first 30 days of follow up. Short term outcomes are the outcomes after the 30 first postoperative days up to the first year and long-term outcomes were those after the 1st postoperative year.

2.3 Statistical analysis:

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

3. Results:

3.1 Demographic data

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

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

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

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

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

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

3.2 Procedure results (Table III).

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

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

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

The technical success rate was 100%.

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

3.3 Early outcomes

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

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

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

3.4 Short and long-term outcomes:

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

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

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

3.5 Professional activity:

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

4. Discussion

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

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

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

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

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

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

5. Conclusion

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

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358

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)

359

360

Table II: Pre-operative symptoms N = 36

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

^{*}NTOS Neurogenic Thoracic Outlet Syndrome. [†]ATOS: Arterial Thoracic Outlet Syndrome

[‡]ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. [§]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)
Aneurysmorraphy	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 [†] (n=12)	NTOS [‡] (n=14)	ANTOS [§] (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 [†] (n=12)	NTOS [‡] (n=12)	ANTOS [§] (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. [†] ATOS: Arterial Thoracic Outlet Syndrome. [‡] NTOS: Neurogenic Thoracic Outlet Syndrome. [§] ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. VTOS: Venous Thoracic Outlet Syndrome.

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

Median age	38.5 [30;46]	
	N	(%)
Male	6	(18)
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Smoking	18	(55)
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Collarbone fracture	1	(3)
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Scoliosis	3	(9)
Cervical discopathy	3	(9)
Cervical osteosynthesis	1	(3)
Shoulder tendinopathy	1	(3)
Shoulder capsulitis	1	(3)
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Table 2: Pre-operative symptoms N = 36

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

^{*}NTOS Neurogenic Thoracic Outlet Syndrome. [†]ATOS: Arterial Thoracic Outlet Syndrome

[‡]ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. [§]VTOS: Venous Thoracic Outlet Syndrome.

Table 3: Procedure data and complications N = 36

	N	(%)
Sub clavicular access	36	(100)
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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)
Aneurysmorraphy	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 [†] (n=12)	NTOS [‡] (n=14)	ANTOS [§] (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 [†] (n=12)	NTOS [‡] (n=12)	ANTOS [§] (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. [†] ATOS: Arterial Thoracic Outlet Syndrome. [‡] NTOS: Neurogenic Thoracic Outlet Syndrome. [§] ANTOS: Arterial and Neurogenic Thoracic Outlet Syndrome. VTOS: Venous Thoracic Outlet Syndrome.