

Cone-beam CT Opportunities in Hand and Wrist Assessment in Patients with Psoriatic Arthritis

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Aims and objectives

One of the most severe forms of psoriasis which significantly decreases the patients' life quality is the joints damage - Psoriatic arthritis (PsA). According to the different authors data it varies from 5 to 47 % among all the cases of skin and joints simultaneous lesions [1-4]. Along with this, PsA is diagnosed in 5-13 % patients with early-stage inflammatory joints diseases [2, 4]. It was found out that about 60-70 % of psoriasis cutaneous manifestations precede the arthritis and only in 10-20 % of cases both these psoriasis symptoms develop concurrently. But for all that the diagnosis is established only after the occurrence of joint damage in order of 20 % of the disease cases [2, 5].

For example in the US population PsA affects an estimated 520,000 patients, and many of them rate it as a large problem in everyday life. The prevalence varies wide depending on the extent of skin involvement, which demonstrates the importance of performing broadly representative studies to measure the prevalence of PsA [6].

The characteristic feature of PsA is the varying severity articular syndrome, including acute asymmetrical polyarthritis with individual involvement of the joints of distal upper and lower limbs segments: distal interphalangeal joints (DIPJ), metatarsophalangeal joints (MTPJ), I carpometacarpal joints, and I interphalangeal joints (IFJ), as well as involvement of three or more axial joints - axial arthritis [1, 7].

The first stage of radiodiagnostics in patients with PsA is remains to be the standard radiography (SR), which could be supplemented by the polypositional researches or by the digital microfocuss radiography with direct multiple images magnification if necessary. Among leading radiographic signs of the pathology are: dislocations and subluxations, ankylosis, osteolysis, as well as, the presence of bone erosions and enthesophytes in the tendons attachments. However, SR has not always allows assessment of bone structure changes in patients with PsA [2, 7-9].

Nowadays, as a result of the development of up-to-date special-purpose cone-beam computed units, it became possible to examine distal segments of the upper and lower limbs. Cone-beam computed tomography (CBCT) imaging is based on scanning the region of interest with usage of a pulsed X-ray beam. It is collimated so that the radiation is structured in the form of a cone. The tissue-attenuated X-ray radiation then reaches a flat-panel detector. The use of cone-beam technology means that a single turn of the X-ray tube around the target generates a primary image ready for further post-processing. Another important advantage of CBCT vs. multi-slice CT is the potential for a significant reduction in exposure dose, due to the short duration of direct X-ray irradiation and high sensitivity of the flat-panel detector. Recent numerous studies have demonstrated that CBCT of distal segments of upper and lower limbs with its high spatial resolution and wide spectrum of images post-processing has a high accuracy, sensitivity and specificity in the detection of pathological bone structure remodeling. This affect remains even in cases when its size do not exceed 1-2 mm [10-16]. These capabilities and advantages

mean that CBCT provides an expedient alternative to multi-slice CT for the examination of the hands of PsA patients.

The actual literature indicates absence of publications on applicability of CBCT for PsA patients. Despite the obvious advantages of the technique, the hand and wrist CBCT opportunities in identification of the leading X-ray signs of PsA main forms are not detected; the pathological changes assessing mechanism of hand and wrist CBCT in patients with PsA, including dynamic observation is not created; there is no standardized protocol for the description of the results of such examinations. Moreover, the role and place of CBCT in the diagnostic algorithm in patients with PsA has not been specified yet. All these factors have become the basis for performing this study.

Before performing the study the following aims and objectives were formulated:

- to indicate the hand and wrist CBCT opportunities of the leading X-ray signs identification of the PsA main forms;
- to determine CBCT advantages compared to SR in hands and wrist joints studies in patients with PsA;
- to develop a standardized protocol for the hand and wrist CBCT pathological changes description in patients with PsA and unification of the received data;
- to clarify the role and place of the hand and wrist CBCT in the diagnostic algorithm in patients with PsA.

Methods and materials

The group of 26 patients with determined diagnosis of PsA in anamnesis and with diagnostically significant indicators in accordance with CASPAR classification was formed. Among them there were 10 women and 16 men at the age from 24 to 65. According to anamnestic data the duration of articular pain syndrome was 17.2 ± 1.9 months, the amount of body surface area (BSA) was 9.8 ± 2.6 %, the psoriasis severity index (PASI) came to 12.1 ± 3.2 , and dermatological quality of life index (DQLI) became 8.6 ± 1.0 . Moreover, the complaints, the results of the laboratory studies and the data of the hands and wrists SR of each patient ($n = 26$) was analyzed.

In this group of patients CBCT of the hands and wrists was performed for the dynamic control implementation. Before scanning each patient signed a voluntary informed consent to participate in the X-ray study using CBCT. CBCT of the hands and wrists was carried out using a cone-beam computed unit (NewTom 5G, QR s.r.l., Italy). It has the following technical characteristics: 200 × 250 mm flat-panel detector size, 180 × 160

mm maximum field of view, and a 360° gantry rotation around the region of interest. The hand and wrist scanning was performed from the distal metaphysis of the forearm bones to the nail ends of the distal finger phalanges. Settings were the following: scan mode - «patient scan» (exposure time - 3.6 s, X-ray tube boosting voltage - 110 kV, current - 0.6#0.8 mA), scan pattern - «regular scan», scan time - 18 s. The CBCT hand and wrist examinations were carried out in special-purpose positioning setups allowing full coverage of the region of interest.

The hands and wrists joints changes have been assessed by the presence of the joints spaces narrowing and dilation, bone proliferation (enthesophytes, diaphyseal and metaphyseal periostitis), concentric and eccentric erosions, osteolysis of the articular surfaces with the formation of the «pencil-in-cap» deformities, resorption of the terminal fingers phalanges, joints subluxations.

All the patients were conventionally divided into 2 groups according to the forms of PsA: symmetric polyarthritis (n = 15) and arthritis mutilans (osteolytic variant) form (n = 11). There were no patients with isolated lesions of the DIJ in the observation group.

CBCT studies were performed repeatedly to 12 patients due to the PsA exacerbation. The obtained results were compared with the data of the previous studies.

In addition calculations of direct costs of different ray methods of the hand and wrist examination have been performed and analyzed. The received results were compared also.

Results

SR data allowed revealing the characteristic signs of PsA symmetric polyarthritis variant (n = 15) and mutilans (osteolytic variant) form (n = 11) in wrists and hands: irregular narrowing of the joint spaces due to ankylosis, erosions of the articular surfaces, bony proliferation in the form of ossification in the interphalangeal ligaments and enthesophytes. Arthritis mutilans form was represented mostly by osteolysis with severe damages of bones surfaces. High spatial resolution and wide range of CBCT images post-processing allowed identifying and determining the precise localization of bone structure pathological remodeling areas and enthesophytes which size was even less than 1 mm. Such small changes were not visualized reliably with SR. CBCT images of the wrists and hands were distinguished by high spatial resolution, optimal signal-to-noise ratio, uniform accuracy and dynamic range grayscale, which allowed estimating not only of bone structure, but dense soft tissue formations as well: muscles, ligaments and tendons (Fig. 1, a-c).

As an example of the CBCT application in patients with PsA two clinical observations are presented.

Patient D., 39 years old with PsA, symmetric polyarthritis variant, without widespread manifestations. Activity 1. Enthesopathy. Limited psoriasis vulgaris.

Upon admission to the hospital complained of pain in the right knee joint during physical activity, stiffness in the knee, ankle and hands and wrists joints, right hand DMPJ deformation, recurring pain in the sacrum.

Psoriasis duration was within 8 years. Pain in the right knee disturbs during last 9 years. Arthrocentesis with removal of fluid regarding recurrent synovitis was performed 3 years ago. Last 1.5 years the patient notes a progressive deformity of the right wrist distal IFJ, increased pain in the right sacrum and both ankles. Several courses of non-steroidal anti-inflammatory drugs have been provided without any significant effect. The patient's father suffered from psoriasis vulgaris.

According to the laboratory data rheumatoid factor and cyclic citrullinated peptide (CCP) antibody test were negative; erythrocyte sedimentation rate (ESR) was 8 mm/hour; C-reactive protein - 2.5 mg/L.

SR data allowed revealing the characteristic signs of PsA symmetric polyarthritis variant in wrists and hands with irregular narrowing of the joint spaces due to ankylosis, articular surfaces erosions and deformities mostly in wrist joints. During CBCT of hands and wrists of the patient the additional information was obtained. It became possible to identify and clarify the spatial arrangement of erosions, cysts and bony proliferation signs in the form of ossification in the interphalangeal ligaments even the smallest ones by its size (less than 1 mm), and to assess the soft tissue condition as well. It should also be noted that the number of detected erosions and cysts was almost 2,3 times higher with CBCT than with SR. On the CBCT images the signs of calcification in the tendons attachment of the deep flexor muscles of the right hand I-II fingers and the I finger of the left hand were determined. These changes were not visualized reliably on SR. CBCT with its post processing capabilities enabled to clarify the relationships between the articular surfaces at the level of the wrist joints: signs of ankylosis were visualized between lunate and capitate, trapezoid and trapezium, capitate and navicular bones. In all the other wrist joints convincing signs of ankylosis were absent (Fig. 2, a-f). Simultaneously the data proves that SR did not allow to visualize the signs of articular surfaces ankylosauria at that level.

After 10 months due to worsening of the joint syndrome CBCT exam was performed again. While comparing the obtained results with the results of previous SR and CBCT studies a higher intensity of characteristic signs of PsA was marked. For example, the number of identified erosions and cysts increased up to 24 %.

Patient K., 48 years old with PsA, arthritis mutilans (osteolytic variant).

There were complains of the right wrist joints, bilateral MCPJ and DMFJ pain and swelling, limitation of movement in these joints as well. Manifestation of psoriasis was diagnosed 14 years ago. Over the past 5 years the patient was followed up by the rheumatologist with

pain and swelling of the hands and wrists joints. Anti-inflammatory therapy (Piascledine) courses during the month annually were conducted without any positive effect. The admission to the hospital was due to appearance of sharp movements' restriction and pain in the wrists and hands joints.

According to the laboratory data rheumatoid factor and cyclic citrullinated peptide (CCP) antibody test were negative, erythrocyte sedimentation rate (ESR) - 19 mm/hour, C-reactive protein 4.5 mg/L.

CBCT data allowed revealing the characteristic signs of PsA arthritis mutilans form in wrists and hands with osteolysis of the IV-V distal phalanx bases with the «pencil-in-cap» deformities, articular surfaces deformation and irregular narrowing of the IV-V DMPJ spaces of the left hand due to ankylosis, bone proliferation in the form of ossification in the interphalangeal ligaments and enthesophytes were revealed mostly in hands joints (Fig. 3, a-e).

During CBCT of the hands and wrists compared to the SR the additional information was obtained. Thanks to CBCT post processing capabilities it became possible to identify and clarify the relationships between articular surfaces in the IV-V DMPJ: signs of ankylosis were absent at the V DMPJ, but were visualized reliably at the center of the IV DMPJ space. The data of SR did not allow excluding the signs of articular surfaces ankylosauria at the level (Fig. 4, a-d).

A standardized protocol for the description of hand and wrist CBCT in patients with PsA was developed and tabulated (See the Table 1) for the purpose of data unification, as well as, for process optimization of the general or quantitative count of the detected changes, according to any of the usual methods for PsA joint-change assessment.

Information about hand and wrist changes in PsA obtained in the course of post-processing using sequential analysis of cross-scans and multiplanar reconstructions is recorded in the standardized protocol (erosion and narrowing are marked with scores (from 0 to 5), while the remainder are marked with '+' or '#' signs). Changes of metacarpal bones, distal finger phalanges, and the CMCJ, MCPJ and IPJ were marked in the table with a hyphen and denoted according to their sequence numbers.

Subject to clinicians' needs, standardized protocol data can be used not only to indicate the radiological signs of the pathologic process but also to calculate comparable scores both in respect of selected general or quantitative methods of assessing PsA-caused changes in the joint, by summing the scores of the items required. The data obtained from CBCT hand and wrist scans of PsA patients and recorded according to the standardized protocol are more readily visualized, and this substantially simplifies comparison of cone-beam study results, which were conducted in dynamics for assessment of the response to the treatment being used.

Regardless of the disease form and variant in all the patients there was a significant advantage of CBCT in the assessment of hands and wrists bones and joints changes.

The number of additionally detected proliferative and osteolytic changes specific to PsA with CBCT was exceeded 1.8-4.1 times in comparison with SR.

As a result of calculation and comparison of the direct costs for wrists and hands different ray researches (See the Table 2) it was found that its results were comparable for CP and CBCT. In addition, the implementation of CBCT is approximately 3.6 times cheaper than MSCT of this anatomical segment and MRI - in 7.2 times.

Images for this section:

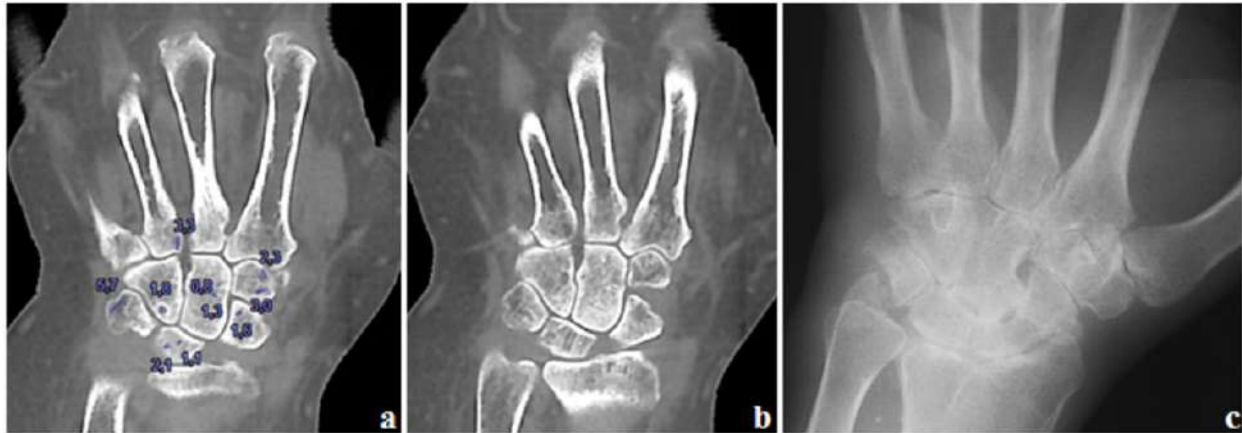


Fig. 1: Right hand CBCT images (a, b) and SR (c) of the patient with PsA symmetric polyarthrititis variant. High spatial resolution and wide range of CBCT images post-processing allows identifying and determining the precise localization of bone structure pathological remodeling areas and enthesophytes which size is even less than 1 mm. The soft tissue thickening and loss of its differentiation is also visualised

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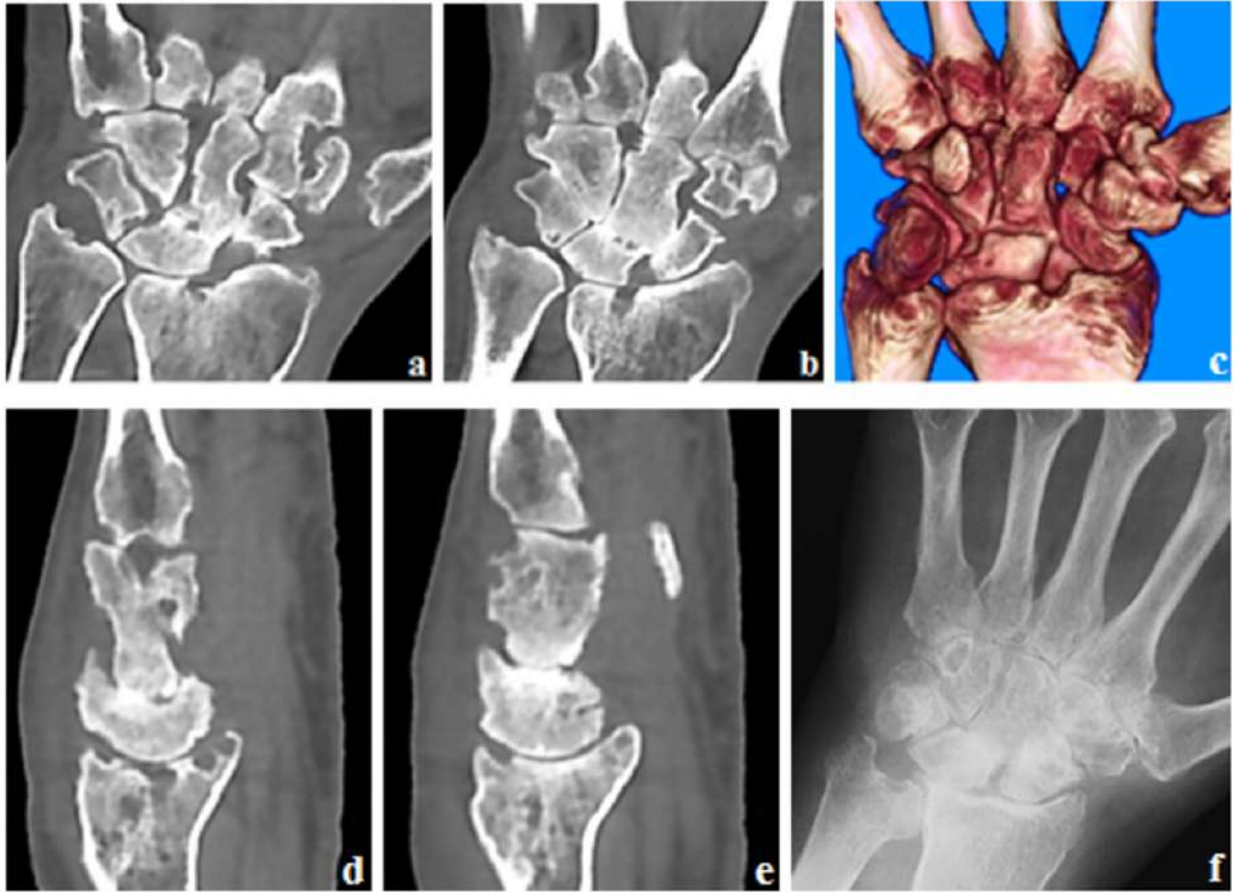


Fig. 2: Right hand CBCT images (a-e) and SR (f) of the patient with PsA symmetric polyarthritis variant. Signs of ankylosis are visualize between lunate and capitate, trapezoid and trapezium, capitate and navicular bones. In all the other wrist joints convincing signs of ankylosis is absent

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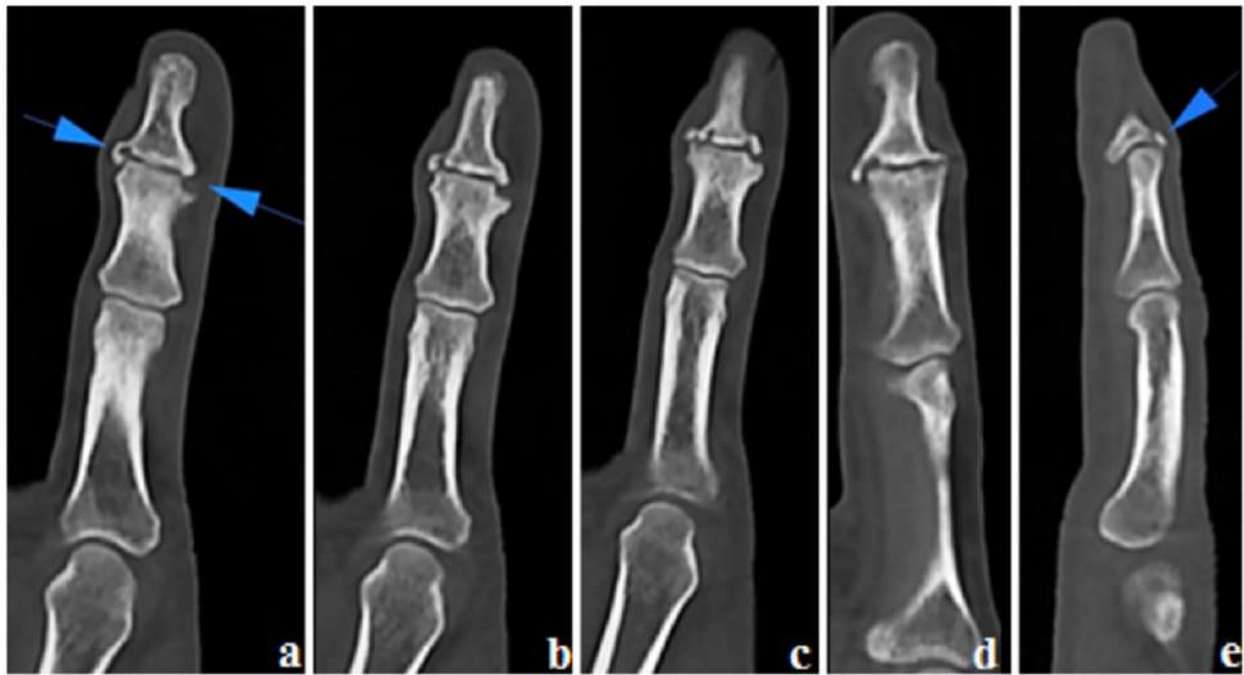


Fig. 3: IV-V fingers of the left hand CBCT images (a-e) of the patient with PsA mutilans form. Articular surfaces deformation and irregular narrowing of the IV-V DMPJ spaces, bone proliferation in the form of ossification in the interphalangeal ligaments and enthesophytes

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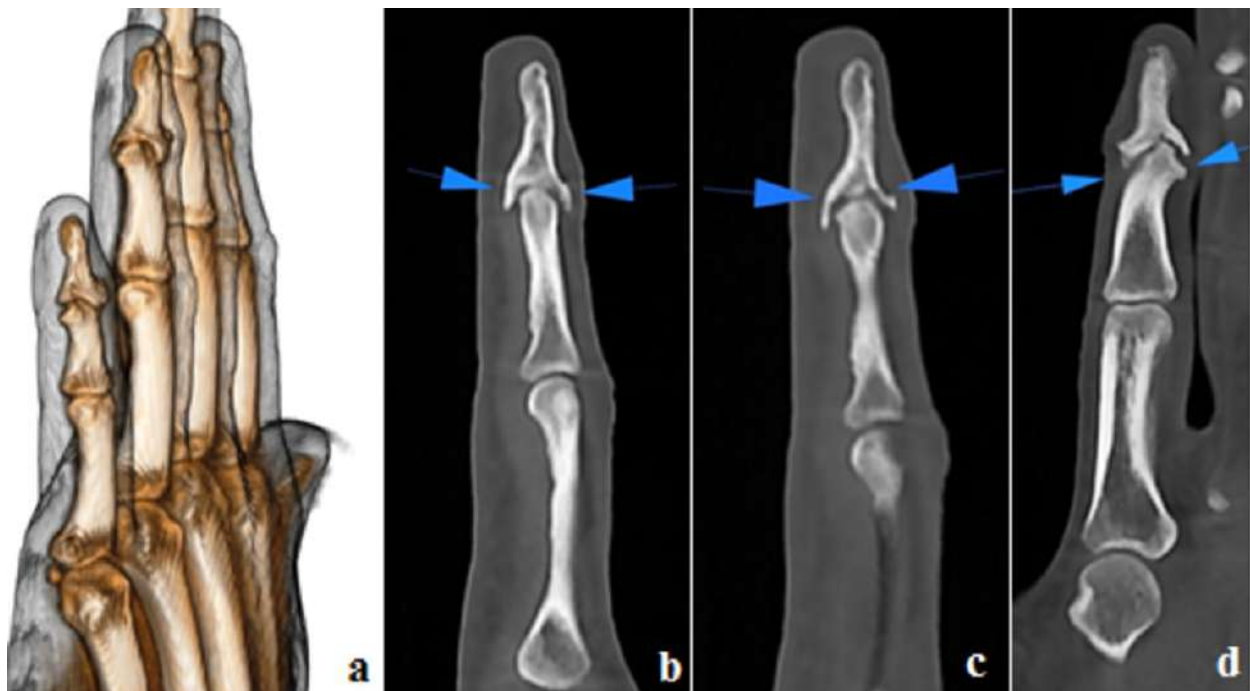


Fig. 4: Left hand CBCT images (a-d) of the patient with PsA mutilans form. «Pencil-in-cap» deformities at the level of the IV DMPJ

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Name of the Study	Direct cost, €
Ultrasound	12.3
SR	11.7
CBCT	14.9
MSCT	54.3
MRI	106.8

Table 2: Direct Cost Indicators for ray researches of hand and wrist

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Joints		Soft tissues	Narrowing	Subluxations	Bone proliferation
Radiocarpal		-	1	-	-
Radio-ulnar		-	0	-	-
Wrist		-	1	-	-
Carpometacarpal		-	0-0-0-0-0	-	-
Metacarpophalangeal		-	0-0-0-0-0	-	-
Proximal interphalangeal		-	1-1-1-1	-	-
Distal interphalangeal		IV-V	0-1-1-3-3	-	+
Bones	Porosis	Cysts	Erosions	Osteolysis	Bone proliferation
Distal ulnar epiphysis	-	0	0	-	-
Distal radial epiphysis	-	0	0	-	-
Scaphoid	-	0	0	-	-
Lunate	-	0	0	-	-
Triquetral	-	0	0	-	-
Pisiform	-	0	0	-	-
Trapezium	-	0	0	-	-
Trapezoid	-	0	0	-	-
Capitate	-	0	0	-	-
Uncinatum	-	0	0	-	-
Metacarpal	-	0-0-0-0-0	0-0-0-0-0	-	-
Proximal phalanx	-	0-0-0-0-0	0-0-0-0-0	-	-
Middle phalanx	-	0-0-0-0	0-0-5-2	«pencil-in-cap» IV,V	IV,V heads enthesophytes
Distal phalanx	-	0-0-0-0-0	0-0-0-5-3	«pencil-in-cap» IV,V	IV,V basis enthesophytes

Table 1: Sample Standardized Protocol for Description of Hand and Wrist Cone Beam Computed Tomography in Patient with PsA. Notes: calculation of erosions, cysts and joints narrowing was carried out on points by analogy with the method of Sharp van der Heijde modification

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Conclusion

Taking into account low radiation dose, high spatial resolution with the ability to identify even less than 1 mm bone structural remodeling, and relatively low direct cost of the study, CBCT could be considered as a first stage method for the diagnosis characteristic changes of the hand and wrist bones and joints in patients with PsA. Additionally, this technique could be used in dynamics, while monitoring the therapy effectiveness, replacing gradually SR.

Application of the standardized protocol for hand and wrist CBCT in patients with PsA allows unification and structuring of the examination description and accelerates its completion. Moreover, use of the suggested protocol simplifies interpretation of the obtained results, when CBCT is used to assess the hand and wrist pathological changes in dynamics, for determining the response to the treatment being provided.

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