Rapidly Progressive Osteoarthritis: Biomechanical Considerations

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• Osteoarthritis • Knee malalignment • Meniscal dysfunction
• Osteochondral unit injury

The American College of Rheumatology defines osteoarthritis (OA) as a heterogeneous group of conditions that leads to joint signs and symptoms that are associated with defective integrity of articular cartilage, and associated changes in the underlying bone and at the joint margins.[1] Although OA is a multifactorial disease process, early cartilage damage and ultimate loss of articular cartilage is a central feature and a significant contributor to clinical symptoms. The rate of progression of tissue damage and clinical symptoms can vary substantially between patients. A clinical challenge in managing patients with OA is differentiating individuals at risk for rapidly progressive disease. A potential role of imaging is identification of specific biomarkers that are prognostic of rapid OA progression. In clinical care such indicators could guide lifestyle changes or treatment recommendations in select patients at greatest risk for rapid onset of OA. In research, identifying subjects likely to have rapid OA progression would provide more efficient clinical trials by shortening the observation period or allowing for a smaller sample size.

It is difficult to identify specific features predictive of OA progression using radiographic methods. A systematic review of 1004 studies conducted prior to 2003 identified 37 studies meeting the inclusion criteria for quality and suggests that knee pain, radiologic severity at baseline, sex, quadriceps strength, knee injury, and regular sport activities are not related to OA progression.[2] For other factors, the evidence was limited or conflicting. The more recent use of magnetic resonance (MR) imaging in clinical studies of OA has the potential to provide additional imaging biomarkers that may be better predictors of OA progression. In a cohort of 43 subjects, Biswal and colleagues[3] found that anterior cruciate and meniscal tears along with focal chondral lesions in the central weight-bearing zones were predictive of more rapid OA progression. A recent report from the Multi-center Osteoarthritis Trial (MOST trial) identified high body mass index (BMI), meniscal damage, meniscal extrusion, and any high-grade MR imaging feature defined as a Whole-Organ Magnetic Resonance Imaging Score (WORMS) score of 2 or more as baseline risk factors for fast cartilage loss over a 30-month period.[4] However; because these features were present in both slow and rapid progressors, they did not predict the rate of OA

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progression. Further study is needed to determine whether combination of imaging biomarkers or greater refinement of potential biomarkers will improve differentiation of those individuals who are likely to have rapidly progressive OA.

An underlying hypothesis for rapid cartilage loss in patients with OA is that perturbation from normal joint mechanics produces locally high biomechanical strains that exceed the material properties of the tissue, leading to rapid destruction. Several imaging findings are associated with focally high biomechanical forces and thus are potential candidates for predictive biomarkers of rapid OA progression. In this article, the authors focus on 3 aspects of knee biomechanics that have potential MR imaging correlates, and which may serve as prognostic biomarkers: knee malalignment, meniscal dysfunction, and injury of the osteochondral unit.

KNEE MALALIGNMENT

The causes of varus and valgus malalignment are multifactorial, and can lead to an imbalance in loading of knee articular cartilage. Local factors within the joint, such as loss of joint congruence through bone and cartilage injury, anterior cruciate ligament disruption, and meniscal degeneration and extrusion, play a role in determining alignment.[5] Other causes of acquired varus and valgus malalignment include osseous remodeling, osteophytes, and ligament and capsular damage resulting from chronic repetitive microtrauma and tissue remodeling.[6] Prior surgical procedures including osteotomy, meniscectomy, and meniscal debridement may also affect knee alignment.[7,8] Childhood malalignment has been proposed to have a high association with OA. In a natural history study by Schouten and colleagues,[9] patients with childhood varus or valgus malalignment had a fivefold increase in risk of OA. Deviation from neutral alignment at the hip, knee, or ankle will also affect load distribution at the knee.[10]

As illustrated in **Fig. 1**, static assessment of knee alignment can be made using the mechanical axis determined from full-length standing views of the lower extremities. The mechanical axis of the lower extremity is represented on radiographs by a line drawn from the center of the femoral head to the center of the talus. Mechanical axis deviation is measured by a perpendicular line drawn from the center of the knee to the mechanical axis on the anteroposterior radiograph. In a neutrally aligned limb, the mechanical axis passes just medial to the midpoint of the knee between the tibial spines. In a varus knee, the mechanical axis deviates medially, increasing the load on the medial

Fig. 1. (*A*) Medial compartment OA with medial deviation of the mechanical axis (*solid line*) and approximately 12° of varus malalignment of the knee (*dashed line*). (*B*) Lateral compartment OA with lateral deviation of the mechanical axis (*solid line*) and approximately 15° of valgus alignment (*dashed line*).

compartment. When the mechanical load-bearing axis passes lateral to the tibial spines, a valgus knee increases stress on the lateral compartment.

Knee alignment in the frontal plane is based on the relative angle between the mechanical axis of the femur and tibia. The mechanical axis of the femur passes from mid femoral head to center of the intracondylar notch. The mechanical axis of the tibia extends from the tibial spines to the mid talus. Measurement of knee alignment with the mechanical axis has been criticized for pelvic radiation exposure, higher cost, and the need for specialized equipment. A study by Kraus and colleagues[11] demonstrated a high correlation between the data obtained from full-limb measures of the mechanical axis and short-film measurements using the anatomic axis of the distal femur and proximal tibia. In the tibia, the mechanical and anatomic axes are the same, but they differ in the femur where the anatomic axis is defined by the line that bisects the distal femoral diaphysis. In this study, the anatomic axis measurement was offset a mean 4.2° valgus from the mechanical axis measurement (3.5° in women and 6.4° in men).