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Original Article

# Magnetic Resonance as a Method for Diagnosis for Traumatic Lesions by Brachial Plexus Avulsion

## *Ressonância magnética como método para diagnóstico das lesões traumáticas por avulsão do plexo braquial*

Yussef Ali Abdouni[1] João Pedro Farina Brunelli[1] Ramiro Joaquim de Carvalho Neto[1]
Karina Todeschini[2] Antônio Carlos da Costa[2]

[1] Hand Surgery and Microsurgery Service, Hospital Santa Casa de Misericórdia de São Paulo, São Paulo, SP, Brazil
[2] Hospital Santa Mônica, Erechim, RS, Brazil

**Address for correspondence** João Pedro Farina Brunelli, MD, Rua Leopoldo Bier, 825, Conjunto 301, Porto Alegre, RS, 90620-100, Brazil (e-mail: brunelli.joao@gmail.com).

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## Abstract

**Objective** The incidence of traumatic brachial plexus injuries has been increasing considerably in Brazil, mainly due to the increase in the number of motorcycle accidents. The aim of the present study is to evaluate the sensitivity and specificity of magnetic resonance imaging (MRI) in the diagnosis of brachial plexus avulsion lesions, comparing it with the findings of physical and intraoperative examination.

**Methods** A total of 16 patients with brachial plexus injury were prospectively evaluated and treated at the hand surgery outpatient clinic from our service. All patients underwent MRI of the brachial plexus, and the findings were inserted on a table, as well as the physical examination data, and part of the patients had the plexus evaluated intraoperatively.

**Results** In the present study, the accuracy of MRI in the identification of root avulsion was 100%, with 100% sensitivity and specificity when comparing imaging with surgical findings.

**Conclusion** Magnetic resonance imaging showed high sensitivity and specificity, confirmed by intraoperative findings, which allows considering this test as the gold standard in the diagnosis of avulsion in traumatic brachial plexus injuries.

**Keywords**
- brachial plexus/diagnostic imaging
- brachial plexus/injuries
- brachial plexus/surgery
- peripheral nerve injuries
- magnetic resonance imaging
- diagnosis differential

* *Study developed at the Hospital Santa Casa de Misericórdia de São Paulo, São Paulo, SP, Brazil.*

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## Resumo

**Objetivo** A incidência de lesões traumáticas do plexo braquial vem aumentando consideravelmente no Brasil, principalmente devido ao aumento do número de acidentes de motocicleta. O objetivo do presente estudo é avaliar a sensibilidade e a especificidade da ressonância magnética (RM) no diagnóstico das lesões por avulsão do plexo braquial, comparando com os achados do exame físico e do intraoperatório.

**Métodos** Foram avaliados prospectivamente 16 pacientes com lesão do plexo braquial atendidos no ambulatório de cirurgia da mão de nosso serviço. Todos os pacientes foram submetidos ao exame de RM do plexo braquial e os achados foram inseridos em uma tabela, assim como os dados do exame físico, e parte dos pacientes teve o plexo avaliado intraoperatoriamente.

**Resultados** No presente estudo, a acurácia da RM na identificação de avulsão de raízes foi de 100%, com 100% de sensibilidade e especificidade comparando-se achados da imagem e cirúrgicos.

**Conclusão** A RM mostrou alta sensibilidade e especificidade, confirmadas por achados intraoperatórios, o que permite considerar este exame como padrão outro no diagnóstico de avulsão nas lesões traumáticas do plexo braquial.



**Palavras-chave**

- plexo braquial/diagnóstico por imagem
- plexo braquial/lesões
- plexo braquial/cirurgia
- traumatismos dos nervos periféricos
- imagem por ressonância magnética
- diagnóstico diferencial


## Introduction

The incidence of traumatic brachial plexus injuries has increased considerably in Brazil, mainly due to the increase in the number of motorcycle accidents.[1] The most common mechanism of injury is traction,[2] which can cause two types of injury: preganglionic, in which the roots are avulsionated next to their origin in the spinal cord, or postganglion, which may present a pattern of complete rupture of the nerve or the continuing lesion.[3] It is common for both lesion patterns to occur in the same individual.

Consequently, it is important to identify tools that allow more accurate diagnosis to improve decision-making related to nerve reconstruction and, consequently, improve prognosis. The diagnosis of brachial plexus lesions is mainly based on physical examination, with electroneuromyography as the most widely used auxiliary tool in the literature.[4] Imaging tests are still indicated in the case of preganglionic lesions, and myelotomography (myelo-CT) is considered by many authors the "gold standard" for the identification of pseudomeningoceles.[5]

Recently, with the popularization of magnetic resonance imaging (MRI), it was observed that it can evaluate, in addition to preganglionic involvement, alterations also in the postganglional part of the brachial plexus. Because it is a less invasive method than myelo-CT, MRI carries a lower risk of complications and becomes a viable option for a more accurate diagnosis of brachial plexus lesions.[6]

Magnetic resonance imaging findings in the radicular avulsions of the brachial plexus include, in addition to pseudomeningoceles, interruption of the root path proximally to the vertebral foramen, edema or retraction of the distal nerve to the lesion, displacement of the spinal cord to the opposite side, and denervation of the posterior paraspinal muscles, especially the spinal eers.[7]

The aim of the present study is to evaluate the sensitivity and specificity of MRI in the diagnosis of brachial plexus avulsion lesions, comparing its findings with those of physical and intraoperative examination.

## Material and Methods

We prospectively evaluated 16 patients with brachial plexus injury treated at the hand surgery outpatient clinic of our service. All patients underwent MRI of the brachial plexus, and the findings were inserted on a table, as well as the physical examination data.

Physical examination was performed in detail, evaluating motor function of each muscle - when feasible individual muscle evaluation - or muscle group function - when individual testing impossible. We graded muscle strength according to the British Medical Council system, and tested the sensitivity of each dermatome. Physical examination findings suggestive of preganglionic lesion scans were also recorded and gathered in a separate table.

The inclusion criteria of the present study were patients between 18 and 60 years old with brachial plexus injury due to high-energy trauma. The exclusion criteria were patients with lesions resulting from open trauma and patients who did not present at least one sign of root avulsion on physical examination or MRI. All tests were performed with the Achieva 1.5T device with specific sequences for evaluation of the brachial plexus.

All patients included in the present study signed the free and informed consent form, and the research project was previously authorized by the Research Ethics Committee of our institution under number 16594813.0.0000.5479.

## Results

Twelve patients were included in the present study, 7 males and 5 females, with ages ranging from 22 to 60 years old (mean of 37.3 years old). All patients suffered a motorcycle accident that led to brachial plexus injury. Six lesions

affected the right upper limb and six lesions affected the left upper limb, with no bilateral lesions in this series. Among the patients evaluated, 10 individuals presented at least 1 of the dermatomes with sensitivity alterations, being considered anesthesia, hypoesthesia or paraesthesias (►**Table 1**). Only 1 patient (patient 8) did not present motor deficits in the muscle groups evaluated (►**Table 2**), and this finding was compatible with the evidence of preganglionic injury only in the root of C7. Regarding the clinical findings suggestive of root avulsion, 4 of the 12 patients evaluated were positive in at least 1 of them (►**Table 3**), and all MRI findings confirmed the clinical suspicion.

**Table 1** Sensory examination of the individuals included in the study for affected root and type of deficit

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C5 | N | N | N | P | H | A | A | N | N | A | A | N |
| C6 | H | A | N | A | A | N | A | N | P | A | A | H |
| C7 | N | A | N | P | H | N | A | N | P | A | A | H |
| C8 | N | A | N | N | N | N | A | N | N | A | P | N |
| T1 | N | N | N | N | N | N | A | N | N | A | N | N |

Abbreviations: A, anesthesia; H, hypoesthesia; N, Normal; P, paraesthesias.

To evaluate the accuracy of MRI (►**Table 4**) in the detection of root avulsion, we considered for the calculation of sensitivity and specificity only the operated patients in whom it was possible to directly visualize the avulsion roots. The findings gathered in ►**Table 4** are illustrated in ►**Figures 1** to **6**, which present the MRI sections representative of each avulsion sign evaluated in the present study. Among the 10 operated patients, 9 had avulsion of at least 1 root, findings compatible with MRI (all except patient 9). Patient 9 did not present any signs of avulsion during surgery, a finding compatible with MRI. With this, we can affirm that, in the present study, the accuracy of MRI in the identification of root avulsion was 100%, with 100% sensitivity and specificity when comparing MRI and surgical findings.

## Discussion

Computed myelotomography has long been considered the gold standard for imaging diagnosis of root avulsions in the

**Table 2** Detailed motor examination of the individuals included in the study

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trapezium | M5 | M5 | M5 | M5 | M5 | M5 | M0 | M5 | M5 | M4 | M5 | M5 |
| Great dorsal | Tropic | M5 | FUNC | M1 | M5 | M5 | M0 | M5 | M1 | M4 | M0 | M5 |
| Deltoid | M1 | M0 | M2 | M1 | M0 | M5 | M0 | M5 | M0 | M1 | M0 | M4 |
| Pectoral | FUNC | FUNC | FUNC | M4 | M0 | M2 | M0 | M5 | M1 | M0 | M0 | M4 |
| Supraspinal | M0 | M0 | M2 | M1 | M0 | M1 | M0 | M5 | M0 | M0 | M0 | M3 |
| Infraspinal | Mo | Mo | M2 | M1 | M0 | M1 | M0 | M5 | M0 | M0 | M0 | M3 |
| R. minor | Mo | M0 | M2 | M1 | M0 | M4 | M0 | M5 | M0 | M0 | M0 | M0 |
| Subscapularis | Mo | M0 | M2 | M1 | M0 | M4 | M0 | M5 | M0 | M0 | M0 | M2 |
| Flex. elbow | M0 | M2 | M3 | M1 | M0 | M1 | M0 | M5 | M2 | M0 | M0 | M4 |
| Ext. elbow | M2 | M0 | M4 | M4 | M0 | M5 | M0 | M5 | M4 | M0 | M0 | M3 |
| Sup. forearm | M3 | M0 | M5 | M1 | M2 | M5 | M0 | M5 | M2 | M0 | M0 | M2 |
| Pron. forearm | M5 | M0 | M5 | M4 | M2 | M5 | M0 | M5 | M2 | M0 | M4 | M3 |
| Flexoextension wrist | M5 | M0 | M5 | M2 | M3 | M5 | M0 | M5 | M5 | M0 | M0 | M3 |
| MCP - Metacarpophalangeal Flexoextension | M5 | M0 | M5 | M4 | M3 | M5 | M0 | M5 | M5 | M0 | M3 | M5 |
| Prehension | M5 | M0 | M5 | M5 | M3 | M5 | M0 | M5 | M5 | M0 | M2 | M5 |
| Abduction fingers | M5 | M0 | M5 | M5 | M4 | M5 | M0 | M5 | M5 | M0 | M5 | M5 |

**Table 3** Clinical signs of the individuals included in the study suggestive of avulsion of preganglionic roots

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horner | N | N | N | N | N | N | N | N | N | N | N | N |
| Serratus deficit | N | N | N | N | N | N | Y | N | N | N | Y | N |
| Rhomboids deficit | N | N | N | N | N | N | Y | N | N | N | Y | N |
| Pain in insensitive limb | N | N | N | N | Y | N | N | N | N | Y | N | N |

Abbreviations: N, no; Y, yes.

**Table 4** Magnetic resonance imaging findings suggestive of avulsion of preganglionic roots

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pseudomeningocele | N | Y | N | Y | Y | Y | Y | N | N | N | Y | Y |
| Medullary bypass | N | Y | N | N | Y | Y | Y | N | N | N | Y | Y |
| Paraspinal atrophy | Y | N | Y | N | N | N | Y | N | N | N | Y | N |
| Discontinuous roots | Y | Y | Y | N | Y | Y | Y | N | N | N | Y | Y |
| Retracted, sinuous, thickened roots or presence of mass | Y | N | N | N | Y | Y | Y | Y | N | Y | Y | N |
| Spinal cord changes | N | Y | N | N | Y | Y | Y | N | N | Y | Y | N |

Abbreviations: N, no; Y, yes.

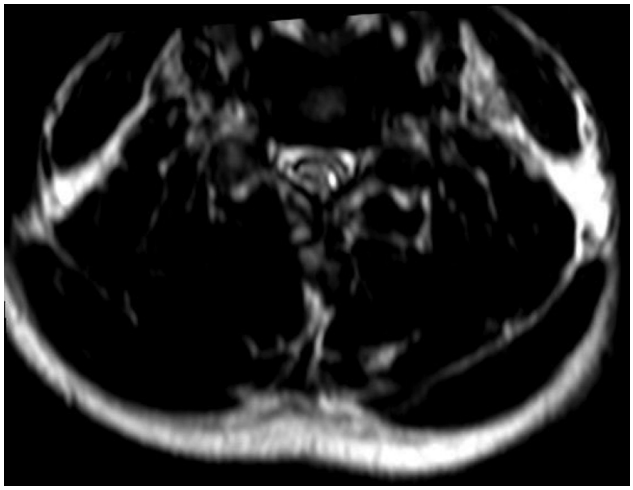

**Fig. 1** Spinal cord alteration (avulsion myelopathy) on the left with midline deviation.

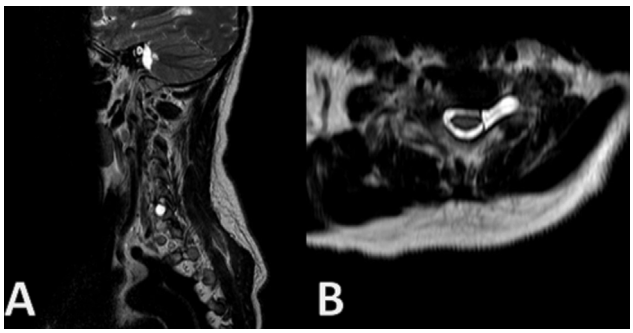


**Fig. 2** (**A**) Pseudomeningocele in sagittal cut. (**B**) Pseudomeningocele in axial cutting.

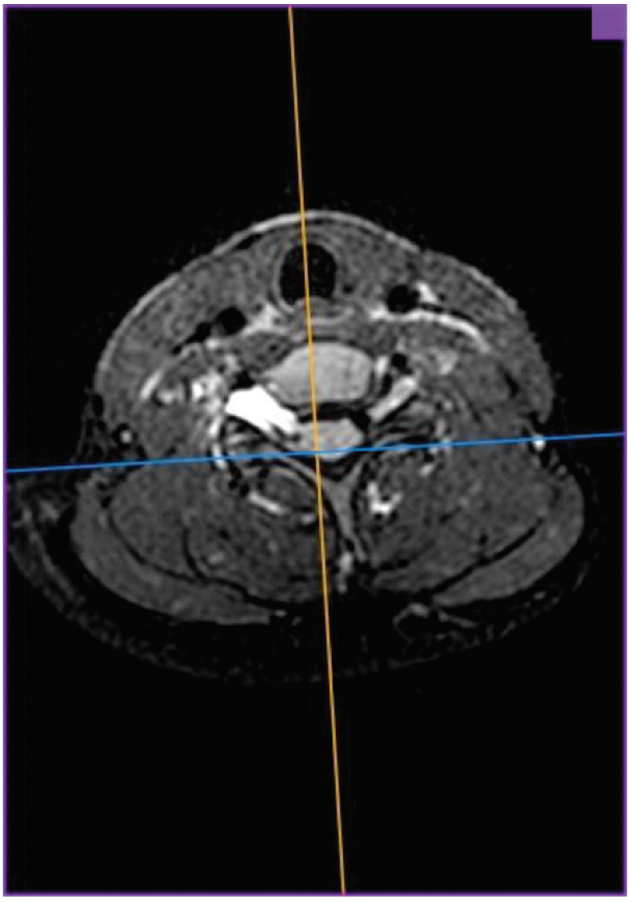

**Fig. 3** C6 right preganglionic root discontinuous.

brachial plexus. However, its scope is restricted to the observation of pseudomeningoceles and presents the inconvenience of being an invasive method, with rates of adverse effects to contrast injection that can reach 35%.

Wade et al.[8] considered the accuracy of MRI to detect lesions by avulsion, and Carvalho et al.[5] found an accuracy of MRI of only 52%. These results are due to the use of conventional MRI sequences, which are not suitable for the diagnosis of brachial plexus lesions. Sequences with fine cuts are fundamental for intradural visualization of cervical roots. Doi et al.,[9] in a retrospective study with 35 patients, observed sensitivity and specificity of MRI to detect the presence of root avulsion of 92.9 and 81.3%, respectively, while in myelo-CT the sensitivity and specificity were 92.9 and 75.8%, respectively, with no statistically significant difference between the 2 methods. In a multicenter study with 157 cases, Tagliafico et al.[7] demonstrated that MRI has high sensitivity and specificity for the diagnosis of brachial plexus lesions but drew attention to the possibility of false-positive results. In the present study, MRI showed sensitivity of 100% and specificity of 100%, compared with 44.44% and 100%, respectively, of the physical examination, according to the findings of Doi et al.[9] and Tagliafico et al.[7].

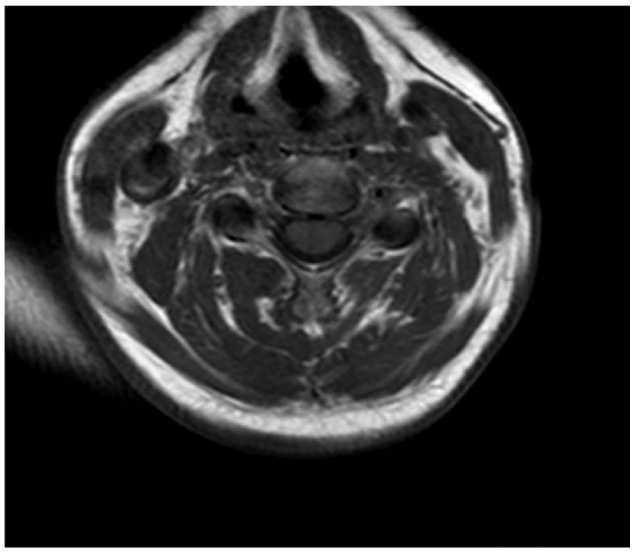

**Fig. 4** T1-weighted axial section demonstrating multifidus atrophy in the C6 plane, compatible with chronic denervation.

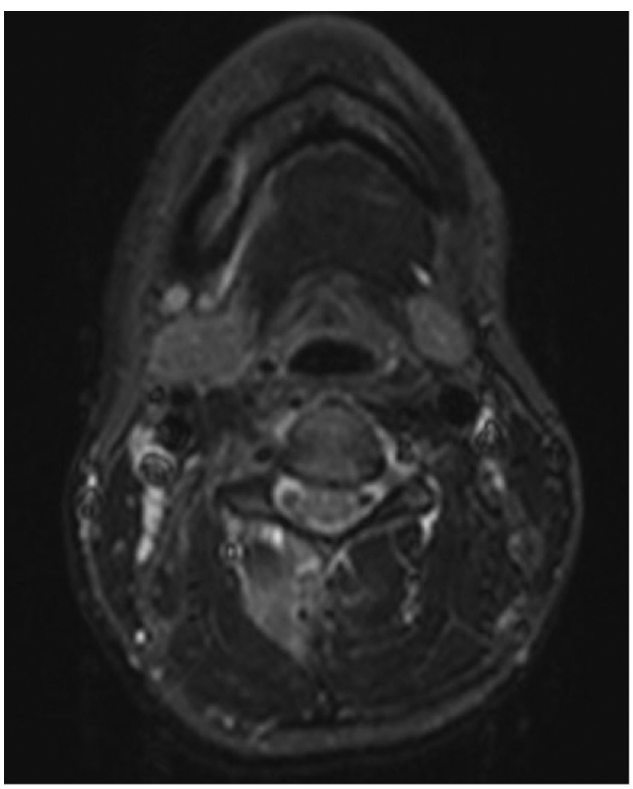

**Fig. 5** Plexus axial STIR demonstrating edema of the right paravertebral musculature, compatible with acute denervation.

The higher the energy of the trauma, the greater the risk of root avulsion. Carmo et al.,[10] in a retrospective study, observed the presence of avulsion of $\geq 1$ root in 95.5% of the patients with total brachial plexus injury, while in partial lesions, this index was 53.5%.

Edema and/or atrophy of the paravertebral musculature on the same side of the lesion has also been related to more severe lesions, with avulsion and consequent denervation of this musculature due to involvement of the dorsal spinal branch.[11]

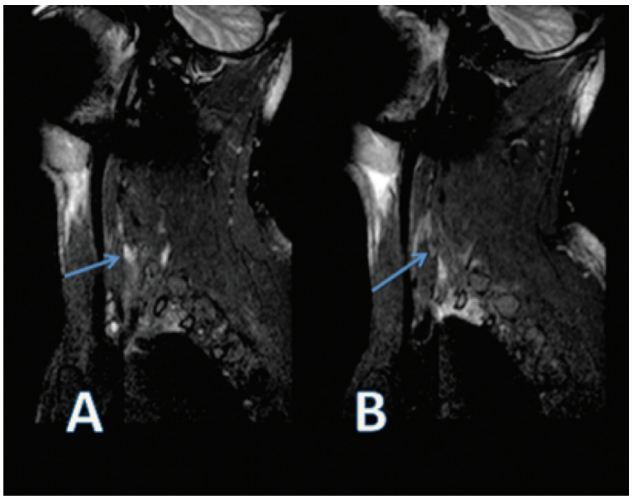


**Fig. 6** (**A**) thickening and hypersignal of C7 root. (**B**) Normal root for comparison.

An interesting study demonstrated the ability to detect brachial plexus avulsion lesions by comparing MRI with intraoperative or electroneuromyography findings.[12] This study, however, had a small sample, and the image criteria used depended on the direct visualization of the avulsion root or the formation of pseudomeningocele to diagnose avulsions, which are specific findings, but less sensitive than the combination of the six criteria presented in our series, which may offer a superior diagnostic accuracy.

Interpretation of MRI for root avulsion is difficult. An MRI image can be considered positive for root avulsion when the loss of continuity or absence of the nerve root in the path between the spinal cord and the foramen output is perceived. The normal nerve root follows an oblique (posterior to anterior to anterior and cranial to caudal) course from the spinal cord to the existing intervertebral foramen. Therefore, MRI can also be considered positive for avulsion if there is an abnormal course/position of the spinal nerve because if a root has been avulsed from the spinal cord, then it will adopt a more caudal and horizontal position in the path to the foramen. The present study found avulsion of roots as main findings in MRI, which were present in 91.66% of the cases. The most avulsed root was C7 (83.33%), followed by C6 and C8 (58.33%), T1 (41.66%) and finally C5 (12%).

On the other hand, clinical findings classically associated with avulsion showed very low sensitivity in our study, characterizing them as bad for screening purposes. They presented high specificity, however, and can be considered confirmatory avulsion when present.

We could observe a broad spectrum of sensory and motor deficits, which were exposed in detail, along with the findings compatible with avulsion (clinical and MRI), which can be evaluated in ►**Tables 1** to **4**.

## Conclusion

Magnetic resonance imaging showed high sensitivity and specificity, confirmed by intraoperative findings, which

allows considering this test as another standard in the diagnosis of avulsion in traumatic brachial plexus lesions.

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Conflict of Interests
The authors have no conflict of interests to declare.

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