Correlation between findings on stress X-rays (Telos) and MRI in patients with anterior knee instability

**Poster No.:** C-1687  
**Congress:** ECR 2014  
**Type:** Scientific Exhibit  
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**Keywords:** Musculoskeletal soft tissue, MR, Conventional radiography, Comparative studies, Trauma  
**DOI:** 10.1594/ecr2014/C-1687

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Aims and objectives

To correlate the findings on stress X-rays (Telos) with those on MRI in patients with anterior knee instability and suspected anterior cruciate ligament (ACL) lesions; to evaluate possible discrepancies between the two techniques.
Methods and materials

We reviewed the findings on stress X-ray and MRI examinations in 103 patients with anterior knee instability examined in 2010 and 2012.

The ACL is the main anterior stabilizer of the knee (Figure 1). It is an intra-articular and extrasynovial ligament. The ACL is attached to the posterior part of the medial surface of the lateral femoral condyle and to the anterior intercondylar area of the tibia, anterolateral with respect to the anterior intercondylar eminence. We can distinguish three bundles with different functions: the anteromedial bundle, the intermediate bundle, and the posterolateral bundle.

The most common site of ACL tears is the middle third. Nevertheless, partial tears are more common in the anteromedial bundle.

ACL tears are often associated with injuries to the medial collateral ligament, meniscus, and articular capsule, as well as with bone contusion and avulsion fractures.

There are diverse mechanisms of ACL injury: one common mechanism consists of forced hyperextension and mild flexion in association with internal and varus rotation. Another common mechanism is valgus flexion and external rotation of the tibia / internal rotation of the femur with the foot planted on the ground (Figure 2).

ACL injuries should be diagnosed early. Many maneuvers and dynamic tests are used in physical examinations to detect and reproduce the typical, pathognomic "pop" caused by the pathologic anterior displacement of the tibia: Anterior drawer test, Lachman test, "Pivot shift test", etc. (Figure 3).

It is essential to examine the knee systematically and to compare it with the uninjured contralateral knee.

When an ACL lesion is suspected, MRI is the modality of choice to confirm clinical suspicion and evaluate associated lesions. Nevertheless, especially in cases of chronic instability, stress X-rays are a fast and easily performed complementary test with proven efficacy.

The technique for stress X-ray examinations, also known as Telos, of the knee consists of acquiring two lateral X-ray images, one with the knee at rest and the other while applying an anterior force over the musculature of the calf while fixing the femur and ankle (Figure 4). The knee should be extended or slightly flexed (<20°). Variable force can be applied.
In our center, we apply forces ranging from 18 kp to 26 kp, depending on the patient's age, weight, height, etc. (Figure 5).

The anterior displacement of the tibia with respect to the femur is compared between the images acquired at rest and those acquired when the force was being applied. We trace a line parallel to the surface of the joint and then a perpendicular straight line between the femoral condyles and another between the two tibial condyles. Finally, we measure the distance between these two lines.

The reference values are:

- displacement < 5 mm is considered normal (Figure 6)
- displacement between 5 mm and 10 mm is considered laxity of the ACL (Figure 7)
- displacement > 10 mm is considered rupture of the ACL (Figure 8)

It is important to remember that physiologic laxity varies among subjects, so it is essential to compare the injured knee with the healthy knee.

MRI is the most reliable imaging test to study the morphology of the knee. In our center, the MRI protocol for knee examinations comprises coronal STIR and T1-weighted sequences, sagittal and coronal proton density and T2-weighted turbo spin echo sequences, and axial T2-weighted gradient echo sequences.

The ACL is seen as a set of low-signal bundles that fan out distally, where adipose tissue fills the spaces between them (Figure 9).

ACL lesions can present as:

- complete tears (interruption, horizontal disposition of bundles, or impossibility to distinguish the bundles)
- partial tears (partial interruptions or thinning)
- intrinsic lesions (edema of the fibers, hazy appearance, loss of parallelism among bundles)

Indirect signs on MRI can also help us diagnose ACL tears: significant anterior displacement of the tibia, increased angulation/curvature of the PCL, or dorsal displacement of the lateral meniscus beyond the dorsal limit of the tibial epiphysis.

Acute injuries to the ACL often occur together with other lesions: foci of subchondral bone lesions in the middle portion of the lateral femoral condyle and/or in the dorsolateral
segment of the tibial epiphysis, fractures - bone avulsions, medial collateral ligament injury, meniscal lesions … (Figure 10). The patellar tendon can also have increased signal intensity in some cases, most often in its tibial portion.

Chronic partial tears of the ACL are sometimes difficult to diagnose by MRI because no edema is seen. In some cases, scar tissue can simulate an intact ligament (Figure 11).
Fig. 1: Anatomy of the knee.

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Fig. 2: ACL injury mechanism. The forced hyperextension can injure the ACL (and the external ligaments).

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Fig. 3: Physical examination: anterior and posterior drawer tests. If the anterior drawer test is positive, we have to think about an ACL tear. If the posterior drawer test is positive, we have to think it could be a rupture of the PCL.

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Fig. 4: Telos exam. Patient position during the exam. The leg should be extended or slightly flexed (<20°). In first time we take a radiography in stress and then another applying a force.

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**Fig. 5:** Telos. Right: rest radiography. Left: radiography applying an anterior force of 25kp.

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Fig. 6: Normal Telos. Anterior displacement of the tibia < 5mm.

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Fig. 7: Ligamentous laxity. Anterior displacement of the tibia between 5 and 10mm.

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Fig. 8: Ligamentous tear. Anterior displacement of the tibia >10mm.

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Fig. 9: MRI. Standardized knee study. A- axial T2-weighted gradient echo sequence, B and C: sagittal and coronal proton density sequences, D- coronal STIR sequence.

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Fig. 10: 25 year-old patient with a history of trauma that presents a partial tear of the ACL of the left knee. The MRI shows joint effusion and bone contusion at both femoral condyles, predominantly in the medial condyle.

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Fig. 11: Chronic partial tear of the ACL. T2 sagittal DP shows a hypointense heterogeneous structure corresponding to a chronic ACL rupture.

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Results

We reviewed the stress X-ray, MRI, and surgical findings in the 103 patients with clinical instability included in our study.

Stress X-ray findings were normal in 21 cases and pathological in 82 (23 laxity and 59 tears). MRI findings were normal in 22 cases and pathological in 81 (17 partial tears and 64 complete tears).

We correlated the findings on the two imaging tests and elaborated a table to show where they were concordant and where they were discordant.

Analyzing the results, dividing the findings into normal, partial tear, and complete tear (Figure 12, Table 1), we see that:

- Of all the patients with normal findings on MRI (n=21), 15 had normal stress X-ray findings, 3 had laxity, and 4 had tears. Thus, in this group the findings from the two imaging tests were concordant in 68%.
- Of all the patients with MRI findings of partial ACL tear (n=17), 8 had stress X-ray findings indicative of laxity, 5 had normal findings, and 4 had findings indicative of a complete tear. Thus, in this group, the findings from the two imaging tests were concordant in 47%.
- Of all the patients with MRI findings of complete ACL tear (n=64), 51 had stress X-ray findings indicative of complete tear, 12 had stress X-ray findings indicative of laxity, and 1 had normal findings. Thus, in this group, the findings from the two imaging tests were concordant in 80%.

If we group the results into normal vs. pathological findings (Figure 12, Table 2), we see that:

- Of all the patients with normal findings on MRI (n=21), 15 had normal findings and 7 had pathological findings on stress X-rays, yielding 68% concordance.
- Of all the patients with pathological findings (partial or complete tear) on MRI (n= 81), 75 had pathological findings and 6 had normal findings on stress X-rays, yielding 92% concordance for tears.

In patients with ACL grafts (n=17), the correlation between the two imaging tests was better than in those who had not been operated on (Figure 13).
In those with normal MRI findings (n=7), stress X-ray findings were normal in 5, indicative of laxity in 1, and indicative of rupture in 1.

In those with MRI findings of partial tear (n=4), stress X-ray findings were normal in 2, indicative of laxity in 1, and indicative of rupture in 1.

In those with MRI findings of complete tear (n=5), all 5 had stress X-ray findings indicative of rupture.

Thus, the concordance was 71% for normal findings, 50% for partial tears, and 100% for complete tears.

If we group the results into normal vs. pathological findings, we see that 7 of the 17 patients had normal MRI findings and 5 of these had normal stress X-ray findings and 2 had pathological stress X-ray findings. We also see that all of the 10 patients with pathological findings on MRI also had pathological findings on stress X-rays.

We analyzed all these results in an SPSS table, applying the chi-square test and Cohen's kappa coefficient (which eliminates randomness).

- In the entire group, when we separated the findings into normal, partial tear, and complete tear, the kappa coefficient was 0.51, representing moderate concordance between the two imaging tests. When we classified the findings as normal or pathological, the kappa was 0.61, representing good concordance between the two imaging tests.

- In the group of patients with ACL grafts (n=17), when we separated the findings into normal, partial tear, and complete tear, the kappa coefficient was 0.46, representing moderate concordance between the two imaging tests. When we classified the findings as normal or pathological, the kappa was 0.71, representing very good concordance between the two imaging tests.

We also analyzed the data to determine the sensitivity and specificity of stress X-rays in relation to MRI.

Sensitivity is the percentage of patients with tears correctly classified as having tears; in other words, it represents the probability that a patient that has a tear will have positive result on the imaging test. Sensitivity is thus the test's ability to detect a tear.

Specificity is the percentage of patients without tears correctly classified as not having tears; in other words, it represents the probability that a patient without a tear will have a negative result on the imaging test. Specificity is thus the test's ability to detect the absence of a tear.
Sensitivity = True positives / (True positives + False negatives) = 75 / (75 + 7) = 92%

Specificity = True negatives / (True negatives + False positives) = 15 / (15 + 7) = 68%

Predictive values can also be extrapolated from our data. The positive predictive value (PPV) is the proportion of true positives, in other words, the proportion of patients with tears correctly identified as having tears. The negative predictive value (NPV) is the proportion of true negatives, in other words, the proportion of patients without tears correctly identified as not having tears.

PPV = True positives / (True positives + False positives) = 75 / (75 + 7) = 91.4%

NPV = True negatives / (True negatives + False negatives) = 15 / (15 + 6) = 71.4%

Against a gold standard of MRI findings, stress X-rays had a sensitivity of up to 92% and a specificity of 68%, with a PPV of 91.4% and an NPV of 71.4%.

In patients with ACL grafts, the sensitivity was 100% and the specificity was 71.4%. The PPV was 83% and the NPV was 100%.

Of the 103 patients, 82 were men and 21 were women (Figure 14). The kappa coefficient for the men was 0.62. The kappa coefficient for the women was 0.58, but in this case the value of p was greater than 0.05, so the concordance was not statistically significant. Nevertheless, the failure to reach significance is probably related to the small sample size (n=21), and increasing the sample size would probably result in a statistically significant concordance as was found in the group of men.

The sensitivity of stress X-rays was 88% in the women and 93% in the men. The specificity was 75% in the women and 66% in the men. The PPV was 93% in women and 91% in the men. The NPV was 60% in the women and 75% in the men.

To analyze the results in function of patients' ages, we classified patients into those younger than 35 years old and those older than 35 (Figure 15); 57 were younger than 35 and 46 were older than 35. The kappa coefficient was 0.88 in those younger than 35 and 0.32 in those older than 35. The sensitivity was 97% in those younger than 35 and 85% in those older than 35. The specificity was 91% in those younger than 35 and 45% in those older than 35. The PPV was 98% in those younger than 35 and 83% in those older than 35. The NPV was 91% in those younger than 35 and only 50% in those older than 35.
We observed that multiple factors affect the results; some of these are related to the observer, some to the equipment, and others to the patient:

- Interobserver differences in diagnosis

- Anomalies in the calibration of the stress X-ray apparatus for exact reproducibility

- Variation in the angulation and rotation of the knee when acquiring stress X-rays

- Similar velocity and vector in applying stress

- Appropriate muscle relaxation: various studies have shown that anesthesia increases the difference in the displacement of the two knees

- Variability in the physical conditions of patients that compensate for the instability of the knee despite ACL tears (quadriceps strength).

In some patients, even when the ACL is completely torn, the rest of the structures of the knee can compensate, so the instability of the knee will not be evident and stress X-ray findings will be normal but MRI will show a partial or complete tear of the ACL.

- Time from injury to examination: a posttraumatic contraction reflex can be present in acute lesions; patients with chronic instability can have greater laxity.

- In postsurgical patients, metal artifacts can cause distort the findings and hinder the correct assessment of the graft.

- In patients with ACL grafts, despite the good concordance between stress X-rays and MRI found in our study and the good sensitivity and specificity of stress X-rays, it is essential to obtain a baseline postoperative study with which to compare the degree of instability with respect to the residual (figure 16).

- Although the sensitivity of stress X-rays is very good, the specificity is not as good—nearly 30% of patients with partial or complete ACL tears will have normal findings on stress X-rays.
Fig. 12: Results in all patients.

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**Fig. 13:** Results in operated patients.

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Table 1

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Table 2
**Fig. 14:** Results in men and women.

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**Fig. 15:** Results en patients younger than 35 and older than 35.

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**Fig. 16:** Graft rupture. Correlation between Telos and MRI. In the stress Telos there’s a displacement of the tibia of 13mm. MRI shows an irregular thinning of the graft that suggests it is broken.

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Conclusion

In patients with anterior knee instability, we found good concordance between the findings on MRI and stress X-rays. In patients with ACL grafts, the concordance between the two imaging tests is better, and the sensitivity and specificity of stress X-rays increases. Likewise, in patients under 35 years of age, the sensitivity and specificity are higher (97% and 91%, respectively).

Thus, we conclude that stress X-ray examination is a good test to detect ACL lesions, especially in younger patients. However, although the concordance between the two tests is good in suspected ACL injuries, stress X-rays alone are not sufficient for screening because they are not specific enough.

Various factors can influence the results of stress X-rays.
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