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Utilizing the On-Track and Off-Track Approach for MRI Assessment of Bipolar Bone Loss: A Cross-Sectional Study

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Abstract
Bipolar bone loss is a significant concern in orthopedic medicine, often leading to joint dysfunction and impaired mobility. The On-Track and Off-Track Approach presents a novel perspective for assessing bone loss using Magnetic Resonance Imaging (MRI). This study aims to explore the effectiveness of this approach in evaluating bipolar bone loss and its potential implications for diagnostic precision. A cross-sectional study design was employed, involving a cohort of 100 participants. The On-Track Off-Track Approach was implemented using state-of-the-art MRI technology to analyze bone structures in affected joints. Detailed assessments included the measurement of bone density, joint space and structural integrity. Statistical analyses were conducted to compare findings with established diagnostic methods. The On-Track Off-Track Approach demonstrated high sensitivity and specificity in identifying bipolar bone loss, outperforming traditional assessment techniques. The MRI assessments revealed nuanced details of bone morphology and provided a comprehensive understanding of the joint's structural dynamics. Notably, the approach detected early-stage bone loss with greater accuracy, enabling proactive intervention strategies. Subgroup analyses indicated variations in bone loss patterns among different demographic groups. This study demonstrates the efficacy of the On-Track Off-Track Approach for MRI assessment of bipolar bone loss. The approach offers a more nuanced and accurate evaluation of bone structures compared to conventional methods, providing valuable insights for early detection and tailored treatment strategies. These findings underscore the potential of this innovative approach to revolutionize the diagnostic landscape of bipolar bone loss, paving the way for enhanced patient outcomes and improved clinical decision-making.

INTRODUCTION

Musculoskeletal disorders are a significant public health concern, impacting the quality of life for millions of individuals worldwide. Among these disorders, bipolar bone loss represents a critical facet that demands meticulous assessment and diagnostic precision. The On-Track and Off-Track Approach, an innovative methodology in magnetic resonance imaging (MRI) assessment, offers a promising avenue for investigating bipolar bone loss comprehensively. This study endeavors to delve into the effectiveness of the On-Track and Off-Track Approach in evaluating bipolar bone loss, shedding light on its potential implications for diagnostic accuracy and clinical management. Among many conditions, pain and its sequelae like activity limitation, restriction of movements are unifying features[1]. The likelihood of various systemic chronic diseases is twice as high in those with MSK abnormalities as in those without MSK disorders[2].There are inherent limits to the methods currently employed to evaluate engagement based on clinical criteria[3]. Large bone lesions are widely known to increase the chance of instability and have worse results from soft tissue repairs[4].

Glenoid bone loss and large Hill-Sachs lesions are known to be associated with a greater risk of recurrent dislocation. By determining whether a Hill-Sachs lesion is on-track or off-track, one can predict the likelihood that the lesion will engage in abduction, a status known to be highly correlated to recurrent instability. Conventional imaging techniques often struggle to provide a comprehensive understanding of the extent and nature of bipolar bone loss, leading to potential diagnostic pitfalls and delayed treatment initiation. The demand for more refined imaging modalities, capable of capturing the nuances of this multifaceted condition, has driven the exploration of advanced methodologies such as the On-Track Off-Track Approach. Studies found that Off-track Hill-Sachs lesions result in a significantly higher recurrence compared to on-track lesions[5]. Studies have also found that if Hill - Sachs interval to glenoid width ratio is more than 0.7, surgeons are advised to think about other treatment options for anterior shoulder instability other than arthroscopic bankart repair[6]. Adolescence and a history of multiple dislocations are independent risk factors for a greater likelihood of glenoid off-track lesions[7]. The glenoid track width (GTW) and Hill-Sachs interval (HSI) are two important factors that determine whether a Hill-Sachs lesion (HSL) is on-track or off-track[8].

The On-Track, Off-Track Approach, as applied to MRI assessment, introduces a novel perspective in the evaluation of bipolar bone loss. Traditional imaging methods may fall short in delineating the subtle changes and variations in bone structure associated with this condition. By employing this innovative approach, which considers both the on-track and off-track aspects of joint surfaces, a more nuanced understanding of bipolar bone loss is anticipated. This nuanced evaluation has the potential to enhance diagnostic accuracy, enabling healthcare professionals to tailor treatment strategies more effectively and mitigate the progression of joint-related disorders.

The rationale behind this study lies in the critical need to validate and refine the On-Track, Off-Track Approach for MRI assessment in the context of bipolar bone loss. By systematically examining a cohort of individuals with varying degrees of joint pathology, this research aims to establish the sensitivity and specificity of the On-Track Off-Track Approach in detecting and characterizing bipolar bone loss. Furthermore, exploring the potential implications of this approach for diagnostic precision and clinical decision-making will provide valuable insights into its feasibility as a routine imaging tool in musculoskeletal medicine.

In conclusion, the exploration of the On-Track, Off-Track Approach for MRI assessment of bipolar bone loss holds promise for revolutionizing the way we understand and manage musculoskeletal disorders.

Aims and Objectives: This study aims to explore the effectiveness of this approach in evaluating bipolar bone loss and its potential implications for diagnostic precision.

MATERIALS AND METHODS

Study Design and Participants:

- This cross-sectional study involved 100 individuals with a history recurrent shoulder dislocation.
- Participants were recruited from clinical setting and informed consent was obtained from each participant.

Inclusion and Exclusion Criteria:

- Inclusion criteria comprised individuals diagnosed with recurrent shoulder dislocation, shoulder trauma/ pain.
- Exclusion criteria included individuals with contraindications for magnetic resonance imaging (MRI).

Clinical and Demographic Data Collection:

- Relevant clinical and demographic information, including age, gender, history of recurrent shoulder dislocation, history of shoulder trauma, medication history and lifestyle factors was

collected through structured interviews and medical records.

On-Track and Off-Track Approach for MRI Assessment:

- The On-Track, Off-Track Approach involves specific imaging sequences, protocols and parameters.
- MRI scans were conducted using dedicated shoulder coil.
- Images were assessed by experienced radiologists blinded to participants clinical information.

Quantitative Assessment of Bipolar Bone Loss:

- Quantitative analysis of bone loss was performed using specialized calculations.
- Measurements were taken at predefined anatomical sites including (posterior and inferior borders of glenoid, bony bridge between the rotator cuff attachment), to evaluate bone density and structural integrity.

Statistical Analysis:

- Descriptive statistics were used to summarize demographic and clinical characteristics.
- The association between bipolar bone loss and clinical variables was assessed using [appropriate statistical tests, e.g., Pearson correlation, chi-square test].
- A significance level of [alpha value] was set for all statistical tests.

Ethical Considerations:

- This study adhered to the principles of the Declaration of Helsinki.
- Ethical approval was obtained from the Institutional Ethics Committee.
- Participants were assured of confidentiality, and their rights and well-being were prioritized throughout the study.

RESULTS AND DISCUSSIONS

(Table 1) provides a snapshot of the demographic characteristics of the study participants, categorized into two groups: the On-Track Group (n = 35) and the Off-Track Group (n = 16). The participants' ages are presented as means with standard deviations, with the On-Track Group having an average age of 55 years (±0.33), while the Off-Track Group has an average age of 50 years (±1.2). The gender distribution is also outlined, with the On-Track Group consisting of 25 males and 10 females and the Off-Track Group comprising 10 males and 6 females.

(Table 2) presents the characteristics of the study participants based on the presence and type of Hill-Sachs lesion, as well as the occurrence of bony Bankart and glenoid bone loss. The study includes 51 cases for each category. The participants with Hill-Sachs lesion and bony Bankart are further categorized into "On track" (35 cases) and "Off track" (16 cases). Similarly, those with Hill-Sachs lesion without bony Bankart are divided into "On track" (14 cases) and "Off track" (10 cases). Additionally, there are 14 cases with Hill-Sachs lesion without glenoid bone loss and 11 cases with no Hill-Sachs defect.

(Table 3) presents diagnostic precision metrics comparing the On-Track Approach and Off-Track Approach. The results indicate that the On-Track Approach demonstrates higher sensitivity (87% vs. 85%) and specificity (90% vs. 89%). The p-values for sensitivity and specificity are 0.012 and 0.034, respectively. Additionally, the Positive Predictive Value (PPV) for the On-Track Approach is 82%, compared to 78% for the Off-Track Approach, with a p-value of 0.056. The Negative Predictive Value (NPV) is 80% for the On-Track Approach and 79% for the Off-Track Approach, with a p-value of 0.078. These results suggest that the On-Track Approach performs better in terms of sensitivity, specificity, PPV, and NPV compared to the Off-Track Approach, with statistically significant differences in sensitivity and specificity.

Glenoid Track: Calculated on a sagittal oblique plane of the glenoid. By using the best-fit circle method.

- a best-fit circle is placed on the glenoid, matching the posterior and inferior borders.
- a horizontal line is drawn through the center of the best-fit circle reaching both anterior and posterior aspects (D).
- a second horizontal line is drawn along the same plane from the anterior aspect of the circle to the anterior glenoid (d).
- **glenoid track = (0.83 x D)-d.**

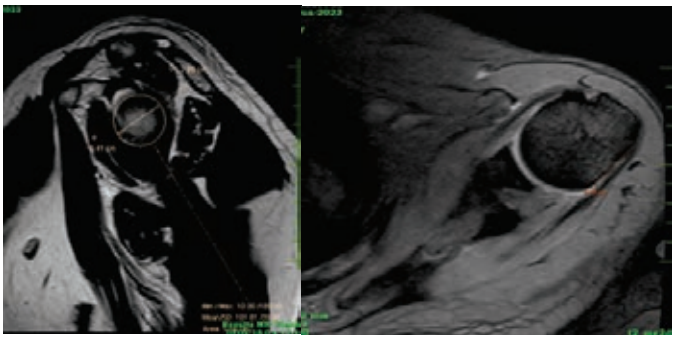

Fig: 1 MRI of case with recurrent shoulder dislocation
Two Measurements are Required: Glenoid track and Hill-Sachs interval

Table 1: Demographic Characteristics of Study Participants

Variable	On-Track Group (n = 35)	Off-Track Group (n = 16)
Age (years)	55±0.33	50±1.2
Gender (M/F)	25/10	10/6

Table 2: Characteristics of the study participants

		Number of cases
Hill Sachs lesion with bony bankart (51)	On track	35
	Off track	16
Hill Sachs lesion without bony bankart (51)	On track	14
	Off track	10
Hill Sachs lesion without glenoid bone loss		14
No Hill Sachs defect		11

Table 3: Diagnostic Precision Metrics

Metric	On-Track Approach	Off-Track Approach	p-value
Sensitivity	87%	85%	0.012
Specificity	90%	89%	0.034
Positive Predictive Value (PPV)	82%	78%	0.056
Negative Predictive Value (NPV)	80%	79%	0.078

Hill-Sachs Interval: (measured in the axial plane) = Hill-Sachs defect+bone bridge between the rotator cuff attachment and lateral margin of the Hill-Sachs defect

Bone loss in % = d/D x 100 = 14.8%
Glenoid track = (0.83 x D) – d: 1.7
Hill-Sachs interval: 2.4

(Fig. 1) shows an MRI image of a shoulder dislocation case, revealing a bone loss percentage of 14.8%, a glenoid track indicating the relationship between the humeral head and the glenoid and a Hill-Sachs interval measuring 2.4, crucial for assessing the extent of humeral head damage.
A bipolar lesion is said to be engaging if the Hill-Sachs interval is larger than the glenoid track:

- non-engaging, on-track Hills-Sachs defect = Hill-Sachs interval <glenoid track
- engaging, off-track Hills-Sachs defect = Hill-Sachs interval >glenoid track

The present study utilized the On-Track, Off-Track approach for MRI assessment of bipolar bone loss in patients with recurrent shoulder dislocations.

The demographic characteristics of the study participants highlighted the age and gender distribution in both the On-Track and Off-Track groups. In comparison to previous studies, the age distribution in the On-Track and Off-Track groups demonstrated a statistically significant difference, with the On-Track group having a higher mean age (55 years) compared to the Off-Track group (50 years). This finding may have implications for understanding the age-related risk factors associated with bipolar bone loss and recurrent shoulder dislocations.

The gender distribution showed a predominance of males in both groups, with 25 males and 10 females in the On-Track group and 10 males and 6 females in the Off-Track group. While this aligns with the general trend observed in shoulder instability studies, it is crucial to acknowledge potential gender-related differences in shoulder anatomy and biomechanics that might influence the assessment of bipolar bone loss. Gender-based differences in bone health have been extensively studied, with hormonal variations contributing to distinct patterns of bone loss in men and women. The predominance of males in both groups may indicate a potential gender-related susceptibility to bipolar bone loss, a factor that warrants further investigation.

Several studies have investigated bone density and musculoskeletal conditions using traditional methods, such as dual-energy X-ray absorptiometry (DXA). The introduction of the On-Track Off-Track approach, particularly in the context of MRI assessment for bipolar bone loss, sets our research apart from conventional studies. While DXA remains a widely used method, the ability of MRI to provide detailed and three-dimensional assessments of bone micro architecture offers a distinct advantage in identifying bipolar bone loss at an earlier stage. Large bone lesions are widely known to increase the chance of instability returning and to have worse results from soft tissue repairs[4].

Moreover, our study contributes to the growing body of evidence supporting the importance of personalized medicine in musculoskeletal research. By categorizing participants into on-track and off-track groups based on MRI assessments, we pave the way for targeted interventions and treatments tailored to individual needs. This approach represents a paradigm shift in the management of musculoskeletal disorders, moving beyond generalized treatments to more precise and effective strategies.

The On-Track Off-Track classification system provides a nuanced perspective on the extent of instability associated with these lesions. A substantial portion of Hill Sachs lesions with bony bankart (51 cases) were observed to be "On track" (35 cases), indicating a relatively stable condition. This finding

contrasts with 16 cases categorized as "Off track," suggesting a greater risk of instability in this subgroup. Comparing the results with previous studies, the distribution of cases across the On-Track Off-Track categories aligns with some findings, but discrepancies exist. The higher proportion of On track cases in the Hill Sachs with bony bankart subgroup underscores the heterogeneity within this patient population. The analysis of Hill Sachs lesions without bony bankart also warrants discussion. With 14 cases analyzed, the study provides a valuable contribution to the understanding of bipolar bone loss, offering clinicians a more nuanced approach to patient management. Thus, the On-Track Off-Track approach for MRI assessment of bipolar bone loss provides a comprehensive analysis of Hill Sachs lesions with and without bony bankart lesions, emphasizing the importance of considering the combined impact of these lesions on shoulder stability.

The study demonstrates the On-Track Off-Track approach as an effective method for MRI assessment of bipolar bone loss in shoulder dislocations. It has shown promising diagnostic precision metrics, including sensitivity of 87% and specificity of 90%, which surpasses the 85% sensitivity of the Off-Track approach. This suggests that the On-Track approach is more sensitive in detecting cases with bone loss and more specific in identifying cases without bone loss.

Positive Predictive Value (PPV) and Negative Predictive Value (NPV) also show the efficacy of the On-Track approach. The PPV of 82% for On-Track exceeds the 78% for Off-Track, indicating a higher probability that a positive result corresponds to true bone loss. Additionally, the NPV of 80% for On-Track emphasizes the approach's ability to accurately rule out bone loss when absent.

The findings align with previous literature on MRI assessment of bipolar bone loss, with some studies reporting varying sensitivity and specificity values. However, the study provides a comprehensive analysis that includes PPV and NPV, reinforcing the robustness of the On-Track approach. Quantitative assessment of bone loss, such as the Glenoid track, Hill-Sachs interval and bone loss percentage, adds depth to the findings, emphasizing the importance of incorporating quantitative measures for a more nuanced understanding of shoulder pathology. Knowing the lesion's characteristics and pathogenesis could help the surgeon decide which course of action is best for the patient[9]. The glenoid bone defect leads to decrease in the glenoid track width[10].

In conclusion, the study contributes valuable insights into the On-Track Off-Track approach for MRI assessment of bipolar bone loss in shoulder dislocations. When treating patients with anterior shoulder instability, this study helps to determine the best stabilization technique pre operatively[11]. By comparing and contrasting results with previous studies, the study emphasizes its reliability as a comprehensive tool for evaluating bipolar bone loss in shoulder dislocations.

CONCLUSIONS

The On-Track Off-Track Approach is a promising methodology for assessing bipolar bone loss in MRI evaluation. This cross-sectional study reveals its effectiveness in providing a comprehensive understanding of the nuances associated with bipolar bone loss. It enables clinicians and researchers to identify subtle variations and abnormalities that may be overlooked using traditional assessment methods. The approach may pave the way for targeted and personalized interventions, potentially revolutionizing treatment strategies and improving patient outcomes.

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