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Musculoskeletal Disorders: DSA-like Bone Subtraction with 320-Detector row CT

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Introduction

CT is a frequently used imaging method for the evaluation of bone lesions and densely calcified soft tissue musculoskeletal lesions. It elegantly demonstrates the lesion's contours and the reactive changes of the bone and periosteum adjacent to it, features which are fundamental for lesion characterization. Some lesions however require further analysis to reach a conclusive diagnosis or narrow down the possible differential diagnosis. The intravenous injection of contrast media is one of the most frequently used tools to help in the characterization of musculoskeletal lesions.

On CT, enhancement after iodinated contrast injection is readily seen in lytic and non-calcified soft tissue lesions. The visualization of contrast enhancement in non-lytic bone lesions is however practically impossible with conventional CT techniques because the high density of trabecular and cortical bone obscures the visualization of the hyperdense iodinated contrast. This represents one of the main advantages of MRI over CT for the evaluation of non-lytic or densely calcified lesions because in MR calcium does not directly interfere with the visualization of the contrast media.

The typical example of a non-lytic, enhancing bone anomaly with major diagnostic implications is the so called bone marrow edema pattern (BMEP). BMEP can be present in association with multiple tumors, inflammatory, degenerative and traumatic conditions and is composed of a mosaic of different histologic anomalies (fibrosis, trabecular thickening, cellular infiltration and to a lesser extent edema)[1]. BMEP invariably enhances and its identification is important for lesion characterization and may have significant prognostic implications which can directly influence patient management[2]. Normally BMEP is only seen on MR since the normal bone precludes the visualization of this anomaly on CT.

DSA-like (Digital subtraction angiography) bone subtraction is a CT technique that allows removal of calcifications and bone (both cortical and trabecular) without affecting the visualization of adjacent contrast enhanced structures. This technique allows the identification of contrast enhancement on CT of a non-lytic bone lesion and can be useful in various clinical settings such as tumor characterization, tumor staging, occult fractures and inflammatory diseases. Additionally DSA-like bone subtraction can be performed with conventional CT protocols (pre- and post-contrast) as well as with dynamic CT perfusion.

DSA-like bone subtraction offers a great advantage over conventional density-based bone subtraction techniques on CT. In the latter methods the bone and calcification are segmented from the adjacent vessels and soft tissue based on their density and morphology. When there is intra-osseous enhancement there is no difference in morphology or in density making it impossible to separate the bone from contrast enhancement. As a result, intra-osseous contrast enhancement is removed along with the bone with the consequent loss of important diagnostic information. In this manuscript a description of the principles of this technique is provided along with examples of its clinical applications (Case 1 and 2).

Basic principles

As its name implies DSA-like bone subtraction uses the same principle of bone subtraction as used for interventional radiologic procedures. A mask for subtraction of the anatomic region to be studied is acquired before contrast injection. Contrast is then injected and the post-contrast image acquisition is performed normally. During post-processing the two image sets are registered so that every anatomic structure corresponds exactly. Finally the registered image sets are subtracted. Since for X-ray based imaging methods calcium and metal are usually the only spontaneously dense structures to be found before contrast injection the result of the subtraction is an image set in which bone and other hyperdense structures have been completely removed and only the enhancing structures remain (Case 1 and 2).

Image registration is at the heart of DSA-like bone subtraction. If the pre- and post-contrast volumes are not meticulously matched pixel by pixel, artifacts are introduced into the subtracted images. Most of these artifacts are related to patient motion between the two acquisitions. Together with the greatly reduced acquisition time provided by current 320-detector row CT scanners (less than 0.5 s for the whole volume) the use of non-rigid registration algorithms can help overcome motion related artifacts. With the development of robust registration algorithms dedicated to the bone analysis, intra-osseous enhancement can be confidently identified.

Until now, this type of bone removal was not available in clinical practice because the subtraction of conventional helical acquisitions is technically demanding and time consuming. 320-detector row CT scanners can image up to 16 cm in a single rotation of the X-ray tube using a sequential acquisition mode. Using this type of acquisition the subtraction of pre- and post-contrast volumes is simpler and faster. Similar to DSA, a pre-contrast volume (mask) is subtracted from a post-contrast one and after post-processing a new volume, in which only contrast enhancement remains, is generated.

Material and methods

Dedicated bone subtraction algorithms were used for the evaluation of patients referred for CT imaging at our institution for the diagnostic work-up of suspected bone lesions. All CT images were acquired with a 320-detector row CT scanner (Aquilion ONE, Toshiba Medical Systems, Otawara, Japan) using a sequential scan mode before and after injection of iodinated contrast media. An iterative reconstruction algorithm (AIDR 3D) was used and the tube output parameters (kV, mAs) were adapted to the patient body habitus in order to keep the exposure dose to a minimum.

The images were then post-processed using SURESubtraction Ortho software. The subtracted images were compared to conventional CT images and correlated to MRI when available. Selected cases that demonstrate the added diagnostic value of DSA-like bone subtraction are presented.

Clinical experience

There are many potential clinical applications of DSA-like bone subtraction. From our experience this technique is particularly useful in the following clinical contexts:

Identification of BMEP

CT studies are often performed for the evaluation of osteomyelitis or spondylodiscitis, however structural bone anomalies and bone changes may not be present in the acute phase, precluding diagnosis at this stage. In some clinical contexts, such as diabetic foot ulcers, decubitus ulcers, back pain and fever, the visualization of BMEP is highly predictive of intra-osseous spread of infection and has obvious implications for patient management. The presence of BMEP is also a key feature for the diagnosis of stress fractures and

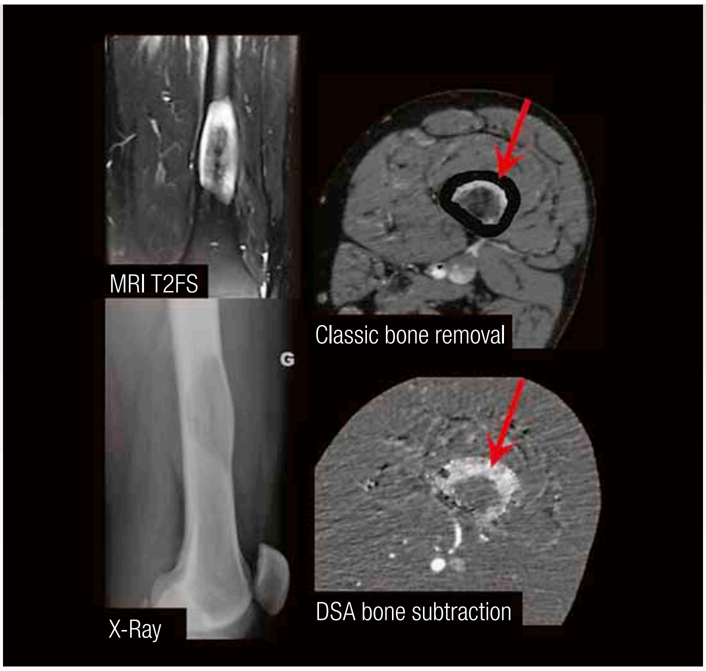
Case 1

Why is it different?

Focal lytic bone lesion with marked cortical thickening in an elderly patient.

Cortical enhancement has a similar density than the cortical bone and is taken away with classic bone subtraction.

With DSA bone subtraction the full extent of cortical enhancement is demonstrated. This patient has a biopsy proven focal Paget's disease.



Paget's disease

bone-on-bone impingement (osteochondromas, hypertrophic bone callus, wrist and ankle impingement syndromes). When conventional CT is inconclusive, a complementary imaging method, usually MRI or scintigraphy, has to be performed to reach diagnosis [3]. The use of DSA-like bone subtraction algorithms can help identify areas of BMEP on CT scans which can expedite the diagnosis, since in many of these cases CT is the first evaluation method employed. The ability to detect BMEP on CT also increases the diagnostic possibilities when MRI is not available (pacemaker, cochlear implants, agitated or claustrophobic patients).

Localization of occult bone lesions

Multiple benign and malignant conditions may present as a non-lytic, non-sclerotic bone lesions which are not identifiable on conventional CT. The identification of an intra-osseous enhancing lesion is of significant clinical importance because this finding may be related to early metastatic disease or aggressive bone tumors. Although CT with bone subtraction is not a screening tool, CT is performed in a wide set of clinical situations and the ability to detect this type of bone lesion may be important for patient management. As with all current CT acquisitions, subtracted images can be reformatted in any plane, which in our experience offers a welcome aid in the planning and execution of CT guided bone biopsies.

Characterization of lytic bone lesions

Bone tumors occur frequently as non-specific lesions on imaging. The diagnosis in these tumors relies on invasive procedures (percutaneous or surgical biopsy) for the histologic confirmation of the lesion's nature. Relatively few lytic bone lesions are known to be associated with BMEP on the adjacent bone marrow, which acts in these cases as a distinguishing feature. This is the case for osteoid osteomas, osteoblastomas, chondroblastomas and eosinophilic granulomas [4]. DSA-like bone subtraction adds the possibility of using conventional CT to non-invasively diagnose these lesions, sparing the patient additional invasive diagnostic tests.

Local staging of lytic bone lesions

Aggressive bone lesions may demonstrate microscopic invasion of the bone adjacent to its margins. The non-invasive differentiation between tumor invasion and reactive bone change is difficult and sometimes impossible since both of these anomalies are associated with abnormal enhancement in non-lytic bone adjacent to a bone mass [4]. Accurate local staging is one of the cornerstones of curative surgical resection of bone tumors. DSA-like bone subtraction can demonstrate enhancement adjacent to an aggressive bone lesion assisting in accurate local staging. Additionally this technique may have a potential role in association with other MR based imaging techniques in the characterization of peritumoral anomalies.

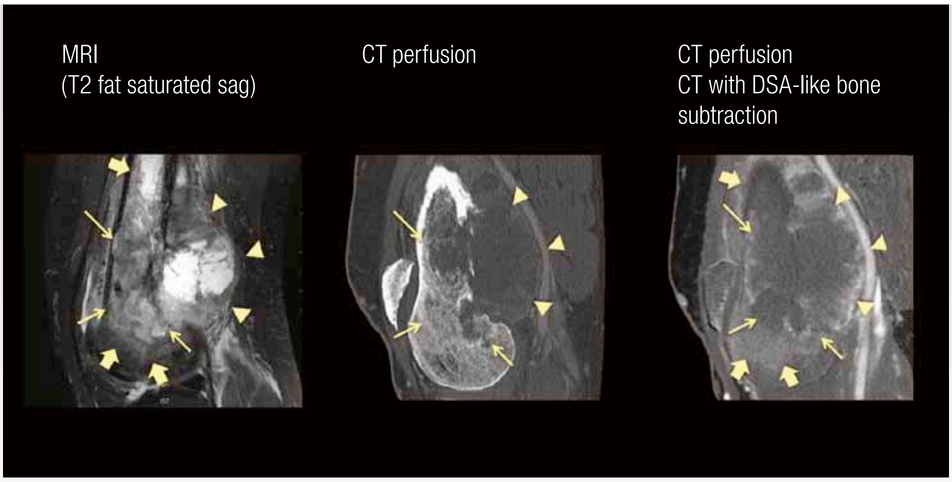
Assist perfusion analysis (ROI placement) when performing CT perfusion of bone lesions

With the major dose reduction offered by new developments in CT technology, mainly related to better and larger detectors and iterative reconstruction algorithms, CT perfusion can now be used in a wider range of clinical applications. This is particularly true for the upper and lower limbs, where the tissue sensitivity to radiation is very low with a resultant low effective dose. CT perfusion of bone lesions can be difficult because of the adjacent high density bone. Although contrast enhancement in non-lytic bone is measurable on CT perfusion it cannot be seen. How can you measure something you cannot see? Where should you place the ROI? Bone subtraction is of great assistance in these cases. Once subtraction allows the enhancing area to be visualized the ROI can be correctly placed increasing the accuracy of CT perfusion results.

Case 2

This lesion has three components

Soft tissue (arrowheads), lytic bone (thin arrows) and nonlytic bone (fat arrows). As expected MR imaging can depict all three components.
In conventional CT perfusion, however the nonlytic component is not seen. With DSA-like bone subtraction enhancement is seen in the nonlytic areas of the bone, matching the enhancement seen on MR. This information has obvious importance in the surgical planning.



Local staging of a lytic bone lesion, 64 year old female, Femur sarcoma

Conclusion

The use of CT scanners with a wide detector design offers the possibility of DSA-like bone subtraction, which has many potential applications in the evaluation of musculoskeletal disorders. This technique helps locate, characterize and stage malignant and benign bone lesions. It also has an important role in CT perfusion of bone tumors, assisting in the selection of the region to be analyzed. Enhancement in a non-lytic bone lesion may have major diagnostic implications and is currently evaluated by MRI. DSA-like bone subtraction increases the diagnostic power of CT in various clinical situations helping reach a conclusive or highly probable diagnosis for patients with musculoskeletal disorders.

References

[1] Blum A, Roch D, Loeuille D, Louis M, Batch T, Lecocq S, et al. [Bone marrow edema: definition, diagnostic value and prognostic value]. J Radiol. 2009 dez; 90(12):1789–811.
[2] Walsh DA, McWilliams DF, Turley MJ, Dixon MR, Fransès RE, Mapp PI, et al. Angiogenesis and nerve growth factor at the osteochondral junction in rheumatoid arthritis and osteoarthritis. Rheumatology (Oxford). 2010 out; 49(10):1852–61.
[3] Toledano TR, Fatone EA, Weis A, Cotten A, Beltran J. MRI evaluation of bone marrow changes in the diabetic foot: a practical approach. Semin Musculoskelet Radiol. 2011 jul; 15(3):257–68.
[4] James SLJ, Panicek DM, Davies AM. Bone marrow oedema associated with benign and malignant bone tumours. Eur J Radiol. 2008 jul; 67(1):11–21.

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