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CASE REPORT

Computed tomography guided navigation assisted percutaneous ablation of osteoid osteoma in a 7-year-old patient: the low dose approach

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Abstract Osteoid osteoma (OO) is a benign tumour that can cause severe pain and functional limitation to children and young adults; the treatment of choice is image-guided ablation. Due to the very small size of the lesion, detection and accurate needle placement may be challenging. Computed tomography (CT) offers very detailed imaging of the skeleton and is the modality of choice for the detection of small OO and for ablation guidance. Nevertheless, CT-guided positioning of the ablation applicator is linked to significant radiation exposure, particularly for the paediatric population. This case describes the successful use of a novel CT-based navigation system that offers the possibility of accurate ablation with only minimal radiation exposure in a paediatric patient.

Keywords Osteoid osteoma · Ablation · Radiation exposure · CT-navigation systems · ALARA

Introduction

Osteoid osteoma (OO) is a benign tumour associated with typical severe nocturnal pain that responds to salicylates. It most frequently affects children and young adults. The lesion is small in size; in 50% of the cases it is located in the metaphysis or diaphysis of the femoral or tibial bones; however it may be located in other parts of the skeleton such as the flat bones, feet and hands [1, 2]. Diagnosis is usually performed with plain x-rays or computer tomography (CT) and the treatment of choice is percutaneous CT-guided ablation [3–8].

Due to the small size of the lesion, "free-hand" CT guidance may be challenging and might require applicator repositioning and significant radiation exposure, particularly for paediatric patients. Significant efforts have been made to reduce the exposure of the "free-hand" approach, mainly by using low-radiation CT techniques either on phantoms in view of establishing low-dose protocols or by using cone-beam CT imaging, but with equivocal results [9, 10]. Navigational systems have been developed to offer real-time needle guidance and reduce the number of corrections during placement, aiming to increase precision and reduce radiation exposure. Nevertheless, the systems that have been on the market require real-time CT fluoroscopic needle guidance; therefore no significant reduction of radiation has been achieved yet [11].

The purpose of this case is to describe our experience with a novel, state-of-the-art computer-assisted CT-guided navigation system, which offers the possibility of quick and accurate electrode placement *without* continuous screening, hence significantly reducing the number of scans and the radiation exposure of the procedure.

Case report

A 7-year-old boy initially presented in a regional hospital because of pain and fluid collection in the left hip joint. The boy stayed in the hospital for 5 days and received antibiotic treatment with clindamycin even though the blood and collection fluid were sterile. Magnetic resonance imaging (MRI) revealed oedema of the left femoral head and suggested the presence of an osteoid osteoma (OO). A CT confirmed the

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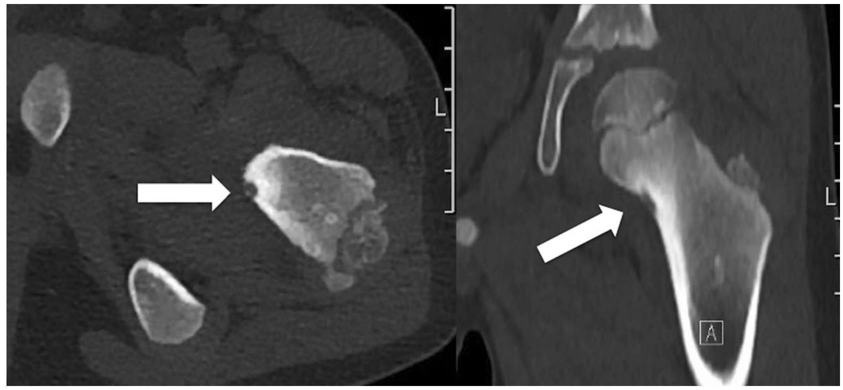

Fig. 1 Axial and sagittal CT pictures confirming the 5-mm lesion in the medial aspect of the left femoral neck

presence of a 5-mm OO in the medial-inferior part of the left femoral neck with a sclerotic reaction (Fig. 1). The patient was then discharged with painkillers and was referred to a tertiary care centre in view of percutaneous treatment.

Treatment under general anaesthesia with radiofrequency ablation was chosen through a lateral approach. The use of a CT-guided navigation system was considered the best option to reduce radiation exposure during needle placement. The CAS-One navigation system (Cascination AG, Bern Switzerland) was used. After being anaesthetised, the patient was placed in supine position with elevation of the left hip and immobilised in a vacuum fixation system (iSYS Medizintechnik GmbH, Kitzbühl, Austria). Six reflective spheres (optical markers) were positioned in an array distribution in the anterior and lateral upper surface of the thigh. The navigation system is based on the interaction between the optical markers and a 3D infrared camera. A CT scan of the region with 1-mm slice reconstruction was performed and the images were fused with the registration information from the optical markers. The position of the markers was confirmed in the fused image and planning of the entry point and end target followed. Once the pathway had been chosen, a mechanical arm with another three markers was positioned adjacent to the skin entry point (Fig. 2).

The lesion distance from the skin was 5.4 cm. Local anaesthesia and a skin nick were made at the entry point. A battery bone drill (OnControl, Arrow OnControl, Teleflex, Shavano Park, TX, USA) was inserted through the mechanical arm guide and advanced 3.5 cm (Fig. 3).

A low-dose CT fluoroscopy scan was performed to confirm the position (Fig. 4a). The drill was advanced for another 1 cm and a biopsy was obtained (Fig. 4b and c). The drill was intermittently used for a total of 5 min.

Once the biopsy had been obtained the biopsy needle and mechanical arm of the navigator were removed and a 1-cm tip radiofrequency ablation electrode (Cooltip, Medtronic, Minneapolis, MN, USA) was inserted through the drill needle (Fig. 5).

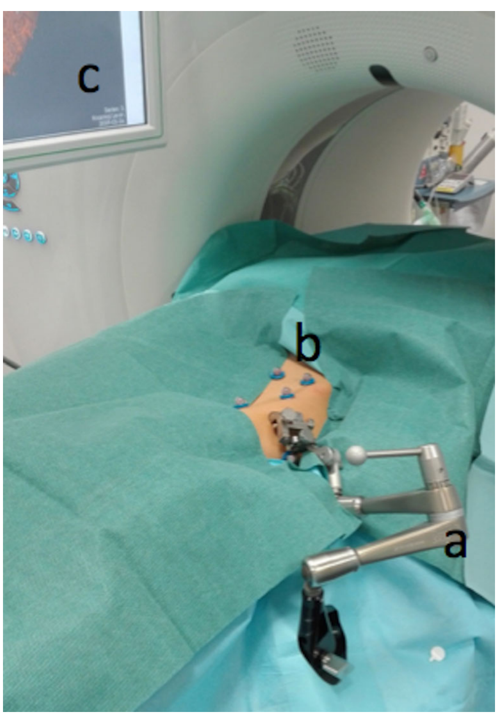

Fig. 2 Set-up of the navigation system: **a** mechanical arm placed at the entry point of the needle; **b** optical markers positioned in the array; **c** screen of the navigation system

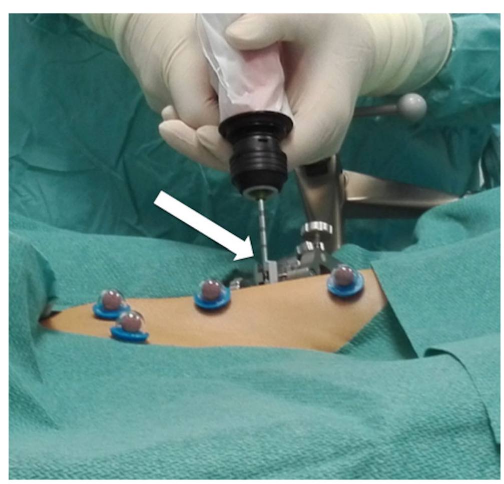

Fig. 3 Bone drill inserted through the guide of the mechanical arm of the navigation system (*arrow*)

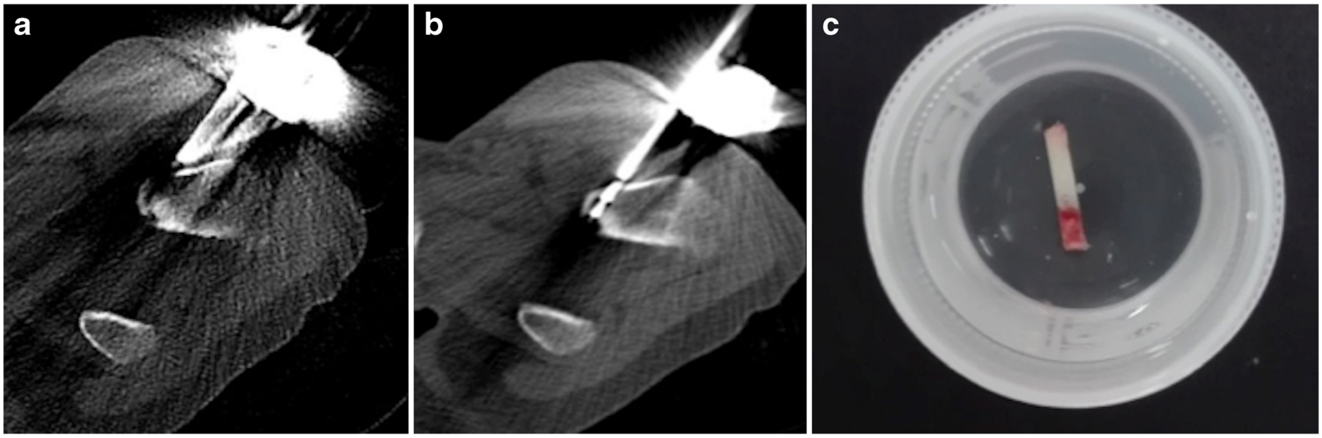

Fig. 4 **a** Low-dose (spiral scan: 50 mAmp, 100 KV) CT picture confirming the position of the bone drill in the lateral aspect of the femoral neck. Note the significant artefact of the mechanical arm of the navigation system. **b** The inner bit of the drill was removed and a bone biopsy trephine needle was inserted (biopsy mode scan; 84 mAmp, 100 KV). **c** The obtained biopsy specimen; the sclerotic bony part (*white*) and the nidus (*red*) can be distinguished

Ablation of the lesion followed for 6 min with a final temperature of 90°C. Long-acting local anaesthesia was used; the electrode and the drill access needle were removed. A low-dose control scan was performed to exclude any bleeding (Fig. 6). In total we performed three spiral scans and seven biopsy mode scans, for a total of ten scans including the final control. The total dose length product (DLP) of the whole procedure was 36 mGycm. The DLP multiplied by a factor k equal to 0.019 (for the anatomical area exposed) leads to an effective dose of 0.68 mSv [12].

The patient had a pain-free night and the next morning full movement of the articulation was restored. He was discharged the next day. Follow-up at 2 months with x-ray excluded any fractures. The child has been fit and well and without any symptoms since the day after the procedure.

Discussion

CT-guided ablation of osteoid osteoma is an established treatment. A few years ago, Rimondi et al. [3] reported their experience with 106 patients with OO in various locations of the skeleton who were treated with RFA with good results. CT guidance at that time was initially performed with 3-mm slices at 2-mm intervals and then with contiguous 1-mm slices and multiplanar reconstruction. Radiation exposure was an issue from the early days and operators tried to reduce the dose by halving the amperage during the needle insertions and final check. The skin insertion point was marked with a radio-opaque landmark and the needle trajectory designed was multiplanar. Manual drills were used and penetration was slow with intermittent scans to control the position of the drill until the nidus was reached.

Procedure time was significantly reduced with the use of mechanical drills [13, 14]. Schnapauff et al. [14] reported 23 cases where a battery-charged drill (OBM, Arrow OnControl, Teleflex, Shavano Park, TX, USA) was used and compared the procedure time, number of scans and radiation exposure with those obtained from historical manual bone biopsy systems or conventional orthopaedic drills. The median procedure time was 7 min compared to 13 min using the classical approach and the median number of performed CT scans to assess the drill position was

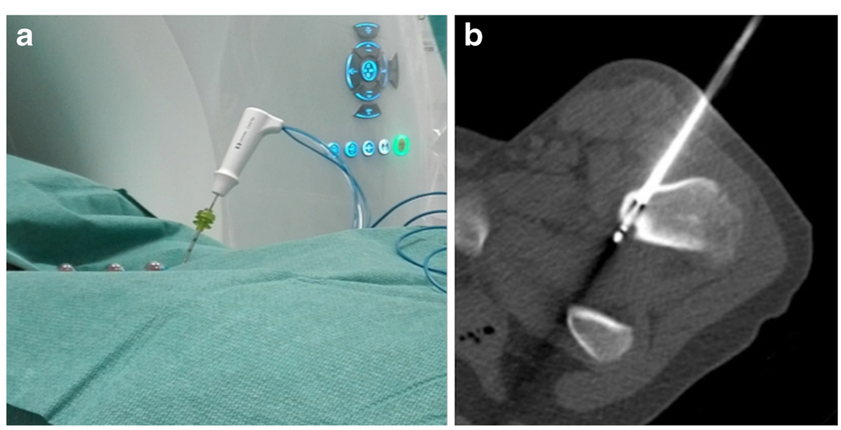

Fig. 5 **a** RFA electrode inserted through the needle of the drill; **b** position of the electrode within the lesion (biopsy mode scan; 84 mAmp, 100 KV)

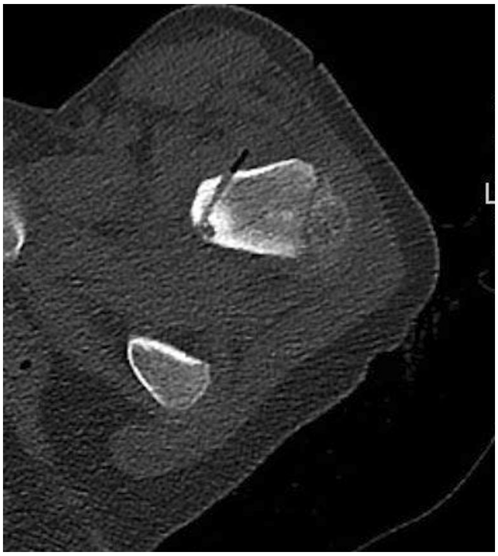

Fig. 6 Post-procedure low-dose scan indicating the channel of access and excluding any bleeding

26 compared to 24.5 with the conventional drill. In our case the intermittent drilling time was approximately 5 min and the number of scans was ten (3 spiral and 7 biopsy mode scans) because of the guidance from the navigation system that offered us straight access to the lesion.

Accurate needle guidance is indeed the true limiting factor of the procedure. Navigation systems have been developed to offer straight access without the need for continuous needle position correction. Busser et al. [11] reported their experience with the use of a navigation system for the treatment of five patients (median age 18 years; range 5–51 years) with OO. The authors evaluated the technical success of needle placement and the clinical outcome after follow-up. The lesions were located in the femur in two cases, in the tibia in one, in the acetabulum in one and in the body of L5 in one. Median nidus size was 6.8 mm (range 5–10.2 mm). The navigation system used was the XperGuide (Philips XperCT) software tool, which in essence creates a hybrid picture based on the CT information and live fluoroscopy. The needle trajectory was planned after CT pictures had been obtained and the path was fused onto real-time fluoroscopy pictures. Needle placement was accurate; however the authors did not mention any reduction of the radiation dose with this system. In our case the navigation system offers the possibility to draw a line from the skin to the lesion and accurate needle placement can potentially be performed without further scanning. The only operator-dependent part is deciding the access. When the access path has been confirmed, the needle guidance device is aligned with the navigation system and the drill or needle is inserted in the mechanical arm of the system; if planning is accurate the needle can reach straight into the lesion without real-time imaging. A factor that contributes to accurate placement is also the complete immobilisation of the patient within the vacuum system. The system also offers the possibility of parallel electrode placement with a variety of geometric patents for the treatment of larger tumours with other modalities (i.e. treatment of liver tumours with irreversible electro poration) [15].

Furthermore, navigation systems have been used in an intraoperative setting. In a study of 66 cases Cheng et al. [10] reported their experience with the use of intraoperative 3D cone beam CT (O-Arm) with or without surgical navigation. Patients were divided in three groups according to the use of a navigation system or not in the intraoperative setting (groups 1 and 2) and the use of standard CT "free hand" guidance (group 3). The navigation system in this case obtained satisfactory results in terms of radiation reduction when compared to the traditional CT scan but not to the standard intraoperative imaging guidance. The mean DLP was 446.62 mGycm with the navigation system, 379.78 mGycm with the single O-Arm and 1058.83 mGycm with the traditional CT "free-hand" technique. In our case the DLP was 36 mGycm, so nearly ten times than the O-Arm. In addition the O-Arm is present in very few hospitals, whereas the system that we used can be applied with any conventional CT scanner, which is present in every hospital.

We conclude that as percutaneous ablation is becoming more established in clinical practice, radiation exposure has to be reduced and treatment precision increased. This novel technology appears to be very useful for ablation guidance, particularly for small lesions in challenging locations. To our knowledge this is the first use of this system for the treatment of osteoid osteoma.

Compliance with ethical standards

Conflict of interest IRB approval was obtained for retrospective review of the cases where the specific navigation system was used in the department.

The navigation system is owned by the Department of Radiology and is used in everyday clinical practice. None of the authors has any conflicts of interest with the manufacturer.

Author 1: None
Author 2: None
Author 3: None
Author 4: None

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