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Original Article

# Magnetic Resonance Image Characterization of Knee Meniscus Signal Intensity using Crue's Approach: Results from a Multi-centre Evidence

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**ABSTRACT**

This study aimed to characterize knee meniscus signal-intensity using magnetic resonance imaging. Our research included knee MR images of 138 subjects from multi-centres in Nigeria, between September 2016 and December 2017. Knee images were retrieved from patients' folder of MRI scanners and transfered to a DICOM workstation (Onis 2.6) for image analysis. Knee meniscus was characterized into 0, 1, 2 & 3 grades using Crue's grading approach. Our research revealed 58% incidence of meniscal lesion. Study yielded a significant relationship between meniscal lesion and gender ($p < .005$) with a greater proportion of these lesions in women than in men. Meniscal lesions showed significant association with osteoarthritis (OA) ($p < 0.05$). Grade 3 lesions (actual tears) were largely of horizontal configuration.

## INTRODUCTION

Injury to the meniscus is common among athletes and in the general population (1). Its incidence is becoming increasingly alarming, accounting for a significant proportion of orthopedic consultations (2). Several research evidences have identified sport injury as the leading cause of meniscal lesions, especially those with vertical configurations, while degenerative meniscal injury is fast becoming visible in the general population, and common among persons greater than 40 years (3). The menisci serve several important functions, which include providing stability to the knee joint, lubrication and lateral load distribution. A torn meniscus disrupts knee joint biomechanics, and exposes the individuals to joint disabilities, which affect their social and economic lives (4). Traditional clinical approaches to knee meniscal evaluation have proven to be unreliable in many cases of knee meniscal injury. For instance, an evidence documents low sensitivity of arthroscopy to subtle intra-meniscal lesion, with cases of deteriorating patient's condition and accelerating osteoarthritis post arthroscopy (1). The inclusion of MRI into routine orthopedic prescriptions has changed the paradigm in knee management. Several studies have reported an improved evaluation of the meniscus following adjunctive imaging with MRI. A recent publication has recommended a preoperative MR imaging prior to any invasive knee joint procedure, and this has been endorsed by renowned orthopedic surgeons to be a viable approach when contemplating knee surgery following suspected meniscal involvement (1, 4, 5). Preoperative MRI has reportedly reduced the number of diagnostic arthroscopy, as a standalone tool for meniscal lesion in more than a third of patients (6). The application of MRI for meniscal evaluation has significantly

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transformed care for knee joint lesions and improved recovery. This is due to the inherent high tissue characterization of MRI, and its multi-planar and multi-parametric abilities. The MRI demonstrates an intact meniscus as a homogeneous low signal intensity structure having a triangular and bow-tie configuration on coronal and sagittal planes in all sequences, while meniscal lesions (degenerative and actual tear) is characterized with high signal intensity (7). However, only high signals intensity in contact with articular surfaces are indicative of actual meniscal tear [8], albeit, with high Positive Predictive Values (PPV), if high signal intensity area in contact with meniscal surfaces is obvious in at least two consecutive image slices (1).

An estimated 25,000 cases of meniscus injury is reported yearly in England, while in the USA, meniscal lesion accounts for a significant number of knee joint pathologies, with estimated 2million cases of arthroscopies performed yearly (9). This statistics is expected to precipitate studies around the meniscus globally. In Africa yet, research on the meniscus is scarce, and to the best of our knowledge, not a single study on knee joint disease processes in Nigeria, has underpinned the meniscus despite its roles in knee joint biomechanics and disease processes. The absence of comprehensive statistics in meniscal lesion suggests a gap in the management pathways for knee joint pathology in this region. From observation, there is lack of consistency in meniscal lesion interpretation by radiologists using MRI, as different grading and substandard methods are evident, to define and characterize the knee meniscus. This has the potentials to undermine the diagnostic yield of MRI, and poses difficulties to patient care and treatment outcomes. This study aimed to characterize meniscal signal intensity on MRI, and determine its association with common knee joint conditions, gender and age. In addition, investigators assessed consistency with defining and characterizing the meniscus in knee MRI reports.

## MATERIALS AND METHODS

### Research Design

A cross-sectional retrospective design was used for this study. The study was conducted in two major Nigerian cities: Abuja and Port Harcourt, and image data of knee MRI and patients' reports were retrieved from the console of MRI scanners of the following facilities: Trans-view diagnostics (Port Harcourt), Georges, Port Harcourt and Medicaid Diagnostics in Abuja. We obtained **a**pproval from each facility under study. Investigators included Knee MR Images of adults, 20 years and above as high signal intensity from the popliteal vasculature may mimic meniscal lesion in children. Patient's data with history of surgery and implants was excluded from the study. Only MR image data demonstrating the meniscus with sections ≤ 5m, and cases with radiologists' reports were included in the study.

### Procedure and Data Synthesis

Data was extracted from knee MRI images of patients between June 2016 and December 2017. Only images with standard protocols and sequences for Knee MRI were included. Image data obtained from patients' electronic folders were transferred to a DICOM workstation (Onis version 2.6) on a PC were personal details were anonymised and images analysed. The Crues' grading system was used to characterize MRI signal intensity of the meniscus, a criterion known as the "Two Slice Rule" was utilised to improve positive predictive value (PPV). It asserts that, in order to describe a meniscal lesion as tear, the MRI high signal intensity should interact with articular surfaces in not less than two contiguous slices in all three planes, otherwise, such high signal intensity is termed as intra-meniscal lesion. A radiologist with 10 years' experience in cross-sectional imaging, classified the knee meniscus into three categories. The meniscus having focal non-articular high signal intensity on MRI was classified as Crues' grade 1 lesion. Linear or horizontal high signal intensity area not contacting any articular surface described Crues' Grade 2 lesion. Abnormal (high) signal intensity extending across a large portion of the meniscus, and communicating with at least one surface of the meniscus, was classified as Grade 3 meniscal lesion, which is actual meniscal tear. We further grouped the high signal intensities into two: intra-meniscal lesion (grades 1 and 2) and actual meniscal tear (grade 3). Actual meniscal tear (grade 3) was classified based on their injury patterns (morphology) into vertical, oblique and horizontal grade 3 lesions. Patient's information including demographics and clinical details were retrieved for analysis.

### Statistical Analysis

Measure of agreements for the presence and absence of meniscal lesion between MRI meniscal reports and investigators' grading were estimated using kappa coefficient which values were interpreted as poor (k = 0); slight (k = 0.0–2.0); fair (k = 0.2–0.40); moderate (k = 0.41-0.60); excellent (k = 0.61-0.8); and near perfect as (k = 0.81-1.00). Descriptive statistics was performed for subjects' demographics (age). Knee meniscal grades (1, 2 and 3) were grouped and presented in Bar charts. The frequency table was used to present the proportion of different configurations of actual meniscal tear (Crues' grade 3 lesion), and for consistency of grading system and description of lesion anatomical location. Data were analysed using the Chi-square test to determine meniscal lesion association with MRI report, indication, gender and age. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software Version 21.0., and statistical significance was set a priori at $p \leq 0.05$.

## RESULTS

A total of 183 knee image data made up this study: 40% female and 60% male. Of this total, 58% had abnormal (high) meniscal signals, while 42% patients accounted for normal menisci. Of the cohort with high meniscal signal intensity (lesion), the medial meniscus accounted for 65% (35), surpassing the lateral (35%) by almost 2-fold (Figure 1). The number of grade 1 lesions in the group

with (abnormal signals (lesions) was 26, while grades 2 and 3 accounted for 37 and 17 of the total with high signal intensity respectively (Figure 2). The posterior horn of the medial meniscus had the highest frequency (49%) of abnormal MRI signal (high signal intensity) ($p < 0.05$). The posterior horn of the lateral meniscus accounted for 23% followed by the anterior horn with about 12% in this cohort. Anterior horn of the lateral meniscus was 10% of the total with abnormal meniscal signal, while the mid-bodies of the medial and lateral menisci were 5% and 1% of the cohort with high signal intensity areas respectively(Figure 3). Meniscal lesion was more in women than in men ($p <0.05$) (Table 1), and significantly associated with osteoarthritis (OA) and anterior cruciate ligament tear (ACL). Study showed a significant association between actual meniscal tear and age groupings with the category > 40 years having a higher incidence of this lesion than the younger population. Actual meniscal tear (Crues' grade 3 lesion was largely of horizontal configuration (58%) ($p < 0.05$) (Figure 4). Knee joint pain and sport injury (SI) were significantly associated with meniscal lesion ($P < 0.05$) (Table 2). Excellent measure of agreement was reached for the presence and absence of meniscal lesions between Radiologists and investigators ($k = 0.79$; $p < 0.05$). About 48% of reports of the meniscus with high signal intensity areas adopted a combination of more than one grading methods from radiologists. About 49.8% of reported knee MR images did not indicate affected segment of the meniscus (Table 3), leaving 50.25% with reports clearly stating affected meniscal segment.

**Table 1.** Pearson's Chi test of association between gender, meniscal lesion and osteoarthritis, age and meniscal lesion

| Pearson's chi test of association | Value | df | *p* |
|---|---|---|---|
| Gender * Meniscal Lesion | 128.00 | 4 | 0.000 |
| Gender & osteoarthritis | 99.54 | 4 | 0.000 |
| Grade 3 lesion (actual tear) * Age | 1.48 | 3 | 0.000 |

**Table 2.** Pearson's Chi test of association between meniscal lesion and knee pathology

| Pearson's Chi test of association between Meniscal lesion and knee pathology | Value | df | *p* |
|---|---|---|---|
| Meniscal Lesion * Bone Marrow Edema | 0.47 | 6 | 0.490 |
| Meniscal Lesion * Posterior cruciate ligament injury | 0.83 | 2 | 0.660 |
| Meniscal Lesion * Anterior cruciate ligament injury | 16.61 | 1 | 0.011 |
| Meniscal Lesion * osteoarthritis | 11.01 | 1 | 0.001 |
| Meniscal Lesion * Knee pain | | 34 | 0.001 |
| Meniscal Lesion * Sport Injury | 76.50 | 34 | 0.001 |

**Table 3.** Showing if MRI Reports indicate segments with meniscal lesion

| | Frequency | Percentage (%) |
|---|---|---|
| Yes | 41 | 50.25 |
| No | 39 | 49.75 |
| Total | 80 | 100 |

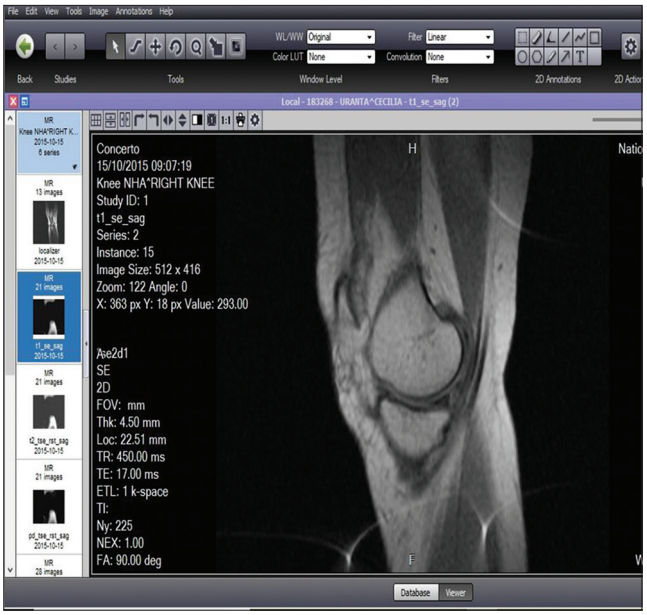


**Figure 1.** Grade 3 meniscal high signal intensity area (lesion) with a horizontal configuration at the posterior meniscus

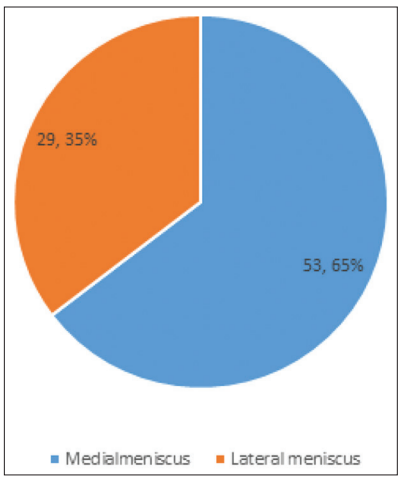


**Figure 2.** Frequency of lesion in the medial and lateral menisci

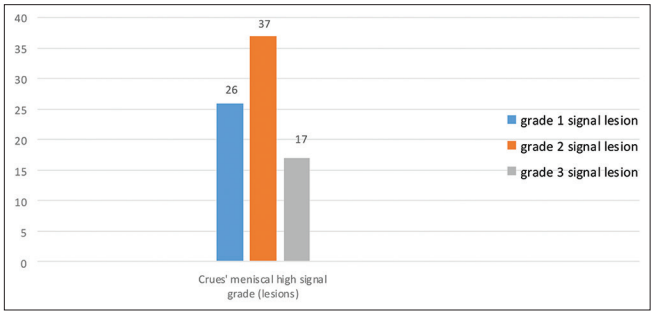


**Figure 3.** Distribution of meniscal grade types

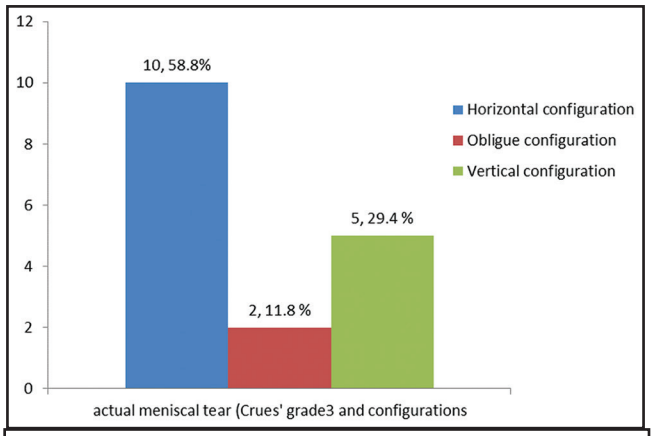


**Figure 4.** Grade 3 meniscus according to signal intensity morpholog

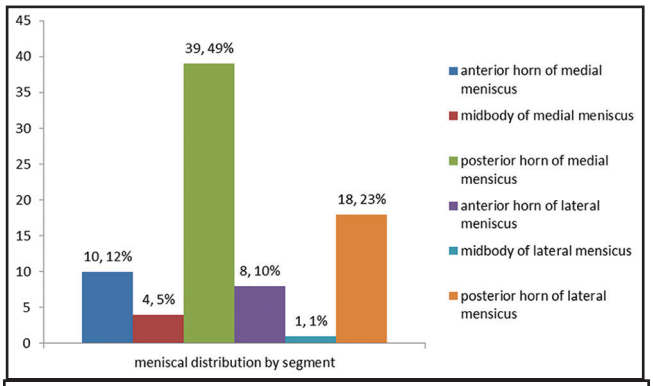


**Figure 5.** Proportion of meniscal lesion (high signal areas) by anatomical segments

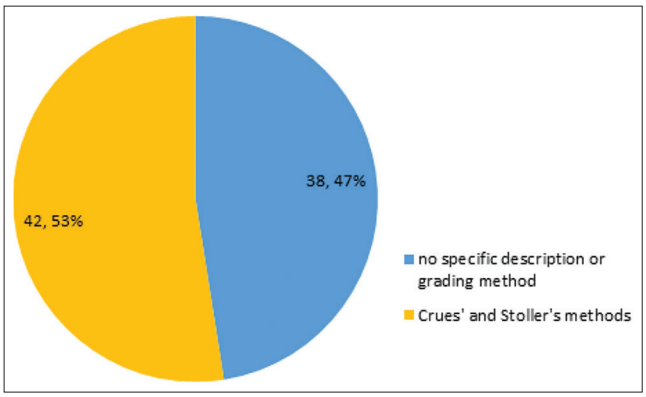


**Figure 6.** Meniscus descriptions according to radiologists' reports

## DISCUSSION

Magnetic Resonance Imaging (MRI) has received the endorsements of renowned orthopedic surgeons as an invaluable tool for investigating the meniscus (5). The current study provides an evidence of signal intensity characterization of the meniscus with MRI from a multi-centre data in Nigeria. In this study, we sought to determine meniscal lesion incidence, age- and gender-based impacts on meniscal lesion, as well as the association between meniscal lesion and other knee joint disease processes. High meniscal signal intensity (lesion) was present in 80 of the 138 patients, which is a proportion, about 58% of the entire sample, while 58 patients had intact meniscus (Figure 1). The number of normal meniscus in our study was lower than that reported by Nada and Anijeed, (5). Such differences may have resulted from racial, genetic composition, environmental disparities and sampling technique. In the cohort with high meniscal signal intensity (lesion), the medial meniscus accounted for 65% (35), surpassing the lateral (35%) by almost 2-fold (Figure 2). This outcome is similar to a recent evidence, and is reported to result from the wider surface area of the medial meniscus, which increases propensity for tear especially at the posterior horn (10). Crues' grade1 lesion was present in 33% of meniscus with abnormal MRI signal (high), whereas grade lesion yielded 49% of abnormal MRI. This result was similar to that reported by Rao et al. (10). In their study, grade-2 meniscal lesion accounted for 43% of the patients with meniscal involvement, and was the most prevalent lesion type. Our research reveals that Crues' grade 3 MRI lesion represented 21% of the cohort with meniscal lesion contrary to a similar work by Rao et al. (10), who stated grade 3 meniscal lesion as the category with the highest frequency. This disparity is however, unsurprising, as factors including race, environmental and genetic composition may underlie such variation. Nonetheless, according to Karanjot et al. (11).

If a patient manifests clinical signs of meniscal disorder, then signal grade 3 lesion, may be likely in a significant proportion of lesions reported as grade-2 signal lesion in low-resource settings where most MRI scanners are of low-field category. While many studies have paid little attention to intra-meniscal lesion, a study has argued that cracks or degenerative changes to the meniscus have the potential to progress to actual meniscal tear by creating a tip-associated strain-stress concentration capable of causing meniscal tissue damage, especially of the horizontal configuration (12, 13, 14). This point emphasizes the need to reevaluate suspected high meniscal signal intensity and its potentials to deteriorate knee joint kinematics. Meniscal segment with the highest proportion (39, 49%) of meniscal leison was the posterior horn of the medial meniscus. This was followed by the posterior horn of the lateral meniscus, which accounted for about 23% of the total number with meniscal lesion. Lesion incidence in the posterior horn was significantly more than the other segments. The anterior horn of the medial meniscus recorded about 12% of meniscal lesion, while the anterior horn of the lateral meniscus counterpart was 10% of the total number with meniscal lesion (Figure 3). The results of the current study corroborate the findings of Crues et al. (15). In their study, the posterior horns accounted for 57% compared to the 16% involving the anterior horn. The mid-body of the medial meniscus and the lateral meniscus were the least, being 5% and 1% respectively. Findings were similar to a study conducted in India by Karanjot et al. (11). The results of the current study corroborate the findings of Crues et al. (15). In their study, the posterior horns accounted for 57% compared to the 16% involving the anterior horn. These results, however, are not unlikely as the medial meniscus is seen to bear more weight, especially at the posterior horn which happens

to be the widest segment (16). In addition, the posterior horns of both menisci are relatively less mobile compared to the midbody and anterior horns, and since they bear more weight, have wider dimension and lower collagen-proteoglycans composition, they are more prone to injury (17).

Recent publications have reported an increase in meniscal lesion incidence to at least six in every 1000, with male gender having almost a 3-fold preponderance compared to female (2, 14, 18). Our yield in this regard was in discordance as, results revealed a higher proportion of meniscal lesions in female than in male which is in agreement with a study by Chiang et al. (19). In addition, we obtained a similar gender-specific impact when we compared the proportion of meniscal lesion in gender in the cohort with osteoarthritis (OA) (table 1.0). Studies have underpinned some factors in meniscal lesion, which include genetic composition, load-bearing posture in women and tissue-water composition (MRI T2 value) at the posterior horn, which is higher in female than male, independent of age. In addition, fibro-chondrocyte composition have been identified in women in higher proportions compared to men. Higher incidence of meniscal lesion in women have been linked to this parameter (19). In a similar study, Klaus et al. [4], noted a higher prevalence of meniscal lesion in female to be linked with Leptin and some other Adipocytokines. We observed a significant association between meniscal lesion and OA in our investigation, in consonant with studies conducted by Eglund et al. (20).

Meniscal lesion incidence did not quite increase with age as it was fairly even across age grouping in the present study. Nonetheless, we found a significant difference in incidence between these groups when our comparison was limited to actual meniscal tear (grade 3 lesion) with the group greater than 40 years having a higher incidence of this lesion than the younger population. Interestingly, our yield is unsurprising, as studies have highlighted increased MRI T2 values with age. Findings clearly indicate increased tear vulnerability with age, and changes may be attributable to several age-related factors, which include a reduction in proteoglycans-water composition and other physiologic aging processes (19). Based on available evidences, the mechanism of injury has a lot to do with age, lifestyle and work-related activities, which affect meniscal lesion, its extent and morphology (21). A study (22) has shown significant associations between meniscal lesion and other knee joint conditions. Our research did not substantiate such associations with Posterior Cruciate Ligament (PCL) tears, bone marrow edema and Baker's cyst (BC). However, OA and anterior cruciate ligament (ACL) tear showed a significant association with meniscal lesions in consonant with previous studies. We found out that Crues' grade 3 lesion was largely of horizontal configuration (Figure 4), which explains why patients 40 year and above had significantly higher proportion than the younger group. This variation in tear morphology could influence treatment method and outcome (22). Our result also shows that longitudinal and oblique lesions, which were common in young patients, contributed just a little proportion to grade 3 lesions (Figure 5). This tells us that actual tears (grade 3 lesions) were largely of a chronic mechanism than acute activities. Our findings agree with results from a similar study conducted by Englund et al. (20) in the US.

Amongst indications for knee MRI in the present study, knee joint pain and sport injury (SI) were found to be significantly associated with meniscal lesion (table 2). However, there have been several arguments as to whether meniscal lesion is associated with knee pains, or if such elicited pains result from other knee joint disease processes like OA, synovitis, anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) tear. Nonetheless, a study has underpinned meniscal lesion in painful knee joints (3). A few studies have shown that knee joint pains can result from meniscal lesion (3,22). However, some studies have reported such pains to emanate from degenerative knee joint processes. Another study has linked this pain to a particular segment of the meniscus with lesion. In their opinion, the outer zone, which is highly vascularized and innervated, is probably the region eliciting such pains, while the inner zone, which is sparsely vascularized, does not elicit pains when damaged. Damage to the meniscus is known to distort conversion of axial forces to hoop stresses and this affects the lateral distribution of these loads, and further increases axial contact pressure precipitating degenerative changes known to cause pains (23).

An excellent measure of agreement was obtained on the presence and absence of meniscal lesions between Radiologists views and findings from investigators. Albeit, in terms of classifying these lesions, we observed inconsistencies in meniscal signal characterization as different MRI signal intensity grading systems were used by different knee MRI reviewers . Albeit, in terms of classifying these lesions, we observed inconsistencies in meniscal signal characterization as different MRI signal intensity grading systems were used by different knee MRI reviewers. We observed that, out of 80 menisci with high signal changes in the present study, about 48% were reviewed and reported as meniscal lesion without a specific grading system for describing the meniscus (Figure 6), while the rest grading systems where not specific, but rather a mixture of more than one grading methods from radiologists reports. About 50% of these meniscal lesions were reported without indicating the affected segment of the meniscus (Table 3). Patient's recovery depends largely on image analysis of the meniscus, as clinical evaluation is not always specific and findings hardly correlate with patients' symptoms. From such observations in the current study, there is a dire need for a consensus on meniscal signal intensity and knee joint evaluation. This understanding alongside adaptation of sequences to improve meniscal assessment in this region would be of significance to patients, radiographers and orthopaedic surgeons.

## CONCLUSION

The incidence of meniscal lesion from our multi-centre study was 58%, with significantly higher proportion of lesion seen in female than in male. The grade 3 lesions were largely of horizontal configuration, which associated with age, gender and osteoarthritis. Poor description and characterization of meniscus by radiologists was evident, and this suggests the

need for consensus regarding MRI knee joint and meniscal evaluation in this region.

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