IMAGING IN LOWER EXTREMITY TRAUMA

Seppo Koskinen, M.D., Ph.D
Helsinki Medical Imaging Center
Helsinki University Hospital
Töölö Hospital
seppo.koskinen@helsinki.fi

Plain radiographs with complimentary CT are the cornerstones in evaluating lower extremity trauma. Ultrasound will reveal muscle and tendinous injuries, but the method is largely operator-dependent. MRI, on the other hand, is the most versatile imaging method to evaluate bone and soft tissue injuries. In this presentation, I outline the use of MRI in the setting of lower extremity trauma, including selected trauma related to pelvic structures. The topics in this talk include most common fractures, easily missed fractures around the knee, occult fractures, to assess the extent of intra-articular fracture with associated soft tissue and ligamentous injuries. Moreover, the each imaging technique is briefly discussed with the emphasis of CT and MRI. Also, a new dedicated extremity CT is presented.

RADIOGRAPHY

Standard AP and lateral views are usually diagnostically adequate for assessment of joint and lower extremity bone trauma. In more complex anatomic joint structures, such as wrist, elbow, shoulder, ankle, and foot, however, superimposing bones make image interpretation challenging and less easy. Therefore additional views are needed. In general, diagnosis of fractures can be performed quickly using radiographs and it provides relevant information as to whether adjacent joints are involved and how the fracture fragments are positioned. In multitrauma patients and in severe comminuted joint fractures the quality of the radiographs may suffer from inappropriate positioning of the joint due to pain and from soft-tissue swelling of the acutely injured joint. Thus, additional imaging with other modalities is essential.

CT

MDCT allows for simultaneous acquisition of multiple sections within a single tube rotation and all scanners offer subsecond rotation speed, thus increasing performance substantially. The increased performance of MDCT can be invested in faster and longer scans, or thinner scans. Faster scanning reduces movement artifacts and longer scans can be taken in a single breath-hold, especially benefiting emergency trauma patients. Thinner sections make it possible to acquire a near isotropic dataset with high spatial resolution and reduced partial volume effects that allow volumetric imaging and reconstruction of arbitrary MPRs. The position of the body part scanned is not crucial, due to use of these high-quality reformats. This feature is extremely useful in imaging if the joints. Image noise grows as section collimation is reduced, and to maintain a low level of noise either the radiation dose needs to be raised or thicker sections reconstructed. In clinical practice, thicker sections are reconstructed from raw data, either axially or in any desired plane using MPR functionality. MDCT with MPR is helpful in disclosing complex joint fracture patterns in extremities where they reveal occult fractures and also the exact number of fracture components and their degree of displacement. The value of MDCT in the imaging of complex acetabular and pelvic ring fractures has been well established.

Although DSA that has been the reference standard for the diagnosis of traumatic vascular injuries, it is giving way to faster, less invasive and less personnel intensive imaging techniques, such as MDCT angiography. This is especially useful when imaging polytrauma patients with lower extremity injuries with potential vascular trauma. In spite of this, DSA still has a role in stab injuries, especially when catheter-based endovascular techniques for vascular trauma management are considered.

In addition to conventional CT scanners, cone-beam CT method has recently been implemented to orthopedic imaging. Recently, dedicated extremity CBCT-scanners have been introduced. This approach is logical, since CBCT-scanners offer high spatial resolution with voxelsize in clinical practice typically 0.4x0.4x0.4 mm3. It has an easy installation, and low radiation dose compared to conventional CT-scanners. This method offers exciting possibilities in orthopedic imaging in general. It provides a potential one-stop-shop for various orthopedic problems, such as subtle fracture detection and post-traumatic evaluation of fracture consolidation, especially when osteosynthesis material has been used. Moreover, this technique allows imaging in comfortable, sitting position or even in patients lying on a hospital bed.

MRI

High-field MR scanners (1.5T) with proper equipment that includes multi-channel coil design with parallel imaging offer excellent image quality in reasonable time. Open-configuration scanners offer better access to patients with multiple trauma. The lower field strength (0.2-0.5 T), however, has the disadvantage of lower spatial resolution and increased imaging time. 3T scanners, on the other hand, offer excellent spatial resolution, increased signal-to-noise –ratio (SNR) and eventually shorter imaging time.

Imaging protocols are designed according to anatomic target. As a rule of thumb, I first image with a large field-of-view (FOV), and then focus on the specific target. It is worthwhile to follow the scanning “on-line”, as you may are able to tailor your protocol according to findings. Also, by doing this, you are able to give at least a provisional diagnosis to the clinician.

Spin echo or fast-spin echo –based sequences are the workhorse of MSK trauma imaging. as they offer good SNR and spatial resolution with relatively reasonable imaging time. Also, manipulating excitatory pulse characteristics, echo and repetition time these sequences provide a good soft-tissue contrast. Gradient echo –sequences (GE) are less commonly used, but due to their inherent physical properties this sequence may be used to reveal foreign bodies causing local field inhomogeneities. These areas are seen as signal void, so well seen using GE-sequences, that the phenomenon has been coined as “blooming effect”. GE sequences do, however, offer thin slice thickness that may be useful in assessing avulsion fractures and intra-articular fragments and when visualization of small anatomic details is required. Assessing bone marrow pathology, the GE-sequence is notoriously inferior to spin-echo based sequences.

Since trauma is associated with haemorrhage and oedema to soft tissues, I usually start imaging using a fluid sensitive sequence STIR or T2-weighted with fat saturation using relatively large field of view. Usually the former offers more homogeneous suppression of fatty structures, and is less sensitive to field inhomogeneities caused by orthopaedic hardware. The disadvantage is poor SNR. Spectral fat-saturation, on the other hand, has better SNR, but is more sensitive to field inhomogeneities. This may be a problem when, for example, the imaging target is far from magnetic field isocenter, or the patient has orthopaedic hardware.

T1-weighted images show bone marrow pathology, such as fracture related edema, and is very useful in evaluating muscles. Cortical structures are evaluated best with this sequence. Whereas fluid-sensitive sequences show fracture associated edema, fracture line may actually be seen as a hypointense signal in T1-weighted images. Sometimes the fracture line is less conspicuous, and administration of intravenous contrast may be helpful. The T1 relaxation of the edema surrounding fracture is shortened, making it brighter leaving the fracture-line black. This method is sometimes useful in evaluating stress fracture of the femoral neck, where the prompt diagnosis is of utmost importance. Also, i.v. contrast may be administered to assess the vascularity of non-unions.

T2-w sequences (without fat-suppression) delineate tendons and muscles well. Although fat and fluid are bright on FSE (turbo spin-echo), muscle details are usually well seen. Proton-density images, with or without fat-suppression are useful in evaluating the menisci

The use of MR in orthopedic trauma has mainly been limited by cost and availability. Also, the relatively long scanning time has been a limiting factor. In spite of these restrictions, MRI yields important information no other imaging modality can offer in patients who have sustained a musculoskeletal trauma.

COMMON FRACTURES IN PELVIS AND LOWER EXTREMITY

PELVIC RING WITHOUT DISRUPTION
- Avulsion fx's
- Isolated pelvic bone: iliac wing, lower sacrum, coccyx

PELVIC RING WITH DISRUPTION
- Lateral compression
- Anteroposterior compression
- Vertical shear
- Combined

SACRUM: ZONE I, II AND III

ACETABULUM
- 5 common fractures (90% of all acetabular fx's)
  - both column
  - T-shaped
  - transverse + posterior wall
  - transverse
  - posterior wall

HIP AND PROXIMAL FEMUR
- Posterior and anterior dislocations
- Femoral head
- Femoral neck: subcapital and transcervical
- Torchanteric
- Intertrochanteric
- Subtrochanteric

PATELLA
- Transverse
- Vertical
- Stellate
- Lateral dislocation

KNEE
- Posterior and anterior dislocation
- Tibial plateau: I-VI
- Avulsions
  - ACL
  - PCL
  - Segond

ANKLE
- A,B,C-type
- Maisonneuve
- Pilon
- Tillaux
- triplane fracture

HINDFOOT
- Subtalar dislocation
- Talus: head, neck, body, posterior and lateral process
- Calcaneus: w/wo subtalar joint involvement

MIDFOOT
- Navicular
- Cuboid
- Lisfranc injuries: homolateral, divergent

BASE OF V-MT
- Jones
- Avulsion fx

SELECTED INJURIES IN MRI

HIP ❖ occult fractures ❖ cartilaginous injuries and labral tears ❖ AVN ❖ stress fractures ❖ hamstring avulsions ❖ injuries to quadriceps origo	**THIGH** ❖ stress fractures ❖ compartment syndromes	**KNEE** ❖ tibial condylar fractures with associated soft tissue injuries. ❖ knee dislocations with arterial and nerve injuries ❖ growth-plate injuries
LEG ❖ Compartment syndromes	**ANKLE** ❖ periarticular soft-tissue ligamenetous disruptions ❖ occult fractures ❖ osteochondral lesions	**FOOT** ❖ Lisfranc fracture-dislocation ❖ stress fractures ❖ plantar fascia

EASILY MISSED INJURIES AROUND THE KNEE

Tibial plateau fx, Segond fx, stress-fx of proximal tibian, fx's and dislocations of fibular head, osteochondral fx's, Salter-Harris type I fx, stress-fx's of growth plate (fx=fracture)

SUGGESTED READING

Cerezal L, Abascal F, Canga A, García-Valtuille R, Bustamante M, del Pifial F. Usefulness of gadolinium- enhanced MR imaging in the evaluation of the vascularity of scaphoid nonunions. AJR 2000;174:141–9

De Cock J, Mermuys K, Goubau J, *et al*. Cone-beam computed tomography: a new low dose, high resolution imaging technique of the wrist, presentation of three cases with technique. *Skeletal Radiol* 2012;**41**:93–6

Eustace SJ. Magnetic Resonance Imaging Of Orthopedic Trauma. Lippincott Williams & Wilkins. Philadelphia, 1999.

Eustace S, Brophy D, Denison W. Magnetic resonance imaging of acute orthopedic trauma to the lower extremity. Emergency Radiology 1997;4:30-7.

Faccioli N, Foti G, Barillari M, *et al*. Finger fractures imaging: accuracy of cone-beam computed tomography and multislice computed tomography. *Skeletal Radiol* 2010;**39**:1087-95

Falchi M, Rollandi GA. CT of pelvic fractures. Eur J Radiol 2003;50:96–105.

Haapamäki VV, Kiuru MJ, Koskinen SK. Foot and ankle injuries; analysis of multidetector CT findings. Am J Roentgenol 2004;183:615–22.

Haapamäki VV, Kiuru MJ, Koskinen SK. Lisfranc fracture dislocation. Diagnosis with multidetector CT. Foot Ankle Int 2004;25:614–9.

Haapamäki VV, Kiuru MJ, Koskinen SK. Multidetector CT diagnosis of adult elbow fractures. Acta Radiol 2004;45:65–70.

Haapamäki VV, Kiuru MJ, Koskinen SK. Multidetector CT in shoulder fractures. Emergency Radiol 2004;11:89–94.

Haapamäki VV, Kiuru MJ, Mustonen AOT, Koskinen SK. Multidetector Computed Tomography in Acute Joint Fractures. Acta Radiol 2005;46:587-98.

Hughes PM. Low-energy injuries of the lower limb. RSNA Categorial course in diagnostic radiology: Emergency radiology 2004;197-215.

Kaplan PA, Helms CA, Dussault R, Anderson MW, Major NM. Musculoskeletal MRI. WB Saunders, Philadelphia, PA, 2001

Katsanos K, Sabharwal T, Carrel T, Dourado T, Adam A. Peripheral endografts for the treatment of traumatic arterial injuries. Emergency Radiology 2009;16:175-84.

Klingenbeck-Regn K, Schaller S, Flohr T, Ohnesorge B, Kop AF, Baum U. Subsecond multi-slice computed tomography: basics and applications. Eur J Radiol 1999;31:110–24.

Klöppel R, Schreiter D, Dietrich J, Josten C, Kahn T. Frühes klinisches management nach polytrauma mit 1-und 4-schicht-spiral-CT. Radiologe 2002;42:541–6.

Leidner B, Beckman MO. Standardized wholebody computed tomography as screening tool in blunt multitrauma patients. Emergency Radiol 2001; 8:20–8.

Mack MG, Balzer JO, Herzog C, Vogl TJ. Multidetector CT: head and neck imaging. Eur Radiol 2003;13 Suppl 5: M121–6.

Mahesh M. The AAPM/RSNA physics tutorial for residents: search for isotropic resolution in CT from conventional through multiple-row detector. RadioGraphics 2002;22:949–62

Mattila KT, J. Kankare J, Kortesniemi M, *et al*. Cone beam CT for extremity imaging. EPOS Abstract, ECR 2011, Vienna March 3-7, 2011

Mustonen AOT, Koivikko MP, Kiuru MJ, Salo J, Koskinen SK Postoperative use of MDCT in tibial plateau fractures: frequency, indications, findings, and appropriateness in clinical outcome. Am J Roentgenol 2009;193:1354-60

Mustonen AOT, Koivikko MP, Lindahl J, Koskinen SK. MRI of acute meniscal injury associated with tibial plateau fractures: prevalence, type, and location. Am J Roentgenol 2008;191: 1002-9.

Novelline RA, Rhea JT, Rao PM, Stuk JL. Helical CT in emergency radiology. Radiology 1999;213:321–39.

Peltola EK, Lindahl J, Hietaranta H, Koskinen SK. Knee dislocation in overweight patients. Am J Roentgenol 2009;192:101-6

Rydberg J, Buckwalter KA, Caldemeyer KS, Phillips MD, Conces DJ Jr, Aisen AM, et al. Multisection CT: scanning techniques and clinical applications. Radiographics 2000;20:1787–806.

Shah N, Anderson SW, Vu M, Pieroni S, Rhea JT, Soto JA. Extremity CT angiography: application to trauma using 64-MDCT. Emergency Radiology 2009;16:425-32.

Soto J, Lucey BC, Editors. Emergency Radiology, Mosby Elsevier Philadelphia 2009.

Zbijewski W, De Jean P, Prakash P, *et al*. A dedicated cone-beam CT system for musculoskeletal extremities imaging: design, optimization, and initial performance characterization. *Med Phys* 2011;**38:**4700-13