



CASE REPORT

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Occult femoral fracture: be aware of dual energy computed tomography

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Abstract

A 74-year-old man was admitted to our emergency department following minor trauma. Plain radiographs and standard computed tomography (CT) scans revealed no signs of fractures. Subsequently, virtual noncalcium (VNCa) images were reconstructed, showing a linear area of bone marrow edema (BME) resembling a femoral neck fracture. Magnetic resonance imaging (MRI) was performed to confirm the presence of BME and an associated intraspongious fracture. In an emergency setting, dual-energy CT (DECT) and VNCa images can successfully identify occult femoral fractures, especially in patients with mild symptoms and minor trauma, thereby preventing misdiagnosis.

KEYWORDS

bone marrow edema, dual-energy CT, emergency setting, occult femoral fracture, virtual noncalcium

1 | BACKGROUND

Occult femoral fractures, not detectable on routine radiographic imaging and also on standard computed tomography (CT), are not so rare, accounting for 2%–10% of all hip fractures.¹ They are more commonly seen in specific patient categories such as the elderly, individuals with osteoporosis, athletes, or in patients with a history of trauma. These fractures can result from various mechanisms, such as high-impact trauma (e.g., automobile accidents, falls from a significant height) or repetitive stress (e.g., in long-distance runners). Elderly patients, especially those with compromised bone density, are at greater risk.² The diagnostic algorithm typically includes, at first, an accurate clinical examination. Patients may report vague symptoms, such as thigh pain, tenderness, swelling, or difficulty bearing weight. Physical examination may reveal focal tenderness

and discomfort. Standard x-rays may not reveal any clues, especially in the early stages. Ultrasound could be useful to assess the soft tissues surrounding the femur, representing an initial bedside examination especially for patients over 70 years; the diagnostic accuracy for occult femoral neck fracture is low.³ Accordingly, additional imaging modalities, including CT, are often performed, revealing fractures not visible on x-rays in a high percentage of the cases. However, CT, especially for intraspongious fracture has a sensitivity of 94% and specificity of 100%.⁴ Despite being a suitable test for suspected occult hip fractures, conventional CT may struggle to accurately show the full extent when there is no cortical discontinuity or trabecular displacement. Dual-energy CT (DECT) imaging can enhance the visualization of subtle cortical or trabecular discontinuities by highlighting details in areas that could be otherwise missed. Magnetic resonance imaging (MRI) is the best exam for detection of occult fractures, and it is considered the gold standard, with a sensitivity of 100% and a specificity ranging between 93% and 100% in identifying bone marrow edema (BME) as a sign of intraspongious

List of abbreviation: BME, bone marrow edema; CT, computed tomography; DECT, dual-energy CT; MRI, magnetic resonance imaging; VNCa, virtual noncalcium.

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fracture.⁵ Although cardiac devices and other ferromagnetic materials may not pose a strict contraindication for MRI examination, most of them being MRI-safe nowadays, MRI scans are time-consuming procedures and time taken to prepare and perform an MRI could delay critical medical interventions. Emergency situations require quick diagnosis and treatment. For these reasons, MRI is not typically used in emergency settings to diagnose suspected hip fractures, particularly in patients with cardiac devices. Instead, quicker, safer, and more readily available imaging techniques are preferred to ensure rapid and effective patient care.⁶ DECT is a recently commercially available technology that is used in a growing number of healthcare institutions, offering numerous benefits thanks to the possibility of acquiring data with two different x-ray energy spectra, at high and low levels. This does not always reflect the reality in peripheral hospitals, which often have limited budgets and may prioritize other essential medical equipment and services, making it difficult to allocate funds for more expensive machinery. Different materials can be differentiated on the basis of their differential energy-dependent x-ray absorption behaviors. In the setting of occult fracture, virtual noncalcium (VNCa) technique, a post processing technique, can be used to remove trabecular bone from the images, improving the visualization of bone marrow and its potential changes in composition related to a trauma. However, the literature at support is still lacking and all the potential of this method is still unknown by the majority of physicians working in the emergency department. With this case report of femoral neck nondisplaced fracture diagnosis, not visible on x-rays and on conventional CT images, we aimed to make aware non radiologists and radiologists working at emergency department that there is a game changer technique able to depict occult fracture avoiding misdiagnosis.

2 | CASE PRESENTATION

A 74-year-old man, presented to our emergency department after stumbling at home. He experienced immediate right hip pain and is unable to bear weight on the affected leg. He had history of osteoporosis, hypertension, managed with antihypertensive medications, and type 2 diabetes controlled with oral hypoglycemic agents. On physical examination, the patient appeared distressed. There was mild tenderness over the right hip, and subtle resistance at any movement of the affected leg. Blood tests were normal except for renal function, which was impaired. Initial x-rays of the right hip showed no evidence of fracture (Figure 1). However, due to the worsening pain and the inability to bear weight, in agreement with the orthopedic surgeon the patient was referred to a CT scan. In our institution all CT scans are acquired using a dual energy protocol throughout a dual source DECT of third generation, that as largely documented in the literature, reduces radiation dose to patients and offer a multiparametric evaluation (iodine mapping, VNCa, fat and calcium quantification, and stone composition analysis) in addition to the conventional density-based assessment. CT standard images (Figure 2) in gray scale showed no signs of fracture. For this reason, patient was dismissed and sent home. The day after patients was admitted again at our emergency department complaining right hip pain. The orthopedic surgeon, in agreement with the radiologist, reviewed the CT images of the day before, not only evaluating the standard gray scale images but also reconstructing VNCa images, to assess the presence of occult fractures. On VNCa reconstructions was clearly visible a linear area of BME extending from the femoral neck to the trochanteric region, consistent with intraspongious fracture with a measured attenuation value of 78.6 HU at the fracture site consistent with an acute fracture. Placing a ROI on the contralateral femoral neck on VNCa image measured an attenuation of -7.1 HU, indicating no

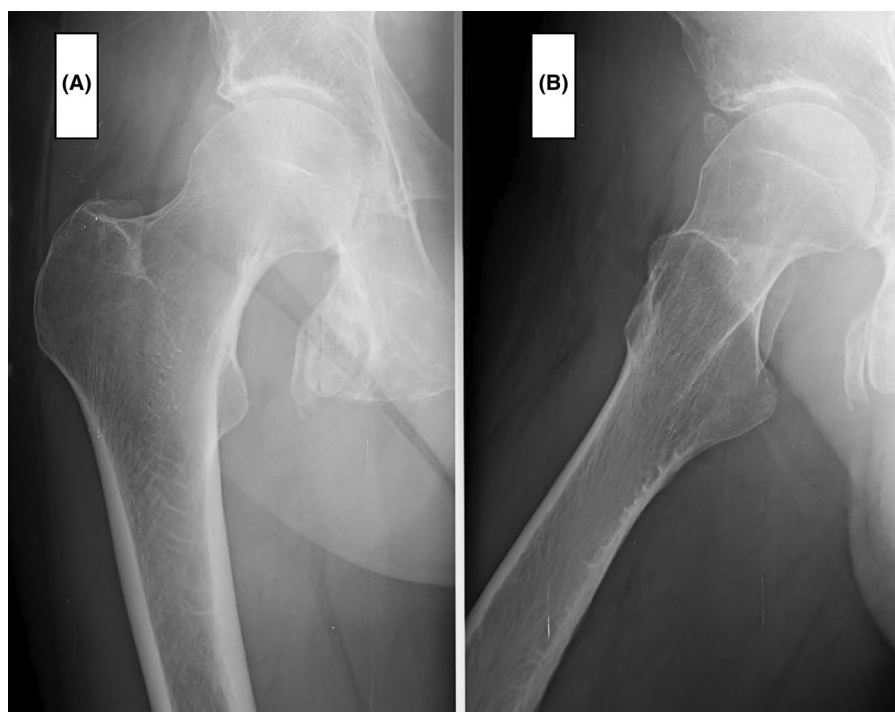


FIGURE 1 Anteroposterior (A) and lateral (B) radiographs of the right hip show no acute bony abnormality.

FIGURE 2 Coronal multiplanar reconstruction (MPR) computed tomography image shows no evidence of fracture (A). Magnification on the femoral neck and trochanteric region showing the integrity of the bony cortex (B).

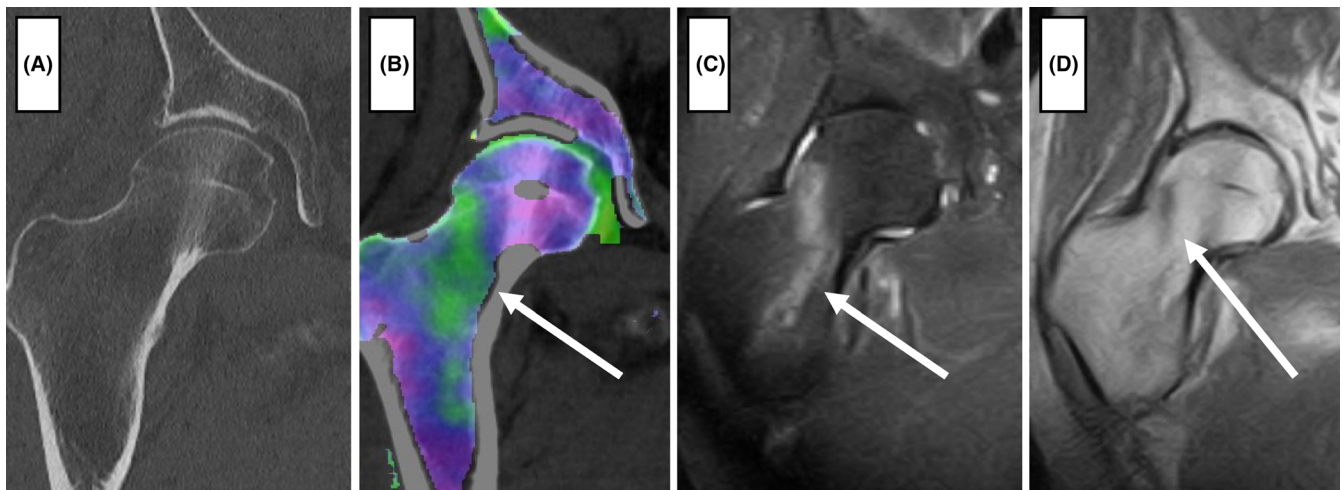
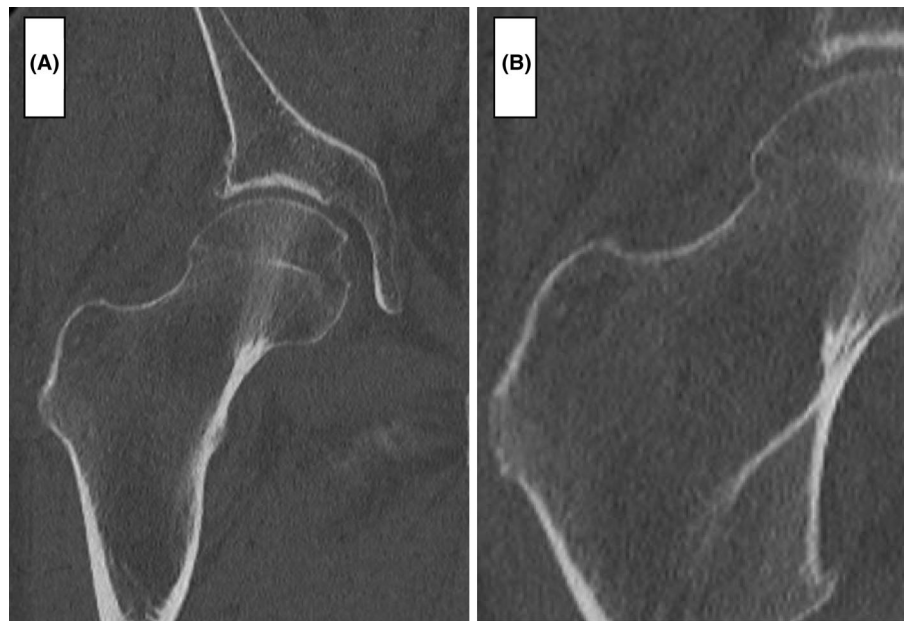


FIGURE 3 Coronal MPR computed tomography image shows no signs of bone fracture (A). DECT VNCa image reveal a hyperdense area in the right femoral neck with extension to trochanteric region suggesting a bone marrow edema (B), the arrow indicated green shaded region), which was confirmed by T2 STIR-weighted and T1-weighted images at MRI (C, D; arrow). DECT, dual-energy CT; MPR, multiplanar reconstruction; MRI, magnetic resonance imaging; STIR, short-tau inversion recovery; VNCa, virtual noncalcium.

BME.⁷ For didactical purpose, MRI was performed on the same day, confirming the findings documented using CT (Figure 3). Considering his comorbidities and the potential impact of surgery, the orthopedic surgeon decided on conservative management with close monitoring. The patient was initially managed with pain medications and was referred to a pain management specialist. He was then started on a tailored physical therapy program to maintain mobility and prevent complications associated with immobility.

3 | DISCUSSION

DECT and the VNCa reconstructions, should be considered a one-stop shopping diagnostic modality in the setting of trauma considering its high diagnostic yield to depict subtle or occult fractures.

We documented a case in which, at the beginning, intraspongious fracture was not depicted by both x-ray and conventional CT and the patient was dismissed improperly.

BME, usually caused by trauma, is very difficult to detect on conventional CT imaging because it produces very subtle changes in CT attenuation and density values, not visible on bare eyes. DECT postprocessing techniques can overcome these limits. For the evaluation of BME, is it possible to reconstruct images called VNCa in which the trabecula are removed from the images using the three-material decomposition method. This is based on the different photon absorption properties of three predefined materials using the low- and high-kilovoltage peak spectra.^{8,9} Using the postprocessing applications specific to bone marrow evaluation, a color map in different color spectrum is extracted where normal yellow bone marrow is present. An increased attenuation related

to edema is represented in different color spectrum, easy to detect.

Additionally, to improve visualization, overlay images can be created, where the color-coded VNCA images are superimposed on the grayscale images to visualize the blending of bone marrow contents onto the anatomical images.

In 2010, Pache and coworkers were the first to use this technique to demonstrate BME.¹⁰ Since that, few studies evaluate the advantages of this method, especially in emergency settings. Due to its high sensitivity for bone marrow changes, clinical applications are numerous, but not still understood and reported into routine clinical practice by radiologists and non radiologists.

Subsequently, many studies and reviews have attempted to demonstrate the utility of DECT in evaluating the effectiveness in early identification of BME as a sign of occult fracture in an emergency setting.¹¹⁻¹⁶

CT has numerous advantages compared to MRI in an emergency department; it provides high spatial resolution for bone imaging with high-resolution details of bone structures. This is essential for subtle fractures detection, where the continuity of the cortical bone is assessed.

CT imaging is faster and less sensitive to motion artifacts than MRI. In cases where patient cooperation or immobilization may be difficult, CT offers a practical advantage. The reduced acquisition time contributes to a quality diagnostic image, especially in emergency or trauma conditions where patients have low compliance and are unable to remain still.

If metallic implants are present, CT allows beam hardening artifacts reduction thanks to iterative reconstruction systems. Metal artifacts can obscure the surrounding anatomy and potentially limit the diagnostic capabilities of imaging modalities. In patients with metallic implants the ability of CT to minimize these artifacts is crucial.

Several recent studies have highlighted the use of DECT as potential one-stop-shop imaging in the emergency setting for select indications, such as differentiating contrast material and blood in stroke, identifying acute pulmonary embolism or bowel ischemia by means of iodine mapping, characterizing adrenal masses, and characterizing gallbladder or renal stones.¹⁵

In our manuscript, DECT evaluation helped reach a confident diagnosis of acute intraspongious fracture, which was then confirmed by MRI.

4 | CONCLUSION

Most of the patients with clinical suspicious of femoral fracture are dismissed improperly, after a standard radiographs, as false negative vary between 3% and 10%.⁴ VNCA images has the potential to reduce medical errors and legal implication related to misdiagnosis.

Accordingly, the use of DECT helps increase reader confidence in making diagnoses by providing additional information not detectable with conventional CT, lowering the number of unnecessary follow-up

studies recommended and the associated costs compared to relying solely on conventional CT.

DECT should be considered an essential tool for healthcare professionals dealing with orthopedics and traumatology; it has the potential to be used as one-stop shopping exam, avoiding the use of MRI.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ETHICS STATEMENT

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Sapienza University of Rome.

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