Pediatric rheumatology

Assessment of the joint recesses and tendon sheaths in healthy children by high-resolution B-mode and power Doppler sonography

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Abstract

Objective

To describe or determine reference values for the intracapsular cavity and its joint recess of the hip, knee and joints of the hand and for the tendon sheaths of fingers, examined with B-mode gray-scale ultrasonography (US) and power Doppler (PD) in healthy children.

Methods

Sixty healthy children (31 boys and 29 girls; age range 2-16 years) were examined bilaterally with gray-scale and PD US (after obtaining the informed consent), using a standardized technique. The maximum distance from bone surface to the outer margin of the capsule (namely, intracapsular cavity) and its joint recess of hip, knee, wrist, non-thumb metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joints of the hand were measured with US. Mean values ± 2 SD (standard deviation) were indicated as reference values.

Results

None of the children showed joint hip fluid. In 5% of the children younger than 5 years an intra-capsular PD flow signal was detected in the posterior layer of the hip capsule. Fluid was detected in 60 % of the suprapatellar recesses. A small amount of fluid was detected within synovial recesses of the fingers, most commonly in the 2 MCP and PIP joints. Less frequently, a hypoechoic rim was detected around the finger flexor tendons on the palmar surface of the metacarpal bone.

Conclusion

High-resolution US evidences a normal small amount of fluid located at the MCP and IFP joint recesses and/or the flexor tendon sheaths without any PD flow signal in healthy children, that is relevant for interpreting ultrasonographic findings in children with inflammatory diseases.

Key words

Musculoskeletal ultrasonography, children, synovial recess, tendon sheath.

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Abbreviations:
ICC: Interclass correlation coefficient
MRI: Magnetic resonance image
MC: Metacarpal
MCP: Metacarpophalangeal
PD: Power Doppler
PIP: Proximal interphalangeal
PP: Proximal phalanx
SD: Standard deviation
SP: Suprapatellar
TAC: Tomography axial computerized
US: Ultrasonography

Competing interests: none declared.

Introduction

Ultrasonography (US) has been widely used in musculoskeletal adult disorders, and it has been less frequently used in children (1-5). US has the "real-time" capacity to compare symptomatic and asymptomatic sides, it is easily accepted by a child and sedation is no required. US is a rapid proven imaging technique for identifying synovitis and joint effusion in pediatric inflammatory diseases (1, 2). It is known that joint inflammatory activity is related to synovial vascularization (6), that is detect with power Doppler (PD) technique as an increased synovial flow in the swollen joint (7, 8). US is particularly appropriate for immature skeleton in which there is an increased ratio of cartilage to the bone (9). Moreover, US clearly shows the cartilage of unossified epiphysis as a mainly anechoic well-defined shaped structure that should not be confused with fluid; by applying pressure with transducer, fluid is displaced. US detects the ossific nucleus that is formed initially in the central vascularized portion of the epiphyseal cartilage of the long bones several weeks before it becomes visible radiographically.

At US, except for the hip joint, there is currently a lack of definition of normal anatomy in children that should be taken into account when interpreting sonographic findings. Standard US reference values have been established in adult patients (10), but there are few studies in childhood. The purpose of our study was to describe or determine reference values for the intracapsular cavity and its joint recess of the hip, knee, wrist and joints of the hand and for the tendon sheaths of fingers, examined with B-mode gray-scale ultrasonography (US) and power Doppler (PD) in healthy children.

Materials and methods

This study included a prospective US study of the hip, knee, wrist and hand joints in 60 healthy children. The study was approved by the institutional review board. Informed consent was obtained from parents and children before the US examination.

Subjects

Sixty healthy children were examined with B-mode gray-scale and PD US. Bilateral US examination of the hip, knee, wrist, second through fifth MCP joints, and second through fifth PIP joints of hands were performed on each child (n = 1320). There were 31 boys and 29 girls, with age range from 2 to 16 years. They were stratified into 3 groups according to the musculoskeletal development: group 1, children ≥ 2-5 years of age; group 2, 6-10 years of age; group 3, 11-16 years of age.

A physician performed a previous physical examination to confirm the clinical normality of the children's joints.

Methods

The US examinations were performed, by one investigator, with a Logiq 7 scanner (General Electric Medical System, USA). The technical parameters of the examinations included 8-14 MHz linear transducer, pulse repetition frequency of 800Hz, with a gain setting increased to the highest value not generating power Doppler signals under the bony cortex.

All children were first investigated with B-mode gray-scale US, PD US examination was also performed immediately afterwards. The US image acquisition time was approximately 25 minutes per patient – it was longer for some of the youngest children (≈50 minutes). The sonographer took measurements immediately after finishing US examination. This procedure was chosen to save time in dealing with the youngest children.

The authors chose for this study the joints more frequently affected in rheumatic diseases. The US examinations and measurements were performed according to a standardized systematic approach (11). Scanner settings were uniform for all measurements. Each anatomical region was examined on two perpendicular scanning planes, but only we obtained the following measurements for the study analysis.

In the hip, an anterior approach was used in the sagittal plane parallel to the long axis of the femoral neck with the leg in neutral position (spontaneous outward rotation) with the patient supine. The anterior joint capsule comprises an anterior and posterior layer, lined by a minute synovial membrane;

both layers can be identified separately by anterior recess when some joint fluid is inside (as an anechoic area). At US, the edge of hip capsule appears as a thin hyperechoic line overlying and in close contact with the femoral head and neck. We perpendicularly measured the maximum capsular distance in the hip joint as the distance from the middle anterior concavity of the femoral neck to the outer margin of the anterior layer of the hyperechoic capsule (12) (Fig. 1).

In the knee, the probe was positioned just cranial to the superior edge of the patella, with the patient in supine and with the lower extremities parallel to each other. We identified two anatomical structures. Firstly, the suprapatellar recess (SP) was scanned in the longitudinal plane with 30º flexion of knee. The maximum anterior-posterior thickness was measured by applying firm compression with the probe over the SP recess (13). (Fig. 2) Secondly, the medial and lateral recesses were scanned in transverse plane with the knee in full extension and we measured their maximum anterior-posterior thickness.

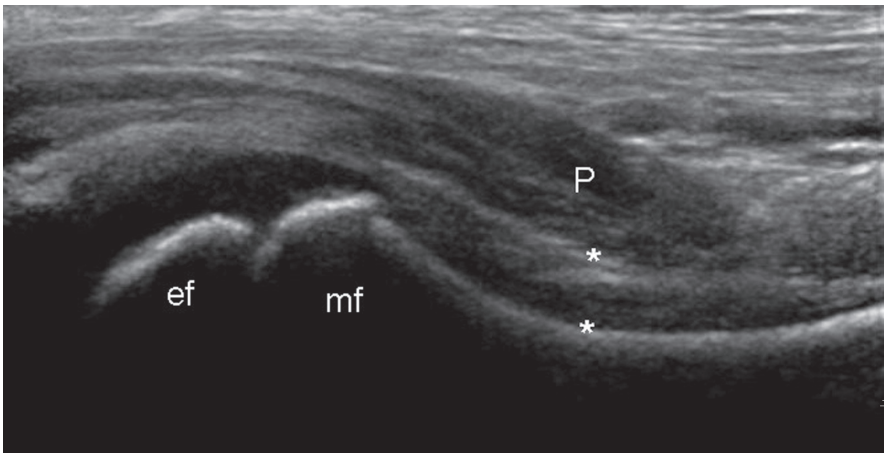

Fig 1. Hip (6 years old). Oblique-sagittal US image of the anterior joint capsule. The maximum distance femoral neck-capsule of the hip was measured perpendicularly from the middle anterior concavity of the femoral neck to the outer margin of the anterior layer of the hyperechoic capsule (between cursors). **ef**: epiphysis of femur, **mf**: metaphysis of femur, **P**: ileopsoas muscle.

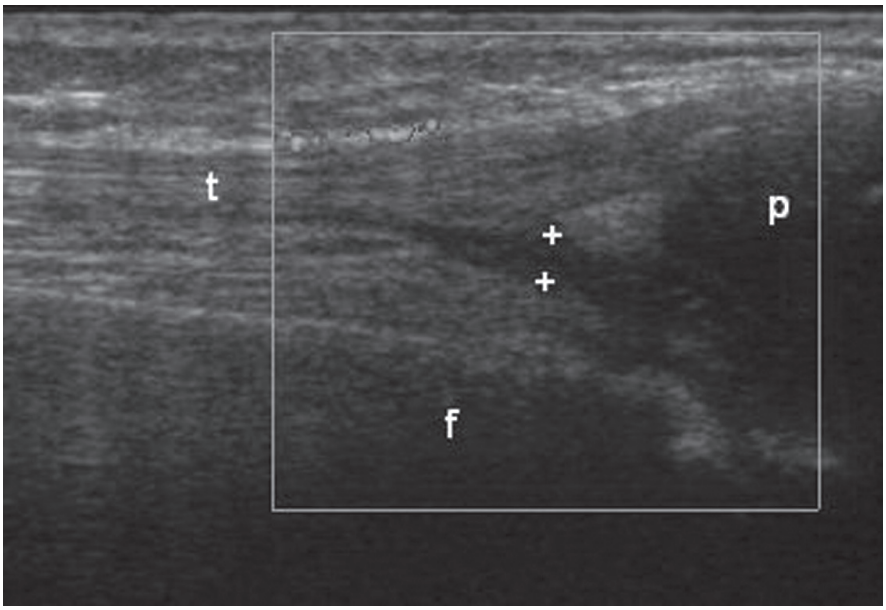

Fig 2. Knee (4 years old). Longitudinal US image of the suprapatellar recess. The maximum anterior-posterior thickness (between cursors) was measured perpendicularly to surface of the femur. **f**: femur, **p**: patella, **t**: quadriceps tendon.

To examine the hands, the child was in a sitting position with his hands palm-side down in a neutral position on an examination table, or in some cases, the child was lying down close to his or her parent, with his hands palm-side down on the bed and placed to the side of the body. A liberal amount of coupling gel was applied. The wrist joint was scanned in the longitudinal plane (Fig. 3). Because of its complicated structure and ossification of carpal bones at different ages, there is a lack of clear and reproducible reference points in assessment it. So, we chose to measure the dorsal cartilage thickness in order to indicate a reference point in healthy children for future US studies comparing to the wrist involved in inflammatory diseases, where some radiographic study has detected cartilage loss (14).

The intracapsular cavity of each finger joint was investigated in the longitudinal plane, from a dorsal and palmar orientation (MCP and PIP joints) in extended position. In normal conditions, at the longitudinal view, the outer margin of capsule is so close to the deeper margin of the tendon that both margins cannot be identified separately. We perpendicularly measured the maximum distance of bone-capsule as the distance from the dorsal and palmar metaphyseal surfaces of osseous metacarpal (MC) head to the outer margin of the capsule in MCP joint (Figs. 4A and 4B), and from the dorsal and palmar metaphyseal surfaces of the proximal phalanx (PP) bone to the outer margin of capsule in PIP joint. As well, the synovial recess over the bone surface was measured when it was visualized (Figs. 5A and 5B).

The synovial sheath of the flexor tendon which was identified as a slightly hypoechoic area, was clearly detectable on the transverse scan at the edge of the tendon's profile. The presence of a well-defined anechoic area within the tendon sheath was considered as fluid. Tendon sheath thickness was measured on longitudinal scan mainly at the MCP joint in the point of the largest diameter in the image (15) (Fig. 4B).

Reliability

Family and relatives of the authors made up the 12 subjects that we recruited to

carry out the reliability study. Intraobserver reliability of the US examination was bilaterally evaluated with six children, two children per stratified groups of age. In these children, the principal investigator repeated the US examination after one week to calculate intraobserver reliability.

Also, it was decided to carry out interobserver reliability as a second objective. A further six children were bilaterally examined twice in the same day to calculate interobserver reliability, firstly by one investigator and secondly by another investigator immediately afterwards. The investigators had not knowledge of one another's results.

Due to distances obtained in non-thumb PIP joints of children were different between two examiners, at the end of the study both examiners reached a consensus on the exact localisation for measuring method. A second examination on nonthumb PIP joints was carried out after this consensus in order to assessment interobserver reliability in this selected region.

Statistical analysis

The results of this study are expressed as mean, standard deviation and the minimum and maximum values in the tables. SPSS (version 8) software was used for all statistical analysis. A *p* value less than 0.05 was considered statistically significant. The *t*-test was used to compare the mean values between both sides to show changes with limb dominance, as well to compare the mean values between sexes. The ANOVA test (parametric variables) and the Kruskal-Wallis test (non-parametric variables) were used to analyze the differences between 3 patient groups for the hip, knee and wrist joints. Interobserver and intraobserver reliability were assessed with determination of the interclass correlation coefficient (ICC).

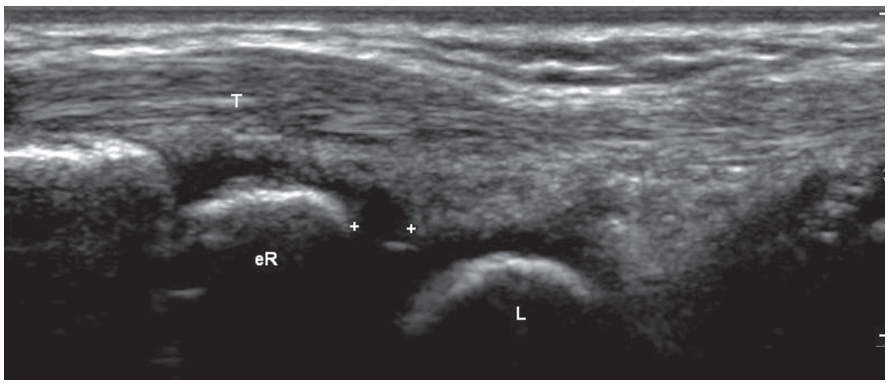

Fig 3. Wrist (7 years old). Longitudinal US image of the wrist with measurement of the dorsal cartilage thickness (between cursors) parallel to the inner margin of the extensor tendon. **eR**: epiphysis of radius, **L**: semilunate, **T**: extensor tendon.

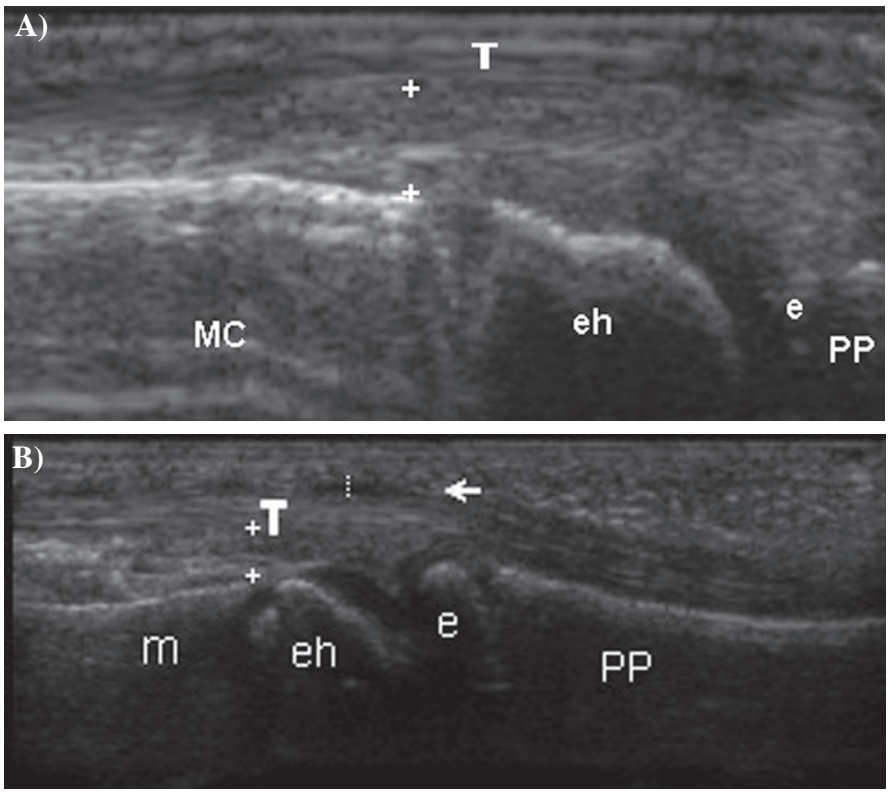

Fig 4. Finger (8 years old). Longitudinal US images of the dorsal (**A**) and (**B**) the palmar aspect of the MCP joint. The maximum anterior-posterior distance of intracapsular cavity (between cursors) was measured perpendicularly from the dorsal (**A**) and palmar (**B**) bone surface of metacarpal head to the deeper margin of the tendon. At the longitudinal view, the outer margin of capsule is so close to the deeper margin of the tendon that both margins cannot be identified separately. **eh**: epiphysis of metacarpal head, **e:** epiphysis of phalangeal base, **MC**: metacarpo, **PP**: proximal phalanx, **T**: tendon. Note tendon sheath thickness measured on longitudinal scan in the point of the largest diameter in the image (arrows).

Results

In both sides of all structures studied, the mean values did not differ significantly. Nor did they differ between sexes. The results of the analysis of the US studies are detailed in Tables I and II. We show the mean, standard deviation (SD) and the minimum and maximum values. Our results show that the range of normal values of the measured anatomical structure was wider than it was hoped and then values of SD were high too, this is partly explained by the fact that dimensions of the some measured anatomical structures were so small in some children. We have considered normal reference values as those values included within mean ± 2SD.

Hip

The mean distance femoral neck-capsule of the hip was 5.2 (SD = 0.09) mm (Table I). None showed joint fluid. The mean distance was significantly smaller

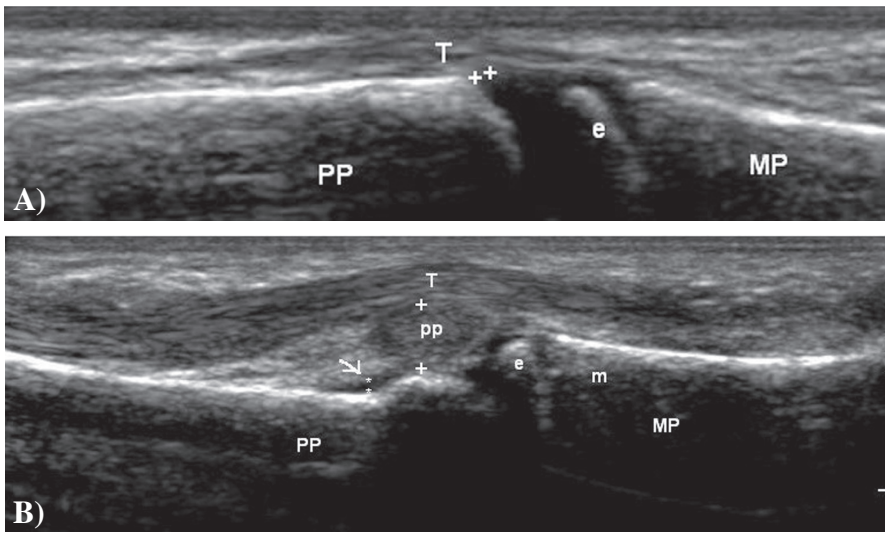

Fig 5. Finger (8 years old). Longitudinal US images of the dorsal (**A**) and (**B**) the palmar of the PIP joint. The maximum anterior-posterior distance of intracapsular cavity (between cursors) was measured perpendicularly from the dorsal (**A**) and palmar (**B**) bone surface of proximal phalanx head to the deeper margin of the tendon. At the longitudinal view, the outer margin of capsule is so close to the deeper margin of the tendon that both margins cannot be identified separately. A small amount of fluid was detected within synovial recess over the palmar surface of the metaphysis of proximal phalanx bone (arrows). **e**: epiphysis of middle phalanx, **m**: metaphysis of middle phalanx, **MP**: middle phalanx, **ppl**: palmar plate, **PP**: proximal phalanx, **T**: tendon.

Table I. Measured anatomical structure; mean, SD, minimum and maximum (Total number of joints examined: 120).

Anatomical structure	Mean value (mm)	SD (mm)	Min-Max (mm)
Hip: distance femoral neck-capsule	5.2	0.09	2.8-6.8
Wrist: dorsal radial cartilage thickness	0.9	0.6	0-3
II MCP dorsal distance intracapsular cavity*	0.6	0.4	0.1-2.4
III MCP dorsal distance intracapsular cavity*	0.6	0.4	0.1-2.3
IV MCP dorsal distance intracapsular cavity*	0.5	0.4	0.2-1.7
V MCP dorsal distance intracapsular cavity*	0.7	0.6	0.2-0.9
II MCP palmar distance intracapsular cavity*	0.8	0.7	0.2-3
III MCP palmar distance intracapsular cavity*	0.6	0.4	0.2-1.8
IV MCP palmar distance intracapsular cavity*	0.5	0.3	0.2-2
V MCP palmar distance intracapsular cavity*	0.6	0.2	0.2-1.3
II PIP dorsal distance intracapsular cavity*	0.6	0.3	0.2-1.7
III PIP dorsal distance intracapsular cavity*	0.7	0.2	0.3-1.6
IV PIP dorsal distance intracapsular cavity*	0.6	0.3	0.2-2.1
V PIP dorsal distance intracapsular cavity*	0.6	0.4	0.1-2
II PIP palmar distance intracapsular cavity*	0.5	0.1	0.2-1
III PIP palmar distance intracapsular cavity*	0.4	0.1	0.1-0.7
IV PIP palmar distance intracapsular cavity*	0.4	0.1	0.2-1
V PIP palmar distance intracapsular cavity*	0.3	0.1	0.2-0.9

SD: Standard deviation; Min: Minimum; Max: Maximum; MCP: metacarpophalangeal joint; PIP: proximal interphalangeal joint.
*The maximum anterior-posterior distance of the intracapsular cavity in finger joint was measured perpendicularly from bone surface to the deeper margin of the tendon. At the longitudinal view, the outer margin of capsule is so close to the deeper margin of the tendon that both margins cannot be identified separately.

in the group of children younger than 5 years (4.6 mm; $p = 0.03$); but there were no differences between the other two groups ($p = 0.9$). Also, in the former group, a single intra-capsular PD signal in the posterior layer of the capsule was detected in 5% (n = 6) of the hip joints.

Knee

We detected fluid in 60% of the SP recesses, and also in the parapatellar lateral (58.3%) and medial (33.3%) recesses (Table II). Comparing the mean thickness of knee recesses among different age groups, only the group between the ages of 2-5 years showed a thickness of the medial recess smaller (mean, 0.04 mm) than in the other groups, but this difference was not statistical significantly ($p = 0.07$). Doppler signal was not detected in any of the knees examined.

Hand

The mean of the dorsal thickness of the radial cartilage was 0.92 (0.6) mm; the mean thickness was larger in the group of children younger than 5 years but it was not statistical significantly (1.2 mm; $p = 0.057$). We did not visualize any synovial recess with fluid in the radiocarpal joints examined in the neutral position.

In the fingers, we identified a mean distance of intracapsular cavity of 0.59 (0.4) mm on the dorsal metacarpal head of the second MCP joint. The measurements of the other finger joints are showed in Table I. A minimal amount of fluid was detected within synovial recesses as a well-defined anechoic area like small pouch over the palmar surfaces of the metaphysis of MC and metaphysis of proximal phalanx bones of the some fingers, most commonly on the second MCP joint and the second PIP joint. An anechoic rim was detected around some finger flexor tendons, the results are described in Table II. Doppler signal was not detected in any of the wrists and fingers examined.

Reliability

In the intraobserver reliability, the interclass correlation coefficient (ICC) values for analysis of the separate joints were: hip ICC = 0.97, bursa SP ICC = 0.88, medial recess ICC = 0.97, lateral recess ICC = 0.89, wrist ICC = 0.84, dorsal MCP mean ICC = 0.95 (ICC range II-IV dorsal MCP joints, 0.91-0.99), palmar MCP mean ICC = 0.92 (ICC range II-IV palmar MCP joints, 0.83-0.97), dorsal PIP mean ICC = 1, palmar PIP mean ICC = 0.62 (ICC range II-IV palmar PIP joints, 0.4-0.9), mean ICC in flexor tendon sheath of fingers = 0.83 (range, 0.5-1).

While in the interobserver reliability interclass correlation coefficient (ICC) values for analysis of the separate joints were: hip ICC = 0.97, bursa SP ICC = 0.96, medial recess ICC = 0.9, lateral

recess ICC = 0.72, wrist ICC = 0.72, dorsal MCP mean ICC = 0.86 (ICC range II-IV dorsal MCP joints, 0.65-0.98), palmar MCP mean ICC = 0.87 (ICC range II-IV palmar MCP joints, 0.6-0.98), dorsal PIP mean ICC = 0.6 (ICC range II-IV dorsal PIP joints, 0.4-0.92), palmar PIP mean ICC = 0.6 (ICC range II-IV palmar PIP joints, 0.3-0.8), mean ICC in flexor tendon sheath of fingers = 0.9 (range, 0.8-0.98).

The principal differences identified between investigators were the assessment of maximum thickness of the joint space in the PIP joints. Interobserver agreement improved in a second examination on the hands carried out in other six patients (dorsal PIP mean ICC = 0.78, palmar mean PIP ICC = 0.8)

Table II. Measurements of synovial recesses and finger flexor tendon sheaths with fluid detected by US; mean, SD, minimum and maximum.

Anatomical structure	Mean value (mm)	SD (mm)	Min-Max (mm)	[◊]No. joints
Suprapatellar recess midline, longitudinal diameter	1.3	0.7	0.3-3.4	72
Parapatellar recess, lateral transverse diameter	0.9	0.6	0.3-3.8	70
Parapatellar recess, medial transverse diameter	1	0.5	0.2-1.9	40
II MCP palmar synovial recess	0.8	0.7	0.2-1	10
III MCP palmar synovial recess	0.6	0.4	0.3-0.6	6
IV MCP palmar synovial recess	0.5	0.3	0.4-0.8	8
II PIP palmar synovial recess	0.5	0.1	0.2-0.9	30
III PIP palmar synovial recess	0.4	0.1	0.2-0.7	26
IV PIP palmar synovial recess	0.4	0.1	0.2-0.8	28
V PIP palmar synovial recess	0.4	0.1	0.2-0.6	20
II finger tendon: hypoechoic rim	0.3	0.1	0.1-0.6	64
III finger tendon: hypoechoic rim	0.3	0.1	0.1-0.5	78

SD: Standard deviation; Min: Minimum; Max: Maximum; MCP: metacarpophalangeal joint; PIP: proximal interphalangeal joint. [◊]Number of joints in which a small amount of fluid was detected within synovial recesses as a well-defined anechoic area like a small pouch over surfaces of the MC and PP bones or in knee joint.

Discussion

Different imaging studies in the hip joint of healthy children have confirmed a good correlation both between US and magnetic resonance image (MRI) measurements (12), and between US and tomography axial computerized (TAC) measurements (16). The current choice of US in pediatric population is based on the ability to image multiple joints in one examination period in clinical practice, as well as, to be a child-friendly and economical imaging technique. Moreover, PD US is becoming a highly promising technique for detection of joint inflammation in early arthritis in childhood (17, 18).

Nowadays, the main limitation of US in childhood is the lack of standardization in its use. On the other hand, a standard knowledge of anatomy is essential for good interpretation of US findings in children with rheumatologic diseases.

At US, the anterior recess in the hip of the healthy child may be not visible if there is no fluid inside, as we could show in our study. Our measurement of the mean capsular distance in the hip was in agreement with previous studies (12, 16, 19). We found that the mean capsular distance varies according children's ages. A previously published US report disagreed on this issue (12). Further studies are needed to address that subject.

In the present study, the posterior layer of the hip capsule showed a single intracapsular Doppler flow signal only in the youngest children (aged less than 5 years); it corresponds with the ascending cervical artery (20). Chung suggested a progressive reduction of the number of small feeding arteries of the femoral head with age, which could explain it (21). We only did a qualitative evaluation of the PD signal, because the quantitative measurement was not the aim of our study.

US demonstrated a minimal amount of fluid within SP and parapatellar recesses in a percentage of healthy knees as anechoic fluid-filled bursae with regular margins. We found the mean synovial thickness of SP recess similar to previous studies in their control groups (18, 22). There was no statistically significant correlation between age and thickness of the knee recess and there are no studies reporting such a correlation.

PD signal was not detected in healthy knees. On the contrary, Doria *et al*. (18), after a contrast agent injection, showed a mild signal in their control group by color Doppler technique. This discrepancy can be explained by making use of B-mode and power Doppler technique without contrast agent in our study. No PD signal in healthy joints constitutes a point of interest to support the usefulness of PD in early assessment of the vascularity of the synovial membrane in inflammatory joint diseases (18, 23).

As far as we know, there are no studies which have identifyied US findings in the wrist and fingers joints of healthy children, which makes interpretation and comparison difficult. These studies have only been carried out amongst the adult population (10, 24, 25). When US examination of a normal finger is performed in a neutral position, as it was in our study, the outer margin of the finger joint capsule and its synovial recess were not easily visualized unless a small amount of fluid is present. Therefore, Klauser preferred to choose a different joint position (with the joint at 20º of palmar flexion) to study the MCP and PIP joints in adults with rheumatoid arthritis (26). Given that it is doubtful whether a child with painful joint can undergo that scanning position, we chose an accessible and painless position for our study.

Neither the wrist nor the finger joints showed flow signal during our PD US scanning.

This agrees with the findings reported by Klauser who used contrast agent injection for her study. On the contrary, Terslev found Doppler signal in the wrist and less frequently in the MCP joints in healthy adults (24).

One of the perceived disadvantages of US is its user dependent nature. We showed a high level of intraobserver and interobserver agreement for the hip, knee and wrist – as did another study (27) – but not for some finger joints of the hand. The number of patients selected for the reliability study was small due to the difficulty in getting younger children to lie still for two consecutive examinations (for interobserver agreement). Moreover, some parents refused to take the child for the second examination (for intraobserver agreement).

In the interobserver reliability, the ICC values in the first examination showed a low level of agreement for the PIP joints of the hand. The possible sources of variability in US measurement of PIP distances include the difficulty of establishing capsule landmark in its measurement when there is no fluid or synovitis in that joint and the small size of the anatomic structures.

Despite the relatively small number of children included, we believe our findings offer the potential for standardized examination and documentation as an adjunct study to further research in this field. We believe that studies with a large number of patients should be performed on each joint, mainly on hand joints, in order to confirm the preliminary data. As well, we have to point out that transducers with frequencies of ≥ 10 MHz equipped with Doppler should be used in order to obtain high sensitivity of US in detecting the presence of the above-mentioned findings.

Based on preliminary results, we conclude that high-resolution US evidences a normal small amount of fluid located at the MCP and IFP synovial recesses and/or the flexor tendon sheaths with no PD flow signal, as well as in the knee recesses – as it was already known – in healthy children, which is relevant for interpreting ultrasonographic findings in children with inflammatory diseases.

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