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Evaluation of Different MRI Sequences in Diagnosis of Cause and Effect in Thoracic Outlet Syndrome

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Abstract

Background: Thoracic outlet syndrome is a rare pathological condition characterized by compression of the neurovascular bundle at the thoracic outlet region. Many imaging modalities could be used in the evaluation of TOS, but MRI plays an important role in the diagnosis of the cause and detecting the compressed structures.

Aim of Study: To evaluate the role of different MRI sequences in detecting the cause of compression in TOS and detect the affected (compressed) neurovascular structure.

Patients and Methods: A total of 35 patients with signs of TOS (neurogenic, vascular, or combined) were included in the study. MRI examination was performed for all patients including axial, sagittal, and Coronal T2WI, sagittal STIR, 3D STIR SPACE, and DWI sequences.

Results: MRI revealed the cause of compression was bony in 13 cases, compressing hypertrophied muscle was seen in 12 cases, combined hypertrophied muscle and prominent C7 transverse process in 1 case, and compressing fibrous bands was detected in 4 patients, while compression by soft tissue masses was detected in 2 cases, and no compressing cause was detected in 3 patients.

In the 31 patients with radiological signs of neurogenic TOS, as shown in MRI, the affected neural segment exhibits high signal intensity in the 3D STIR SPACE sequence with no detectable thickening and restricted signal in the DWI sequence.

Conclusion: MRI is the preferred modality of choice in the diagnosis of TOS; its role is not only to diagnose the cause of compression but also to detect the compressed edematous nerve segments that support the diagnosis.

Key Words: *Thoracic outlet syndrome – MRI – MRI sequences.*

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Introduction

THORACIC outlet syndrome is a rare complex pathological condition characterized by compression of the neurovascular bundle at the region of the thoracic outlet **[1]**. The cause of compression could be congenital or acquired **[2].**

The diagnosis of TOS is done with history, clinical examination (provocative tests), cervical plain radiography, electrodiagnostic tests, and brachial plexus MR neurography. However, in patients with suspected vascular affection, other imaging modalities may be needed to confirm the diagnosis as dynamic Doppler US and/or CT angiography **[3,4].**

The new advances in MRI offer a great chance in diagnosis of the cause of compression and the effect of compression especially on the brachial plexus.

Many challenges were found to hinder the management of cases suffering from TOS, such as lack of sensitivity and specificity of a single test in the diagnosis of the cause of compression especially at the scalene triangle and pleural apex, also that most cases are treated conservatively (non-operatively) and hence lack of reference gold standard. However

Abbreviations:

TOS : Thoracic outlet syndrome.
SPACE : Sampling Perfection with Application optimized Contrasts using different flip angle Evolution.
EMG : Electromyogram
STIR : Short Tau inversion recovery.
DWIBS : Diffusion-weighted whole-body imaging with background body signal suppression
ms : Millisecond.
AP : Anteroposterior
AS : Anterior scalenus muscle
MS : Middle scalenus muscle
BP : Brachial plexus
nTOS : Neurogenic thoracic outlet syndrome
MCA : Motor car accident.

surgical treatment may be offered if the symptoms persist **[4]**.

The main concern of our study is to assess the role of MRI in the diagnosis of the cause of compression in TOS, especially the neurogenic type. The secondary objective was to assess the role of different MRI sequences in the diagnosis of the cause and effect of compression i.e. which sequences are more sensitive in detecting the cause of compression and which sequences are more sensitive in detecting the affected neural bundle segment.

Patients and Methods

Study participants:

A prospective cross-sectional study was done from December 2019 to March 2024 in Radiodiagnosis Department, Assiut University Hospital. The study protocol was approved by the "Institutional Review Board" IRB local approval number is 04-2024-300375, and informed consent was obtained from every patient.

A total of 35 patients with signs of TOS (neurogenic, vascular, or combined) were included in the study. Intraoperative findings were available in 4 patients, while two patients with breast cancer metastases were treated with chemotherapy, and the other patients were treated conservatively.

Inclusion criteria:

The examination was performed in patients presenting with clinically suspected TOS, after history taking, clinical examination, and EMG regardless of the age and gender of the case. For the patients with clinically suspected vascular compression (five cases) CT angiography of the chest and upper limb with the arm in neutral and abducted positions was performed.

Exclusion criteria:

In the current study, any patients who were contraindicated for MRI examination (as patients having cardiac pacemakers, patients with metallic prostheses not compatible with MRI, or patients with severe claustrophobia) have been excluded.

Also, any patient with contraindications to CT angiography as pregnant ladies or patients with hypersensitivity to contrast media was excluded from CT angiography examination.

MR image acquisition:

MRI was performed with Siemens Sempra 1.5 Tesla superconducting MRI scanner, with an 8-channel neurovascular coil. Patients were scanned in a supine position with the arms positioned beside the body in a neutral position, the head entering the scanner first. Patients were asked to reduce swallow activity and body movement during the scanning.

MR sequences:

Our protocol includes Sagittal STIR TR/TE 5000/42 ms, FOV 240 mm, and acquisition time 3:57 min. Axial, sagittal, and coronal T2WI TR/TE 4000-5000/100-120 ms, FOV 220-240 mm, and acquisition time 3:20 min. Coronal 3D T2 STIR SPACE TR/TE 3000/183 ms, FOV 280 mm, and acquisition time 4:00 min. Coronal DWIBS TR/TE 2900/63 ms, FOV 370 mm, and acquisition time 1:00 minthe total acquisition time is 18:57 min.

The scanning ranges superiorly from the upper edge of the 4^{th} cervical vertebral body down to the lower edge of the 2^{nd} dorsal vertebral body; posteriorly from the posterior edge of the spinal canal to the sternoclavicular joint anteriorly. Both sides include the head of the humerus. The slice thickness was 3 mm. Sagittal views were taken parallel to the curvature of the cervical spine. Axial views were dead axial. While coronal views were dead coronal involving both sides for comparison, especially in T2 STIR sequences and DWI.

Image processing and analysis:

The original images were obtained by conventional sequences (T2WI) and sagittal T2 STIR, DWIBS sequence scanning, and 3D T2 STIR SPACE, which were imported into Siemens MR Workspace for 3D reconstruction. The maximum intensity projection (MIP) was reconstructed. Two conjoint senior radiologists of 13 and 15 years of experience interpret the images.

Statistical analysis:

Statistical analysis was carried out with the SPSS software 23.0 version. Continuous data were expressed as mean ± SD, while categorical data are expressed as numbers and percentages.

Results

In this study, there were 35 patients, 28 females and 7 males (80% were females and 20% were males), aged 29.7±9.6 years (age ranges from 6 years to 50 years). Duration of the complaint is 18.3 ±19.9 months (range from 1 month to 5 years).

The study showed that 20 patients complained of the right upper limb affection, 14 patients complained of the left upper limb affection, and only one patient complained of bilateral upper limb affection.

The study revealed that 30 patients (85.7%) were presented clinically with a manifestation of neurogenic TOS in the form of upper limb pain, numbness up to the weakness of the shoulder and arm, three patients (8.6%) complaining of vascular TOS in the form of upper limb swelling (edema) and blueness of the hand and arm, while only two patients (5.7%) presented with combined neurogenic and vascular manifestation.

Usually, symptoms of neurogenic TOS come and go but often they are worse by limb activity or in a certain position.

MRI findings:

MRI examination of the patients revealed that 31 patients showed imaging signs of neurogenic TOS in the form of increased signal intensity of the compressed segment of the brachial plexus in 3D STIR SPACE sequence with restricted signal in DWI, while vascular compression was exhibited in only one patient in the form of compressed subclavian artery by a cervical rib and these findings were confirmed with CT angiographic examination with the arm in neutral and abducted position, and no abnormality was depicted in 3 patients.

Cause of compression:

MRI detected the cause of compression in most of the cases, it revealed that cause of compression was bony in thirteen cases (eleven cases with prominent C7 transverse processes, one case with mal-united fractured clavicle, and one case with cervical rib), prominent C7 transverse process appeared slightly extend beyond the T1 transverse process.

While compressing hypertrophied muscle was seen in twelve cases (eight cases of hypertrophied anterior scalenus muscle, three cases of hypertrophied middle scalenus muscle, one case with hypertrophied subclavius muscle), the hypertrophied muscle exceeded 1 cm in its AP diameter with obliteration of fat plane around the compressed nerve segment.

One patient has both prominent C7 transverse processes with hypertrophied middle scalene muscle.

Compressing fibrous bands were detected in four patients. The fibrous band appeared as a thin hypointense structure in T2WI traversing the thoracic outlet structure.

While two cases showed that the cause of compression was metastatic soft tissue masses in females with primary breast cancer and the metastatic lesions either compress the brachial plexus or infiltrate it, the metastatic lesions exhibited variable signal intensity, being iso to hyperintense in T2Win hyperintense in 3D SPACE STIR sequence with restricted signal in DWI.

Although no definite compressing cause was depicted inthree cases.

Affected structure and effect of compression:

The study contains 35 patients, 30 cases of them complain from only neurogenic TOS, 3 cases complain from only vascular TOS, while 2 cases complain from vascular and neurogenic TOS, so the total number of neurogenic cases is 32, and the total number of vascular cases is 5 cases.

In the patients (31 of 32 clinically suspected cases=96.8%) with radiological signs of neurogenic TOS as shown in MRI we found that the affected neural segment exhibited high signal intensity in 3D STIR SPACE sequence with no detectable thickening of the nerve segment and restricted signal in DWI sequence.

In five cases with clinically suspected vascular TOS (3 vascular and 2 combined vascular and neurogenic) CT angiography was performed and vascular compression was detected in only one case in both MRI and CT angiography examination.

While 3 cases had no compressing cause and no MRI abnormality of the brachial plexus segments.

Site of compression:

Interscalene triangle was the commonest site of BP compression (12 cases representing 34%) which was caused by AS or MS hypertrophy, followed by neuroforamen as the 2nd common site for compression (11 cases representing 31%) caused by prominent C7 transverse process. Compression of BP in the costoclavicular triangle was depicted in 4 cases (11.4%) and caused by fibrous band (2 cases), malunited fracture clavicle (1 case), and hypertrophy of subclavius muscle (1 case), while BP was compressed in the supraclavicular region in 3 (8.5%) cases caused by compressing fibrous band in 2 cases and cervical rib (1 case), the whole segments of brachial plexus were compressed along its whole course in 2 cases (5.7%) caused by metastatic soft tissue masses. (Tables 1,2).

Patient management:

Only 4 patients were operated on after MRI examination, 1st case with a fibrous band, The operative finding revealed a compressing fibrous band, the patient improved after the operation for a few months the pain recurred.

2nd case had a cervical rib with subclavian artery compression; surgical excision of the cervical rib was done with post-operative improvement of the symptoms.

In the 3rd case of scalenus medius muscle hypertrophy, middle scalenectomy was done with post-operative improvement of the symptoms.

4th case was post-traumatic brachial plexus injury (MCA) with a malunited fractured clavicle compressing the divisions of the brachial plexus, with also post-traumatic neuroma formation at the course of middle and lower trunks, operative findings were as shown in MRI examination and operative repair was performed accordingly.

While patients complaining of breast cancer metastases were treated with chemotherapy.

The rest of the patients underwent a hydrostatic reduction in the scalene triangle as a confirmatory test and then were candidates for conservative treatment by injecting local anesthetic.

Table (1): Shows the details of compressing cause, the affected segments and site of compression as detected in 3D STIR SPACE and DWI sequences.

Cause	Affected segments	No. of patients	Site of compression
Prominent C7	C7 (6 cases) C8 (2 cases) Both C7, C8 (3 cases)	11	Neuroforamen
Cervical rib	Subclavian A (1 case)	1	Supraclavicular region
Malunited fractured clavicle	Divisions of brachial plexus (1 case)	1	Retroclavicular region
Prominent C7 and hypertrophied muscle	Trunks (1 case)	1	Scalene triangle
Hypertrophied SA muscle	C6 (2 cases) C7 (1 case) Trunks (5 cases)	8	Scalene triangle
Hypertrophied SM muscle	C6 (1 case) Trunks (2 cases)	3	Scalene triangle
Hypertrophied subclavius muscle	Divisions (1 case)	1	Costoclavicular triangle
Fibrous band	Trunks (2 cases) Divisions (2 cases)	4	Supraclavicular or retroclavicular regions
Mass lesion	All segments (2 cases)	2	Along the whole course

Table (2): Shows the included MRI sequences and its role in detecting the cause of compression.

Cause	No. of patients	3D STIR SPACE	DWI	Axial T2WI	Sagittal T2WI	Coronal T2WI
Prominent C7	11	Yes	No	No	No	Yes
Cervical rib	1	No	No	No	Yes	Yes
Malunited fractured clavicle	1	Yes	No	Yes	Yes	Yes
Prominent C7 and hypertrophied SM	1	Yes	No	Yes	Yes	Yes
Hypertrophied AS muscle	8	No	No	Yes	Yes	Yes
Hypertrophied MS muscle	3	No	No	Yes	Yes	Yes
Hypertrophied subclavius muscle	1	No	No	Yes	Yes	Yes
Fibrous band	4	No	No	Only in 3 cases	Only in 2 cases	Yes
Mass lesion	2	Yes	Yes	Yes	Yes	Yes

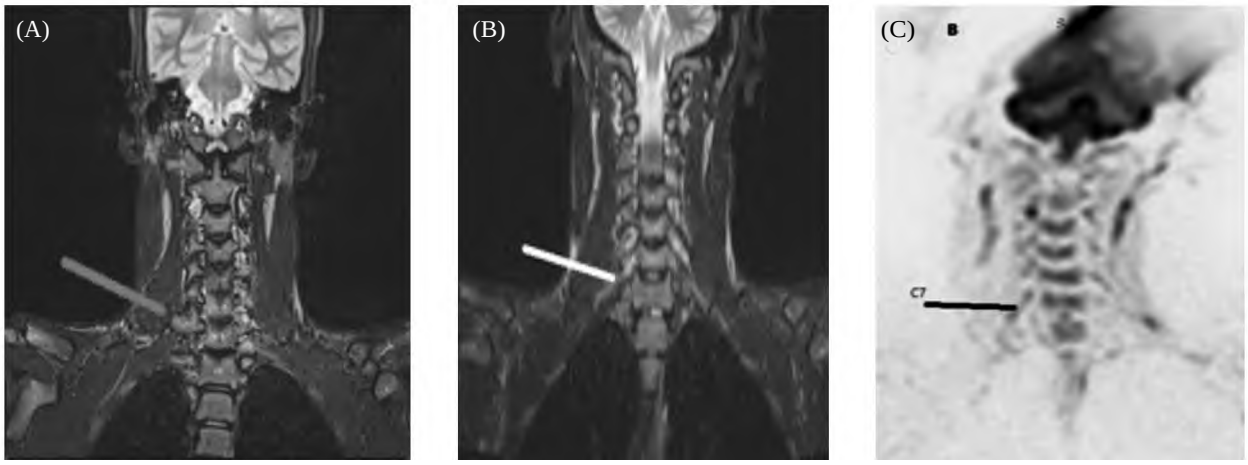

Fig. (1): Male patient, 35 years old complained from right upper limb pain of 5 months duration. (A,B): Coronal 3D STIR, (C): Coronal DWI. Showing prominent right C7 transverse process (red line) in A, subtle edema of right C7 nerve root in B, with restricted signal of right C7 nerve root in C.

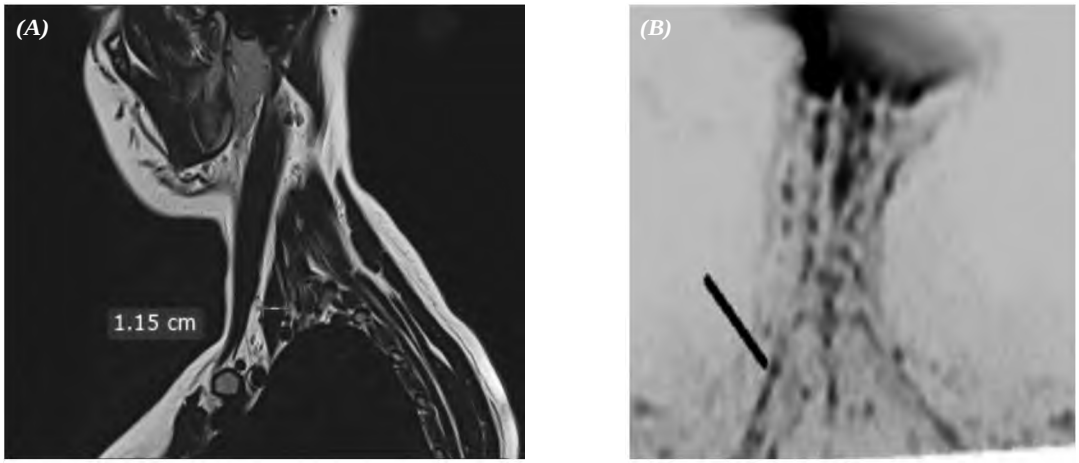

Fig. (2): Female patient 28 years old complained from right upper limb pain of 2 years duration, (A): Sagittal T2WI showing hypertrophied anterior scalene muscle, (B): Coronal DWI showing restricted signal (edema)of the right upper trunk (black line).

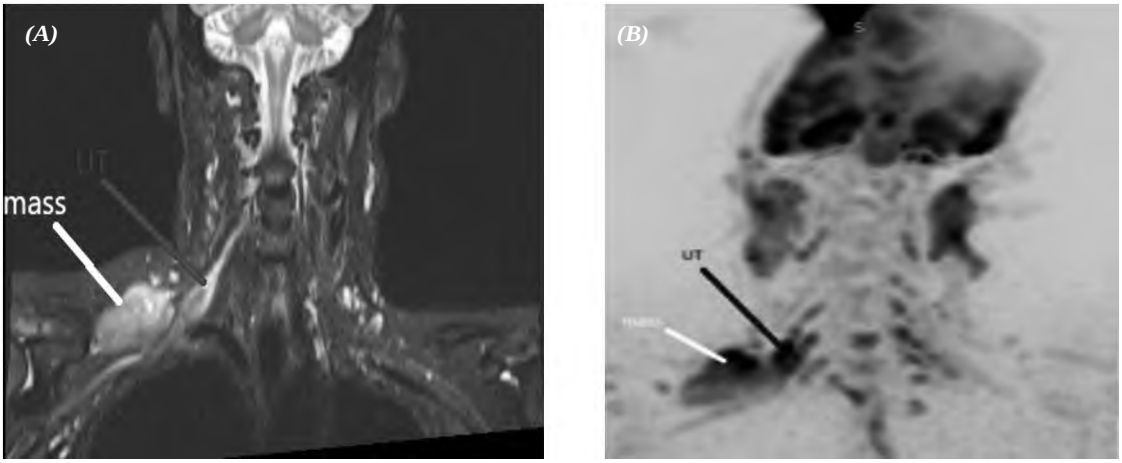

Fig. (3): Female patient 49 years old complained from breast cancer with right upper limb pain of 1 year duration, (A): Coronal 3D STIR SPACE, (B): Coronal DWI showing soft tissue mass lesion compressing the right brachial plexus upper trunk with thickened edematous upper trunk with restricted signal in DWI.

Discussion

MRI is considered the imaging modality of choice in detecting the cause of compression in TOS.

In concordance with other studies neurogenic TOS is more common in females and symptoms appear in the adult age group from 20-50 years old ***[5,6,7]***.

Our study revealed that neurogenic TOS represents 88% of TOS cases in agreement with (Jones et al., Illig et al.) ***[2,8]*** who stated that nTOS represents 90% of adult cases of TOS.

While vascular and combined vascular and neurogenic TOS represent 12% of cases in concordance with other studies ***[2,9,10,11]***.

Many imaging modalities could be included in the diagnosis of TOS as conventional cervical X-ray, ultrasonography, Doppler, CT, CT angiography, and MRI.

MRI offers a non-invasive, non-radiating imaging modality with better soft tissue characterization of the in the examined field ***[4]***.

So, MRI is considered the most convenient imaging modality to identify not only the cause of compression but also the affected nerve segment, to our knowledge no previous studies have assessed the MRI performance in detecting the affected edematous compressed nerves.

In agreement with (Hallinan et al.) ***[12]*** we also prefer imaging of bilateral BP to detect subtle signal change in the affected nerve segment compared to the normal side which occurs in n TOS.

Fat-saturated coronal T2WI better differentiate the relatively T2 hyperintense BP nerve segments from the surrounding muscles ***[13]***, however, this

study found that fat-saturated 3D STIR SPACE images are beneficial not only in differentiating the nerve fibers from the surrounding muscle but also in detectedthe microstructural changes of the compressed edematous nerve (affected segment) also.

As (Hardy, A., et al.) [4] the hypertrophied muscle is considered when its thickness exceeds 10 mm.

Previous studies revealed that MRI detected narrowing of the costoclavicular space due to subclavius muscle hypertrophy and narrowed retro pectoral space during postural maneuver [14], or abducted arm position to detect vascular compression in the costoclavicular space [15,16] while this study revealed narrowed inter scalene triangle due to rather an anterior scalene or middle scalene muscle hypertrophy, narrowed costoclavicular space with subclavius muscle hypertrophy of malunited fractured clavicle, nerve compression in its exiting foramen due to prominent C7 transverse process.

Also, MRI detected a compressed subclavian artery between the cervical rib and 1st rib, which was detected in CT angiography and confirmed intraoperatively. And so, MRI is beneficial in detecting both the soft tissue and bony compression causes.

According to Aralasmak, A., et al. [13] hypertrophied AS or MS muscles compress the BP in the scalene triangle, while hypertrophied subclavius muscle compresses the BP in the costoclavicular area, fibrous band compresses the BP, and subclavian vessels from above.

The study revealed that neurogenic TOS is the commonest and most common to occur in the inter scalene and costoclavicular triangles representing 34% and 31% respectively in agreement with (Aralasmak, A., et al., 2012) and (Demondion et al., 2003) [13,14].

Compression of BP in the retro pectoral region is very rare [13] and in this study, no case showed compression of the BP at the retro pectoral space.

Contrast-enhanced MR imaging is not required in the diagnosis of nTOS but it is beneficial in other cases as in differentiating tumors, inflammation, and post-operative and post-irradiation conditions [17].

The main limitation of our study was the lack of a reference standard for surgical findings, and this is because surgical treatment of cases of TOS was not preferred in our center as recurrence of symptoms was reported because of post-operative scaring which re-compress the neurovascular bundle, and this was observed in one of the included cases which were operated with symptoms recurrence few months postoperatively. The other limitation was the small sample size, and this was referred to the rarity of this affection.

Conclusions and recommendations:

MRI is the imaging modality of choice in cases of TOS management, not only to diagnose the cause of compression but also to detect the compressed edematous nerve segments which supports the diagnosis especially if surgical treatment is not the 1st line of treatment for fear of symptoms recurrence due to post-operative scarring.

We recommend further studies with larger sample sizes to assess the role of MRI in detecting the cause and effect of compression in TOS patients.

Availability of data and materials: The data that support the findings of this study are available from Radiology department, Assiut University but there are restrictions apply to availability of data, which used under license for this study, and so weren't publicly available. Data were available from author upon request with permission of head of Radiology department, Assiut University.

Competing interests: Author declare that she had no competing interests.

Declarations:

Ethics approval and consent to participate: This study had approval from Egypt, Assiut University, Faculty of Medicine Research Ethics Committee. All patients participated in this study signed an informed written consent for participation.

Consent for publication:

All patients included in this research gave written informed consent to publish the data contained within this study.

Ethical considerations:

1- Risk Benefit assessment for all patients was indicated for the examination during this study.
2- Confidentiality: All patients' data were confidentially kept.
3- The research done by scientifically qualified and trained personnel only.
4- The procedures included in this study had been already used in hospital and centers in and outside Egypt.

Competing interests: Author declare that she had no competing interests.

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تقييم تسلسلات التصوير بالرنين المغناطيسي المختلفة في تشخيص السبب والنتيجة في متلازمة مخرج الصدر

متلازمة مخرج الصدر هي حالة مرضية نادرة تتميز بضغط الحزمة الوعائية العصبية في منطقة مخرج الصدر. يمكن استخدام العديد من طرق التصوير في تقييم هذه الحالة، لكن التصوير بالرنين المغناطيسي يلعب دوراً مهما في تشخيص السبب واكتشاف الهياكل المضغوطة.

تم تضمين ٣٥ مريضاً يعانون من علامات متلازمة مخرج الصدر (عصبية أو وعائية أومجتمعة) في الدراسة. تم إجراء فحص التصوير بالرنين المغناطيسي لجميع المرضى باستخدام عدة متسلسلات.

كشف التصوير بالرنين المغناطيسي أن سبب الانضغاط كان عظميا في ١٣ حالة، وشوهد ضغط العضلات المتضخمة في ١٢ حالة، والعضلات المتضخمة مجتمعة والعملية المستعرضة البارزة في حالة واحدة، وتم الكشف عن ضغط العصابات الليفية في ٤ مرضى، بينما تم الكشف عن الضغط بواسطة كتل الأنسجة الرخوة في حالتين، ولم يتم الكشف عن سبب ضغط في ٣ مرضى.

تم استنتاج ان التصوير بالرنين المغناطيسي هوالطريقة المفضلة في تشخيص متلازمة مخرج الصدر. دوره اليس فقط لتشخيص سبب الانضغاط ولكن أيضاً للكشف عن الأجزاء العصبية المضغوطة والتي تدعم التشخيص.