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ORIGINAL ARTICLE

Comparative Analysis of MRI and 3D CT in Quantifying Glenoid Bone Loss: A Study on Anterior Shoulder Instability

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Abstract

Background: The glenohumeral joint is characterized by its ball and socket configuration, offering the widest range of motion among major human joints. However, its shallow glenoid socket predisposes it to instability. This instability is mitigated by static and dynamic stabilizers. Glenoid bone loss, including Osseous Bankart and compression deformity, contributes to recurrent instability. Various imaging modalities, such as CT and MRI, are employed to assess glenoid bone loss, with methods like the Griffith Index and best-fit circle used for quantification. This study aims to evaluate MRI's accuracy in quantifying bone loss in glenoid compared to 3D CT in participants with anterior shoulder instability. **Materials and Methods:** The research was carried out at a specialized medical facility offering tertiary care services in south India. Approval was obtained from the ethical committee, and consent waiver was granted for PACS utilization. MRI and CT examinations were performed on participants to assess glenoid bone loss. MRI utilized a 1.5-T Ingenia system, while CT scans were conducted using multidetector CT scanners. Image analysis involved the best-fit circle method was employed to quantify bone loss. **Results:** Fifty-seven male participants with an average age of 30.72 ± 7.32 years participated. Bone loss measurements were comparable between CT and MRI. ICC and correlation coefficients indicated strong agreement between CT and MRI measurements. MRI detected Hill-Sachs lesions more frequently than CT ($p<0.05$) and identified ALPSA, rotator cuff, and labral ligamentous injuries not diagnosed by CT. **Conclusion:** MRI demonstrates high accuracy in quantifying bone loss in glenoid and diagnosing soft tissue injuries, making it a valuable tool for anterior shoulder instability assessment. By reducing the need for additional CT scans and minimizing radiation exposure, MRI emerges as the preferred imaging modality in such cases.

Keywords: Anterior shoulder instability, Glenoid bone loss, MRI, 3D CT, Soft tissue injuries

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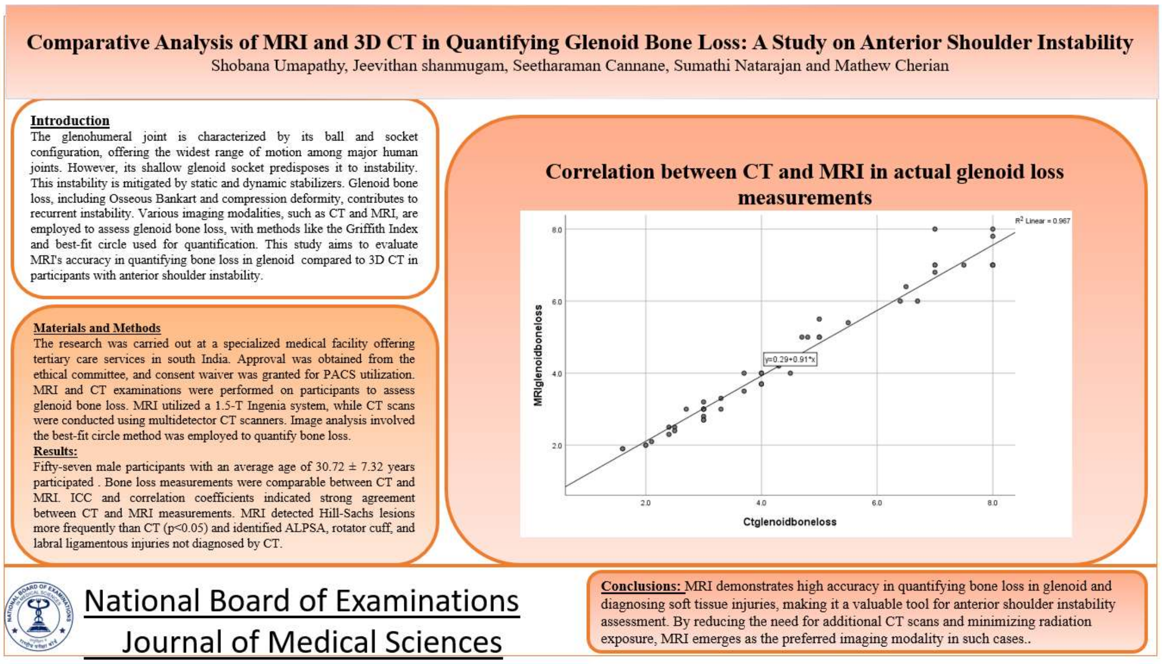
Graphical Abstract



Introduction

The glenohumeral joint constitutes a ball and socket configuration, created by meeting of the glenoid fossa in the scapula with that of the humerus head. This anatomical arrangement affords the glenohumeral joint the widest range of motion. Nonetheless, its inherent instability arises from the shallow nature of the glenoid socket. To counteract this instability, the joint relies on a multifaceted system of both static and dynamic stabilizers. Static stabilizers encompass various structural components such as bone, cartilage, capsule, and ligaments, which provide passive support to the joint structure. Conversely, dynamic stabilizers encompass the muscular elements surrounding the shoulder joint. These muscles play an active role in maintaining stability by dynamically adjusting tension and controlling movement across the joint. Through coordinated contraction and relaxation, they stabilize the joint during various movements and positions, thereby mitigating the risk of dislocation or injury [1].

There are two important types of glenoid bone loss in the context of shoulder injuries: Osseous Bankart and glenoid compression deformity or erosion. Osseous Bankart refers to a fracture that happens along the front lower part of the glenoid rim. On the other hand, compression lesions involve the flattening of the front edge of the glenoid bone [2]. Both acute bony Bankart injuries and gradual bone erosions resulting from recurrent instability contribute to glenoid bone loss. In first-time traumatic dislocations, the prevalence of glenoid bone loss stands at 40%, while in cases of recurrent dislocations, it rises significantly to 85% [3].

A spectrum of imaging modalities is employed to assess glenoid bone loss, encompassing classic radiographs, CT scans with both 2D and 3D reconstructions, MRI, and MR arthrography. In each various techniques exist to quantify glenoid bone loss using CT and MRI imaging. Among the prevalent methods for calculating glenoid bone loss are width measurements, exemplified by the Griffith Index, and the best-fit circle method. These approaches provide quantitative assessments of bone loss and aid in treatment planning for shoulder instability [4].

Glenohumeral dislocations can result in injuries to the surrounding soft tissues and bones of the shoulder. While MRI is commonly used to assess soft tissue and cartilage damage post-dislocation, computed tomography (CT) with 3D reconstructions is regarded as the preferred non-invasive method for evaluating glenoid bone loss. Nevertheless, CT scans subject patients to notable radiation exposure, equivalent to approximately 25.75 conventional chest radiographs [5].

To comprehensively evaluate both soft tissue and bony injuries, current protocols often involve a combination of CT followed by MRI. However, given the radiation exposure and the need for multiple imaging modalities, there's growing interest in using MRI as a reference standard. MRI not only assesses ligamentous injuries and soft tissue pathology but can also accurately quantify glenoid bone loss.

The objective of this study was to estimate the precision of MRI in measuring glenoid bone loss in comparison to 3-dimensional CT, focusing on the application of the best-fit circle method, particularly in instances of anterior shoulder instability.

Materials and Methods

This study (cross-sectional) was undertaken at a specialized medical facility offering tertiary care services in the western region of South India, with prior endorsment from the IHEC (Institutional Human Ethics Committee). Consent waiver was obtained from the ethical committee for utilizing the Picture Archiving and Communication System (PACS). The study included individuals who underwent both CT and MRI examinations to assess bone loss in glenoid.

MRI examinations of the affected shoulders were performed using a 1.5-T Ingenia system by Philips Medical Systems. The MRI protocol involved acquiring sequences of the glenoid with an 8-channel shoulder coil at 1.5T. A sagittal oblique T1-weighted sequence was selected to accurately depict bony anatomy and measure glenoid bone loss. The parameters used for MRI were as follows: field of view (FOV) of 140 x 140 mm, matrix of 308 x 221, bandwidth of 265 Hz/pixel, acquisition time of 3 minutes and 17 seconds, and slice thickness of 3 mm.

During the study, all patients underwent CT examinations utilizing multidetector CT scanners, specifically the Bright speed VCT 16-slice CT scanner. The CT protocol involved acquiring 3 mm axial images of the glenoid, subsequently reconstructed into 1-mm oblique sagittal and coronal 2D reconstructions. CT parameters were set as follows: 16 x 0.625-mm acquisition, tube voltage of 120 kV, tube current auto mA, and a pitch of 1.375:1. Following data acquisition, 3D reconstructions of each glenoid were generated for further analysis.

For image analysis, the oblique sagittal T1-weighted image of the glenoid was selected. The typical glenoid surface presents a smooth, rounded anterior contour, resembling a pear shape, with the inferior two-thirds resembling a circle [6]. A best-fit circle was delineated on the inferior two-thirds of the glenoid, ensuring maximal contact with the glenoid rim [7]. The Saller axis, representing the long axis of the glenoid, was marked, and the transverse width of the glenoid was measured perpendicular to the Saller line. Additionally, the diameter of the defect in the glenoid bone was measured using the best-fit circle as a guide. The loss of bone was quantified as the width of the best-fit circle not engaged by glenoid bone, expressed both in absolute terms (millimeters) and as an overall best-fit circle width percentage. This meticulous approach allowed for precise assessment and quantification of glenoid bone loss, facilitating comprehensive analysis of the condition. All the images were interpreted by a senior Radiologist who had more than 13 years of experience.

The data collected were entered into Microsoft Excel and subsequently exported for analysis using IBM SPSS version 27. Mean ± SD were used to describe continuous variables, while frequency and percentages were the methods used for categorical variables. To measure the correlation between CT and MRI in total bone loss and percentage bone loss, intra-class correlation coefficients (ICC) were calculated. Additionally, Pearson correlation coefficients were computed to ensure the correlation between the two imaging modalities. To assess the association between CT and MRI in diagnosing Hill-Sachs signs, the chi-square test was employed. P<0.05 was considered significant.

Results

A total of 57 patients were included in the study, The mean age of the study population was 30.72 ± 7.32 with a range of 19-49 years. Among the study participants, 59.6% (34) were between 19- 30 years of age, another 29.8%(17) were between 31 and 40 years and the rest 10.5%(6) were between 41 and 50 years of age. All the study participants were males. The actual bone loss and percentage bone loss in Ct/MRI were more or less similar. (Table 1) Reliability analysis was performed between CT and MRI Values. The reliability measure between CT and MRI showed that MRI values were very much consistent with the CT Values. The Intraclass correlation coefficient (Agreement statistics) was 0.979 for absolute measurement and 0.995 for Percentage loss measurements. The correlation between absolute measurements was 0.984 and for percentage loss measurements was 0.996 signifying a nearly perfect correlation (Figures 1 and 2). In addition, MRI images was able to find out Hill Sachs lesion in 80.7% compared to 61.4% in CT Scan (CSV: 5.160, P<0.05). Additionally MRI was able to find out ALPSA in 22.8%, rotator cuff injury in 43.9% and Labral Ligamentous injury in all the study participants which was not been diagnosed by CT scan (Tables 2 and 3).

Table 1. Descriptive measures of Parameters measured

Parameter	Sub classification	Minimum	Maximum	Mean	Std. Deviation
AGE		19	49	30.72	7.319
Glenoid bone loss	MRI	1.9	8.0	4.391	1.8209
	CT	1.6	8.0	4.514	1.9730
Percentage loss	MRI	7.5	28.3	16.872	6.5020
	CT	7.0	29.0	17.012	6.7183

Table 2. ICC values for actual loss measurement and percentage loss measurement between CT and MRI

Parameter measured	ICC	95% Confidence Interval		Significance	
		Lower limit	Upperlimit	F Value	P Value
Actual loss	0.979	0.962	0.988	100.933	<0.001
Percentage loss	0.995	0.991	0.997	406.969	<0.001

Table 3. Additional findings observed in MRI

Findings observed	Frequency	Percentage	Frequency	Percentage	CSV	P Value
Hill Sachs Lesion	46	80.7	35	61.4	5.160	0.023
ALPSA	13	22.8	0	0	Not Applicable	
Rotator Cuff Injury	25	43.9	0	0		
Labral/ Ligamentous Injury	57	100	0	0		

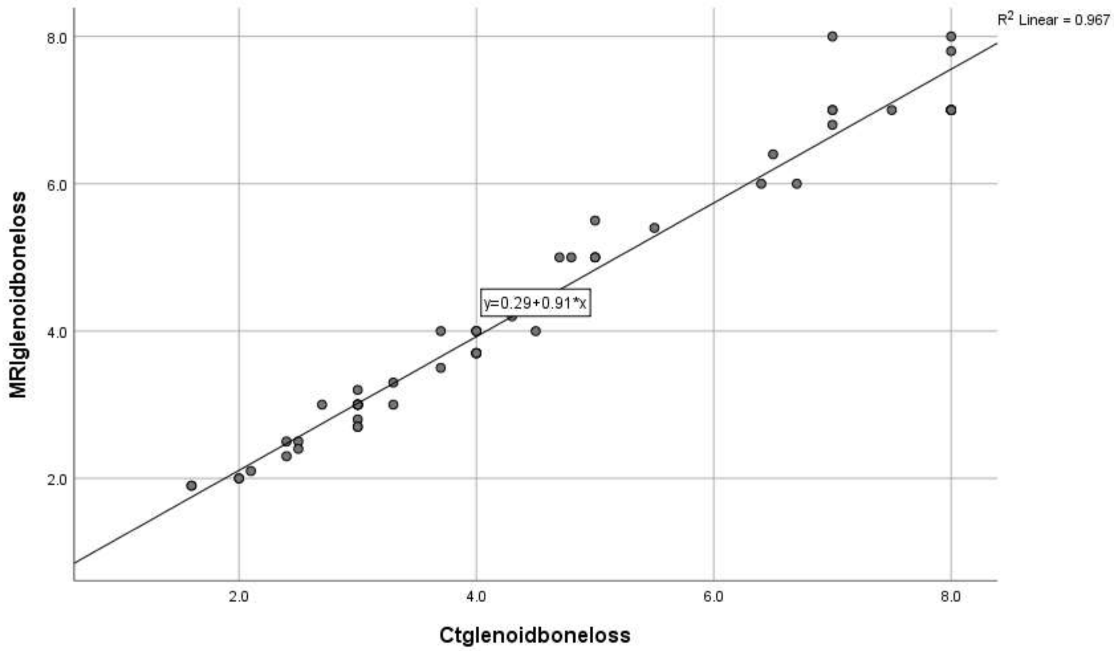


Figure 1: Correlation between CT and MRI in actual glenoid loss measurements

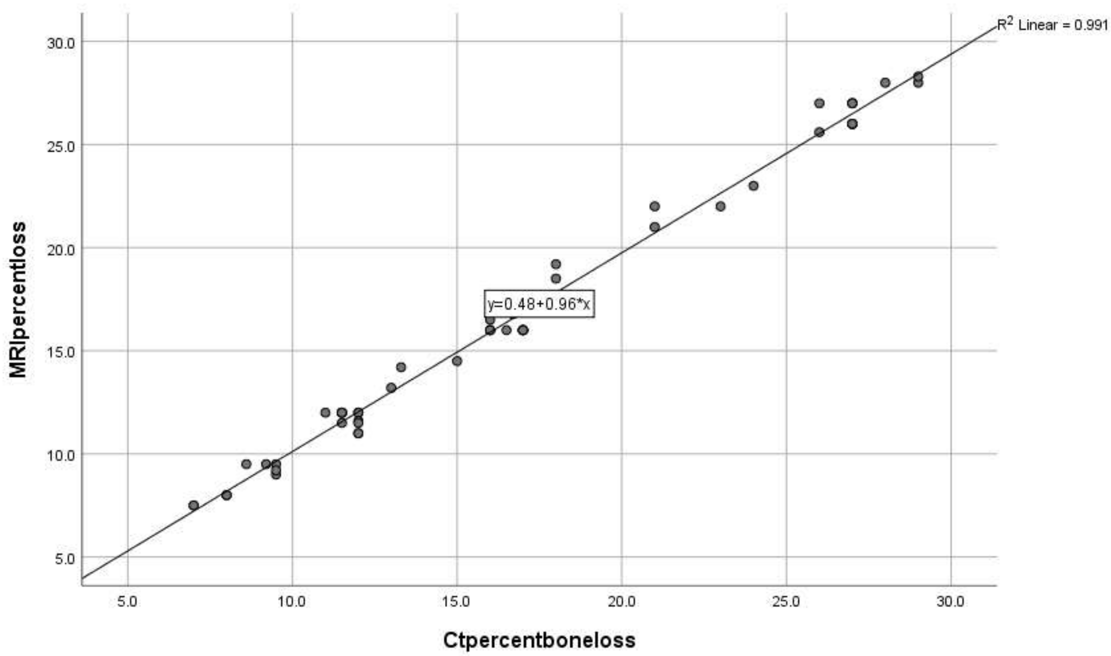


Figure 2. Correlation between CT and MRI in Percentage glenoid loss measurements

Discussion

This study (cross sectional) was done with the aim to find out the role of MRI in assessing the glenoid bone loss in those who encounter a shoulder dislocation. A total of 57 participants who did both CT and MRI were involved in the study.

Anterior shoulder instability stands as the most prevalent form of glenohumeral dislocation injuries, frequently afflicting young males engaged in active sports. Such instability can lead to a spectrum of injuries involving bones, ligaments, and the rotator cuff [8].

Accurate measurement of bone loss in glenoid and associated injuries in soft tisue via imaging is crucial to prevent recurrent dislocation and the need for revision surgeries. Key prognostic factors in anterior shoulder instability include the extent of bone loss in glenoid and the presence of concomitant soft tissue or osseous injuries [10].

Determining what constitutes "severe" bone loss in glenoid lacks universal consensus. Some studies propose critical thresholds, such as 13.4% or 25%, to guide treatment decisions. Mild to moderate bone loss may be managed arthroscopically, while significant bone loss may necessitate open surgery with bone augmentation [3,11,12].

Various imaging modalities, including radiography, arthroscopy, CT, and MRI, aid in quantifying glenoid bone loss. CT, with its multiplanar reformations, has traditionally served as the reference standard due to its accuracy in measuring bone loss. However, concerns arise regarding its failure to assess periarticular soft tissue injuries comprehensively. CT has traditionally been the reference standard due to its availability and ability to provide detailed multiplanar reconstructions. While 3D CT is accurate for surgical planning, it may not adequately address periarticular soft tissue injuries, leading to the incorporation of MRI in some studies [3,13-18].

Comparative studies between 2D or 3D CT and MRI reveal no significant differences in measuring glenoid bone loss. MRI, particularly with the best-fit circle method, exhibits nearly perfect correlation with CT measurements. Additionally, MRI allows for the assessment of associated osseous and soft tissue lesions [19].

MRI emerges as an alternative tool for measuring glenoid bone loss, with comparable accuracy to CT. Studies demonstrate that MRI can effectively diagnose soft tissue injuries, such as stretched inferior glenohumeral ligaments, anterior hyperlaxity, or unrecognized capsular laxity, which may contribute to recurrent instability [19-22].

While 3D MRI reconstructions offer promising capabilities, manual segmentation limits reproducibility and practicality. However, advancements in MRI technology, such as axial 3D dual echo-time T1-weighted sequences with Dixon-based water-fat separation, exhibit potential for accurate measurement of glenoid bone loss [23].

Research by Stecco et al. [19] and Gyftopoulos et al. [23] found that both MRI and CT measurements are equally efficacious in determining bone loss. Our study aligns with these findings, demonstrating a nearly perfect correlation between MRI and CT in quantifying glenoid bone loss using the best-fit circle method.

In addition, our study explores the frequency of associated osseous and soft tissue lesions due to instability of anterior shoulder. Notably, all those with bone loss in glenoid exhibited labral ligamentous injuries, with a 61.5% incidence of rotator cuff tears. This comprehensive evaluation supports MRI's role as a valuable diagnostic tool, accurately quantifying glenoid bone loss and identifying concomitant soft tissue injuries in a single examination. This not only streamlines the diagnostic process but also eliminates the need for an additional CT scan, thereby reducing associated costs and radiation exposure [3].

Conclusion

MRI proves invaluable in quantifying bone loss in glenoid and diagnosing injuries of soft tissue, offering a comprehensive evaluation in a single examination. By obviating the need for additional CT scans, MRI reduces costs and minimizes radiation exposure, making it the preferred imaging modality for anterior shoulder instability assessment.

Statements and Declarations

Conflicts of interest

The authors declares that they do not have conflict of interest.

Funding

No funding was received for conducting this study.

Ethics approval

Ethical approval obtained from all patients.

Human and animal rights

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

For this type of study formal consent is not required.

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