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CORR Insights

CORR Insights®: T1ρ Hip Cartilage Mapping in Assessing Patients With Cam Morphology: How Can We Optimize the Regions of Interest?

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Where Are We Now?

In their study, Anwander and colleagues address the optimization of regions of interest (ROIs) used during advanced parametric cartilage mapping in a prospective cohort of patients diagnosed with cam-type femoroacetabular impingement (FAI). The authors examine this challenging topic by applying three different segmentation strategies: (1) Determining the mean T1ρ value of the entire hip cartilage, (2) assessing all 36 to 54 ROIs individually, and (3) defining the six large ROIs. They conclude that partitioning the cartilage into six moderately-sized regions results in high inter/intraobserver reliability, while also maintaining the ability to detect regional variations in relaxation times versus methods employing a single large ROI or 36 to 54 small ROIs.

The utility of parametric mapping as a biomarker for early chondral-matrix depletion has been established, with multiple techniques of varying clinical feasibility currently available and/or in development [4, 5, 7]. T1ρ provides good sensitivity for changes in chondral proteoglycan content with a reasonable scan time and without the administration of intravenous contrast. It is a particularly promising technique for detecting early chondral-matrix depletion in the clinical setting before those changes become evident on standard MRI sequences [7, 12]. The identification of at-risk cartilage may allow for timely intervention aimed at joint preservation [11].

Where Do We Need To Go?

While we can confirm the efficacy of T1ρ in detecting early chondral wear, consensus regarding the ideal parameters of image acquisition and analysis has not been achieved. Challenges inherent both in the technical aspects of image acquisition and feasibility of segmentation strategies contribute to this problem, as does the fact that expected regional variance of relaxation times varies depending upon the underlying primary pathology. The underlying primary pathology is not always clear, making a universally applicable segmentation strategy difficult to develop [1, 2, 13].

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In formulating a practical approach to parametric mapping, technical parameters of image acquisition must be balanced such that high image quality is achieved within a clinically reasonable scan time. Because T1ρ requires the acquisition of images at multiple spin-lock times, it tends to result in longer overall scan times. Therefore, image optimization, such as can be achieved by increasing spatial resolution or acquiring a greater number of echoes, can become difficult, as scan times become prohibitive [10]. Ideally, images would possess sufficient spatial resolution to allow individual segmentation of both the deep and superficial layers of the femoral and acetabular articular cartilage, as proteoglycan content is known to vary in a predictable way by layer in normal articular cartilage, and early wear often occurs in a fashion that affects this normal stratification [6, 9]. For example, early chondral wear in patients with cam-type FAI often affects the basilar layer of acetabular cartilage focally along the chondrolabral junction because of forces transmitted to this region via the labrum [2]. The ability to resolve and isolate this focal chondral region would theoretically provide superior sensitivity for early chondral wear in patients with cam-type FAI. Incorporating this area as part of a larger ROI may dilute the effects of focal changes in this small region, potentially decreasing sensitivity when evaluating changes in mean relaxation times. Resolving the deep and superficial chondral layers on T1ρ images of the hip, however, is particularly challenging given the relative thinness of the cartilage at this articulation, as compared to joints such as the knee.

The ideal configuration of ROIs is dependent upon multiple factors. As alluded to above, the quality of the images largely determines the extent to which the articular cartilage can be subdivided and segmented, and consideration of the specific pathology of interest is important in localizing ROIs in order to best encompass expected patterns of chondral wear. The size and number of ROIs is also an important consideration, in that segmenting numerous small areas may result in an unwieldy dataset that is overly sensitive to variability within each ROI. At the same time, segmenting large areas can result in decreased ability to detect focal pathologic changes.

For these reasons, striking a balance in terms of image acquisition and ROI configuration is challenging, and requires the consideration of various factors that often are at odds with one another. Going forward, technical advances may facilitate acquisition of higher resolution images while maintaining a reasonable scan time. Further investigations will likely lead to a firmer understanding of the best size, number, and location of ROIs for various specific pathologic processes. Additionally, novel methods of analysis, such as texture mapping, may contribute an additional and more-sophisticated approach to interpreting the information contained within each ROI.

How Do We Get There?

In order to address the remaining challenges inherent in fully developing T1ρ for routine clinical use, progress is desirable on multiple fronts. Technical advances in MRI occur at a rapid pace, driven by a combination of academics, industry, and clinical need; acceleration techniques are currently being applied to the T1ρ sequence in order to accomplish reduced scan time with preservation of image quality [10, 14]. Determination of targeted ROIs for evaluation of specific pathologic processes continues to progress, including the current study by Anwander and colleagues.

Registries provide a robust source of information, commonly amassing a large amount of data in a large number of subjects. In addition to facilitating optimization of ROIs, appropriate registry data may serve as a strong foundation for prospective studies investigating the utility of parametric

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mapping. Parametric mapping could potentially be used as an advanced tool for diagnosis, monitoring, and prediction of outcomes in patients with FAI, as well as a variety of other conditions [3].

Advanced analysis of ROIs utilizing texture mapping is a relatively new concept when applied to quantitative analysis of articular cartilage. While conventional analysis of parametric maps generates a mean relaxation time and standard deviation for each analyzed ROI, texture mapping can provide a more-detailed description of internal variability within a given ROI, providing insight into the degree of tissue disorganization. Tissue disorganization is a feature of early chondral wear, which may not necessarily manifest as overt changes in mean relaxation time [8]. Given that this technique does not require dedicated special image acquisition, and can be used with pre-existing parametric maps or even routine clinical images, further investigation into this method of analysis may be performed on a prospective or retrospective basis.

Advanced imaging techniques like T1ρ and parametric cartilage mapping require thoughtful and precise implementation in order to yield clinically useful information. Certain challenges remain in terms of fully optimizing these techniques for routine clinical use. Still, ongoing investigations continue to result in advances that increase the scope, utility, and feasibility of T1ρ and parametric cartilage mapping, making these sequences a promising noninvasive means for the advanced detection of early chondral wear.

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