European Seminar on Musculoskeletal Imaging '93

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In the first lecture Prof. Pasariello (Rome) presented initial results obtained with a 0.2 T permanent magnet designed to image extremities only. Since only the extremity to be examined is within this small bore magnet, the patient is very comfortable during the examination, and problems with claustrophobia are non-existent. Other advantages of this dedicated system include: low purchase and running costs, easy installation, and good quality images. Disadvantages include limited availability of pulse sequences (i.e. no 3D), limited resolution, and problems with claustrophobia are non-existent. Other disadvantages include limited availability of pulse sequences (i.e. no 3D), limited quality control by radiologists.

The other four lectures of the first morning dealt with initial radiologic and histologic diagnosis of primary musculoskeletal tumors. A specific diagnosis can be made with magnetic resonance (MR) imaging in only a selected number of cases when unusual signal intensities and morphology are taken into account (Bloom, Leiden). Usually tumors have prolonged T1 and T2 relaxation times resulting in low signal intensity on T1-, and high signal intensity on T2-weighted images. Exceptions to this rule of thumb are high signal intensity on T1-weighted images secondary to presence of methemoglobin in subacute hematoma, well differentiated fat in lipoma, hemangiomata, mature myositis ossificans, lipoblastic liposarcoma, etc.; and low signal intensity on T2-weighted images secondary to presence of hemosiderin, low cellularity in combination with mature fibrous tissue, collagen, etc. The use of Gadolinium (Gd) assists in identifying cartilage, as in low grade chondrosarcoma, liquefaction, and viable tumor tissue. When the plain radiographs are combined with the MR examination, accuracy in differentiating benign from malignant is more than 90%. The most important reason to perform MR imaging in musculoskeletal tumors is local staging. Longitudinal T1-weighted spin echo (SE) sequences and transverse T2-weighted SE sequences are used. MR imaging is the most accurate method to evaluate local extension into bone marrow, muscle, fat, cortex, neurovascular bundle, and joint. Other methods for local staging are not necessary on a routine basis. Invasive procedures performed prior to imaging should be avoided since they adversely affect accuracy. Also MR images can be used to guide the biopsy needle.

Since diagnosis of musculoskeletal tumors is a combination of radiologic and histologic diagnosis, awareness of both radiologic (Kroon, Leiden) and histologic (Hogendoorn, Leiden) pitfalls is essential to avoid disasters. Insufficient or misleading clinical information are initial reasons for mistakes. Reasons for radiologic mistakes are: technically poor examinations, unusual radiologic appearance or localization of the tumor, unfamiliarity with normal variants that mimic disease, etc. The heterogeneity of primary musculoskeletal tumors is secondary to the fact that undifferentiated mesodermal cells are the origin of all tumors. This is one of the main difficulties for the pathologist in classifying these tumors based on a small tissue sample obtained with biopsy. Reasons for histologic mistakes are: biopsy material is not representative for tumor (sample error), misleading clinical or radiologic information, previous tumor manipulation, unfamiliarity with bone tumor histology, etc. Radiologic information which is important for histologic analysis of tissue samples are: site of origin (which bone, metaphysis or epiphysis, cortex or marrow, etc.), solitary or multiple lesions present, radiologic diagnosis. Since interpretation of biopsy material is, perhaps with the exception of round cell tumors, not straightforward, the histologic and radiologic diagnosis need to be compatible with each other. Without patient selection the accuracy of the first Yamshidi needle biopsy is 91%. Since tumors of the musculoskeletal system are rare, centralization of diagnosis and treatment is crucial in the interest of patients. The Netherlands Committee on Bone Tumors is an example of a successful centralization. The committee is consulted for ca. 700 new patients per year. A second advantage of centralization is the availability of sophisticated techniques such as immunohistochemistry and chromosome analysis. Although specificity of MR imaging in diagnosis of soft tissue tumors is low, MR is a very accurate method in local staging (de Schep, Antwerpen). The signal intensities reflect, as in bone tumors, certain tissue types, rather than actual histology. Morphology can be useful in making a specific diagnosis. Examples are the fusiform shape of neurogenic tumors, and serpiginous appearance of vascular lesions. Parameters that are indicative for malignancy are: tumor larger than 3 cm, inhomogeneous signal intensity on T1-weighted sequences, absence of low signal intensity on T2-weighted sequences, presence of necrosis. By using these criteria the sensitivity and specificity in predicting malignancy are 81%. Necrosis can be diagnosed with Gd enhanced MR imaging with high specificity, but with low sensitivity.

MR imaging is very effective in detection of recurrent tumor (Vanel, Villejuif). The examination is started with a T2-weighted SE sequence; when signal intensity is low, the examination can be terminated since no recurrence is present (accuracy ca. 99%). Aggressive fibromatosis may have a high signal intensity initially, but recurrent aggressive fibromatosis characteristically has a high signal intensity on T2-weighted SE sequences. When there is a mass with high signal intensity on T2-weighted sequences, recurrent tumor or hygroma are present. Gd can be used to differentiate the two. Inflammatory reaction after radiation therapy has a high signal intensity on T2-weighted images, but there is no mass. Dynamic imaging within 2 minutes after Gd injection can be used to identify viable tumor. Three minutes after injection, reactive tissue also enhances. Subtle enhancement is best evaluated on subtraction images. Monitoring chemotherapy is still a controversial issue. Size alone is not a reliable parameter. So far no reliable early indicators of good or poor response are available.

Dr. Sneath (Birmingham) illustrated the revolution in achieving local tumor control with limb saving surgery. No less than 85% of pa-
tients are treated with resection of the primary tumor, and reconstruction. There has not been a negative effect on local tumor control. Increased survival has focused attention on specific short and long term complications (infection, loosening, fractures) and requirements (accommodation of growing skeleton, fractures, etc.). Residual function after surgical treatment is fair, good, or excellent in ca. 90% of patients.

The goal in imaging bone marrow disease and especially metastases is to obtain high contrast between tumor and normal bone marrow (Seiderer, München). Ingredients in this discussion are the presence of trabecular bone, and the ratio hematopoietic-fatty bone marrow (each fraction constitutes 40-60% of red bone marrow).

Small frequency differences between protons in a cellular (water) and those in a fatty environment, result in low signal intensity on out of phase images of normal red bone marrow because both fractions are more or less in balance. It is essential to select the correct echo time for GE sequences at which the two constituents are out of phase. The relationship is cycled. The echo times at which the spins are out of phase is dependent on the field strength. At 1 T the spins are for instance out of phase at 17 ms. The optimal TE to achieve effective chemical shift dephasing has to be customized for every individual system. The chemical shift decreases with field strength and requires a homogeneous field to be exploited. A second reason for low signal intensity of normal red bone marrow is that the echo time at which the spins are out of phase is dependent on the field strength.

Because field inhomogeneity induced by trabecular bone (which is diamagnetic) is in GE sequences not counteracted by a 180° refocusing pulse, low signal intensity of bone marrow containing trabecular bone is a feature of GE images. These susceptibility effects increase with field strength. Tumor has a high signal intensity because it contains no trabecular bone, nor protons in a fatty environment. Thus good contrast is present between normal bone marrow and high signal intensity of tumor. T1-weighted SE sequences are used in combination with the GE sequence, to increase accuracy for instance in case the balance of fractions is altered as is the case in yellow marrow, or fatty marrow conversion secondary to radiation therapy. When hematopoietic cells are replaced by diffuse tumor without affecting the fat fraction (as in AML), contrast and disease conspicuity may be minimal.

Joint disorders were discussed on the second day of the seminar. The intimate relationship between function and anatomy was elegantly put in a clinical perspective by dr. Obermann (Leiden). Joints can be classified as uniaxial (allowing motion in one plane only), examples are the elbow (hinge joint) and radio-ulnar (pivot) joint; biaxial (allowing motion in two planes), examples are metacarpal (saddle) joints; and polyaxial (multidirectional motion) such as ball and socket joints like hip and humeroscapular joint. Motion may be spin, roll, slide, or combination of the so called chemical shift, results related to motion and can be provided by bony structures, shape of articular surface, meniscus and meniscus analogues (labrum), ligaments, capsule, and muscles.

Coils, pulse sequences, contrast agents, and types of image reconstruction are major factors in optimizing technique for joint imaging (Adam, Aachen). SE sequences are still considered to be the best sequences for joint imaging. They are available on every system, are well evaluated, and performance is with the exception of imaging of cartilage disorders very good. Other disadvantages are limited spatial resolution secondary to relatively thick slices, and long acquisition times. Advantages of 2D and especially 3D conversion GE sequences are shorter acquisition times, increased spatial resolution (thinner slices), image reconstruction in any plane (especially with 3D acquisition), other image manipulation. The pulse angle is added to the parameters to manipulate contrast. The main disadvantage is the increased susceptibility effect. There are many types of GE sequences, with many company attached acronyms. The GE sequence without spoiler pulses was considered the most useful for joint imaging. With fast SE sequences contrast similar to T2-weighted sequences can be obtained with much shorter acquisition times. This is done by using multiple echo trains. The number of echos and the spacing influences image sharpness, especially in the phase direction. Disadvantage of this technique is decreased contrast between water and fat bound protons. Fat suppression can be accomplished by various techniques (CHESS, 2 or 3 point Dixon, STIR). It has been used not only to increase sensitivity of bone marrow imaging, but also to increase sensitivity of imaging cartilage disorders. Magnetization transfer contrast (MTC) can be emphasized by saturating the protein bound water fraction. This can be done in combination with other pulse sequences. This adds yet another parameter to be used in contrast manipulation, the main disadvantage is the considerably increased specific absorption rate (SAR). Diluted intraarticular contrast agents (Gd) have been used to increase the accuracy of MR imaging in displaying cartilage abnormalities, meniscal tears, rotator cuff tears, etc. The somewhat increased accuracy probably does not outweigh the conversion of a noninvasive to an invasive study. Also recent reports indicate the possibility of arthroscopy-like images by delayed imaging after i.v. Gd contrast injection. The era of SE joint imaging seems to be close to its end, clinical utility of the various new pulse sequences, however, needs yet to be determined.

When MR imaging is compared with bone marrow pressure measurements in diagnosing early avascular necrosis (AVN) sensitivity is low (Bloom, Leiden). However, in a clinical setting with symptomatic patients, MR imaging is a sensitive (90%), and specific (95%) imaging modality, which is superior to other imaging methods. The size of the reactive tissue interface, which can be visualized on T2-weighted, or Gd enhanced images and bone marrow edema are indicative for the activity of the disease. Bone marrow edema may be secondary to the self limiting entity called transient ischemic osteoporosis, fractures, or early AVN. The relationship between these entities and bone marrow edema is controversial. Treatment of AVN is the second controversy. In literature there is conflicting evidence concerning the effectiveness of core decompression, and the use of bone struts. In a study comparing surgery and supervised neglect, only the increase of the size of the reactive tissue interface was positively correlated with surgery. Size of AVN seems to be the most important prognostic factor. Further research monitoring biologic behavior of AVN (is it a self limiting disease in the majority of patients?), and response to therapy is needed. AVN in the child occurs as complication of treated congenital hip dislocation and in Perthes disease. MR imaging is used in early diagnosis, when radiographs are normal and persistent symptoms are not consistent with transient synovitis. Even more important is the use of MR imaging to predict prognosis and to plan surgical intervention. In a study comparing MR imaging with radiographs, MR imaging was much more accurate in predicting prognosis. The size of the subchondral fracture is the most important single prognostic factor.

Professor Reiser (Munich, formerly Bonn) gave a comprehensive overview of MR imaging of the knee including normal anatomy, common pitfalls (e.g. transverse and meniscofemoral ligaments, etc.), and pathology. Meniscal tears are graded I, II (degeneration) to III (tear). The sensitivity of combined TI, or proton density weighted SE sequences and T2*-GE sequences is advocated since the accuracy (100%) is higher than that of the separate sequences alone. The sensitivity of SE sequences is lower than that of T2*-GE sequences, but the specificity of SE is superior to that of T2*-GE sequences.

The majority of grade II (degeneration) lesions do not progress to a full thickness tear within several years, they may even become smaller. Following meniscal repair, persistent high signal intensity may be a normal finding. Early stages of chondromalacia still cannot be reliably diagnosed with MR imaging. Subchondral fractures, bone bruises, tears of collateral and cruciate ligaments and spontaneous AVN are diagnosed with high sensitivity. The uniqueness of MR imaging over other diagnostic procedures is that it is a fast non-invasive technique allowing complete evaluation of all important intra- and extra-articular structures. It has been shown that MR imaging is furthermore an important tool in reducing costs and morbidity by decreasing the need for arthroscopy.

MR imaging plays an important role in diagnosis of osteochondral fractures, synovial disease, and ligamentous injuries of the ankle (Maschietti, L’Aquila). Imaging in three planes with 2-4 mm thick slices is advocated. MR imaging is superior to arthroscopy in diag-