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Contribution of MRI to the Diagnosis and Classification of Brachial Plexus Injuries

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: The incidence of brachial plexus injuries (BPI) has increased due to the rise in sports and motor vehicle accidents. Accurate diagnosis through detailed clinical examination followed by magnetic resonance imaging (MRI) is crucial for effective management.

Objective: This study aims to evaluate the diagnostic accuracy of MRI in patients with BPI and to determine the optimal timing and indications for MRI in these patients.

Methods: A study was conducted on 30 patients with BPI. Patients presenting with flail upper limbs or suspected root avulsions underwent immediate MRI, while those without these indications had

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MRI after a delay of 4-6 weeks. MRI was utilized to differentiate between pre-ganglionic and post-ganglionic injuries, as well as mixed injuries, which is vital for determining the timing and type of surgical intervention.
Results: MRI effectively distinguished between pre-ganglionic and post-ganglionic injuries, aiding in the appropriate surgical planning. We recommend MRI scans of the entire upper limb to assess edematous muscles and diaphragm movement patterns. Contrast studies can also be beneficial if not contraindicated.
Conclusion: MRI is a valuable tool in the diagnosis and management of BPI, helping to distinguish between different types of injuries and informing surgical decisions. Immediate MRI is recommended for patients with severe clinical indications, while a delayed MRI may be appropriate for others.

Keywords: Brachial plexus injuries; MRI imaging; motor vehicle accidents; atrophy.

1. INTRODUCTION

The upper extremities are innervated by the brachial plexus, a complex network of nerves originating from the spinal cord. Brachial plexus injuries (BPI) can result from motor vehicle accidents, sports injuries, radiation exposure, and labor-related trauma in neonates [1-3]. Accurate diagnosis and classification of these injuries are crucial for effective management and treatment. Magnetic resonance imaging (MRI) is a widely used diagnostic tool that helps distinguish between pre-ganglionic and post-ganglionic injuries, and assess the severity of muscle edema and atrophy [4-6].

Despite the known utility of MRI in diagnosing BPI, there is limited data on its optimal timing and accuracy in differentiating various types of brachial plexus injuries [7,8]. Additionally, the effectiveness of MRI in providing detailed assessments to guide surgical planning and intervention remains under-explored. This study aims to address these gaps by evaluating the diagnostic accuracy of MRI in patients with BPI and determining the optimal timing for MRI scans [9-12]. By comparing MRI findings with surgical outcomes, this study seeks to enhance the understanding of MRI's role in BPI management and improve clinical decision-making processes.

2. METHODS

The study was conducted on 30 patients with brachial plexus injuries (BPI). MRI scans were performed using a 3 Tesla system (GE Healthcare Discovery 750W with GEM Suite, Milwaukee, WI, USA) and a head-neck forty coil. The following MRI sequences were utilized:

- **Axial T2W**: TE = 114 ms, TR = 4800 ms, FOV = 22 cm, slice thickness = 5 mm, spacing = 1 mm, frequency = 512, bandwidth = 50.
- **Coronal 3D/STIR**: TE = 102 ms, TR = 7000 ms, FOV = 40 cm, slice thickness = 2 mm, spacing = 0, frequency = 256, bandwidth = 35.71.
- **Coronal T1W**: TE = 7 ms, TR = 456 ms, FOV = 22 cm, slice thickness = 4 mm, spacing = 0, frequency = 352, bandwidth = 62.5.
- **STIR neurography**: TE = 90.9 ms, TR = 16081.3 ms, FOV = 40 cm, slice thickness = 3 mm, spacing = 0, frequency = 100, bandwidth = 250.
- **DW neurography**: TE = 73.8 ms, TR = 7000 ms, FOV = 30 cm, slice thickness = 4 mm, spacing = 0.5 mm, frequency = 100, bandwidth = 190.

Additionally, the following specific sequences were performed:

- **Oblique sagittal T2 fat sat**: TE = 110 ms, TR = 5885 ms, FOV = 25 cm, slice thickness = 4 mm, spacing = 1 mm, frequency = 288, bandwidth = 31.25 on the shoulder ipsilateral to the injured brachial plexus.
- **Axial STIR**: TE = 42 ms, TR = 5465 ms, FOV = 35 cm, slice thickness = 4 mm, spacing = 0.5 mm, frequency = 352, bandwidth = 41.67 of the ipsilateral arm.
- **Sagittal T2W**: TE = 76 ms, TR = 3105 ms, FOV = 16 cm, slice thickness = 2.5 mm, spacing = 0.2 mm, frequency = 288, bandwidth = 35.7 of the cervical spine.
- **Axial cube T2**: TE = 90 mm, TR = 1360 mm, FOV = 24 cm, slice thickness = 1.6 mm, spacing = 0, frequency = 288, bandwidth = 83.33 of the cervical spine.

The location of the injury was identified at the root, trunk, division, cord, or terminal branch level and classified as pre-ganglionic, post-ganglionic, or mixed. Injuries were further graded according to the Sunderland classification (Table 1).

Table 1. Table showing degrees of postganglionic nerve injuries (Sunderland classification)

Degree of nerve injury	**MRN (signal intensity)**	**Recovery potential**	**Surgery**
I Neurapraxia	Nerve- increased T2 Signal intensityMuscle- Normal	Full	None
II Axonotemesis	Nerve-increased T2 signal intensity and diffusely enlarged	Full	None
III	Fascicles- enlarged or effaced due toedema Muscles- denervation	Usually slow, incomplete	None or Neurolysis
IV NIC-neuromain continuity	Nerve-focally enlarged with heterogeneous signal intensity. Underlying diffuse abnormality± fascicles disrupted with heterogeneousSI-NIC Muscles-denervation	Poor tonone	Nerve repair,graft or transfer
V Neurotmesis	Complete nerve discontinuity ± hemorrhage and fibrosis in the nerve gap and end- bulb neuroma proximally.Epineurial thickening Muscles- denervation	None	Nerve repair,graft or transfer
Degree of nerve injury	MRN (signal intensity)	Recovery potential	Surgery
VI Mixed injury(I to V)	Variable findings along the circumferential segment of the nerve (I-V) with heterogeneous signal intensity due to fibrosis	Variable, can be poorto none	Neurolysis, nerve repair,graft or transfer

The accuracy of MRI diagnosis of BPI was assessed by correlating MRI findings with intraoperative findings. Out of the 30 patients, 15 underwent surgical intervention. Surgical procedures included nerve grafting, neurolysis, and nerve transfers. The intraoperative findings were documented and compared with the preoperative MRI results to determine the accuracy of MRI in identifying the location and extent of nerve injuries.

MRI findings were also correlated with clinical examinations conducted at the time of injury/MRI and at follow-up three months later. Clinical assessments included motor function tests, sensory evaluations, and electromyography (EMG) studies to monitor nerve recovery and muscle reinnervation.

By comparing MRI findings with intraoperative results and clinical follow-up data, the study aimed to evaluate the diagnostic accuracy of MRI and its utility in the management and surgical planning for patients with BPI.

3. RESULTS

The study comprised 30 patients, with a male predominance (26 males and 4 females), and ages ranging from 11 days to 58 years, with a mean age of 29.4 ± 12.09 years. Left-sided injuries were present in 14 cases, right-sided injuries in 12 cases, and bilateral injuries in 4 cases. Nerve root involvement was identified in 18 cases, trunk involvement in 17 cases, division involvement in 5 cases, and one patient showed no direct injury to the brachial plexus. Preganglionic injuries were observed in 10 patients, postganglionic injuries in 17 patients, and both pre- and postganglionic injuries in three patients.

Specifically, C5 nerve root involvement was noted in 21 patients, C6 in 27 patients, C7 in 18 patients, C8 in 19 patients, and T1 in 14 patients. Grade I injuries were observed in three patients, grade III in nine patients, and grade V in eight patients, with 10 patients exhibiting multiple grades of injuries. Interestingly, no isolated grade II and IV injuries were observed in the study cohort.

The correlation between MRI findings and clinical presentation was found to be excellent. Among the 30 cases, total correlation was observed in 23 cases, while partial correlation was noted in seven cases. Regarding patient outcomes, six patients demonstrated complete recovery, six showed partial recovery, three exhibited minimal recovery, and 15 showed no recovery. Notably, patients with lower grades of injury (grade I/II) tended to exhibit complete recovery, while those with higher grades and extensive injury tended to show minimal or no recovery.

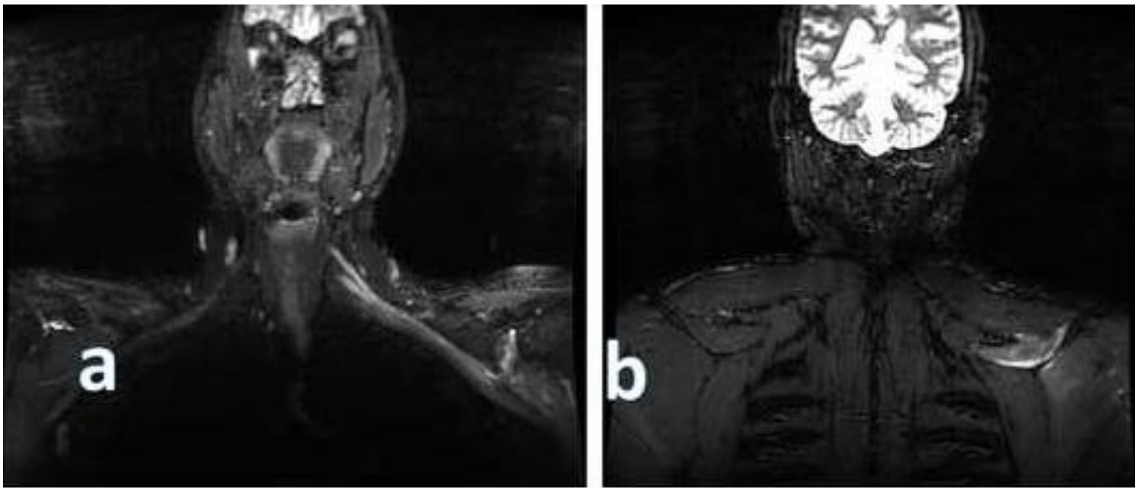

Fig. 1. (a) 3D T2W/STIR coronal images showing slight thickening and hyperintensity of left C5 & C6 postganglionic roots and upper trunk (b) T2W/STIR coronal image showing edema in left supraspinatus and infraspinatus muscles

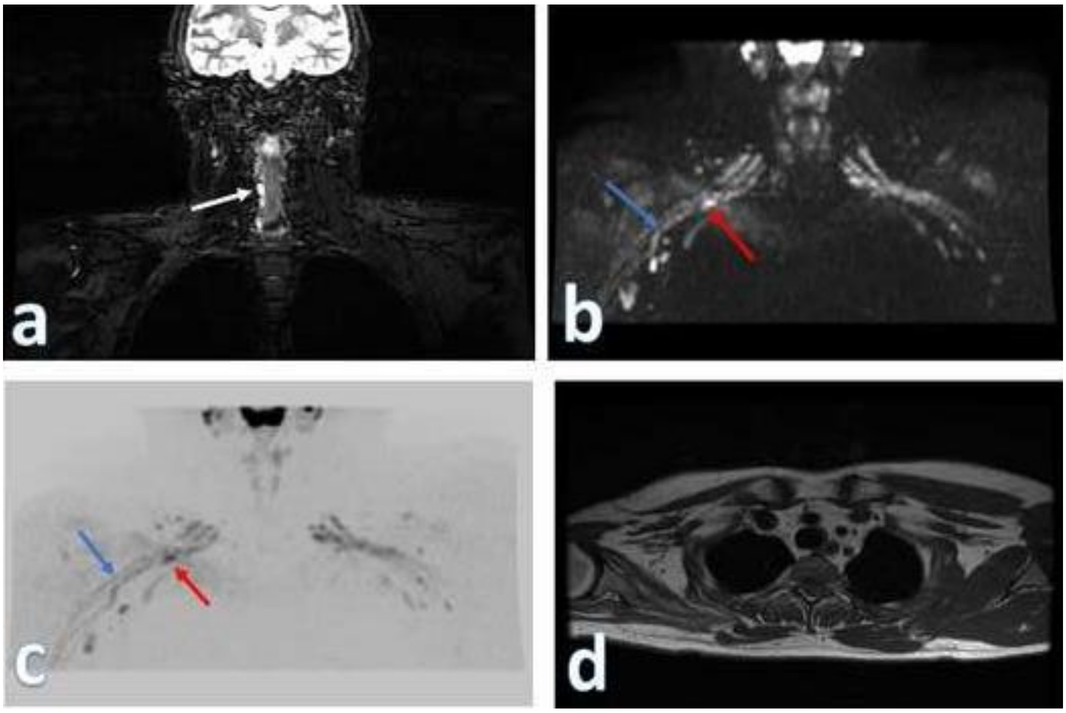

Fig. 2. (a) 3D T2W/STIR coronal image showing pseudomeningocele at right C6 root (white arrow) (b & c) Coronal diffusion weighted image & negative image showing kinking of Posterior cord laterally (there was healed fracture rib at this site) (blue arrow) and discontinuity and end neuroma at proximal fragment (red arrow) at medial cord (d) T1W axial image showing atrophy of infraspinatus, subscapularis, pectoralis major and minor

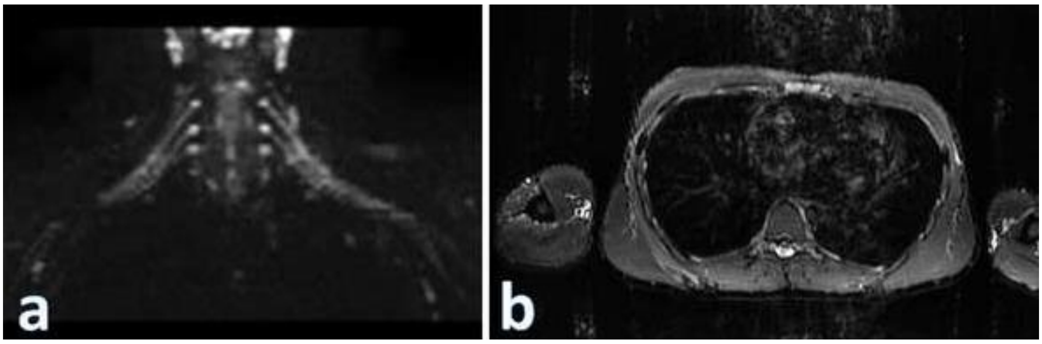

Fig. 3. (a) Coronal diffusion neurography showing normal brachial plexuses (b) T2W/SPIR axial image showing edema and atrophy of right serratus anterior muscle (arrow)

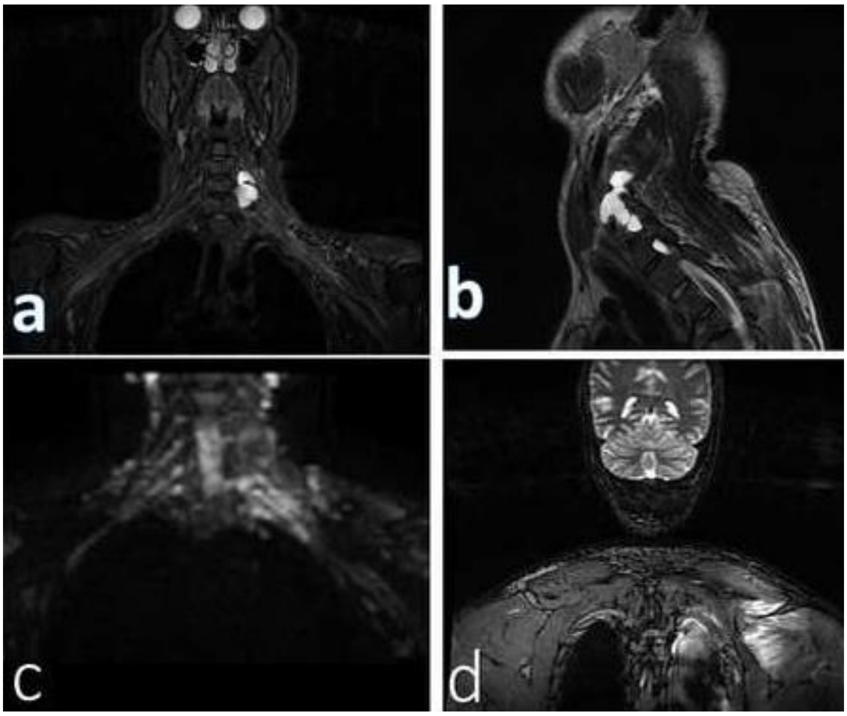

Fig. 4. (a, b & c) 3D T2W/STIR coronal, T2W sagittal cervical spine, coronal diffusion neurography show pseudomeningocele s/o preganglionic injury to left C6, C7, C8 & T1 nerve roots, thickening and irregularity of left postganglionic C6, C7, C8 and T1 nerve roots and left middle and lower trunks (d) T2W/STIR coronal image showing edema of supraspinatus, infraspinatus, fracture left upper ribs and left pleural effusion

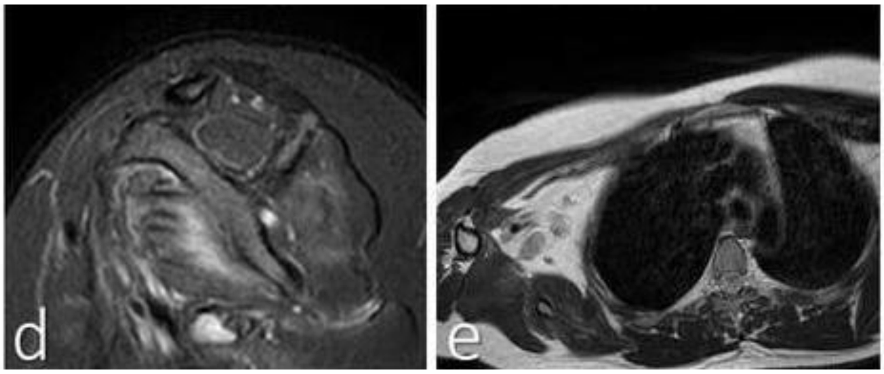

Fig. 5. (a) T2W/STIR coronal image showing pseudomeningocele at right C7 nerve root level (C6-C7 neural foramen)
(b) T2W/STIR coronal image showing discontinuity of postganglionic C5 (red arrow) and C6 (yellow arrow) nerve roots
(c) T2W/STIR sagittal image showing thickening, hyperintensity and blurred fascicles of lateral, posterior and medial cords
(d) T2W/STIR oblique sagittal image showing edema of supraspinatus, infraspinatus, subscapularis and teres minor muscles
(e) T2W axial image showing atrophy of pectoralis major, minor and also infraspinatus and subcapularis muscles

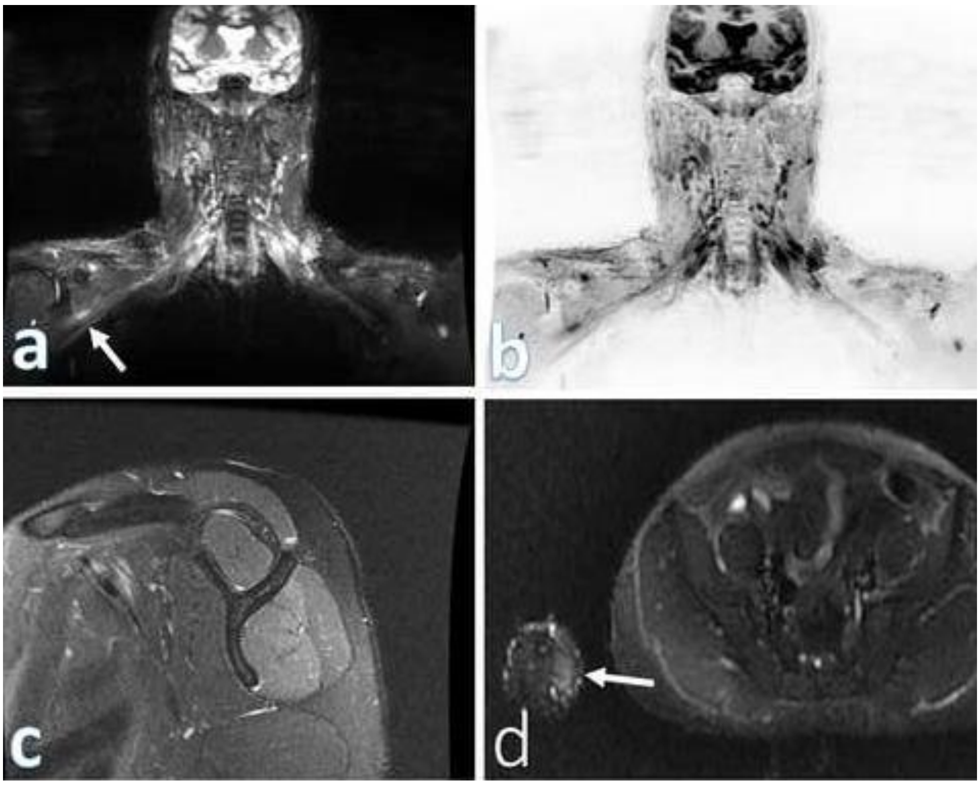

Fig. 6. (a & b) 3D T2W/STIR coronal image and its negative showing hyperintensity and thickening of B/L C5, C6, C7 & C8 postganglionic roots and neuroma in continuity in right lateral cord distally (arrow)
(c) T2W/STIR oblique sagittal image showing slight denervation edema in right supraspinatus, infraspinatus, teres minor and deltoid muscles
(d) T2W/STIR axial image showing edema of biceps brachii muscle (arrow)

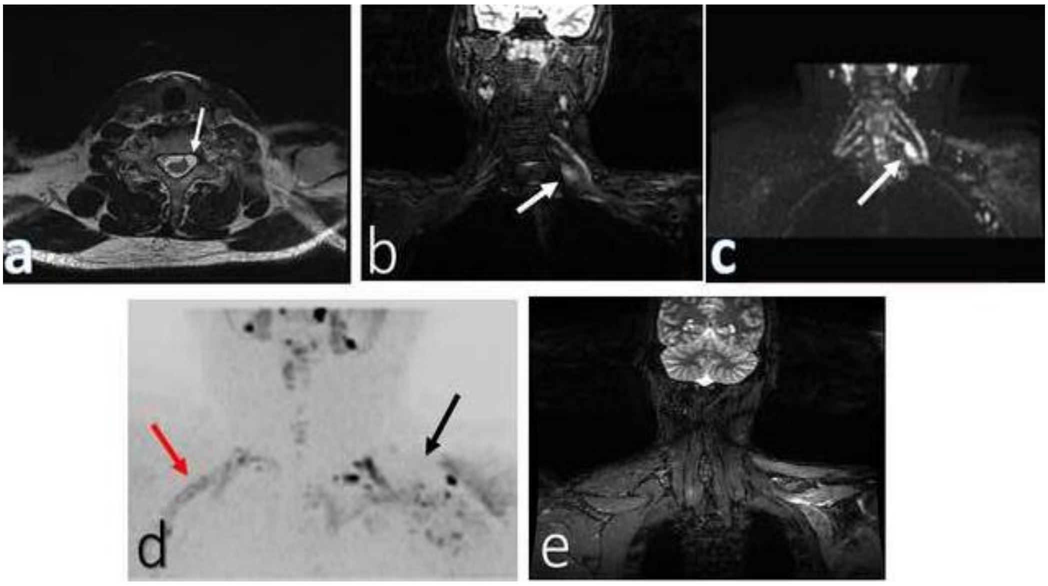

Fig. 7. (a) T2W axial image showing pseudomeningocele at left D1-D2 neural foramen (arrow) (preganglionic injury D1)
(b & c) 3D T2W/STIR and diffusion neurography coronal images showing thickening, irregularity and hyperintensity of left C5 nerve root and neuroma in continuity (arrow) in left C7 postganglionic root
(d) Negative image of diffusion neurography coronal image showing normal cords on right side (red arrow) and discontinuous cords on left side (black arrow)
(e) T2W/STIR coronal image showing edema in left supraspinatus and subscapularis muscles

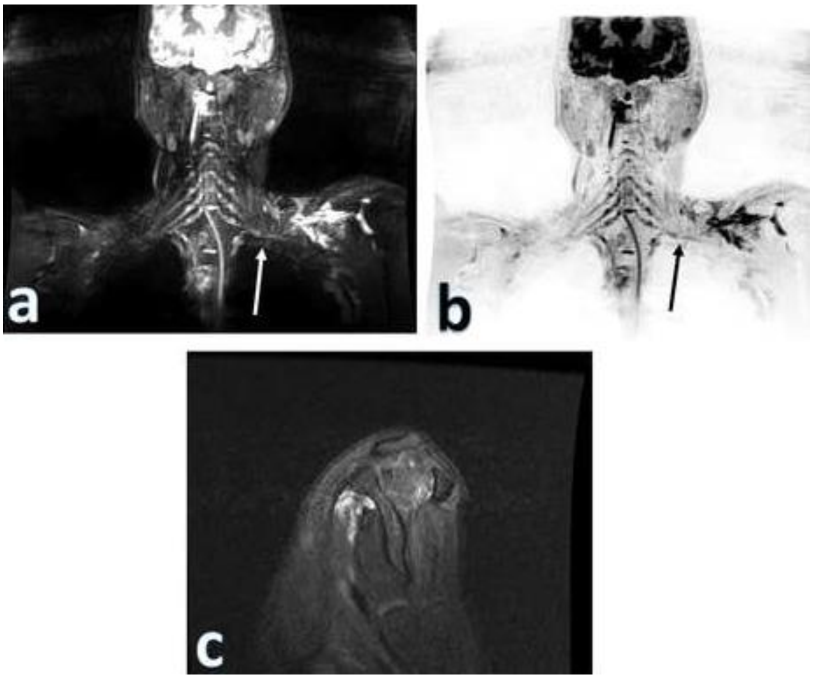

Fig. 8. (a & b) 3D T2W/STIR coronal image and its negative showing entanglement and probable discontinuity of left upper and lower trunk with a small (5mm) gap in lower trunk (arrow) (c) T2W?STIR oblique sagittal image showing edema in supraspinatus, infraspinatus with tear in superior aspect of subscapularis muscle

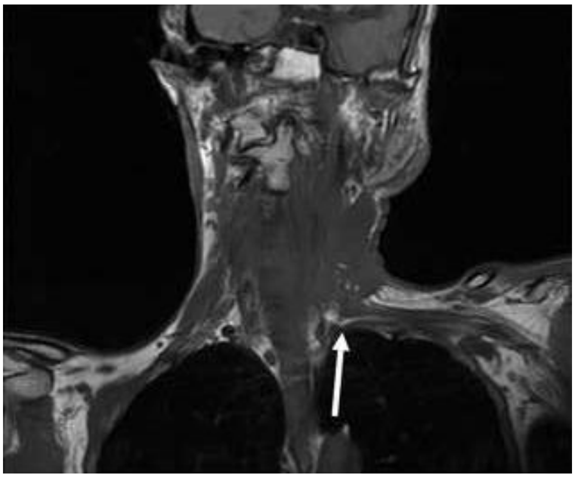

Fig. 9. T1W coronal image showing involvement of left brachial plexus by carcinoma larynx

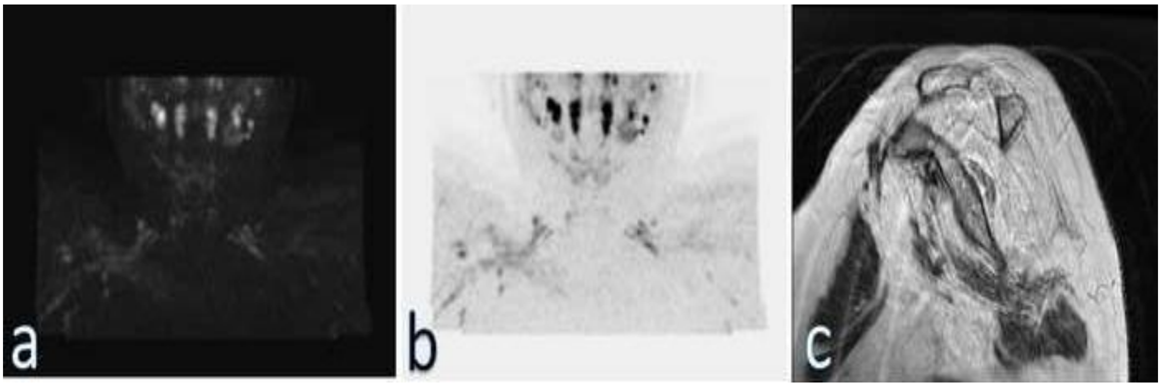

Fig. 10. (a & b) Coronal diffusion neurography and its negative image showing indentation of right brachial plexus by cervical rib (c) T1W oblique coronal image showing gross atrophy of supraspinatus, infraspinatus and subscapularis

4. DISCUSSION

4.1 Main Findings of the Present Study

The findings of this study emphasize the critical importance of accurately classifying BPI based on various factors such as extent, site, and grade of injury, as well as associated injuries and the status of surrounding structures. Such comprehensive classification is pivotal in determining appropriate treatment strategies, whether conservative or surgical, and in predicting prognosis.

MRI emerged as a valuable diagnostic tool in distinguishing between pre- and postganglionic injuries, particularly in cases where both types of injuries were present. This differentiation proved crucial in guiding surgical decision-making. Additionally, detailed diagnostic procedures such as electromyography (EMG) and nerve conduction velocity studies played a significant role in localizing the level of lesion, assessing the severity of axon loss, and monitoring recovery progress.

4.2 Comparison with Other Studies

The findings of this study align with previous research that has emphasized the importance of accurate classification and timely imaging in the management of BPI. Our results corroborate existing literature regarding the utility of MRI in distinguishing between pre- and postganglionic injuries, as well as in guiding treatment decisions. Furthermore, the complementary role of EMG and nerve conduction studies in assessing nerve function and recovery is consistent with established literature in the field.

4.3 Implication and Explanation of Findings

The study's findings have several important implications for clinical practice. Firstly, they underscore the critical role of timely MRI imaging in accurately diagnosing BPI and guiding treatment decisions. The ability of MRI to identify alternative pathologies highlights its utility beyond BPI diagnosis alone. Secondly, the findings emphasize the importance of comprehensive diagnostic approaches, including MRI, EMG, and nerve conduction studies, in optimizing patient care and predicting outcomes.

4.4 Strengths and Limitations

A key strength of this study is its focus on a comprehensive evaluation of BPI using multiple diagnostic modalities, including MRI and neurophysiological studies. The correlation between MRI findings and clinical outcomes underscores the reliability of MRI in assessing BPI. However, limitations such as the small sample size and the need for more extensive imaging protocols to assess the full extent of injury, including forearm and hand muscles, diaphragm movements, and potential benefits of contrast-enhanced MRI, should be acknowledged.

5. CONCLUSION AND FUTURE DIRECTIONS

The judicious integration of various diagnostic modalities, including MRI, EMG, and nerve conduction studies, plays a pivotal role in effectively managing BPI by informing treatment decisions, predicting outcomes, and optimizing patient care. Further research with larger sample sizes and refined imaging protocols is warranted to validate these findings and improve clinical practice in the management of BPI.

MRI is very useful in proper diagnosis and assessment of extent of brachial plexus injury helping in deciding treatment (conservative or surgical) and timing of surgery. MRI also assesses surrounding normal muscles and nerves in terms of their suitability for nerve transfer.

ETHICAL APPROVAL

As per international standards or university standards written ethical approval has been collected and preserved by the author(s).

CONSENT

Written informed consent was obtained from the patients for publication and any accompanying images.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Park HR, Lee GS, Kim S, Chang JC. Brachial plexus injury in adults. The Nerve. 2017;3(1):1-11.
2. Carlstedt T, Anand P, Hallin R, Misra PV, Noren G, Seferlis T. Spinal nerve root repair and reimplantation of avulsed ventral roots into the spinal cord after brachial plexus injury. J Neurosurg. 2000; 93:237-47.
3. Sakellariou VL, Badilas NK, Stavropoulos NA, Mazis G, Kotoulas HK, Kyriakopoulos S, et al. Treatment options for brachial plexus injuries. ISNR Orthopedics. 2014; 2014:1-10.
4. Mallouhi A, Marik W, Prayer D, Kainberger F, Bodner G, Kasprian G. 3 T MRI tomography of the brachial plexus: structural and microstructural evaluation. Eur J Radiol. 2012;81:2231-2245.
5. Yoshikawa T, Hayashi N, Yamamoto S, Tajiri Y, Yoshioka N, Masumoto T, et al. Brachial plexus injury: Clinical manifestations, conventional imaging findings, and the latest imaging techniques. Radiographics. 2006;26(1): S133-S43.
6. Siqueira MG, Martins RS. Surgical treatment of adult traumatic brachial plexus injuries. Arq Neuropsiquiatr. 2011;69(3): 528-35.
7. Moran SL, Steinmann SP, Shin AY. Adult brachial plexus injuries: Mechanism, patterns of injury, and physical diagnosis. Hand Clin. 2005;21:13-24.
8. Warren J, Gutmann L, Figuerca AS Jr, Bloor BM. Electromyographic changes of

brachial plexus root avulsion. J Neurosurg. 1969;31:137-40.

9. Duijnisveld BJ, Henseler JF, Reijnierse M, Fiocco M, Kan HE, Nelissen RGHH. Quantitative Dixon MRI sequences to relate muscle atrophy and fatty degeneration with range of motion and muscle force in brachial plexus injury. Magn Reson Imaging. 2017;36:98-104.
10. Viguie CA, Lu DX, Huang SK, Rengen H, Carlson BM. Quantitative study of the effects of long term denervation on the extensor digitorum longus muscle of the rat. Anat Rec. 1997;248:346-54.
11. Kato N, Htut M, Taggart M, Carlstedt T, Birch R. The effects of operative delay on the relief of neuropathic pain after injury to the brachial plexus: A review of 148 cases. J Bone Joint Surg Br. 2006;88:256-9.
12. Chhabra A, Thakkar RS, Andreisek G, Chalian M, Belzberg AJ, Blakeley J, et al Anatomic MR imaging and functional diffusion tensor imaging of peripheral nerve tumors and tumorlike conditions. AJNR Am J Neuroradiol. 2013;34(4):802-7.

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