Original Article

DOI: 10.7860/JCDR/2026/82446.23420

Radiology Section

Role of Novel ACR Bone-reporting and Data System in Risk Stratification of Bone Tumours in South Indian Population: A Retrospective Observational Study

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ABSTRACT

Introduction: The American College of Radiology (ACR) Bone-Reporting and Data System (Bone-RADS) gave a structured framework for assessing and reporting bone tumours.

Aim: To evaluate the diagnostic performance of the ACR Bone-RADS score on radiographs in assessing bone tumour risk, with a specific focus on associating radiological findings with histopathological outcomes.

Materials and Methods: A retrospective observational study was conducted on 51 patients who underwent radiographic examination for suspected bone tumours between January 2024 and January 2025 at Apollo Institute of Medical Sciences and Research, Hyderabad, India. Bone tumours were categorised as benign, intermediate or malignant based on a reference standard of histology or clinical–radiological consensus by a senior radiologist. Five radiographic characteristics (margin, periosteal reaction, endosteal erosion, pathologic fracture, and extra-osseous mass) were assessed by two radiologists, who calculated a cumulative score (points from radiographic features and cancer history) and assigned a Bone-RADS category to each radiograph. The diagnostic performance of Bone-RADS and inter-reader concordance were assessed using univariate logistic regression analyses and Chi-square analysis.

Results: In the current study, the mean age of the study population was 26.06±13.625 years, and the majority of participants were males. The Bone-RADS score demonstrated good diagnostic performance with an AUC of 0.718 (CI: 0.572, 0.863; p<0.001) and high sensitivity (85.19%) and low specificity (58.33%). Statistically significant radiographic predictors of malignancy in the current study are tumour margination, periosteal reaction, and extraosseous soft-tissue. Excellent interobserver reliability (ICC=0.95) was noted for Bone-RADS point total/category.

Conclusion: The current study findings suggest that the implementation of ACR Bone-RADS in clinical practice enhances diagnostic precision, facilitates communication among healthcare providers, and improves patient management outcomes.

Keywords: Malignancy risk, Musculoskeletal oncology, Radiographs

INTRODUCTION

Due to its widespread availability, cost-effectiveness, and the distinct diagnostic advantages of two-dimensional imaging, conventional radiography is the preferred initial imaging modality for assessing and characterising bone tumours [1].

The Bone-RADS scoring system was recently introduced by the American college of Radiology Bone-RADS committee to facilitate risk stratification and a management approach based on tumour risk using conventional radiographs. This system provides a standardised method for assessing bone tumours, incorporating a patient's history of cancer along with five critical radiographic characteristics: Tumour margins, periosteal reaction, depth of endosteal erosion, presence or absence of pathological fracture, and extra-osseous soft-tissue extension [2,3]. The ACR (American College of Radiology) committee emphasised that the scoring criteria within Bone-RADS were determined through expert consensus, and further validation of the system is required [2]. To date, in the literature, there is only one study done by Park S-Y et al., which validated ACR Bone-RADS [3]. Therefore, the present study was conducted to evaluate the diagnostic performance of the ACR Bone-RADS score in the risk stratification of bone tumours in appendicular bones on conventional radiographs of patients who presented to the current study institute.

MATERIALS AND METHODS

A retrospective observational study was conducted on patients who underwent radiographic examination between January 2024 and January 2025 at Apollo Institute of Medical Sciences and Research, Hyderabad, India for suspected bone tumours in the appendicular bones. Institutional review board approval was taken for the study (RC NO.-AIMSR/IRB/RC/2025/05/13).

Sample size: Sample size included was 51.

Inclusion criteria:

a) Males and females of all age groups, in the range of 6 to 70 years, referred for radiographic examination of suspected bone lesions, were included in the current study.

b) Incidentally detected bone lesions on radiographs were also included in study.

Exclusion criteria:

a) Cases with uncertainty about whether the tumour is benign or malignant, including those lost to follow-up.

b) Bone tumours that are not visible on radiographs.

c) Presence of multiple lesions within a single bone.

d) Smaller lesions (<1 cm), which make characterisation difficult.

Study Procedure

From medical records, clinical data such as age, gender, and prior history of cancer were collected.

Radiographs were evaluated for the five radiographic findings-tumour margins, periosteal reaction, depth of endosteal erosion, presence or absence of pathologic fracture, and extraosseous soft-tissue mass by two radiologists. Each radiologist individually assigned point values to each radiographic feature, according to guidelines published by the ACR Bone-RADS committee, and each patient was assigned a risk category (very low, low, Intermediate, and high-risk) [Table/Fig-1] [2]. A few case examples in the current study are illustrated in [Table/Fig-2,3].

Reference standard: The final diagnosis was established based on:

a) Pathological diagnosis by excision or biopsy;

b) Definitive clinical, initial Magnetic Resonance Imaging (MRI) findings, and serial follow-up imaging {radiographs, Computed Tomography (CT), and/ or MRI} for tumours (in about 17 cases, which were classical do not touch lesions) that are not biopsied based on the clinical-radiological consensus of a senior radiologist (long-serving expert in a tertiary care centre).

Bone tumours in the study, based on final diagnosis, are classified into three categories (benign, intermediate, and malignant), according to the 5th edition of the World Health Organisation (WHO) classification of bone tumours [4,5].

STATISTICAL ANALYSIS

For the bone tumours classified according to the WHO classification, statistical analysis were performed for benign vs intermediate and malignant bone tumours. The odds ratios for each radiographic feature were evaluated using univariate logistic regression analyses and Chi-square analysis. The diagnostic performance of Bone-RADS was evaluated using the Area Under the receiver-operating characteristic Curve (AUC). The sensitivity, specificity, Positive Predictive Value and Negative Predictive Value (PPV and NPV) of the Bone-RADS system were calculated on the assumption that Bone-RADS categories 1-2 (point total 1-4) indicate benign tumours, and categories 3-4 (point total ≥ 5) suggest malignancy. Inter-reader agreements between the two readers for the five radiographic features and the Bone-RADS category were assessed using weighted Cohen's kappa statistics and the Intraclass Correlation Coefficient (ICC). {The degree of agreement was interpreted as follows: <0.20=poor; 0.21-0.40=fair; 0.41-0.60=moderate; 0.61-0.80=good; and 0.81-1.00=excellent}. Statistical analyses were performed with Statistical Package for Social Sciences (SPSS) version 24.0.

RESULTS

A total of 51 patients were included in the study. The mean age of the study population was 26.06±13.625 years, and the majority were males (32 males and 19 females). There is a prior history of cancer in two patients in the current study. On radiographic examination of 51 cases, seven patients were categorised into Bone-RADS 1 category, 11 patients into Bone-RADS 2 category, five patients into Bone-RADS 3 category, and 28 patients into Bone-RADS 4 category based on the ACR BONE-RADS scoring system [Table/Fig-4]. On final diagnosis, 24 cases were proven benign, seven were intermediate, and 20 were malignant according to the WHO grading of bone tumours.

American College of Radiology™

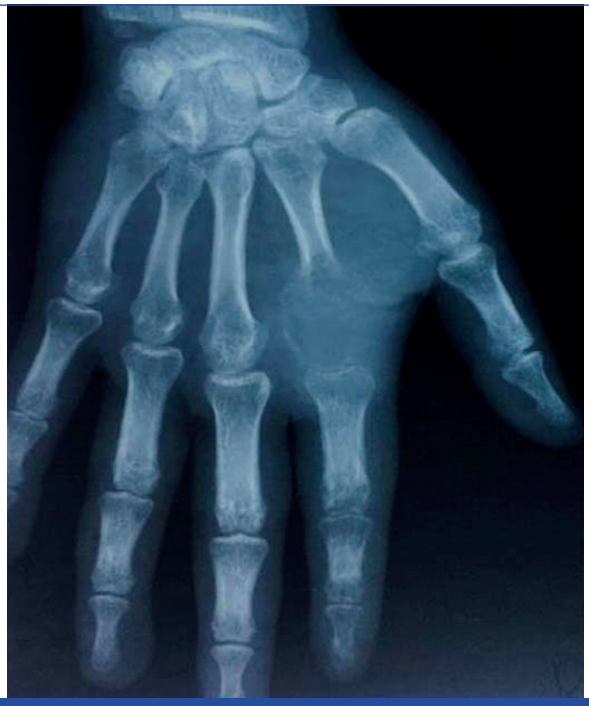
Revised: February 2024

Bone-RADS™ v2023 Assessment Categories and Scoring System

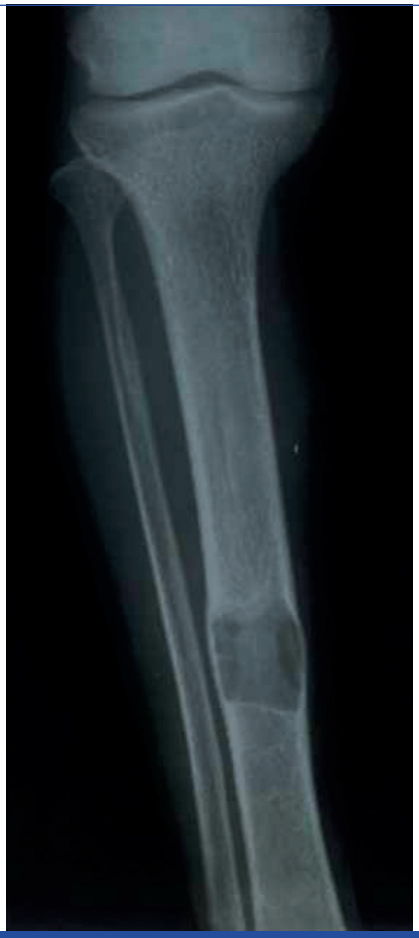
Add All Points to Determine Bone-RADS Score Level and Management	
MARGINS	
IA = 1	
IB = 3	
II = 5	
IIIA-C = 7	
PERIOSTEAL REACTION	
None = 0	
Non-aggressive = 2	
Aggressive = 4	
ENDOSTEAL EROSION	
Mild = 0	
Moderate = 1	
Deep = 2	
PATHOLOGICAL FRACTURE	
If YES = 2	
SOFT TISSUE MASS	
If YES = 4	
KNOWN PRIMARY CANCER	
If YES = 2	
TOTAL POINTS	

Bone-RADS Score	Risk Category	Description	Management
0	Incompletely Characterized Point Total = N/A	Risk cannot be adequately predicted Example: Lucent lesions of the axial skeleton such as scapula, spine, or pelvis	• Further workup is necessary • Additional radiographic views or cross-sectional imaging for further evaluation
1	Very Low Risk Point Total = 1–2	• Pathognomonic benign bone lesion • Classic "Do Not Touch" lesion Example: Non-ossifying fibroma, osteoid osteoma	• If asymptomatic, consider work up to be complete vs annual surveillance to ensure expected stability • If symptomatic or change in clinical presentation, consider advanced imaging and orthopedic oncology referral for treatment of benign tumor
2	Low Risk Point Total = 3–4	• Asymptomatic geographic lytic lesion without suspicious periosteal reaction or deep endosteal erosion • Typical location and/or matrix of a common benign bone lesion Example: Enchondroma, giant cell tumor, aneurysmal bone cyst	• Short interval (3-6 month) surveillance to ensure stability • Consider advanced imaging to assess tumor composition and possibly biopsy to confirm benignity if needed • Consider orthopedic oncology referral for surveillance or treatment of benign tumor
3	Intermediate Risk Point Total = 5–6	• Geographic lytic lesion in a patient with primary malignancy elsewhere Example: Geographic, but ill-defined lytic lesion	• Orthopedic oncology referral for probable biopsy and treatment planning • Recommend advanced imaging such as CT, MRI, or bone scan for further characterization
4	High Risk Point Total ≥ 7	• Malignant until proven otherwise • Geographic lytic lesion with aggressive periosteal reaction or soft tissue mass Example: Non-geographic osteolytic lesion	• Orthopedic oncology referral for recommended biopsy and treatment planning • Advanced imaging for tumor staging including additional sites of disease

[Table/Fig-1]: Bone-RADS 2023 Assessment categories and scoring system.



[Table/Fig-2]: AP radiograph of 22-year-old female showing lesion with changing margins-(IIIa-7points), Periosteal reaction -None (0 points), Endosteal erosion- deep (2 points), Pathological fracture- No (0 points), Soft-tissue mass- yes (4 points), History of any malignancy -No (0 points).Total score is 13 and was stratified into Bone-RADS 4 (high risk) category . Histopathology was suggestive of aggressive GCT.

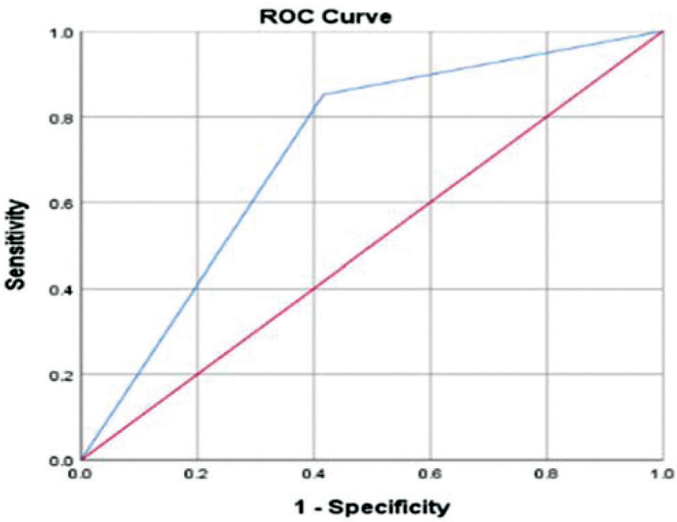


[Table/Fig-3]: AP radiograph of right leg of 48-year-old female with history of carcinoma ovary. Geographic well-defined lesion without sclerotic margins (Ib-3 points), Periosteal reaction- None (0 points), Endosteal erosion- Deep(2 points), Pathological fracture-No (0 points), Soft-tissue mass- no (0 points), History of any malignancy -yes (2). Total score is 7 and was stratified into Bone-RADS 4 (High risk) category. Histopathology was suggestive of metastasis from the primary lesion.

For differentiating benign from intermediate and malignant lesions, the AUC is 0.718 (CI: 0.572, 0.863; p <0.001) for the Bone-RADS risk category. Bone-RADS showed high sensitivity, but specificity is relatively low when malignancy was defined as Bone-RADS categories 3-4 (sensitivity of 85.19% and specificity of 58.33%) [Table/Fig-5].

Characteristics	Benign (n=24)	Intermediate (n=7)	Malignant (n=20)
Mean age (Mean±SD)	21.79±12.322	29.57±16.461	30.16±13.200
Final diagnoses	ABC (4), Chondroblastoma (1) Chondromyxoid fibroma (1) Cystic angioma (1) Enchondroma (4) Fibrous dysplasia (2) Non ossifying fibroma (5) Osteochondroma (2) Osteoid osteoma (2) Osteitis fibrosa cystica (1), Simple bone cyst (1)	Giant cell tumour (6) Paget's (1)	Aggressive giant cell tumours (5), Ewing's (2), Chondrosarcoma (1), Metastasis (2), Multiple myeloma (1) Osteosarcoma (9)
Bone-RADS 1	7	0	0
Bone-RADS 2	7	4	0
Bone-RADS 3	4	1	0
Bone-RADS 4	6	2	20
Total	24	7	20

[Table/Fig-4]: Characteristics of the study population and the bone tumours.



Diagnostic performance of ACR Bone-RADS for diagnosis of malignancy		
Variables	Value	95% CI
Sensitivity	85.19%	66.27% to 95.81%
Specificity	58.33%	36.64% to 77.89%
Positive likelihood ratio	2.04	1.24 to 3.37
Negative likelihood ratio	0.25	0.10 to 0.67
Disease prevalence (*)	52.94%	38.46% to 67.07%
Positive predictive value (*)	69.70%	58.27% to 79.11%
Negative predictive value (*)	77.78%	57.13% to 90.19%
Accuracy (*)	72.55%	58.26% to 84.11%

[Table/Fig-5]: Receiver operating characteristic curves in diagnosis of malignant Bone tumours for Bone-RADS categorisation (blue line) for differentiating benign from intermediate and malignant lesions, the AUCs is 0.718 (CI: 0.572, 0.863; p<0.001) with table showing diagnostic performance of ACR Bone-RADS.

Of the five radiographic features included in Bone-RADS, tumour margination, periosteal reaction, and extraosseous soft-tissue were statistically significant predictors of malignant bone tumours. In particular, tumour margination was highly associated with malignancy, with odds ratios of 42.667 (lower 3.805 and upper 478.419) for margination grades IIIA, IIIB, and IIIC [Table/Fig-6].

In the current study, ICC for the Bone-RADS point total/category (ICC-0.95) and all the radiographic features (Margins- 0.94,

Periosteal reaction-0.8, Fracture-1, Soft-tissue-0.90) showed excellent interobserver reliability. Erosion (0.78) showed good interobserver reliability.

Variables	Benign (n=24)	Intermediate and malignant (n=27)	Odds ratio p-value		Chi-square value
Tumour margination					
Ia	8	1		0.005	
Ib	11	6	4.364	0.210	
II	2	4	16.000	0.043	
III	3	16	42.667	0.002	16.37 (p=0.001)
Periosteal reaction					
None	18	17		0.892	
Non aggressive	6	4		0.633	
Aggressive		6	0.706	0.999	6.274 (p=0.043)
Fractures					
Absent	19	23			
Present	5	4	0.661	0.575	0.317 (p=0.574)
Endosteal erosion					
Mild	19	16		0.294	
Moderate	2	3	1.781	0.553	
Severe	3	8	3.167	0.128	2.562 (p=0.278)
Soft-tissue					
Absent	22	14			
Present	2	13	10.214	0.005	9.702 (p=0.002)

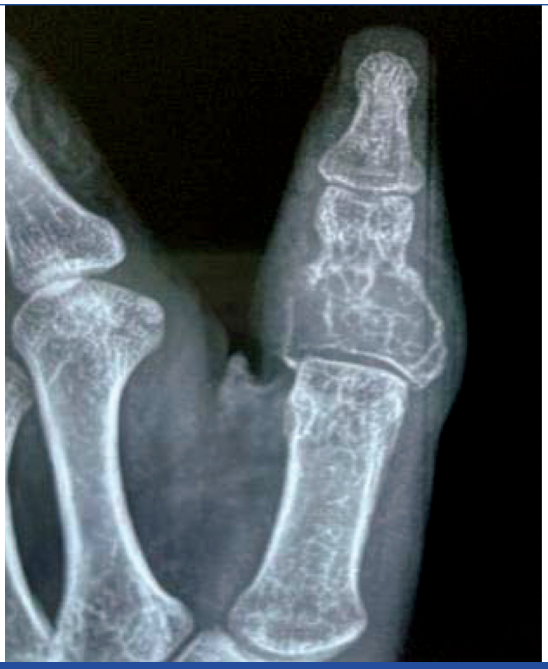
[Table/Fig-6]: Results of univariate analysis for benign vs intermediate and malignant tumours.

DISCUSSION

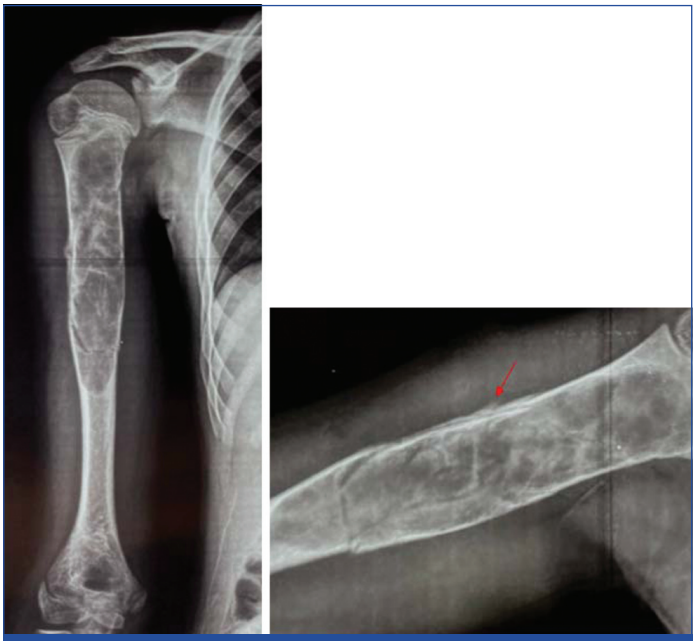
In the current retrospective analysis, the Bone-RADS scoring system, demonstrated strong discriminatory ability for identifying malignant bone tumours, with an AUC of 0.718 (95% CI: 0.572-0.863; p<0.001). These findings for risk stratification categories are in agreement with a study done by Park SY et al., which investigated the ACR Bone-RADS risk stratification system (AUC of 0.895–0.900 for categorisation; sensitivity- 95.2 (91.9, 97.4); negative predictive value -96.4 (94.0, 97.9); specificity - 68.6 (64.4, 72.7); positive predictive value- 61.9 (58.7, 64.9) [3].

Univariate logistic regression analysis showed three radiographic features- Tumour margination, Periosteal reaction, and extraosseous soft-tissue were significant predictors of malignancy in our study, whereas in a study done by Park S-Y et al., all five radiographic features (Tumour margin, Periosteal reaction, Depth of endosteal erosion, presence or absence of pathologic fracture, and extra-osseous extension) were significant predictors of malignancy [3]. Specificity in the current study is relatively low because few benign tumours showed severe endosteal erosion (e.g., enchondromas) [Table/Fig-7] and few of them presented with pathological fracture (e.g., simple bone cyst/ABC) [Table/Fig-8], which increased their total score on radiographic assessment and were stratified into intermediate or high-risk increasing the false positives and decreasing the specificity.

Adding extra parameters like tumour location could enhance the diagnostic accuracy of the current Bone-RADS system. For example, enchondromas, which are the most common bone tumours in the hands, often show significant endosteal scalloping (scoring 2 points) and are frequently linked to pathologic fractures (also 2 points). These characteristics alone can classify a lesion as Bone-RADS 3 or higher, regardless of its margins. Therefore, the authors suggest that incorporating location-specific factors (such as tumours in the hands versus those in long bones) into the current Bone-RADS model may further improve its predictive accuracy.



[Table/Fig-7]: AP radiograph of proximal phalanx of 26-year-old male geographic well-defined lesion without sclerotic margins (Ib-3 point) Periosteal reaction- None (0 points), Endosteal erosion- deep (2 points), Pathological fracture (0 points), Soft-tissue mass- no (0 points) History of any malignancy- No (0 points). The total score is 5 and stratified into Bone-RADS 3 (Intermediate risk) category. The final histopathology was suggestive of enchondroma, which is a benign lesion.



[Table/Fig-8]: Lateral and AP radiographs of the humerus of a 15-year-old female Bone-RADS: Geographic well-defined lesion without sclerotic margins (Ib-3points), Periosteal reaction: Non aggressive (2 points) (arrow in above figure), Endosteal erosion- moderate (1 point), Pathological fracture- Yes (2 points) Soft-tissue mass- no (0 points), History of any malignancy- No (0 points) The total score is 8 and stratified into Bone-RADS 4 (high-risk) category. The final diagnosis after surgical resection was fibrous dysplasia with Aneurysmal bone cyst changes.

In the present study, the Bone-RADS point total/category (ICC=0.95) showed excellent interobserver reliability. All the radiographic features showed excellent interobserver reliability. Erosion (0.78) showed good interobserver reliability. Whereas in a study done by Park SY et al., Interreader agreements were good to excellent for Bone-RADS point total (ICC=0.850), categorisation (k=0.739), and most of the radiographic features (k=0.621-0.822), except for endosteal erosion (k=0.537) and extra-osseous mass (k=0.234) [3].

As recommended by Park SY et al., application of a statistical model, such as logistic regression analysis, to obtain coefficients for each predictor and modification of the additive scoring system with a new cut-off point may show different results or even improve the diagnostic performance of Bone-RADS [3].

Limitation(s)

The present study has several limitations. The sample size is small as it is a single Institutional-based retrospective study. There may be the potential for selection bias as patients are selected from institutional databases.

CONCLUSION(S)

In the current study retrospective analysis, the ACR Bone-RADS system exhibited strong diagnostic performance in distinguishing benign from malignant bone tumours, with high sensitivity and negative predictive value, albeit lower specificity and positive predictive value. These findings underscore the utility of the current consensus-based Bone-RADS scoring system while also highlighting the need for further validation and potential refinement through future studies.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 28, 2025
- Manual Googling: Jan 27, 2026
- iThenticate Software: Jan 30, 2026 (4%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Aug 04, 2025**
Date of Peer Review: **Dec 16, 2025**
Date of Acceptance: **Feb 02, 2026**
Date of Publishing: **May 01, 2026**