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The International Skeletal Society

Musculoskeletal Imaging[1]

In common with other subdisciplines in radiology, musculoskeletal imaging has been affected dramatically by the profound technologic developments that have taken place during the past 2 decades. As examples, although computed tomography (CT) and magnetic resonance (MR) imaging were initially applied to clinical problems other than those that affect the musculoskeletal system, both methods now are used by many on a daily basis to investigate disorders of bones, joints, and soft tissues. They provide information that, until now, was considered impossible to gather in a noninvasive fashion, and, further, they hold great promise for future endeavors related to clinical practice, as well as to research. The opportunities are endless and truly exciting, but with these opportunities has come a challenge. Compared with routine radiography, the images generated with MR imaging and to some extent CT scanning are far more numerous, the planes of section are highly variable, the displays are affected dramatically by the precise imaging parameters that are chosen, and the need to know regional anatomy has never been greater.

Historical Aspects

Routine radiography of the skeleton began shortly after the discovery of the x-ray more than 100 years ago. Worldwide, routine radiography of the skeleton remains one of the most commonly performed procedures and, indeed, in some countries that lack the necessary resources, routine radiography remains the only means by which most disorders of the skeleton are studied. Whereas conventional radiography is excellent as a method to investigate morphologic changes in bones, radionuclide techniques, which were introduced later, provided information regarding the metabolic function of the skeleton. Subsequently, with the introduction and refinement of ultrasonography (US), the morphology not only of the skeleton but also of the soft tissues was investigated. Indeed, US now enjoys great popularity in certain parts of the world (less so in the United States) as a method that can be used effectively to determine the presence and nature of an abnormality located in those parts of the musculoskeletal system that are accessible to a probe placed on the surface of the body. With the later development of CT scanning and MR imaging came the ability to study normal and abnormal tissues with improved contrast resolution and with sectional displays. An initial pessimistic view that MR imaging would not be valuable in the assessment of osseous abnormalities soon disappeared as the unique signal intensity characteristics of marrow were recognized, allowing early identification of a number of disorders that would replace, displace, or infiltrate this tissue. Subsequently, the unmatched diagnostic capabilities of MR imaging when used to study soft tissues and, especially, intra- and periarticular structures became apparent, such that this method now is regarded by many as an indispensable aid in determining the precise cause of dysfunction of virtually any human joint.

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[2]** Entire organ system or region.

See also the article by Kaye (pp 563–564) in this issue.

Current Status

Advances in recent years have been no less dramatic, based in large part on the further nurturing of the marriage of diagnostic imaging and computer technology, a union that currently is rock solid. Digital radiography enables accurate and direct assessment of precise trabecular architecture and, indirectly, allows evaluation of bone density and strength. Pseudo–three-dimensional displays on the basis of imaging data derived from CT scanning or MR imaging and true three-dimensional displays afforded by holography are increasingly vivid and allow clinical colleagues in orthopedics to view pathologic conditions in a way similar to that seen in the surgical suite. Computer-generated models of diseased areas and the ability to operate first by manipulation of data on the screen rather than by dissection of living tissues are not a future dream but rather a current reality. Further, the newest generations of equipment allow real-time CT and MR fluoroscopy, open-configuration MR units provide the access required by interventional radiologists, and low-field-strength dedicated MR units make possible a direct and inexpensive means to survey the extremities (1). The acquisition of three-dimensional, high-resolution images derived from standard MR imaging and CT or MR arthrography makes virtual arthroscopy a real possibility (2). Think of it. One can explore every recess of a joint without ever having to introduce a bulky arthroscope!

Also, in recent years, radiologists have assumed an ever-increasing role as interventionalists. In musculoskeletal imaging, this has translated into a clear demand for radiology participation in a number of procedures that previously had been performed by orthopedic surgeons, neurosurgeons, or anesthesiologists. Therapeutic injections of painful joints, percutaneous biopsy of tumors and tumorlike processes, and resection of localized neoplasms are among the invasive techniques that currently are performed by radiologists. The certain advantages of such participation in patient care include the ability to place a needle, trocar, or catheter precisely in a structure and to document correct placement by recording the site of injection, biopsy, or tissue removal through fluoroscopic, CT, or even MR imaging guidance. Percutaneous resection of tumors and tumorlike processes of the musculoskeletal system has been popular in cases of osteoid osteoma, eosinophilic granuloma, and simple bone cysts; instillation of methyl methacrylate cement and other substances provides stability in instances of skeletal metastasis; and ablation of vascular lesions of the musculoskeletal system through percutaneous embolization is possible. Because careful monitoring of the interventional procedure is ideal, the development of open magnets, rapid imaging sequences, and needles and instruments compatible with magnetic fields has received new attention.

The development of contrast agents compatible with MR imaging has also received recent attention. Although the value of intravenous administration of a gadolinium-containing agent has been well documented in cases of musculoskeletal tumor or infection, this same method appears to have important potential in the investigation of synovial inflammatory diseases and, when delivered as a bolus injection, of benign versus malignant tumors of bone and soft tissue. Direct MR arthrography employing such contrast agents has been used in the investigation of glenohumeral joint instability, recurrent symptoms after meniscal surgery, and osteochondritis dissecans, leading to, respectively, an increased understanding of capsulolabroligamentous variations and disorders of the shoulder, a means to differentiate changes associated with prior surgical invention and those indicative of a new meniscal lesion, and a method that allows detection of instability of an osteochondral fragment (3).

Future Directions

Few of us are clairvoyant enough to be able to predict with any certainty what the future may hold. We believe, however, that technologic, turf, and training issues will receive emphasis. With regard to technology, further advances in MR imaging clearly will occur. Very high tesla magnets will provide increasingly crisp and detailed images of musculoskeletal structures, allowing a degree of magnification similar to that seen through the microscope (4). Pathophysiologic data will be readily available regarding cartilage perfusion, bone and muscle metabolism, and tumor dynamics (5). With regard to muscle, for example, noninvasive imaging should allow the careful monitoring of gene therapy for inherited disorders, the response of inflammatory diseases to innovative therapeutic regimens, the recovery of tissue in patients with neuromuscular disorders, and the effectiveness of training methods in elite athletes, and skeletal muscle motion will be studied by using such recently described methods as phase-contrast velocity-encoded MR imaging and Doppler tissue US. By employing faster MR imaging sequences coupled with open magnet configurations, the normal and abnormal dynamics of countless joints will be explored. By combining three-dimensional imaging acquisition and new computer software programs, real-time and noninvasive exploration of the marrow ("osteoscopy") and spinal canal ("myeloscopy") should be possible. Real-time imaging displays of soft-tissue processes will simulate those seen surgically as tissue planes are peeled away, layer by layer.

The frequency and complexity of musculoskeletal interventional procedures also are likely to increase. Radiologists will compete with anesthesiologists to perform procedures designed to alleviate symptoms related to spinal and extraspinal diseases and, by necessity, will be required to possess an increased understanding of pharmacologic effects of a number of existing or new drugs. Substances will be developed that can be administered percutaneously to replace or reinforce disease processes of bone.

The issues of turf will become ever more complex (6). Even today, the necessity for review of routine musculoskeletal imaging studies by radiologists is being challenged by colleagues in other subspecialties (eg, emergency room physicians, orthopedic surgeons, and rheumatologists) who believe that they are equally (or more) qualified to interpret these studies. Small fluoroscopic units currently are available for use by clinicians in the emergency room or in offices to monitor reduction of displaced fractures and subsequent fracture healing. Further, the increased popularity of dedicated extremity-only MR units, which are being purchased by orthopedic surgeons for office use, leads to the sobering thought that resultant images will be interpreted independent of review by radiologists.

The turf of the radiologist of the future also will be defined by an ever increasingly constringent health care economy. As in other areas of diagnostic imaging, the musculoskeletal radiologist will become a manager of imaging assessment, as he or she will weigh the benefits of an examination or procedure and its cost. The answers to two basic questions will dominate his or her thinking. Will the results of the imaging examination (or examinations) influence the treatment of the patient and, if so, what is the most direct (ie, cost-effective) way to obtain these results? A shift of emphasis from diagnostic imager to imaging consultant will be necessary, as the musculoskeletal radiologist will be required to provide guidance in the choice of a specific protocol from a list that will become increasingly long and complex. Indeed, it will be this very diversity of available imaging methods and techniques that will lead even the highly specialized orthopedic surgeon and rheumatologist to more often seek the opinion of the radiologist.

As they are now, issues of training also will be dominant in the future. Clearly, musculoskeletal specialists in radiology will be required who know the language of the orthopedic surgeon and rheumatologist and who can use this language to communicate with them in a meaningful fashion. How many such specialists will be necessary and just how specialized they need to be (ie, amount of specialized training) are not clear. Accreditation of musculoskeletal imaging fellowships currently is offered in the United States, and certification of trainees in these fellowships may not be far behind. International and, more recently, European and American societies of musculoskeletal radiologists (and, in some instances, colleagues in related specialties as well) now exist whose agendas include, among other things, discussions of some of these issues of technology, turf, and training.

No, we are not clairvoyant, but we believe that the subdiscipline of musculoskeletal imaging is in good health today and the outlook for future development and refinement is promising. Obstacles surely will be encountered in the years ahead, but, as has occurred in the past, they will be negotiated successfully.

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