

A Prospective Study of MRI (3 Tesla) Evaluation of Traumatic Anterior Cruciate Ligament Injuries with Arthroscopy Correlation

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DOI: <http://dx.doi.org/10.21276/ijcmsr.2019.4.4.7>

How to cite this article: P Sindhura, P Suneetha, M Venkatesh, V Udaya Bhaskarini. A prospective study of MRI (3 tesla) evaluation of traumatic anterior cruciate ligament injuries with arthroscopy correlation. International Journal of Contemporary Medicine Surgery and Radiology. 2019;4(4):D29-D34.

A B S T R A C T

Introduction: The incidence of tears is more in adolescents because of the increased outdoor activities and two wheeler usage. MRI was extremely useful in diagnosing complete tear. Aim: The study aimed to describe MRI findings in traumatic ACL injuries and its grading and to correlate MRI findings with arthroscopic findings.

Material and methods: MRI knee joint was done in 30 patients who were referred from orthopaedic department for evaluation of ACL and its associated injuries.

Results: Of 30 patients, 27 (90%) were males and 3 (10%) were females. 24 males had tears both on MRI and arthroscopy, only one female had tear both on MRI and arthroscopy. Right knee has increased incidence of ACL tears than the left knee joint. Mid-substance tears were more common accounting for 42% of the total cases followed by proximal and mid-substance tears (39%), least were distal tears (19%) in our study. The incidence of complete tears were more common in mid-substance. MRI was extremely useful in diagnosing complete tear with 100% sensitivity and 100% negative predictive value whereas clinical examination had 83% sensitivity and 86.9% positive predictive value. The most common sign was altered signal intensity of ACL. Combination of primary and secondary signs were seen in majority of patients accounting for 66% of the total cases. There was good correlation between arthroscopy and MRI in evaluation of complete tears, however there was little discrepancy between partial tears, grade-I and grade-II. Occasionally ACL with altered signal intensity which is given as grade-I on MRI ended up to be grade-II on arthroscopy, so partial tears are having sensitivity and positive predictive values as 75% and 60% respectively. MRI showed 13 medial meniscal tears, 11 lateral meniscal tears, 4 MCL, 4 PCL and 3 LCL tear associated with ACL tears. Medial meniscal tear was the most common associated injury with ACL tear in our study.

Conclusion: We conclude that 3T MRI highly diagnostic for complete ACL tears with good arthroscopic correlation and is therefore the best imaging modality of choice for the evaluation of ACL and its associated injuries in the backdrop of trauma and thus playing a crucial role in the planning of surgery

Keywords: Ligament Injuries, 3T MRI, Arthroscopy, ACL Tears.

INTRODUCTION

The knee joint is the synovial and weight bearing type of joint. Stability of the joint depends on its supporting ligamentous and tendinous structures. Trauma to the knee joint is a significant cause of morbidity in young active individuals.¹ Among all the major knee joint ligaments, anterior cruciate ligament is most frequently injured.² With an annual incidence of 68.6 per 100,000 person-years and 1 in 3500 adults each year, isolated ACL tears remain a common orthopaedic injury.

ACL is an extra-synovial and intra-capsular ligament 3. Intra-articular location causes poor healing of ACL and

prognosis is good in partial tears with intact synovium. Incomplete treatment of ACL injuries causes progressive knee instability and early osteoarthritic changes. Fifty percent of the acute ACL tears are associated with meniscal injuries⁴ and the incidence increases to ninety percent in chronic ACL deficient knees. The articular cartilage lesions incidence increases from 30-40% in acute ACL injuries to as high as 70-80% of knees with chronic instability. The rationale for diagnosing and treating ACL injury is preventing future internal derangements of knee.

An orthopaedician/ arthroscopist need to know the following questions before treating any ACL tears.⁴

1. Normal or abnormal ACL? (if ACL is normal, arthroscopy is not needed).
2. If ACL is abnormal, is it complete or partial tear? (partial tears are treated conservatively where as chronic tears are operated).
3. Injuries to other knee joint ligaments (PCL, MM, LM, MCL and LCL) Early intervention is needed if complete tear of ACL is associated with other injuries.

In majority of patients history and clinical examination play an important role in the diagnosis of ACL injury. Various clinical tests are available such as Lachman test and anterior drawer test for eliciting ACL tears. However the diagnosis of partial tears and associated injuries is difficult by clinical examination alone.⁵

Invasive and costly methods such as arthroscopy and arthrotomy are helpful in the definitive diagnosis of ACL tears. However intervention can be futile if ACL turns out to be normal.

CT Arthrography uses ionizing radiation and is comparatively more invasive than conventional MRI in the imaging of ACL tears in addition to the potential complications of inherent intraarticular injection of iodinated contrast material.

All these contradictory factors led to the need for a less invasive imaging modality for ACL tears for grading and preoperative workup.

Prior to the introduction of MRI in musculoskeletal system in 1980s, invasive arthroscopy was the procedure of choice in early 1970s for the evaluation of ACL tears. MRI is a non-invasive imaging modality and can detect, localize, characterize and delineate various internal derangements of the knee with better visualization of adjacent soft tissues and helps in faster diagnosis there by helping in grading and further management of ACL tears. MRI is well tolerated by patients, widely accepted by clinicians and assists in distinguishing pathological knee conditions that may have similar signs and symptoms.

Imaging is done in T1: Axial/ Sagittal/ Coronal, T2: Axial/ Sagittal/ Coronal, STIR, PD with quadrature knee coil.

The present study involves detailed evaluation of ACL and its grading, along with assessment of associated injuries on MRI in comparison with arthroscopic results. Primary and secondary signs of ACL tear on MRI are also analysed and assessed with arthroscopy to some extent.

The present study designed to describe MRI findings in traumatic ACL injuries and its grading and to correlate MRI findings with arthroscopic findings.

MATERIAL AND METHODS

Source of Data

The main source of data for the study will be patients attending the department of Radio diagnosis, Narayana Medical College, Nellore

Method of Collection of Data (including sampling procedure if any)

All patients referred to the department of Radiology with clinical suspicion Anterior cruciate ligament tear in a period of 2yrs from SEP 2016 to SEP 2018 will be subjected for study.

Inclusion Criteria

The study includes

Both males and females of age group 18-50 years; All the patients who are clinically suspected/diagnosed of traumatic ACL tears.

Exclusion Criteria

Patients with major injuries like liver/spleen rupture and flail chest and patients with unstable vitals in the setting of trauma. Patients suffering from degenerative knee disease. Patient having history of claustrophobia. Patient having history of metallic implants insertion, cardiac pacemakers and metallic foreign body in situ.

Equipment and technique used

The MR examinations were performed on all patients who met inclusion criteria at a 3T whole-body MR system (DISCOVERY 750W 3T MRI GE Healthcare, Chicago, Illinois) using a quadrature knee coil.

Sequences

Axial – T2 Coronal
Coronal – T1 Sagittal PDFS
Sagittal – T2 Axial
3D MERG

Images were taken with the knee in extension and external rotation of 5-10 degree.

Statistical analysis was performed with the help of descriptive statistics using percentages and proportions.

RESULTS

Thirty patients were evaluated, whose age group ranged from 18 to 50 years. The highest incidence of ACL tears was comparatively found in 18- 20 years with a total number of 5 cases accounting for 16%, followed by 21-30 years with 9 cases accounting for 30%. Fewer numbers of cases were seen

MRI	Arthroscopy			Total
	Normal	Partial tear	Complete tear	
Normal	3	2	0	5
Grade-I	4	5	0	9
Grade-II	0	2	6	8
Grade-III	0	0	8	8
Total				30

Table-1: Comparison between mri diagnosis and arthroscopic diagnosis for ACL tear.

Clinical diagnosis	Arthroscopy report		Total
	Tear	Normal	
Tear	20	4	24
Normal	3	3	6
Total	23	7	30
Sensitivity			83.33%
Specificity			50%
Positive predictive value			86.95%
Negative predictive value			42.85%
P < 0.0001			

Table-2: Comparison between clinical diagnosis and arthroscopic diagnosis for ACL tear

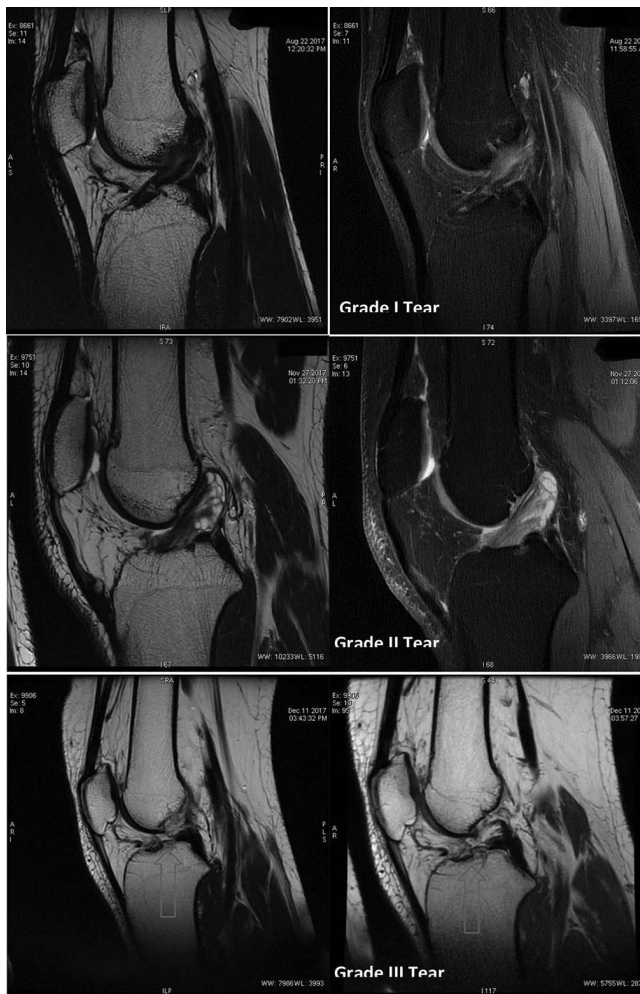


Figure-1: Cases and grades of tear.

MRI	Arthroscopy		Total
	Tear	Normal	
Tear	21	4	25
Normal	2	3	5
Total	23	7	30
Sensitivity			91.3%
Specificity			42.85%
Positive predictive value			84%
Negative predictive value			60%
P < 0.0001			

Table-3: Comparison between mri and arthroscopy for ACL tear

in the age groups ranging from 31-40 years and 41-50 years with 8 cases each and accounting for 27% each. The increased incidence in adolescents might be due to increased outdoor activities like football, kabaddi. Another reason being road traffic accidents due to increased usage of two wheelers in the adolescents. Thirty patients were evaluated of which 27 (90%) were males and 3 (10%) were females. Among the 27 male patients, 24 (88.8%) were having ACL tears and 3 (11.1%) were normal (Table 1) (Table 2).

Out of 30 knees examined clinically, 16 cases (53%) were on right side and 14 cases on (47%) left side. MRI showed, 13 patients had ACL tear on right side and 12 patients on

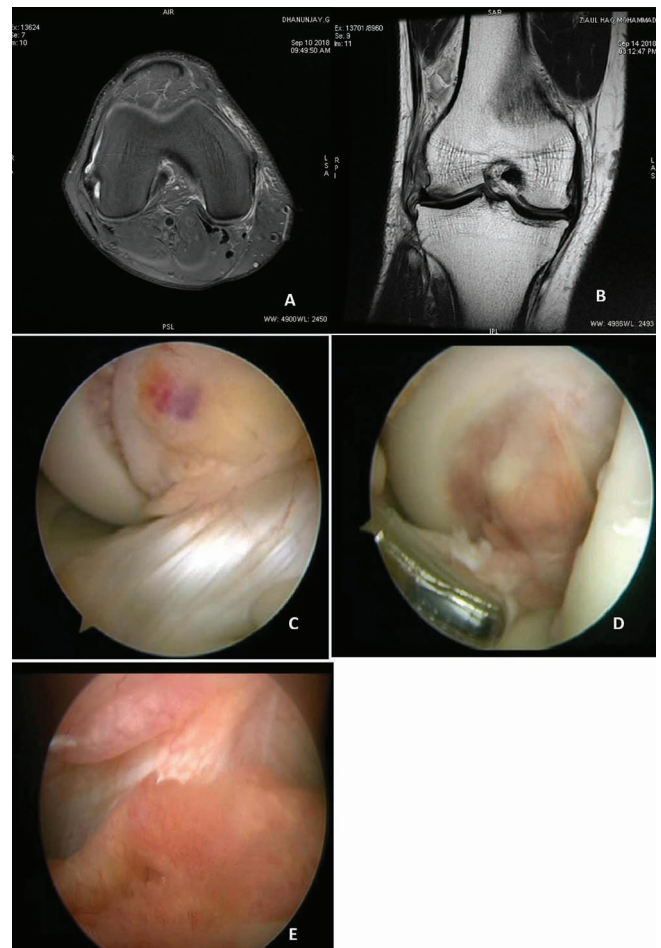


Figure-2: A. Axial T2 FS showing partial ACL tear at insertion. B. Coronal T2 partial tear. C. arthroscopy showing ACL tear. D. ACL tear at femoral attachment. E. arthroscopy showing partial ACL tear

MRI	Arthroscopy		Total
	Complete Tear	Normal	
Complete tear	8	0	8
Normal	0	3	3
Total	8	3	12
Sensitivity			100%
Specificity			100%
Positive predictive value			100%
Negative predictive value			100%
P < 0.0001			

Table-4: Comparison between MRI and arthroscopy for complete ACL tear

the left side. In our study, patients with right knee injury were comparatively most likely to have ACL tear (Table 3) (Figure 1).

30 patients underwent clinical examination for ACL tear. Both anterior drawer and Lachman test were done. By clinical examination 24 were classified as ACL tear and 6 as normal (Table 4) (Table 5). Among the 6 cases which were negative on clinical diagnosis 3 tested positive on MRI and arthroscopy as well. Structure studied, the equipment used

MRI	Arthroscopy		Total
	Partial tear	Normal	
Partial tear (I and II)	6	4	10
Normal	2	3	5
Total	8	7	15
Sensitivity			75%
Specificity			42.85%
Positive predictive value			60%
Negative predictive value			60%
P < 0.0001			
Table-5: Comparison between mri and arthroscopy for partial ACL tear			

(like coil magnet strength, imaging parameters, plane of image and surface coil), imaging protocols and experience of the evaluating radiologist play a crucial role in the imaging accuracy (Figure 2).

DISCUSSION

Thirty patients were evaluated of which 27 (90%) were males and 3 (10%) were females. Among the 27 male patients, 24 (88.8%) were having ACL tears and 3 (11.1%) were normal. There was only 1 positive case (33.3%) of the 3 females and the remaining 2 (66.6%) were normal ACLs. Male preponderance may be due to more outdoor activity, sports participation and more usage of vehicles.⁶ The females were comprising fewer number because most of them lead a sedentary life style. In a meta analysis by Ohi et al males had increased incidence of internal derangement of knee among which ACL was the most common one followed by medial meniscus.⁷

30 patients underwent clinical examination for ACL tear. Both anterior drawer and Lachman test were done. By clinical examination 24 were classified as ACL tear and 6 as normal. Among the 6 cases which were negative on clinical diagnosis 3 tested positive on MRI and arthroscopy as well. Structure studied, the equipment used (like coil magnet strength, imaging parameters, plane of image and surface coil), imaging protocols and experience of the evaluating radiologist play a crucial role in the imaging accuracy. In our study since we used 3 tesla MRI the chances of missing a tear on MRI was less likely even though it was normal on clinical examination, the reason to do MRI in such cases was the clinician suspecting any other ligament injury. The information given by the clinician to the radiologist also plays an important role in the accuracy according to Staniski et al.⁸ In our study different clinicians performed the clinical examination, however one orthopaedic surgeon performed all the arthroscopies. In our study arthroscopic preference was given to complete tears on MRI for repair followed by cases complaining of pain and disability followed by knee trauma even when MRI was only Grade-I.

On evaluation according to the site of tear, isolated mid-substance tear was noted in 11 patients accounting for 42% of the total cases. Isolated femoral (proximal) and tibial (distal) attachment tears were reported as 3 and 5 in numbers accounting for 12% and 19% respectively. In 7

arthroscopically confirmed tears the exact location of tear could not be identified as it seems to involve both mid-substance and femoral attachment. The results in our study are similar to the study by Remer et al and Resnick who reported 70% tears in mid-substance, 5-20% near femoral attachment and 3-10% at tibial attachment.^{9,10} Lakhar, Rajagopal and Rai et al studied 78 ACL tears and concluded that midsubstance was the most common tear location seen in 66.7% of patients.¹¹

In a study conducted by Vander list et al on 353 patients the tears were showing increased incidence in mid-substance (type-III) accounting for 52% of the total cases followed by femoral attachment tears which included proximal avulsion tear (type-I) and proximal tear (type-II) which accounted for 43% (16%+ 27%) and last tibial attachment tears including distal avulsion tear (type- V) and distal tear (type-IV) comprising the combined least percentage of 4% are similar to the results in our study as increased incidence in mid-substance tears (42%) followed by proximal and proximal + mid-substance tears (39%) and least are the tibial tears (19%).¹²

In our study complete tears were common in the mid-substance accounting for 5 of the total 8 complete tears followed by femoral end complete tears. Partial tears were seen in tibial end followed by femoral end.

Patients with trauma to the knee and pain in the knee were subjected to MRI knee joint for evaluation of ACL. Sagittal, axial and coronal sections of the knee were taken in slight external rotation. Tibial and mid-substance of ACL, alignment to femoral intercondylar line were evaluated using sagittal images. Femoral attachment of the ACL is better visualized in axial and coronal images. Oblique sagittal images are important in visualization of proximal and distal ends of ACL for avulsion tears i.e., type 1 and type 5 of Vanderlist e.¹²

STOLLER'S Grading of ACL tears^{13,14}

- **Grade I tears** - represent intra ligamentous injury/sprain without a change in ligament length.
- **Grade II tears** - represent intra ligamentous injury and an increase in ligament length.
- **Grade III tears** - represent complete ligamentous disruption.

Stoller Grade I and II tears were considered as partial tears and grade III tear as complete tear. Norwood and Cross described the ACL as having three distinct anatomical and functional bundles: posterolateral, anteromedial and intermediate.¹⁵ Each bundle contributes to knee function separately and can be torn separately which contribute to partial tears. These partial tears are important cause they can lead to chronic ACL insufficiency. Partial tears that were less than 1/4th of the diameter of the ligament had good prognosis compared to the partial tears that involved half to 3/4th. Thus partial tears can be classified as stable and unstable ligaments. Stable partial tears are treated conservatively and unstable partial tears are treated as complete tears. The sensitivity and specificity between MRI and arthroscopy for partial tears in our study were 75% and 42% which are close to the study conducted by Umans et al with sensitivity ranging from 42-

75% and specificity ranging from 62-89%.¹⁶

Complete tears are the full thickness tears showing end to end transection which are Stoller Grade-III. Our study showed 100% sensitivity and specificity and 100% positive and negative predictive values. The reason for not missing complete tears in our study might be due to better equipment and chances of missing a complete tear are less as it would rise a suspicion of absence full thickness ACL fibres in any of the section when trying to follow it from origin to insertion. The most accurate and reliable sign of an ACL tear was the discontinuity of the ACL in both sagittal and axial planes. MRI has high accuracy for patients with complete ACL rupture according to Ahmad et al.¹⁷

A study by Khanda et al on 50 patients also showed the sensitivity of 86.67% for MRI in detecting ACL tears whereas our study has sensitivity values as high as 91.3%¹⁸. Our results showed that MRI had sensitivity and specificity of 91.33% and 42.71%. Similarly, the positive predictive value and negative predictive value are 84% and 60% respectively. Khan et al concluded that MR had 100% sensitivity and NPV of 70% of diagnosing ACL tears in their study, which was higher than our findings. Clinical examination had sensitivity of 88% and NPV 75% in diagnosing ACL injuries. Our study showed clinical examination and arthroscopy sensitivity and specificity values to be 80% and 50% respectively. The sensitivity values were closer compared to the specificity.

Almost all of the studies discussed above yield almost similar sensitivity and higher specificity to our study in that we are in favor of conducting MRI for diagnostic purposes. While arthroscopy should be restricted for therapeutic purpose, MRI is non-invasive and cost-effective compared to arthroscopy and should always be considered as an option of choice for diagnosing ACL injuries.

In a study conducted by Hristijan et al, on 103 patients 73 patients had arthroscopically proven ACL tears.¹⁹ The specificity and sensitivity of MRI with arthroscopy were 83% and 88% respectively with positive and negative predictive values being 93 and 74.5 which are pretty close to our study. The patients in this study also showed male preponderance and increased incidence in right knee joint similar to our study. The age group included in their study was 16-59 years and our study age group was 18-50 years. The youngest individual was 16 years in their study and 18 years in our study.

Rubin et al, reported 93% sensitivity for diagnosing isolated ACL tears.²⁰ Similarly several prospective studies have shown a sensitivity of 92-100% and specificity of 93-100% for the MR imaging diagnosis of ACL tears.

The results of this study are in accordance to the literature which suggests PPV of MRI is 93% NPV of MRI is 74.5% however our study the PPV was nearly good with and NPV was significantly less which indicates good reliability in not missing a case on MRI which was normal in clinical examination.

All arthroscopies were performed by single orthopaedic surgeon, with experience in knee arthroscopy. At arthroscopy, each bundle was classified as normal, partially torn, or completely torn. Our study also showed decreased sensitivity

and specificity values for partial tears on MRI when compared to the complete tears cause sometimes fibrillations on the surface of the ACL appear as increased signal on MRI which appear normal on arthroscopy without obvious tear. MRI sensitivity and specificity of partial tears is much less than for complete counterparts and near or below the 50th percentile Chronic ACL tears more than 6 months old lack hemorrhage and edema seen with acute tears and can show low signal intensity throughout. So ACL lacking the normal slope on sagittal plane should raise the suspicion for chronic ACL tear. Few cases in our study were presented late leading to decreased sensitivity and specificity for partial tears on MRI. In a study conducted by Omkar P Kulkarni et al on 100 patients suspected to have traumatic ACL injuries, majority of the patients were positive for ACL tears on both MRI and arthroscopy with little discrepancy between partial tears 62. The sensitivity, specificity, PPV and NPV of that study were 90%, 78%, 90% and 72% which were close to our study.

In this study also medial meniscus was the highest associated injury just like our study. In a study conducted by Stanitski et al on 28 patients, analysis was done as three categories.²¹ A bias in our study is that clinical evaluation data were obtained by different orthopaedic surgeon and MRI assessments were done by several radiologist with different expertise. In our study isolated primary signs were seen in 4 (15%) patients majority being complete non visualization of ACL, isolated secondary signs were seen in 5 (19%) patients majority being buckling of PCL and anterior tibial translation. Both primary and secondary signs were seen in 17 individuals accounting for 66%. The most common sign seen in our study is high signal intensity of the ACL seen in 18 patients of the 25 ACL tears on MRI. was close to BN Lakhar, KV Rajagopal and P. Rai et al study conducted on 173 patients of which 78 showed ACL tears, hyperintensity was the most common sign seen in 52 (67%) patients.²² Acute injuries of ACL often show high signal on fluid sensitive sequences which is due to both edema and haemorrhage, our study showed increased signal as the most common feature on MRI when compared to other primary and secondary signs.

Lesions such as high signal in the subchondral bone on fluid sensitive imaging located at the antero-inferior lateral femoral condyle and the postero-lateral tibial plateau due to translational bony impaction of these 2 surfaces at the time of ACL disruption are pathognomonic for ACL rupture. Haemarthrosis is present 100% of the time which is a indication of injury to the knee joint and was seen in 90% of our cases.

In interpretation of MRI, radiologist's experience and training are very important factors. Regarding knee MRI, in most of the studies and in our study as well, the base of reference is arthroscopy in current clinical practice arthroscopy is a technically demanding procedure and the results depend upon surgeon's experience, especially in difficult cases. MRI is the most useful diagnostic technique. The reported accuracy for detecting tears of the ACL has ranged from 70-100%.

CONCLUSION

In this study male patient was three times more likely to have ACL injury compared to the females. Mid-substance

tears were more common in individuals less than 35 years and proximal tears were seen more in individuals more than 35 years. The most common ligament injured in our study is medial meniscus followed by lateral meniscus. Pre-arthroscopic MRI helped in the planning of surgery in our study. The most common Primary signs seen in our study is T2 hyperintense signal involving the ACL. We conclude that 3T MRI highly diagnostic for complete ACL tears with good arthroscopic correlation and is therefore the best imaging modality of choice for the evaluation of ACL and its associated injuries in the backdrop of trauma and thus playing a crucial role in the planning of surgery.

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Source of Support: Nil; **Conflict of Interest:** None

Submitted: 21-02-2019; **Accepted:** 16-03-2019; **Published online:** 20-10-2019