Detection application helps diagnose knee injuries

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A computer-aided detection system uses sagittal proton-density-weighted magnetic resonance images to detect meniscal tears in the knee.

In the next decade, computer-aided detection (CAD) applications for various diagnostic tasks will be developed and then implemented in clinical environments. To date, the majority of CAD applications focus on a limited number of important oncology tasks, mostly related to lung, breast, and colon cancers. Opportunities exist to expand the scope of CAD applications for organ systems and pathologies previously ignored by the image processing community. For example, new CAD applications for advanced musculoskeletal imaging could improve the accuracy and efficiency of human observers, potentially leading to improved patient care. An area of particular interest is orthopedic imaging for the knee.

Injuries of the knee, including meniscal tears, are common in young athletes and older adults; such injuries require accurate diagnosis and, if appropriate, surgical intervention. However, diagnosis of meniscal tears can be challenging for radiologists and physicians who do not have relevant musculoskeletal training. To solve this problem, we designed a CAD application for automatic detection of meniscal tears of the knee.

The arrangement of meniscal fibers is complex. Bands of fibers running in different directions offer maximum resistance to tension and support for relatively heavy body weight (see Figure 1). When meniscal fibers are torn, the support mechanism breaks down, and stability of the internal knee is affected. Without treatment, tears tend to worsen rather than heal.

Meniscal tears and other internal derangements of the knee are commonly diagnosed with the aid of magnetic resonance (MR) imaging. A meniscal tear is detected when the normal shape of a meniscus is disrupted by an abnormal signal, or when part of the meniscus is missing. Specifically, an MR image of a normal meniscus has black triangles of uniform signal. When the meniscus is torn, the triangular shapes are disrupted. Challenges in diagnosing meniscal pathology include differentiating tears from internal degenerative changes, and characterizing tears within the body of the meniscus from those that reach the boundary. In the latter case, surgery may be necessary.

Our CAD system uses sagittal proton-density-weighted or T1-weighted MR images of the knee (see Figure 2). Detection of meniscal tears is performed in three stages, as shown in Figure 3. The first stage involves selection of a region of interest (ROI) and slice. The second stage involves binarization and enforcement of area and shape constraints. The third stage involves scoring the slices for potential tears using two new metrics—breakability and degeneracy—to estimate the probability of linear and degenerative tears, respectively. At the end of the third stage, the system generates a recommendation regarding the torn or normal state of the meniscus.

Continued on next page
Figure 2. Sagittal T1-weighted magnetic resonance image of the knee. Notice the black triangles of the meniscus.

Figure 3. Flowchart of the computer-aided detection system for diagnosing meniscal tears of the knee.

A snapshot of the graphical user interface (GUI) for the CAD system is shown in Figure 4. After a radiologist uses the GUI to select a patient of interest, the system loads standardized DICOM images for analysis. (DICOM stands for ‘Digital Imaging and Communications in Medicine.’) The ROI and lateral and medial compartments of the knee are determined automatically. After analysis, pseudo-color maps are displayed for the extracted meniscus, as well as diagnostic information regarding the presence of a tear for each compartment of the knee. Processing takes less than 30s. The radiologist can make his or her diagnosis with the aid of the CAD recommendation.

To evaluate the CAD system, we obtained 40 retrospective cases with approval from the Institutional Review Board of the University of Maryland. The system detected tears with good sensitivity (83.87%) and specificity (75.19%). We compared these results to the diagnostic decisions made by two board-certified musculoskeletal radiologists who evaluated the same 40 cases. The CAD system compared favorably to the radiologists whose average sensitivity and specificity was 77.41% and 81.39%, respectively. The relative success of our application suggests interesting possibilities for increasing radiologists’ productivity and confidence. Additionally, the use of more sophisticated CAD algorithms for orthopedic imaging tasks could improve patient outcomes.

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