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ORIGINAL RESEARCH

A Comparative study between high resolution ultrasonography vs magnetic resonance imaging findings in brachial plexus injuries

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Abstract
The brachial plexus is a major neural structure that provides sensory and motor innervation to upper extremity. Various diagnostic imaging modalities can be used, such as myelography, CT and MRI. The gold standard being MRI which is the imaging modality of choice for brachial plexus injuries due to its superior soft tissue resolution and multiplanar capabilities. High resolution ultrasonography on the other hand is a dynamic, portable and cost-effective modality for assessment of peripheral nerves. With advancements in the biotechnology, more applications of musculoskeletal ultrasound have been developed in the recent past. Advances in ultrasound scanner and transducer design over the past few years have enabled high-quality sonological imaging of peripheral nerves with resolutions equivalent or better than those of magnetic resonance (MR) imaging in some cases.
Key words: Ultrasonography, Magnetic resonance imaging

INTRODUCTION AND REVIEW OF LITERATURE

The brachial plexus is a major neural structure that provides sensory and motor innervation to upper extremity. Young men are involved in motorcycle accidents are predisposed to traction injury of the brachial plexus. Traumatic brachial plexus injuries affect 1% of patients involved in major trauma.[1]Brachial plexus injuries may cause permanent disability , pain, psychologic morbidity , and reduced quality of life.[2-6]Early evaluation and diagnosis of the level and degree of injury are essential for deciding treatment requirements.

Clinical as well as electrodiagnostic evaluation of peripheral nerves are widely being used in the current era to assess the severity of trauma to peripheral nerves. However, a major limitation is that these approaches are not able to determine the extent of damage to the nerve fibers in the first 6 weeks post trauma.[7] It is most important to assess the extent of severity of injury—that is, to differentiate between the complete avulsion of nerve roots and postganglionic lesion. At present, the most suitable method for this purpose is surgical exploration along with intraoperative electrophysiologic studies.

Various diagnostic imaging modalities can be used, such as myelography, CT and MRI.The gold standard being MRI which is the imaging modality of choice for brachial plexus injuries due to its superior soft tissue resolution and multiplanar capabilities.[8] It plays an important role differentiation of pre and post ganglionic lesions which is important for the management of brachial plexus injury predominantly in the settings of trauma. The disadvantage being that CT and MRI scans for neurographic studies are not always readily available and prove to be costly.

High resolution ultrasonography on the other hand is a dynamic, portable and cost effective modality for assessment of peripheral nerves. With advancements in the biotechnology, more applications of musculoskeletal ultrasound have been developed in the recent past. High resolution ultrasonography is clearly able to illustrate the size of the peripheral nerve, space occupying lesions and variations in the anatomy along the entire course of the normal nerve.[9]

High-resolution ultrasonography (US) has now become one of the first-line modality in evaluating the peripheral nerves. Advances in ultrasound scanner and transducer design over the past few years have enabled high-quality sonological imaging of peripheral nerves with resolutions equivalent or better than those of magnetic resonance (MR) imaging in some cases.[10-12] A recent study compared ultrasonography with magnetic resonance imaging in the evaluation of peripheral nerve disease proved that both imaging modalities had equal specificity (86%), however ultrasound had greater sensitivity than magnetic resonance imaging (93% vs 67%).[13]Although many radiologists usually order magnetic resonance imaging to evaluate peripheral nerve disease, ultrasonography offers several more benefits over magnetic resonance imaging. US being a cheaper modality and faster to perform than magnetic resonance imaging, it can also be used to image the peripheral nerves in patients where magnetic resonance imaging is contraindicated. Ultrasound allows real-time dynamic assessment of peripheral nerves in cases of suspected entrapment syndromes. An peripheral nerve can be quickly evaluated in its entire course with ultrasonography, whereas magnetic resonance imaging on the other hand is limited by coil and coverage constraints.

Ultrasonography also helps in the comparison with the contralateral side. Ultrasonography in addition also has clinical utility in patients with probable peripheral nerve pathology by guiding diagnostic and therapeutic procedures and also by confirming electrodiagnostic findings.[14-16] The drawback of ultrasound is that it is an operator dependent modality and requires time to learn.

Improvements in sonographic technology have also enabled visualization of the brachial plexus in healthy study participants. Although sonography has been used for imaging of peripheral nerve abnormalitiesto our knowledge few reports of its use in the evaluation of patients with a brachial plexus lesionhave been published in the literature. Ultrasonography is capable of imaging normal brachial plexus nerves. Although it has some technical limitations when compared with MR imaging, including the inability to track the roots inside the foramina or behind the clavicle; ultrasonography provides excellent nerve depiction and may be helpful in guidance of brachial nerve injuries.

Normally the roots, trunks and cords appear as homogeneous, hypoechoic structures, tubular in longitudinal slices and oval in axial slices. It is seen that this appearance differs from the appearance of peripheral nerves, the fasciculated nature of which can be clearly identified with ultrasound (hypoechoic bundles embedded in more or less hyperechoic supporting connective tissue and surrounded by the hyperechoic epineurium)[17].

Because ultrasonography can reveal the level of the root of the brachial plexus on the basis of different morphologic characteristics on the vertebral landmarks, it can be used for exact confirmation of the pathologic roots before surgery.

Because of its complex structure and the longitudinal course of its nerves, the brachial plexus can be challenging to conceptualize in three dimensions, which further complicates understanding in standard orthogonal imaging planes. The components of the brachial plexus can be determined by using various key anatomic landmarks. Normal brachial plexus anatomy is assumed for five anatomic landmarks: the neural foramen, interscalene triangle, lateral border of the first rib, medial border of the coracoid process and lateral border of the pectoralis minor muscle.[18]

The first key anatomic landmark, the neural foramen, corresponds to the origin of the brachial plexus and is well demonstrated on axial and sagittal views. Distal to the neural foramen, the spinal nerve divides into ventral and dorsal rami. The dorsal rami extend posteriorly to innervate the paraspinal muscles. The ventral rami are known as the roots of the brachial plexus and course slightly anteriorly toward the interscalene triangle. The roots appear as five stacked points on sagittal images, and the proximal aspect of the first rib is a useful landmark for locating the roots of the brachial plexus in the sagittal plane, as the T1 root is below the rib, while the C8 root is above the rib.

The interscalene triangle, the second key anatomic landmark, is formed by the anterior and middle scalene muscles.The subclavian artery ascends into the interscalene triangle, coursing posterior to the anterior scalene muscle. Within the medial aspect of the triangle, the C5–C7 roots are superior to the artery, while the C8 and T1 roots are posterior to the artery.[18]

The lateral border of the first rib is the third key anatomic landmark. As the trunks continue inferolaterally, each trunk separates into an anterior and posterior division at or near the lateral border of the first rib. At this same location, the subclavian artery becomes the axillary artery. Together, the three anterior and posterior divisions form a triangular cluster of six points just superior to the artery and posterior to the midclavicle.

The medial border of the coracoid process, the fourth key landmark, serves as the landmark for the cords.The fifth and last anatomic landmark is the lateral border of the pectoralis minor muscle, where the cords separate into the five terminal branches.[18]

ANATOMY OF BRACHIAL PLEXUS

The knowledge of formation of brachial plexus and its ultimate cutaneous and muscular distribution is absolutely essential for the intelligent and effective use of brachial plexus block for upper limb surgeries. The close familiarity with the vascular, muscular and fascial relationships of the plexus is equally essential to the mastery of various techniques, for it is these perineural structures which serve as the landmark by which needle may accurately locate the plexus percutaneously. In its course from intervertebral foramina to the upper arm, the nerve fibres are composed consecutively of roots, trunks, divisions, cords and terminal nerves.

FORMATION OF BRACHIAL PLEXUS - Brachial plexus is formed by the union of ventral rami of lower four cervical nerves (C5,6,7,8) and first thoracic nerve (T1) with frequent contributions from C4 or T2. When contribution from C4 is large and from T2 is lacking, the plexus appears to have a more cephalad position and is termed “prefixed”. When contribution form T2 is large and from C4 is lacking, the plexus appears to have a caudal position and is termed “post fixed”. Usually prefixed or post fixed positions are associated with the presence either of a cervical rib or of an anomalous first rib.[19]

ROOTS: The roots represent the anterior primary divisions of lower four cervical and first thoracic nerves. They emerge from the intervertebral foramina and fuse above the first rib to form the trunks.

TRUNKS: The roots combine above the first rib to form the three trunks of the plexus. C5 and C6 unite at the lateral border of the scalenus medius and form the upper trunk. C8 and T1 unite behind the scalenus anterior to form lower trunk and C7 continues as a sole contributor of the middle trunk.

DIVISIONS: As the trunks pass over the first rib and under the clavicle, each one of them divides into anterior and posterior divisions.

CORDS: The fibres as they emerge from under the clavicle, recombine to form three cords. The lateral cord is formed by anterior divisions of upper and middle trunks, lateral to the axillary artery. The anterior division of lower trunk descends medial to the axillary artery forming the medial cord. The posterior divisions of all three trunks unite to form the posterior cord, at first above and then behind the axillary artery. The medial and lateral cords give rise to nerves that supply the flexor surface of upper extremity, while nerves arising from the posterior cord supply the extensor surface.[2]

MAJOR TERMINAL NERVES: Each of these cords gives off a branch that contributes to or become one of the major nerves to the upper extremity and then terminates as a major nerve. The lateral and median cords give off lateral and medial heads of the median nerve and continue as major terminal nerves, the lateral cord terminating as musculocutaneous nerve and medial cord as ulnar nerve. Posterior cord gives off axillary nerve as its major branch and then continues as the radial nerve. In summary, conveniently it can be considered that brachial plexus begins with five roots (C5-T1) and terminates in five nerves (musculocutaneous, radial, axillary, median and ulnar nerves) with its intermediate portions displaying in sets of three, that is, three main trunks which divide into 2 sets of three, which reunite and give rise to three cords. These three cords give off three lateral branches before becoming the major terminal branches of the plexus. [19]

DISTRIBUTION OF BRACHIAL PLEXUS: These are divided into those that arise above the clavicle- the supraclavicular branches and those that arise below it, the infraclavicular branches.

SPECIFIC BRANCHES

Supraclavicular branches

From roots:

1. Nerves to scaleni and longus coli – C5,6,7,8
2. Branch to phrenic nerve – C5
3. Dorsal scapular nerve – C5
4. Long thoracic nerve – C5,6,7

From trunks:

1. Nerve to subclavius –C5,6
2. Suprascapular nerve-C5,6

Infraclavicular branches: They branch from cords but their fibres may be tracked back to spinal nerves.

Lateral cord

1. Lateral pectoral nerve- C5,6,7
2. Musculocutaneous nerve – C5,6,7
3. Lateral root of median nerve- C5,6,7

Medial cord:

1. Medial pectoral nerve- C8, T1
2. Medial cutaneous nerve of forearm – C8, T1
3. Ulnar nerve- C7,8, T1
4. Medial root of median nerve- C8, T1
5. Medial cutaneous nerve of arm – C8,T 1

Posterior cord:

1. Upper subscapular nerve- C5,6
2. Thoracodorsal nerve-C6,7,8
3. Lower subscapular nerve- C5,6
4. Axillary nerve-C5,6
5. Radial nerve- C5,6,7,8,T1[19]

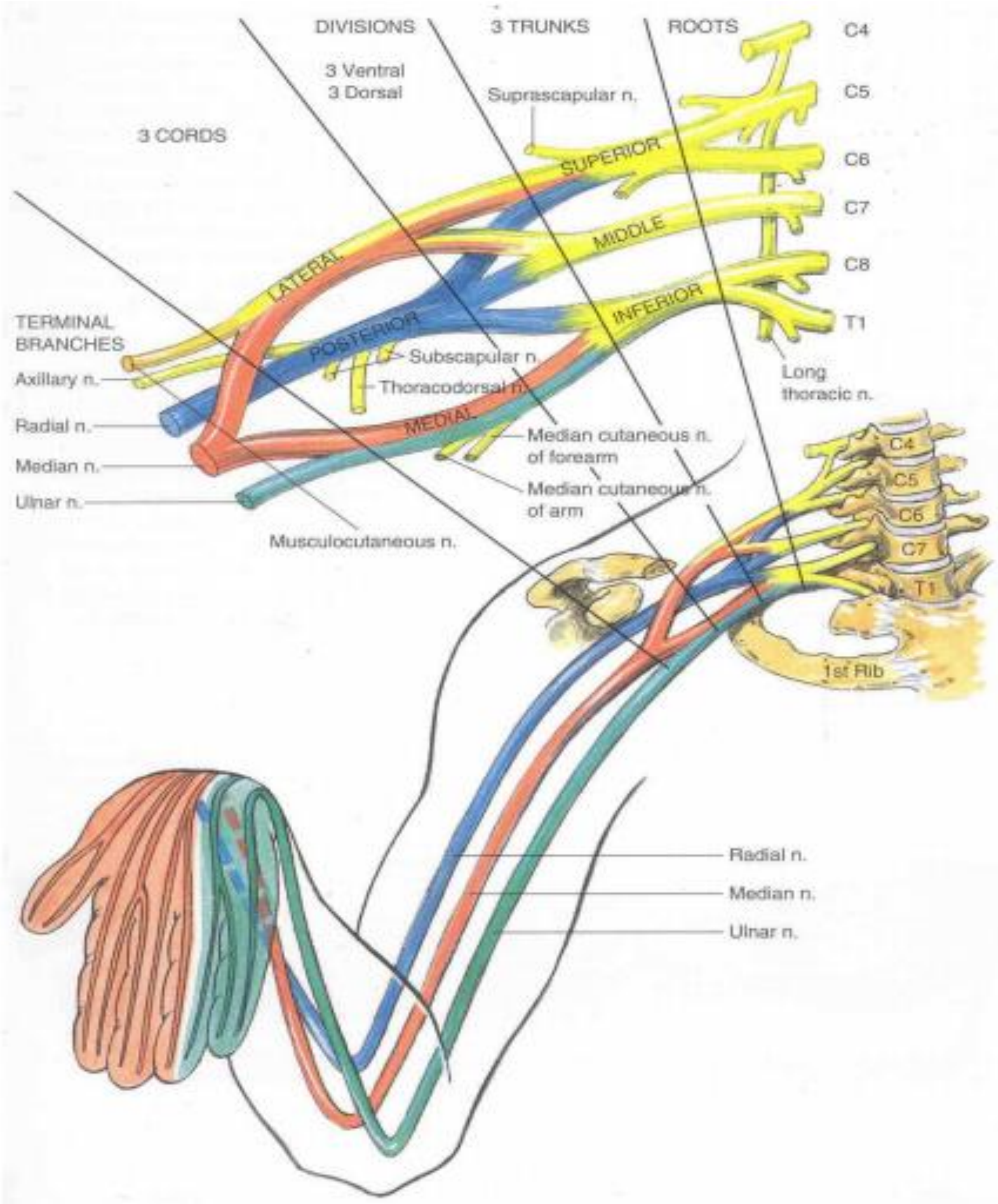


Fig – Anatomy of brachial plexus[19]

In a study conducted by **Peer et al**, ultrasound was done in trauma patients and coronal oblique plane was found the best method for depicting the avulsion of cervical nerve roots. In this study healthy nerve roots were visualised as hypoechoic structures as they were left the intervertebral foramina in caudal and lateral directions.Avulsion injuries were correctly recognized using this method. The only problem being faced was that they could not show the attachment of nerve roots to the spinal cord because of shadowing from bone. Scarring of the brachial plexus was also clearly identified. According to the study it was observed that echogenic soft tissue at the level of scar was scar tissue itself and at this level the nerve was indistinguishable.[20]

Moshe Graif et al conducted a study on 28 patients correlating the clinical, electroconductive and imaging findings of brachial plexus pathologies. There were four main etiological groups: post traumatic brachial plexopathies, tumours(benign and malignant), secondary tumours and post irradiation injuries. Out of the 28 patients,21 patients had surgery done on them. MRI was taken as an alternative gold standard for confirmation of findings in non surgically treated group of patients. The nerves were traced from the level of vertebral foramina and then were followed longitudinally and axially to their axillary region. Disruption in the continuity of nerve and focal scar tissue masses were the main findings in the post traumatic cases.The eight sonographically negative cases were considered of traumatic origin smaller than 12mm in size or located in very small branches of posterior location. Most of the disadvantages were related to the restricted field of view and inability to overcome bony obstacles specially in evaluation of post ganglionic region.[21]

In a study conducted by **Hans Peter Haber** et alfor evaluating the role of sonography in identification of nerve abnormalities in patients with traction injury of brachial plexus found that sonography was technically feasible, although the entire plexus could not be identified. In the study so conducted four men with traction injuries to brachial plexus who went through surgical exploration between October to December 2003 were included. The interval between the injury and examination was taken as 4months. The results showed that when the hypoechoic roots between the transverse processes of vertebrae were absent, avulsion was present. It also showed that the cervical part of brachial plexus was best identified on coronal oblique planes. In the supra and infra clavicular regions, axial oblique plane was most suitable for detecting the pathological lesions. Ultrasonography was able to detect the avulsion in three out of four the cases. It was also appreciated that C5-C7 were better depicted as compared to C8 and T1 nerve roots.[22]

Vargaset al[23] conducted a study with the aim to assess the diagnostic and prognostic value of MRI in traumatic brachial plexus injuries and to determine any correlations among the radiological, clinical and electroneuromyographical (EMG) data from both the initial and follow-up studies. Nine patients with acute traumatic lesions of the brachial plexus were investigated by MRI and EMG withfive patients being used as controls. The MRI was done using fast spin-echo (FSE) T2-weighted and STIR sequences. These scans were independently interpreted by two senior radiologists. Among the nine patients, MRI scans were found as normal in three patients whereas EMG showed distal lesions in two of them. In a further three patients, STIR MRI sequences demonstrated high signal intensities from the trunks and cords of C5 to T1 with persistence of these signal anomalies in one patient and partial regression in the two others after 3 months. In the remaining three patients, three-dimensional T2-weighted sequences showed nerve root avulsions, consistent with the initial EMG findings.

Bernhard Glodny et al, conducted a study to evaluate the role of high resolution ultrasound on patient recruitment for surgery. Twelve patients after blunt shoulder trauma and standardised HR-Ultrasound who underwent plexus surgery were included in the prospective observational study. All findings were compared to electrophysiological data if available and tested against gold standard i.e. surgical validation. Lesions were correctly identified in nine patients. In two patients the lesions were underestimated as compared to the gold standard. Based on HR-US alone 9 out of 11 patients having major lesions underwent early surgery. The analysis showed a high positive (1.0) and an acceptable negative predictive value (0.92), thus proving that high resolution ultrasound as valuable tool for patients with traumatic brachial plexus injury.[24]

Silbermann-Hoffmanconducted a prospective study on 15 patients with post-traumatic axillary nerve paralysis and found three MRI groups of patients: group 1 with normal MRI findings , group 2 having patients with thickening of the nerve, and in group 3 patients a neuroma was found on the axillary nerve at the point of its entry. Neuromas were seen as a nodular or oval hyperintense structures on T2 weighted fat saturated or STIR MRI images, isointense with muscle on T1 weighted images showing enhancement with gadolinium.A good correlation was between radiological, clinical and surgical findings.All of the patients with a normal MRI were found recovered clinically and the patients with neuromas who did not recover clinically required surgical interventions. It was found that fibrosis was not helpful in predicting clinical outcome, as some patients did recover functional activity without treatment while others recovered functional activity after surgical neurolysis.[25]

Minjuan Zheng et al conducted study on 11 patients with suspected brachial plexus trauma, 6 patients with brachial plexus neoplasms and 12 healthy volunteers. The ultrasound findings were then compared with surgical findings. In 24 sites examined (12 subjects examined on both sides). The results were as follows: C5-C7 nerve roots were detected in all cases where as C8 and T1 were seen in 91.7% (22/24) cases. The brachial plexus appeared as three or four discrete rounded hypoechoic nodules between anterior scalene and middle scalene muscle in transverse views at C5-C7 levels. In the trauma group of patients, the normal nerve roots were found interrupted and lesions were seen as thickening and swelling with indistinct inner structures.[26]

In a prospective study by **Yong Sheng Zhu** et al ultrasound examination of brachial plexus was performed in 37 patients. These included 29 patients with nerve root injuries and 8 with tumour. The pre-operative ultrasound findings were then compared with surgical and pathohistological findings. The findings were as follows: Detection of C5-C7 roots was found in all patients whereas C8 was detected in 92% (68/74) cases and T1 was visualized in 51% (38/74) cases. In 29 patients with nerve root injuries, partial injuries or totally interrupted roots were detected in all patients. Cystic masses and neuromas were found in 16 and 23 patients respectively. Surgical explorations revealed that there were 57 avulsions in 29 patients. 2T1 avulsions were missed by preoperative ultrasonography.Thereby the study showed that high resolution ultrasonography is a convenient and accurate imaging modality for diagnosis and location of brachial plexus root lesions.[27]

Caporrino et alcarried out a study which aimed to determine the diagnostic performance of physical examination, of nerve conduction studies (NCS), and of MRI using surgery as reference standard in BP injuries. The sensitivity and specificity of the MRI in detecting post-ganglionic lesions were, respectively, 60% and 59.8%. The conclusion of this study was that, despite the poor performance of the single diagnostic strategies, NCSs and MRI used in conjunction with physical examination could increase the diagnostic accuracy.[28]

In a study conducted by **Van Der Linde 16** trauma patients were examined in 2 years; 15 were male and only one female with the mean age of 30 years. In the study all imaging modalities were considered to be of diagnostic quality except for one CT myelography (CTM) which was interpreted as being of 'poor quality'. This was due to the fact that contrast did not reach the cervical spine, post fluoroscopic infiltration and therefore was not visualised on the CTM images. CTM and MRI imaging was conducted done at an average 98 days following injury (lower limit = 40 days; upper limit = 208 days). CTM was the modality of first choice in 12 occasions. MRI was done before CTM in the remaining four cases. Seven out of 16 (44%) brachial plexus injuries were sustained on the left and remaining nine (56%) injuries on the right side. The major causes of traumatic brachial plexopathies were as follows: motor vehicle accidents (69%), pedestrian vehicle accidents (19%), motorcycle accidents (6%) and blunt trauma (6%) with the majority of patients having polytrauma presenting with multiple upper and lower limb injuries.Clinical presentation included pain, loss of sensation, motor function deficits, wasting of the muscles around the shoulder joint and scapular winging. Horner's syndrome was documented in two patients (13%). Nerve conduction studies were performed on all patients; however, the majority of the results showed mixed sensory and motor deficits involving the C5-T1 nerve roots and were thereby inconclusive.In comparison to CTM, the sensitivity for MRI in the detection of preganglionic nerve root avulsion injuries and pseudomeningoceles was 82%, the specificity 100%, the positive predictive value of 100% and the negative predictive value of 71%. MRI had the same results as CTM for the detection of preganglionic nerve root avulsion injuries and pseudomeningoceles involving nerve roots C7-T1; however, CTM detected some pseudomeningoceles and preganglionic nerve root avulsion injuries at nerve roots C5/C6 of one patient, which was not detected on MRI.[29]

In a study conducted by **Ben Gag Qin et al**,brachial plexus injuries were examined in 33 patients prospectively using 3D DW-SSFP MR neurography (MRN). Results of 3D DW-SSFP MRN were then compared with intraoperative findings. 3D DW-SSFP MRN of brachial plexus has enabled good visualization of the smaller components of the brachial plexus. The postganglionic zones of the brachial plexus was clearly visualized in 26 patients, while the preganglionic zoneswere clearly seen in 22 patients. Pseudomeningoceles were commonly observed in 23 patients. Others finding of MRN of brachial plexus included spinal cord offset (in 16 patients) and spinal cord deformation (in 6 patients). The sensitivity, the specificity and the accuracy of 3D DW-SSFP MRN in diagnosing preganglionic injuries of brachial plexus were 96.8%, 90.29%, and 94.18%respectively.This technique helped in improving the visualisation of brachial plexus and also its extent of injury.[30]

In a study conducted by **Brain Chin[31]** et al to evaluate the role of ultrasound as a diagnostic tool in the assessment of traumatic adult brachial plexus injury. Seven patients were being examined. In four patients the detection of pre- and postganglionic lesions at different levels (C5-T1) with surgical exploration being used as the reference standard was done. Sensitivity of lesion detection was greater in the upper and middle spinal nerves: C5 (93%, confidence interval [CI] = 78%-100%), C6 (94%, CI = 82%-100%), and C7 (95%, CI = 86%-100%) than in the lower: C8 (71%, CI = 36%-95%) and T1 (56%, CI = 29%-81%).**The study concluded that**ultrasound as an effective diagnostic tool for traumatic adult BPI with sensitivity of lesion detection greater in the upper and middle (C5-C7) than in the lower spinal nerves (C8, T1).

A prospective study conducted by A. Gunes to evaluate the role of ultrasound and MRI in birth plexus birth injury in 55 patients (girls/boys = 32:23)having a mean age of 2.1 ± 0.8 monthswith brachial plexus birth injuries between May 2014 and April 2017.All patients had MR imaging under general anesthesia. Nerve root avulsion-retraction, pseudomeningocele, and periscalene soft tissue were accepted brachial plexus injury findings on imaging. Interobserver agreement for MR imaging and the agreement between imaging and surgical findings were estimated using the κ statistic. The diagnostic accuracy of sonography and MR imaging was calculated on the basis of the standard reference, which was the surgical findings. Forty-three patients had pre- and postganglionic injury, 12 had only postganglionic injury findings, and 47% of patients underwent an operation. On sonography, no patients had preganglionic injury, but all patients had postganglionic injury findings. For postganglionic injury, the concordance rates between imaging and the surgical findings ranged from 84% to 100%, and the diagnostic accuracy of sonography and MR imaging was 89% and 100%, respectively. For preganglionic injury, the diagnostic accuracy of MR imaging was 92%. Interobserver agreement and the agreement between imaging and the surgical findings were almost perfect for postganglionic injury (κ = 0.81–1, *P* < .001)[32.]

Wade RG conducted a study to find the role of consecutive diagnostic examinations in patients suffering traumatic brachial plexus injuries between 2008 and 2016. The index test was magnetic resonance imaging at 1.5 Tesla and the reference test was operative exploration of the supraclavicular plexus. It was seen that that identification of root avulsions is of critical importance in traumatic brachial plexus injuries because it alters the surgical management and prognosis. The study was conducted on 29 male patients and diagnostic accuracy of magnetic resonance imaging for root avulsion(s) of C5-T1 was found to be 79%. The diagnostic accuracy of a pseudomeningocoele as a surrogate marker of root avulsion(s) of C5-T1 was found to be 68% in this study. [33]

O Kenechi Nwawka et al conducted a study to evaluate the role of ultrasound as an alternative to imaging in gun shot related brachial plexus imaging as MRI is contraindicated when there are metal fragments in a patient's body. Four types of injuries were recogonised:

nerve transection, neuroma formation, neuritis and perineural scarring. The diagnoses of nerve transection and neuroma on ultrasound were seen in patients with complete denervation on electromyography (EMG). When segmental nerve thickening (neuritis) or perineural scarring, without transection or neuroma, were described on ultrasound, EMG detected mild to moderate denervation. Two patients received reconstructive surgery, both confirming intraoperative findings.[34]

In a study conducted by **Ryckie G. Wade** of 275 adults (mean age, 27 years; 229 men) suffering from traumatic injuries MRI was done between 1992 and 2016. Most participants had been injured in motorcycle collisions (84%). Overall, 72% of patients with brachial plexus injuries had at least one root avulsion (interquartile range [IQR]: 53%–86%); meta-analysis of patient-level data was not performed because of sparse and heterogeneous data. With the nerve root as the unit of analysis, 583 of 918 roots were avulsed (median, 55%; IQR: 38%–71%); the mean sensitivity of MRI for root avulsion was 93% (95% confidence interval [CI]: 77%, 98%) with a mean specificity of 72% (95% CI: 42%, 90%).[1]

In a retrospective study conducted by **Nguyen Duy Hung** and **Nguyen Minh Du**c was performed on 60 patients (47 men and 13 women), having clinical features of brachial plexus injury 3T MRI was doneand then were surgicallytreated from March 2016 to December 2019. The diagnostic function of MRI features for the determination of brachial plexus injury were evaluated and were correlated with intraoperative findings.The root avulsion and pseudomeningocele preganglionic injuries were observed in 57% and 43% of MRIs, respectively, and were commonly observed at the C7 and C8 roots. Nerve disruption and nerveedema were observed in 47.56% and 33.53% of MRIs, respectively, and were commonly observed at the C5 and C6 roots. The sensitivity, specificity, accuracy, positive prognostic value, and negative prognostic value of 3T MRI were 64.12%, 92.90%, 80.33%, 87.50%, and 76.96%, respectively, for the diagnosis of total avulsion, and 68.52%, 83.33%, 80.67%, 47.44%, and 92.34%, respectively, for the diagnosis of nerve disruption. In this study, the most common cause of injury was traffic accidents (73.3%), followed by trauma during childbirth (23.3%). Closed and open injuries accounted for 96.7% and 3.3% of injuries cases, respectively.. The median interval between injury and MRI scan was 53 days (range, 17–419), with 15% of cases scanned within 30 days of injury and 58.3% of cases scanned between 30 and 90 days after injury. The median interval between injury and surgical intervention was 98 days, with 85% of cases being operated on within 180 days of the injury.[35]

Trung NN conducted research study on 40 patients who needed treatment for post-traumatic brachial plexus lesions. Clinical and electrophysiological studies carried out in these patients could not completely exclude the possibility of cervical roots being torn off at one or more levels of brachial plexus and thereby a prospective study was conducted to determine the intraspinal integrity of the affected cervical roots, as well as to determine the accuracy of CT myelography and magnetic resonance imaging (MRI) in the diagnosis of root detachments after traumatic brachial plexus injuries.MRI was done in 15 patients and 60 nerve roots before surgical intervention. Magnetic resonance imaging showed 10 undamaged roots, 23 completely torn roots and 4 partially torn roots. Magnetic resonance images were technically unsuitable for diagnostic tests of 23 cervical roots with accuracy of MRI in making diagnosis was seen only in 52% of cases.In 48% of cases, MRI images showed unreliable or inconsistent results when compared to the results of hemilaminectomy surgery.In total, 135 roots have been examined intradurally.Among them in 64 cases, a complete root tear was observed. Undamaged roots (ventral and dorsal) were found in 56 cases and partial detachment of the ventral or dorsal root was detected in only 15 cases. The complete root separation was more frequently found near the C-7 and C-8 roots.[36]

Shihui Guconducted a studywith aim of quantifying the diagnostic accuracy of ultrasonography in brachial plexus root injury at different stages post-trauma. The study was conducted on 170 patients with root injuries between 2015 and 2019 retrospectively and patients were divided into three groups on the basis of time between injury and ultrasound examination (≤1 month, 1–3 months, >3 months). Diagnosis of complete brachial plexus root injury under ultrasound was determined using a pre-defined criterion, including pseudomeningocele, retraction and rupture. Diagnostic accuracy was thereby calculated based on the basis ofsurgical findings and intra-operative electrophysiological tests. Rates of detection of the cervical (C5–C8) and thoracic (T1) nerve roots under ultrasound were 99.4%, 99.4%, 99.4%, 95.9% and 79.4%, respectively. The sensitivity for complete BP root injury was 0.74, and the specificity was 0.91. There was no significant difference in sensitivity or specificity were observed across time stages. Ultrasound exhibited substantial consistency with surgical findings ($\kappa = 0.70$) for complete root injury at any stage of post-injury[37]

In a study conducted by Pawel Szaro and Mats Geijer on patients suffering from traumatic brachial plexus injuries described acute preganglionic injuries as combinations of post-traumatic pseudomeningocele, absence of roots, deformity of nerve root sleeves, displacement of the spinal cord, haemorrhage in the spinal canal, presence of scars in the spinal canal, denervation of the back muscles, and a syrinx formation. They described that p preganglionic injuries requires nerve transfer surgery, while postganglionic injuries are treated by nerve grafting or are followed up in cases of partial injury. It was suggested in the study that pseudomeningoceles are an unreliable indicator of root avulsion. The study also emphasised the involvement of the interscalene space as indicates injury to the BP roots. MRI signs of brachial plexus injury without rupture manifested as edema of the nerves, which in the MR image is expressed as BP asymmtery[38]

Pawel Szaro and Mats Geijer conducted a study to find the main cause for the avulsion of the nerve roots. Avulsion of C5, C6, and C7 occurred due to distraction forces, which can occur in the coronal placelike when a cyclist or motorcyclist falls on the ground having their head forcibly flexed to the opposite side and avulsion of the nerve roots C8 and T1 mainly occurred when the arm is abducted over the head and force is applied simultaneously on the arm and trunk like in cases fall from a tree holding on to the branch. They also studied that individuals younger than 40 years were mainly involved in traffic accidents and had more severe injuries, while patients over 40 years with a history of anterior shoulder dislocation or humeral fracture often had injury in the region of axillary nerve had poor prognosis. The study also emphasised that roots and trunks of the BP were more prone to injury than the divisions or cords. Injury of the infraclavicular part of the BP can also be associated with injury to the shoulder region, such as anterior shoulder dislocation or proximal humerus fracture. According to the study the most common type of injury is a total rupture of roots C5 to T1 involved in about 75% of cases, followed by upper plexus injuries (C5-C6 injury) in about 20% of cases and with only 3% of cases having lower plexus injuries (C8-T1 injury)[39]

In a study conducted Lao Q et al, in 26 children suffering from trauma, 3 of cases had normal MRI imaging findings, 23 cases had unilateral brachial plexus injury with a total of 73 nerve roots being involved. Among the 23 cases with abnormal MRI findings, there were 19 cases of nerve root thickening (42 nerve roots), 4 cases of nerve root sleeve expansion (5 nerve roots), 17 cases of pseudomeningocele formation (34 nerve roots), 8 cases of nerve root dissection (11 nerve roots), 19 cases with increased nerve signal (43 nerve roots), and 9 cases with an increased signal of the muscles on the affected side. The diagnosis of brachial plexus injury, the sensitivity and the accuracy of physical examination, EMG and MRI were 0.92, 0.86, and 0.88, respectively. The agreement between MRI and physical examination was substantial (κ=0.780, *P*=0.000), and also agreement between MRI and EMG (κ=0.611, *P*=0.005).[40]

AIM OF THE STUDY

1. To compare high resolution ultrasonography with magnetic resonance imaging findingsin brachial plexus injuries.

OBJECTIVE OF THE STUDY

1. To assess brachial plexus injuries on high resolution ultrasonography.
2. To assess brachial plexus injuries on magnetic resonance imaging.

MATERIAL AND METHODS

The present study will be conducted on 30 study participants. Study participants will be the individuals of either gender, attending outpatient department (OPD) or admitted to Sri Guru Ram Das Institute of Medical Sciences and Research, Sri Amritsar with history of brachial plexus injuries referred to Department of Radiodiagnosis and Imaging.

TYPE OF STUDY

Diagnostic study

SETTING

Prospective Study.

SAMPLE SIZE

30 study participants

PATIENT INCLUSION CRITERIA

Study participants with history of injury to brachial plexus.

EXCLUSION CRITERIA

Absolute:

1. Electronically, magnetically and mechanically activated implant e.g. cardiac pacemaker,pacemaker for carotid sinus, insulin pumps, nerve stimulators, lead wires or similar wires.
2. Ferromagnetic or electronically operated stapedial implants,
3. Cochlear implants.
4. Prosthetic heart valves

After taking the informed, written consent of each study participant, detailed clinical history will be recorded, general physical and local examination will be done and highresolution ultrasonography of brachial plexus will be performed bilaterally.

SONOGRAPHY TECHNIQUE

The highresolution sonography will be performed using Philips Affinity 50 with a linear transducer having frequency of 5-18 Mhz.

Brachial plexus Imaging with Ultrasound

The patients will be examined in a semi lateral decubitus position without specific preparation. Coronal oblique planes will be used to identify the transverse processes of the vertebrae as hyperechoic bone prominences with posterior acoustic shadowing. In the groove between the transverse processes, the hypoechoic nerve roots will be visualized as they leave the intervertebral foramina in a downward direction. When the hypoechoic roots between the transverse processes will be absent, the lesion will be classified as an avulsion. The roots and trunks will be followed continuously into the interscalene, supraclavicular, and infraclavicular region by shifting the probe back and forth in an axial plane . Individual nerve roots will be examined closely to identify pathologic conditions, depicted as abnormal soft tissue surrounding the nerve or a transection or loss of clarity of the nerve structure. Colour Doppler sonography will be used to differentiate nerve structures from vessels. The level of individual roots will be identified on the basis of the different morphology of the cervical transverse processes of the vertebrae: The anterior tubercle of the transverse process is selectively absent in the C7 vertebra . The root levels of the upper vertebrae will be identified by counting the number of transverse processes encountered while sweeping the transducer cranially from C7.

This study will be focussing on the feasibility of imaging the brachial plexus with sonography in patients with brachial plexus injury. Using a high-resolution 5-18-MHz transducer, this technique will allow us to visualize healthy nerve structures and root avulsion or nerve injury in the form of neuroma and scar tissue formation. However, a careful technique must be used to differentiate nerve structures from surrounding organs and structures. Many structures of similar echoic appearance, such as muscle fascicles and vessels, course in the same plane, and correct differentiation among them can be difficult. The brachial plexus can be identified by its characteristic location i.e lateral and posterior to the pulsatile subclavian artery and superior to the first rib.

Coronal oblique plane is the most reliable for the accurate depiction of the avulsion of the cervical nerve roots. In this region, the healthy nerve roots will appear as well-delineated hypoechoic structures as they leave the intervertebral foramina in a caudal and lateral direction. Using this coronal oblique plane, all avulsions can be correctly identified by showing empty neural foramina. However, this technique is limited by the fact that we cannot show the attachment of the nerve rootlets to the spinal cord because of shadowing from bone. As a result, isolated intradural damage as reported on MRI may not be immediately obvious on sonographic imaging of the plexus.[8] Sonographic examination of the brachial plexus may reveal scarring, providing clear evidence of injury.

MAGNETIC RESONANCE IMAGING TECHNIQUE

All the patients will undergo examination on Philips AchievaDstream 1.5 Tesla MRI using Sense Body Coil. As the brachial plexus runs in an oblique fashion from superomedial to inferolateral in coronal plane, thereby axial oblique and coronal oblique planes are taken for evaluation. By using this technique, heart and lung are avoided, thereby reducing the motion artefacts.

SEQUENCES	TR (msec)	TE (msec)	TI (msec)	THK/SLICE GAP (mm)	FOV (mm)	NSA
STIR CORONAL	3500-4000	100	135-165	3.5/0.3	350X300	2
T1W CORONAL	400-500	10-16	-	3.5/0.3	350X300	2
T1W AXIAL	400-500	10-16	-	3.5/0.3	350X300	2
T2 FSE AXIAL	3500-4500	90-120	-	3.5/0.3	350X300	2

RESULTS

The study was done on 30 patients from age ranging from 8 years to 72 years with mean age of mean age was 37.90±20.13 years as shown in table1 and graph1. There were 22 males and 8 females involved in our study (table 2 and graph 2).

Table1: Age wise distribution of study subjects (n=30)

Age group	No.	%
Upto 20 years	8	26.7
21-40 years	9	30.0
41-60 years	9	30.0
>60 years	4	13.3

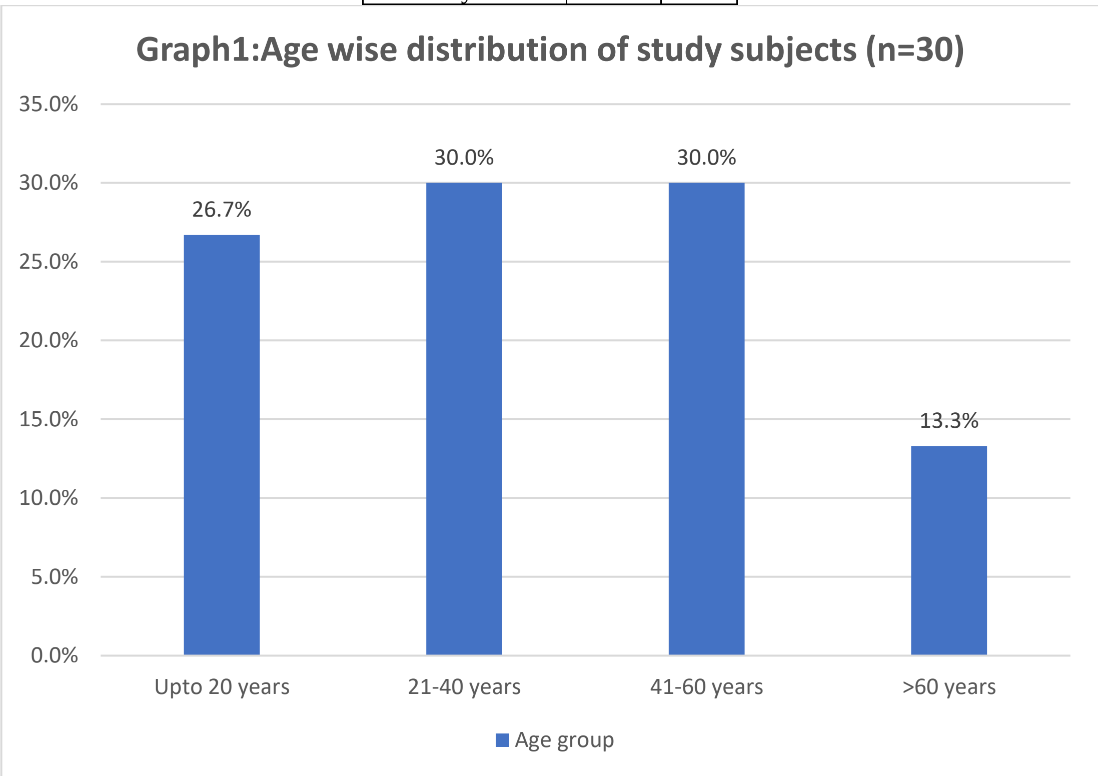
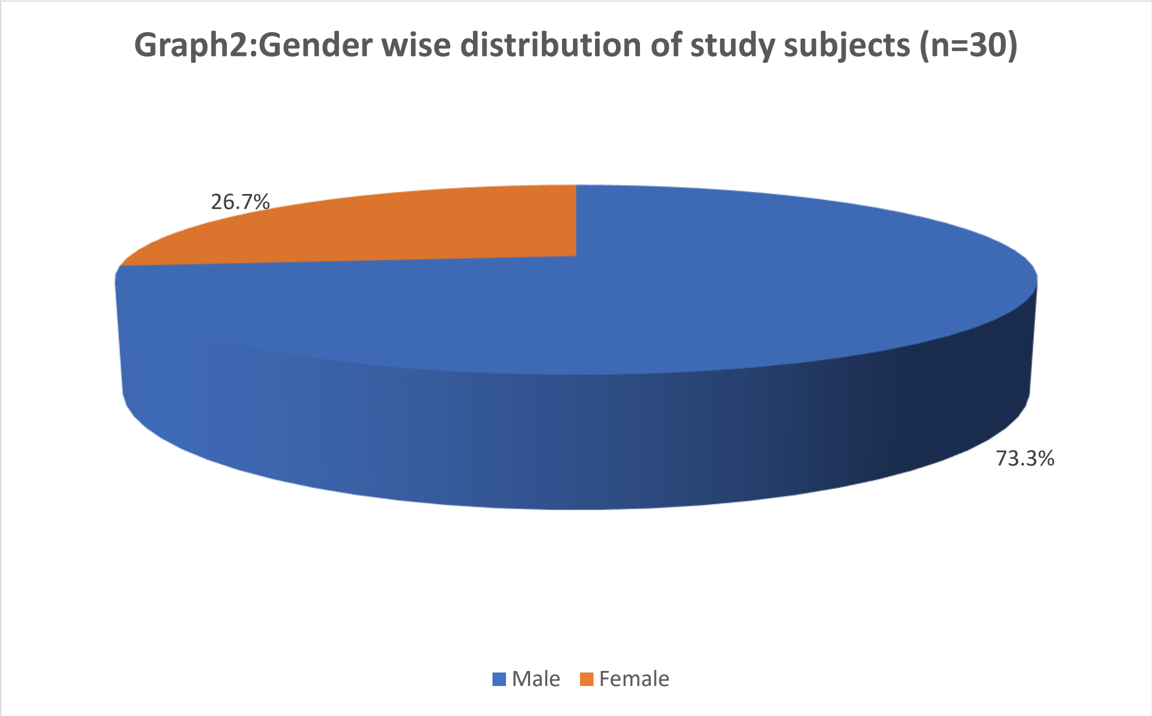


Table 2: Gender wise distribution of study subjects (n=30)

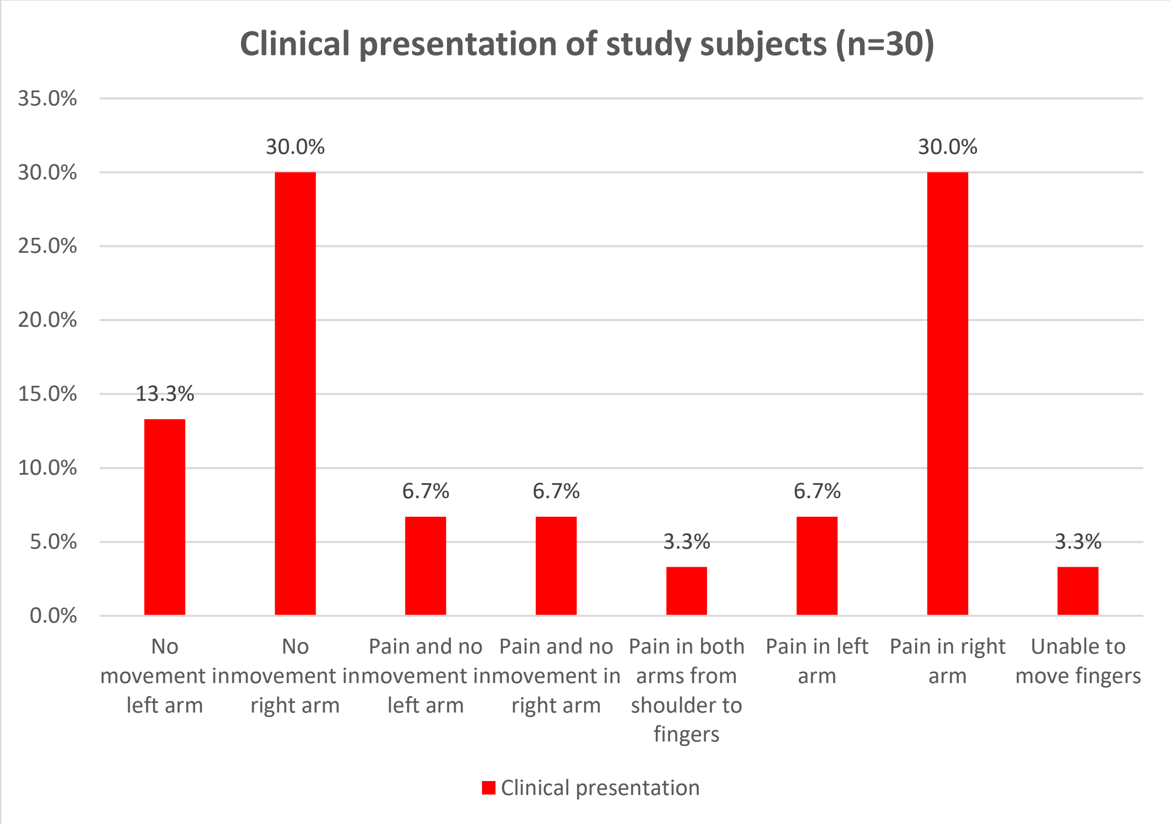
Gender	No.	%
Male	22	73.3
Female	8	26.7



The main clinical complaints of patients suffering from trauma in our study was no movement in right arm in 9 out of 30 cases(30% cases),pain in right arm in 9 out of 30 cases(30% cases) and no movement in left arm in 4 out of 30 cases(13.3% cases) as shown in table 3 and graph 3.

Table3: Clinical presentation of study subjects (n=30)

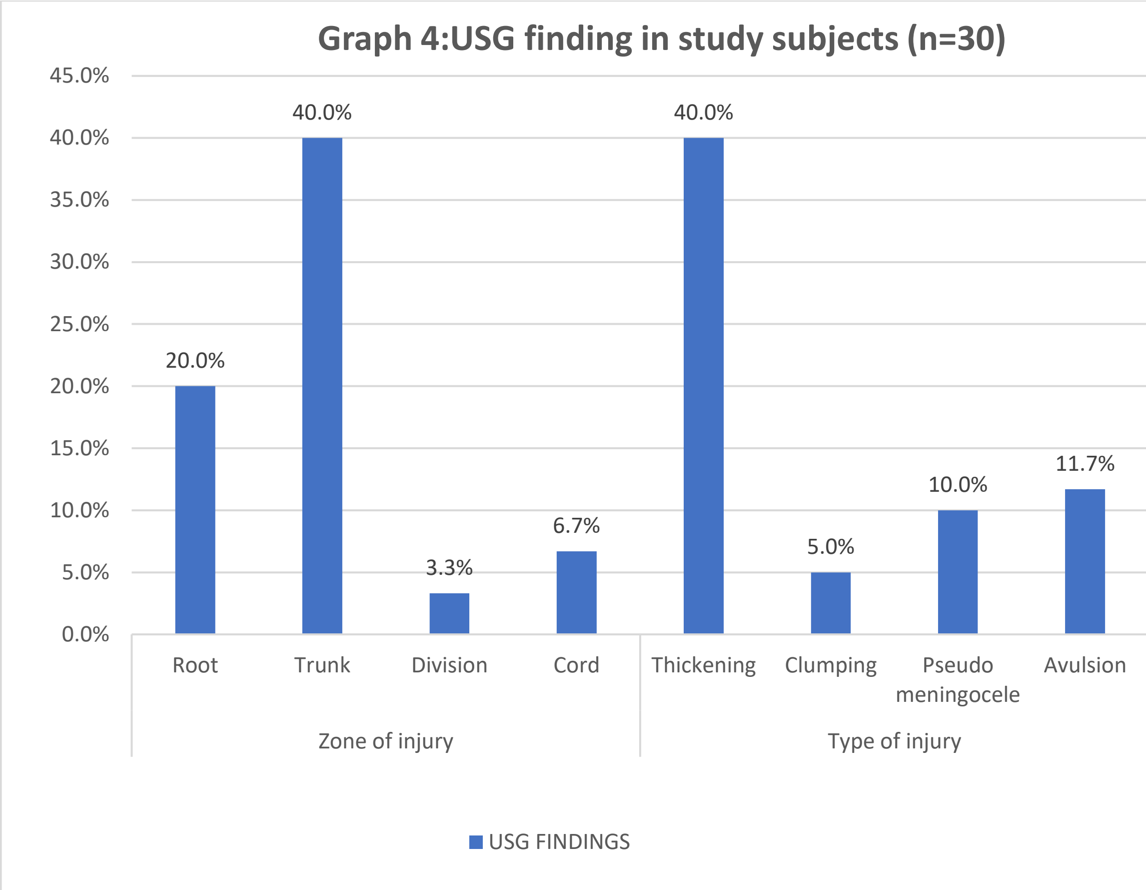
Clinical presentation	No.	%
No movement in left arm	4	13.3
No movement in right arm	9	30.0
Pain and no movement in left arm	2	6.7
Pain and no movement in right arm	2	6.7
Pain in both arms from shoulder to fingers	1	3.3
Pain in left arm	2	6.7
Pain in right arm	9	30.0
Unable to move fingers	1	3.3



Ultrasound findings reveal injuries in 12 zones of roots (20% of cases), in 24 zones of trunks (40% of cases), 2 zones of divisions (3.3% of cases) and 4 zones of cords (6.7% of cases). Thickening involving various nerves seen in 24 nerve zones, clumping was seen involving 3 nerve zones and pseudomeningoceles were seen in 6 nerve zones as in table 4 and graph 4. Additional findings were seen in7 patients as atrophic changes in shoulder muscles.

Table4: USG finding in study subjects (n=60)

	No.	%
Zone of injury		
Root	12	20.0
Trunk	24	40.0
Division	2	3.3
Cord	4	6.7
Type of injury		
Thickening	24	40.0
Clumping	3	5.0
Pseudo meningocele	6	10.0
Additional finding	7	11.7

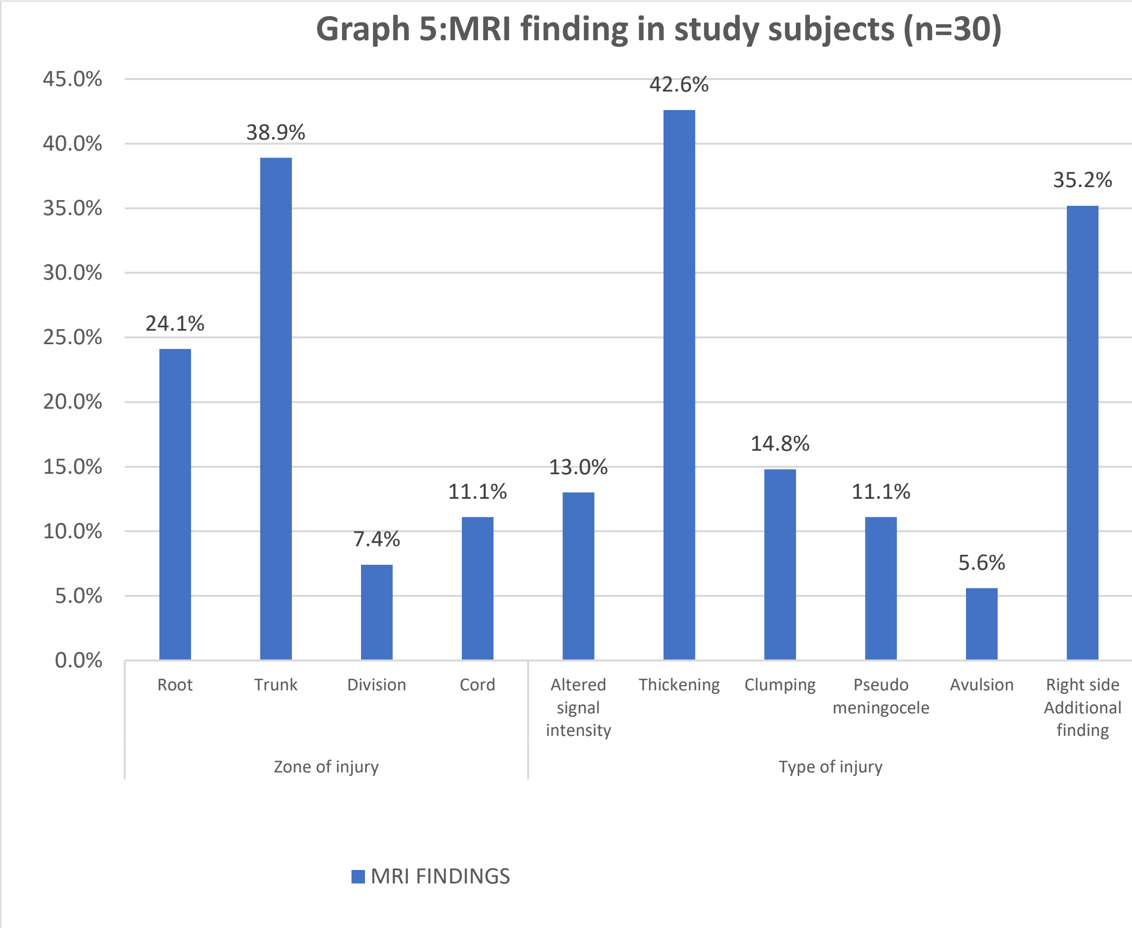


After ultrasound, MRI was done in 27 patients which showed injuries in 13 zones of roots, 21 zones of trunks, 4 zones of divisions and 6 zones of cords. Thickening was seen in 23 zones, 8 involved clumping of nerve zones and pseudomeningoceles were seen in 6 nerve zones as seen in table 5 and graph 5. Additional findings were seen in 19 patients in the form of atrophy of shoulder muscles;edema of shoulder muscles;fractures of clavicle, scapula, ribs& humerus; multiple block vertebrae; nodule in thyroid gland and subacromial bursitis.

Table 5: MRI finding in study subjects (n=54)

	No.	%
Zone of injury		
Root	13	24.1
Trunk	21	38.9
Division	4	7.4
Cord	6	11.1
Type of injury		
Altered signal intensity	7	13.0
Thickening	23	42.6
Clumping	8	14.8
Pseudo meningocele	6	11.1
Avulsion	3	5.6
Additional finding	19	35.2

* in 3 subjects MRI was not done due to metallic implant

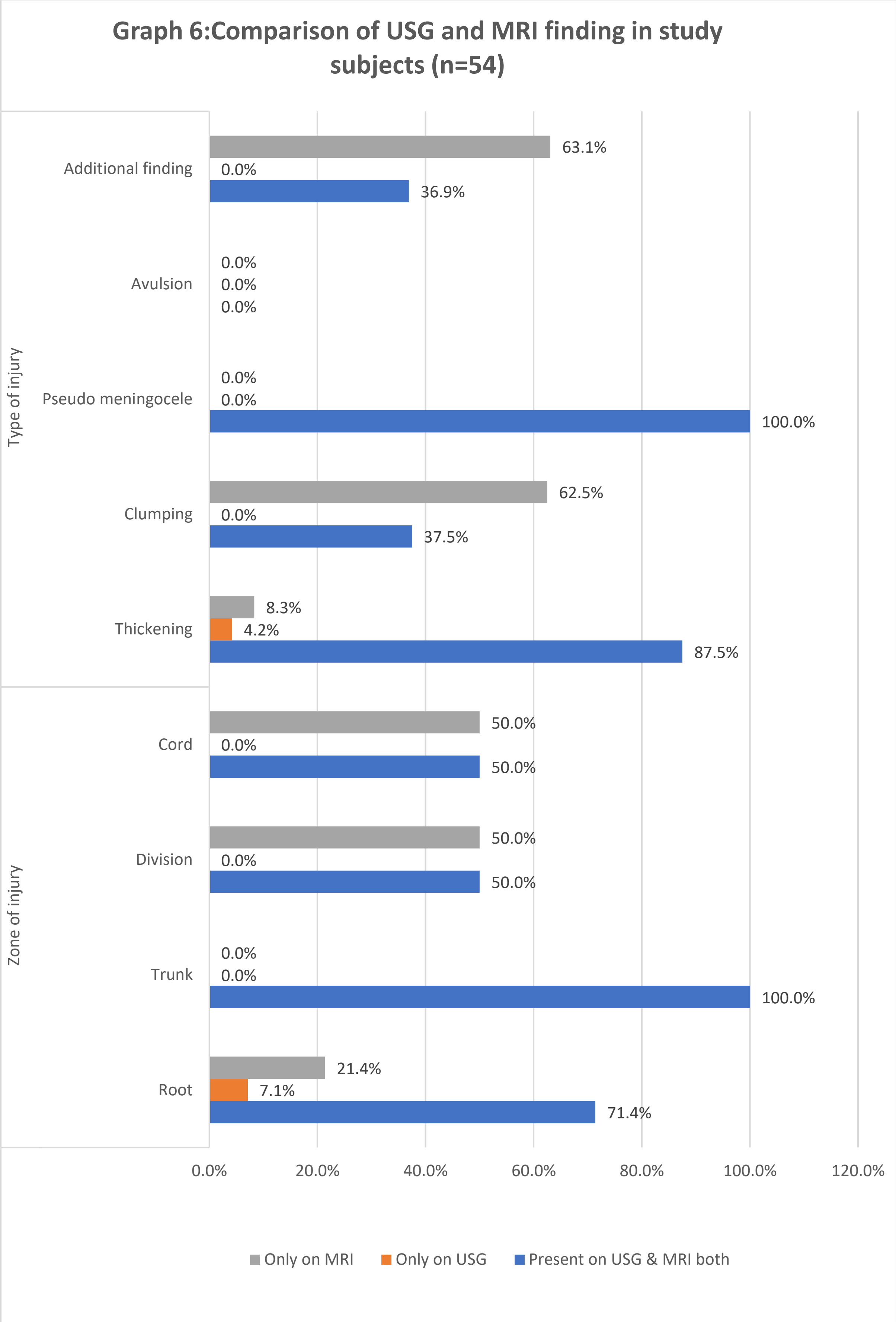


Thereafter, comparison between ultrasound and MRI findings (table 6 and graph 6) were done and kappa values were calculated for various nerve zones as 0.78,1.0,0.64 and 0.64 in roots, trunks, divisions and cords respectively. Ultrasound had perfect agreement in detecting pseudomemingoceles(κ =1.0); near perfect agreement in detecting thickenings (κ =0.88) and moderate agreement in detecting clumping. We were unable to detect avulsions and changes in signal intensity on ultrasound as compared to MRI thereby adding to its limitations.

Table 6: Comparison of USG and MRI finding in study subjects (n=54)

	Present on USG & MRI both	Only on USG	Only on MRI	Kappa value
Zone of injury				
Root	10 (71.4%)	1 (7.1%)	3 (21.4%)	0.78
Trunk	21 (100%)	0	0	1.0
Division	2 (50%)	0	2 (50%)	0.64
Cord	3 (50%)	0	3 (50%)	0.64
Type of injury				
Thickening	21 (87.5%)	1 (4.2%)	2 (8.3%)	0.88
Clumping	3 (37.5%)	0	5 (62.5%)	0.50
Pseudo meningocele	6 (100%)	0	0	1.0
Avulsion	0	-	-	0
Additional finding	7 (36.9%)	0	12 (63.1%)	0.43

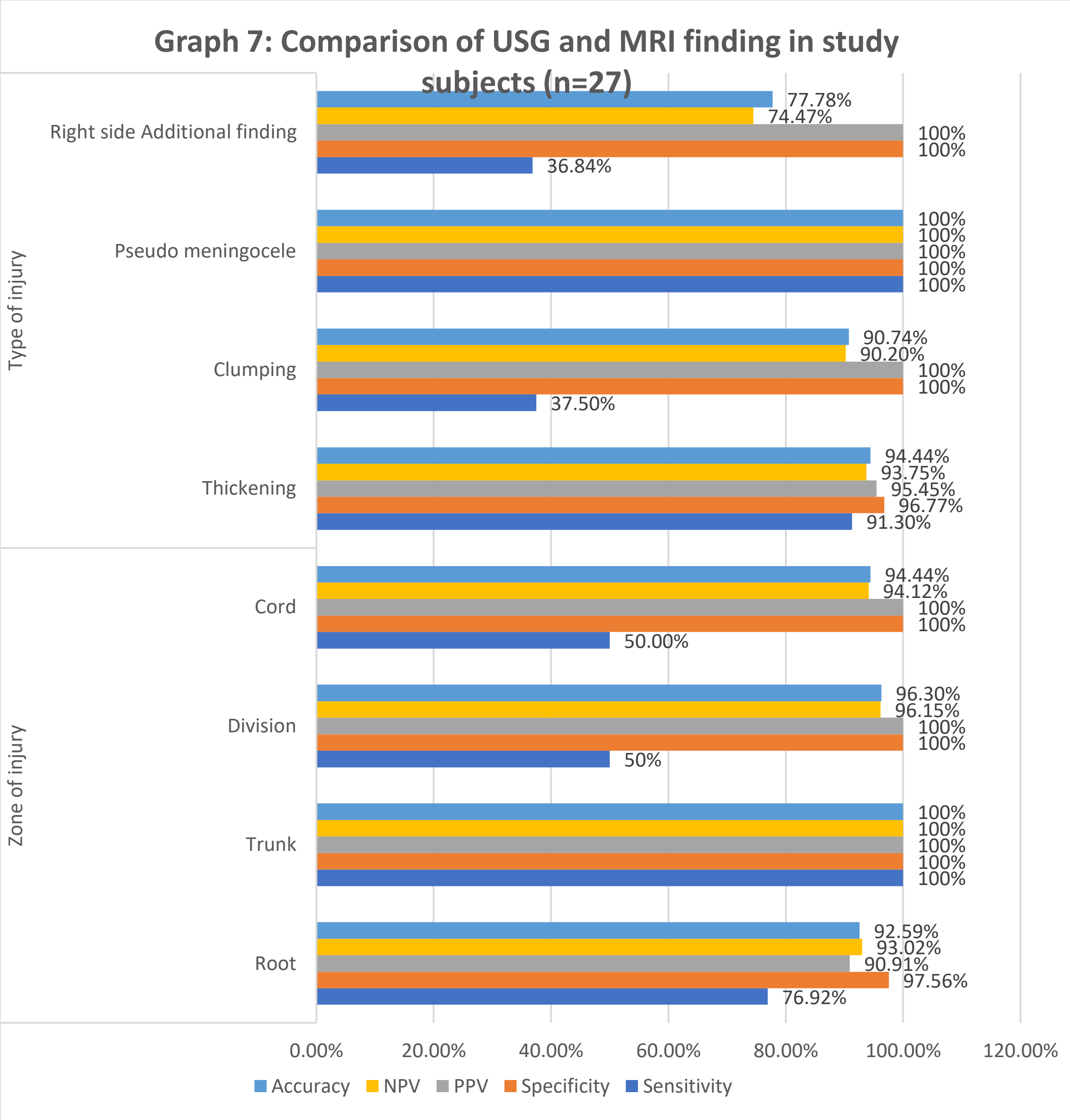
* in 3 subjects MRI was not done due to metallic implant


Graph 6:Comparison of USG and MRI finding in study subjects (n=54)
Type of injury
Zone of injury
Additional finding
Avulsion
Pseudo meningocele
Clumping
Thickening
Cord
Division
Trunk
Root
63.1%
0.0%
36.9%
0.0%
0.0%
0.0%
0.0%
0.0%
100.0%
62.5%
0.0%
37.5%
8.3%
4.2%
87.5%
50.0%
0.0%
50.0%
50.0%
0.0%
50.0%
0.0%
0.0%
100.0%
21.4%
7.1%
71.4%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%
120.0%
Only on MRI
Only on USG
Present on USG & MRI both

Accuracy of ultrasound for detecting injuries in various nerve zones were 92.59%,100%,96.30% and 94.44% in roots, trunks, divisions and cords respectively. The accuracy in detecting thickening was 94.44%, clumping was 90.74% and pseudomeningoceles was 100%. Additional finding were also detected with accuracy of 77.78%. the sensitivity, specificity, positive and negative predictive values are specified in table 7 and graph 7.

Table 7: Diagnostic value of USG in study subjects

	Sensitivity	Specificity	PPV	NPV	Accuracy
Zone of injury					
Root	76.92%	97.56%	90.91%	93.02%	92.59%
Trunk	100%	100%	100%	100%	100%
Division	50%	100%	100%	96.15%	96.30%
Cord	50%	100%	100%	94.12%	94.44%
Type of injury					
Thickening	91.3%	96.77%	95.45%	93.75%	94.44%
Clumping	37.5%	100%	100%	90.2%	90.74%
Pseudo meningocele	100%	100%	100%	100%	100%
Additional findings	36.84%	100%	100%	74.47%	77.78%



Graph 7: Comparison of USG and MRI finding in study subjects (n=27)

DISCUSSION

Injuries to brachial plexus are common to young men in road side accidents, fall from height and in infants at the time of obstructed labor. The interest in assessing the best diagnostic strategy for brachial plexus traumatic lesions lies in the extreme importance of their early diagnosis and treatment. A delay in their identification, indeed, is related to an extremely poor prognosis[41-43]. The surgical treatment usually consists of a micro-reconstructive nerve surgery through direct nerve repair, nerve grafting, or nerve transfer. In order to choose the most suitable therapeutic strategy, clinical examination alone is not enough as it is extremely challenging to differentiate pre-ganglionic from postganglionic injuries.[44-45] A correct diagnosis of brachial plexopathy generally involves both physical and instrumental examinations such as electromyography (EMG), nerve conduction studies, CT myelography, US, or MR imaging [6]. Nowadays, magnetic resonance is considered worldwide as the radiological gold standard for brachial plexopathy and peripheral nerve lesions[47-48].

MRI is currently the technique of choice for imaging the brachial plexus [9,10], but due to the complexity of the brachial plexus and changing orientation of the nerves as they descend, makes identification of individual structures difficult[50]. In addition, MRI is expensive, time consuming, and not readily available.

Sonography overcomes these limitations due to dynamic nature of the scan. This imaging technique in experienced hands is noninvasive, relatively inexpensive, and quick to perform, giving it distinct advantages over MRI.[22]

In our study brachial plexus is focussed using Philips Affinity 50 with a linear transducer having frequency of 5-18 Mhz. With the help of a high resolution probe we were able to visualise healthy roots, trunks, divisions and cords. Whereas, the nerve injuries were recognised as thickened nerve zones (roots, trunks, divisions and cords) as compared from the normal side, clumping in zone of trunks and pseudomeningocele in zone of roots. In addition to nerve zone injuries, atrophy of the shoulder muscles in cases of old trauma is also visualised as a supplementary on ultrasound. A careful method was used to help in differentiation of nerve zone structures from similar structures like muscle fascicles and blood vessels which course in similar plane.Thickening of the nerve roots/trunks might be related to neuroma and/or scar tissue, and in some cases the differentiation between them can be difficult by imaging methods and histopathological correlation is required for differentiating between them[51-52]. Magnetic resonance imaging examination was then done by using PhilipsAchievaDstream 1.5 Tesla MRI with the Sense Body Coil in an oblique fashion from superomedial to inferolateral in coronal plane and then axial oblique and sagittal oblique planes were taken for further evaluation. In three of the patients in our study MRI was not conducted because of metallic implant insitu, those were incompatible with MRI.

In our study, ultrasound was conducted in 30 trauma patients. Ultrasound detected injuries in 41 zone out of 44 zonesdetected by MRI which is used as gold standard in cases of trauma with a detection of 93.18%. In our study we were able to detect root injuries in 12 zones on ultrasound out of 13 cases detected on MRI and in case of trunks injuries, 24 zones of injuries were detect as compared from 23 injuries detected by MRI. This was because MRI was not performed in 3 of our patients because they had a metallic orthopaedic implant in situ. In a study conducted by Chen et al[53], in which ultrasound was used to differentiate between the preganglionic and postganglionic injuries before surgical intervention in 23 patients (21 males and 2 females), majority of the patients were injured in road side accidents. Chen et al were able to detect 100% of root injuries from C5 to C7 as well as for the upper and middle trunks, 84% of injuries at C8 root level,in the lower trunk, and 64% injuries for T1 level in 23 trauma patients. As compared from study conducted by Chen at al. our study had an advantage in successfully detecting injuries in zones of divisions and cords in 6 of our cases.

Doria Mohammed Gad (Doria MG)[47] et al. conducted a study to find the role of MRI in the diagnosis of adult traumatic and obstetric brachial plexus injury compared to intraoperative findings .MRI examination of brachial plexus was done for 37 patients with clinically suspected traumatic or obstetric brachial plexopathy. Twenty-two patients were presented with traumatic brachial plexus injury: 20 males and 2 females, mean age 26.3 years (7–51 years). The other 15 patients presented with obstetric brachial plexus injury out of which 10were males and 5 were females with mean age of 12.8 months (7–28 months).Similar to the study conducted by Doria Mohammed Gad et al. our study alos had more proportion of male patients, that is out of 30 patients examined 22 were male and 8 were female, with mean age of 37.90±20.13 years. In our study most of the patients had injuries due to road side accident, that is 23 out of 30 cases; with only 4 cases due to fall from height and 3 cases due to birth injuries as compared to Doria MG's study,which had greater percentage of birth injury patients. This difference in birth injuries in two studies was due to better health care facilities available in our country.

In our study the sensitivity of ultrasound in detecting injuries in roots, trunks, divisions and cords was 76.92%, 100%, 50% & 50% and accuracy was 92.59%,100%,96.3% and 94.4% respectively. The accuracy in detecting thickening was 94.4%, clumping was 90.74% and pseudomeningocele was 100%.The kappa values showed perfect agreement in detecting pseudomeningoceles (κ =1.0); near perfect agreement (κ =0.88) in detecting thickening and moderate agreement(κ =0.50) in detecting clumping. These findings were similar to the study conducted by Doria MG in which the sensitivity of MRI in detecting root injury was 86%, with specificity 92% and accuracy 90% having κ = 0.792 and *p-value* < 0.005. In this study by Doria MG et al. nerve rupture on MRI had 73% sensitivity, 99% specificity, and 90% accuracy with excellent agreement between MRI results and operative findings with κ = 0.811 and *p-value* < 0.005, while in neuroma formation, MRI had 73% sensitivity, 100% specificity, and 99% accuracy with excellent agreement between MRI results and operative findings with κ = 0.843 and *p-value* < 0.005.The limitation in our study was detection of injuries in the zone of divisions as ultrasound was unable to detect injuries in 2 patients because of hematoma formation in that area due to which divisions were not accurately visualised.

In a study conducted by **Acharya AM**[54], which included all traumaticpatients under the age of 60 years during the study period from 2012 to 2018,brachial plexus injuries were evaluated in 35 patients with MRI using a 1.5 T scanner (PHILIPS ACHIEVA). In his study the mean age of patients suffering brachial plexus injuries was 33 years, which is similar to our study that has mean patient of 37.90±20.13years and the main cause of injury was motor vehicle accidents, that is trauma.**Acharya AM** was able to detect injuries in 27 zone of roots and in 8 zones of trunks & divisions level. Pseudomeningoceles were detected in 28 instances (in 80% cases) having a positive predictive value of 96%. Similarly in our study ultrasound was able to detect 12 root zone injuries,24 trunk zone injuries, two division zone injury and 4 injuries in zone of cords. The major advantage in our study is that we were able to detect pseudomeningocle, which is common finding in cases of trauma in all 8 cases by

ultrasound (8 out of 8cases) having a positive predictive value of 100% with $\kappa = 1.0$ and hence having a strong agreement.
In our study three cases of birth injuries were detected and ultrasound was able to detect injuries in 2 root zones and 4 trunk zones. Pseudomeningocele was seen in one of the case, both on ultrasound and MRI in the zone of root, thickening was also seen in 4 out of 4 cases. Clumping was only seen in one of the case out of 3 cases detected by MRI. Ultrasound had 100% accuracy in detecting pseudomeningoceles and thickenings & 33% accuracy in detecting clumping in cases of birth injuries encountered in our study in cases of birth trauma.**Deepak K Somashekar**[55] et al. conducted a study to ascertain if ultrasound could be used to evaluate post ganglionic brachial plexus in the setting of neonatal brachial plexus palsyin 52 children with neonatal brachial plexus palsy. In their study ultrasound correctly identified 21 out of 25 cases of upper and middle trunk injuries (84% sensitivity for each). Sensitivity in our study could not be calculated because of the smaller sample size in neonatal population.
The limitation in our study was that ultrasound was able to detect only 3 cases of clumping of nerve zones as opposed to 6 cases on MRI.This was because ultrasound was not able to differentiate between thickening and clumping when they existed together in a patient. There were two cases in our study in which ultrasound reported normal brachial plexus as it was not able to detect changes in signal intensity detected by MRI thereby resulting 2 false negative cases on ultrasound modality in our study. Ultrasound in our study was not able to detect avulsions of nerve roots from spinal cord in 3 cases adding to its limitations.
From this study we believe that ultrasound is able to detect injuries in various nerve zones and is able to detect thickenings, pseudomeningocele and clumping with accuracy comparable to that of MRI. Clinical examinations are not very accurate in brachial plexus injuries owing to the complicated plexus design and also the complex nature of the lesions. EMG provides information about the functional involvement, not the localization of the lesion [56]. And thereforedelay from injury to surgical repair is the leading cause of poor outcome[57-59].Thereby in places where MRI facility is not available or is expensive, ultrasound can help in early detection of brachial plexus injuries with accuracy. It is also helpful in patients who are claustrophobic or have a metallic orthopaedic implant in situ and can serve as reliable modality for accurate detection of brachial plexus injury.

SUMMARY

The study was conducted on 30 subjects of either gender attending outpatient department (OPD) or admitted to Sri Guru Ram Das Institute of Medical Sciences and Research, Sri Amritsar with a history to trauma to brachial plexus.
Sonography was done using a linear transducer in a semi lateral decubitus position without specific preparation. The nerve roots were visualised in coronal oblique plane by the first identifying the transverse processes of cervical vertebrae.. Subsequently trunks, divisions and cords were recognized moving gradually in downward direction and laterally. Nerve injuries were recognised as thickened nerve zones (roots, trunks, divisions and cords) as compared from the normal side, clumping in zone of trunks and pseudomeningocele in zone of roots. Magnetic resonance imaging examination was then done with the Sense Body Coil in an oblique fashion from superomedial to inferolateral in coronal plane and then axial oblique and sagittal oblique planes are taken for further evaluation.
There were 22 males and 8 females involved in our study with the mean age of 37.90±20.13 years with 76.67% of patients suffering from road side accident withthe main clinical complaints of no movement in right arm and pain in right arm affecting 60% of patients.

Following were the findings

1. Accuracy of ultrasound for detecting injuries in various nerve zones were 92.59%,100%,96.30% and 94.44% in roots, trunks, divisions and cords respectively.
2. The accuracyof ultrasound in detecting thickening was 94.44%, clumping was 90.74% and pseudomeningoceles was 100%.
3. Ultrasound had substantial agreement in detecting injuries roots (κ =0.78); perfect agreement in detecting in trunks (κ =1.0) and moderate agreement indetecting in injuries in divisions and cords (κ =0.64).
4. Ultrasound had perfect agreement in detecting pseudomemingoceles(κ =1.0); near perfect agreement in detecting thickenings (κ =0.88) and moderate agreement in detecting clumping.

CONCLUSIONS

Clinical examinations and EMG cannot accurately detect site and extent of injury owing to its complex structure.Ultrasound is able to detect injuries in various nerve zones and is able to detect thickenings, pseudomeningocele and clumping with accuracy comparable to that of MRI.Thereby in places where MRI facility is not available or is expensive, ultrasound can help in early detection of brachial plexus injuries with accuracy. It is also helpful in patients who are claustrophobic or have a metallic orthopaedic implant in situ The only limitations being not able to detect avulsions and clumping when clumping and thickenings co-exist in a patient.

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