Pediatr Radiol (2013) 43 (Suppl 1):S41–S47
DOI 10.1007/s00247-012-2592-y

Water-bath method for sonographic evaluation of superficial structures of the extremities in children

Rajesh Krishnamurthy · Jeong Hyun Yoo · Mahesh Thapa · Michael J. Callahan

Received: 11 November 2012 / Revised: 15 November 2012 / Accepted: 19 November 2012

Abstract High-resolution sonography using a stand-off pad or a gel mound is a standard technique for the evaluation of soft-tissue structures of the hands and feet in children. However, the complex curved surfaces of the hands and feet often yield suboptimal contact between the transducer and the skin. Additionally, the small field of view, relative compressibility of the soft-tissue structures by the transducer, patient motion and discomfort from contact of the transducer with the pathology often limit conventional US evaluation. A water-bath technique overcomes these limitations. We present our experience of water-bath technique of superficial sonography in 23 children. Water-bath technique was performed with good patient cooperation and was superior to the standard technique for depiction of shallow skin ulcers, subcutaneous masses, vascular malformations, osteomyelitis and foreign bodies.

Keywords Sonography · Water bath · Extremity · Hands · Feet · Children

R. Krishnamurthy (✉)
EB Singleton Department of Pediatric Radiology, Texas Children's Hospital, Baylor College of Medicine, 6701 Fannin St, Suite 1280, Houston, TX 77030, USA
e-mail: rxkrishn@texaschildrens.org

J. H. Yoo
Radiology Department, Tongdaemun Hospital, Ewha Woman's University College Medicine, Seoul, Korea

M. Thapa
Department of Radiology, Seattle Children's Hospital, University of Washington, Seattle, WA, USA

M. J. Callahan
Department of Radiology, Children's Hospital Boston, Harvard Medical School, Boston, MA, USA

Introduction

Sonographic evaluation of superficial structures of the extremities in children is indicated in a wide array of conditions, including foreign body, infection, vascular malformation, trauma and evaluation of soft-tissue masses [1–5] and is traditionally performed with a heaped-up gel mound or stand-off pad. This technique is highlighted by easy access, reproducibility and safety. The use of a high-frequency transducer provides excellent spatial resolution for superficial structures and simultaneous evaluation of the small and large vasculature. However, there are several limitations of the current technique, including poor contact of the linear high-resolution transducers with the curved contours of the hands and feet, a relatively small field of view afforded by the stand-off pad and the small footprint of the transducer, compression of clinically relevant superficial structures by the transducer and patient discomfort caused by contact of the transducer with the pathology, resulting in motion and a lack of cooperation. A water-bath technique was developed in which the affected hand or foot is immersed in warm water with scanning performed using high-resolution transducers without touching the skin.

Materials and methods

Patient population

We obtained IRB approval to conduct this retrospective review of our experience with the water-bath technique. Twenty-three children with superficial extremity pathology were imaged using a water-bath technique. The distribution of pathology included 4 vascular lesions (2 arteriovenous malformations and 2 infantile hemangiomas), 12 inflammatory conditions (2 cellulitis with soft-tissue abscess, 2

Fig. 1 A disposable plastic bedpan or toy box is used as a water bath (*left*). It is filled with lukewarm tap water to half its height. The affected hand or foot is immersed in the water such that the superior surface is just below the water edge. Scanning is performed with high-resolution linear transducers (*right*), which are placed immediately adjacent to the skin surface, without touching it, simulating the use of conventional US gel

cellulitis with tenosynovitis, 1 cellulitis with osteomyelitis, 1 soft-tissue ulcer without underlying abscess, 3 isolated cellulitis and 3 with suspected synovitis), 6 masses (2 ganglion cysts, 1 lipoma, 1 synovial sarcoma, 1 tumoral calcinosis and 1 hematoma), and 1 penetrating foreign body.

Description of the technique

A disposable plastic bedpan (cost $5) is commonly available in hospitals and was used as the water bath for our study (Fig. 1). If a deeper receptacle was required for examinations of the foot, a 12-in plastic toy box was used as the water bath. The water bath is filled with lukewarm tap water to half its height. The affected hand or foot is immersed in the water such that the superior surface is just below the water edge. Scanning is performed with commercially available high-resolution linear transducers that are placed immediately adjacent to the skin surface, without touching it, simulating the use of conventional US gel. This technique provides a large field of view of the entire cross-section of the hand or foot in most cases (Fig. 2). Adjustments to image quality using appropriate frequency selection, focal zones and Doppler frequencies are made similarly to standard scanning. Keeping the transducer motionless during imaging helps to prevent artifacts arising from the water and affecting the superficial structures. The transducer head is waterproof in all US machines, but users are instructed to check with the manufacturer regarding safety and feasibility of immersing the transducer heads in water. The cable leading from the transducer should not be in contact with the water under any circumstances.

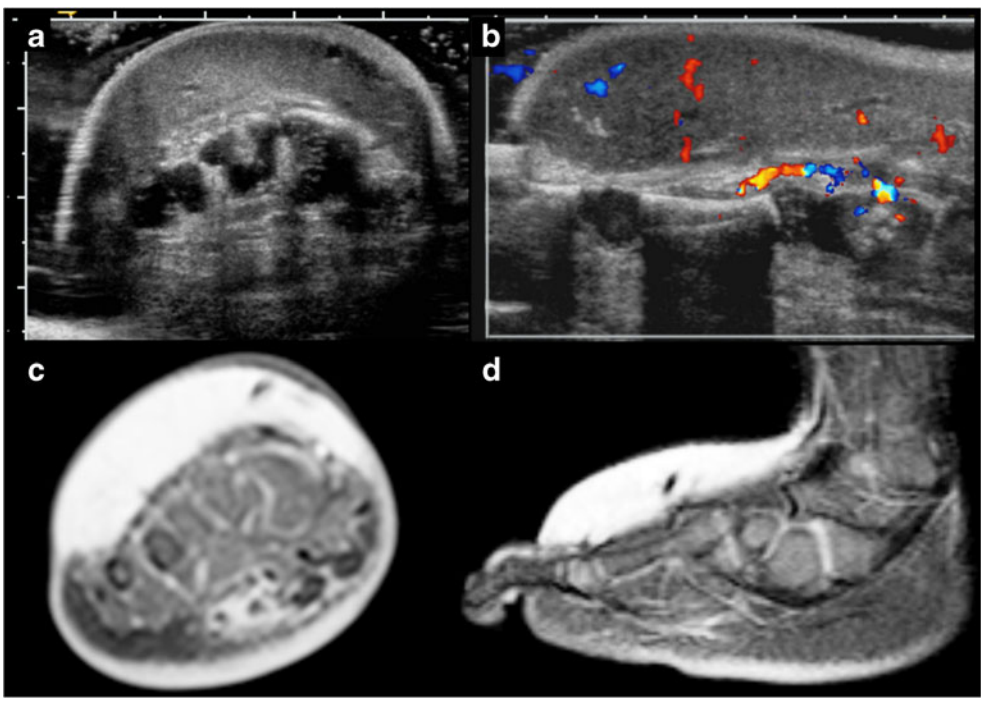

Fig. 2 The water-bath technique provides a large field of view of the entire cross-section of the hand or foot. In this newborn with a large dorsal foot mass, conventional sonography showed only segments of the mass, but the water-bath technique shows the entire foot in cross-section (**a**) and in long axis (**b**), producing images of the mass that were comparable to the short-axis (**c**) and long-axis (**d**) images using post-gadolinium T1-weighted MRI with fat suppression. The diagnosis was infantile hemangioma

Method

We conducted a retrospective review of the utility of adding water-bath scanning to the standard techniques of using a gel mound or stand-off pad. Comparison of the water-bath technique with the standard technique using a gel mound or a stand-off pad was available for 20 of the 23 children. In the cases of these 20 children, a single reader blinded to final diagnosis determined whether the new technique (1) altered diagnosis (yes/no) and (2) improved quality of imaging (yes/no). The final diagnosis was arrived at from follow-up MR imaging in seven cases, surgery/biopsy in four cases, and clinical evaluation and follow-up in all cases.

Results

The water-bath technique changed the diagnosis in three cases, all of which were vascular lesions. It provided superior quality of imaging when compared with the standard technique in all cases with available comparison (20/20 cases).

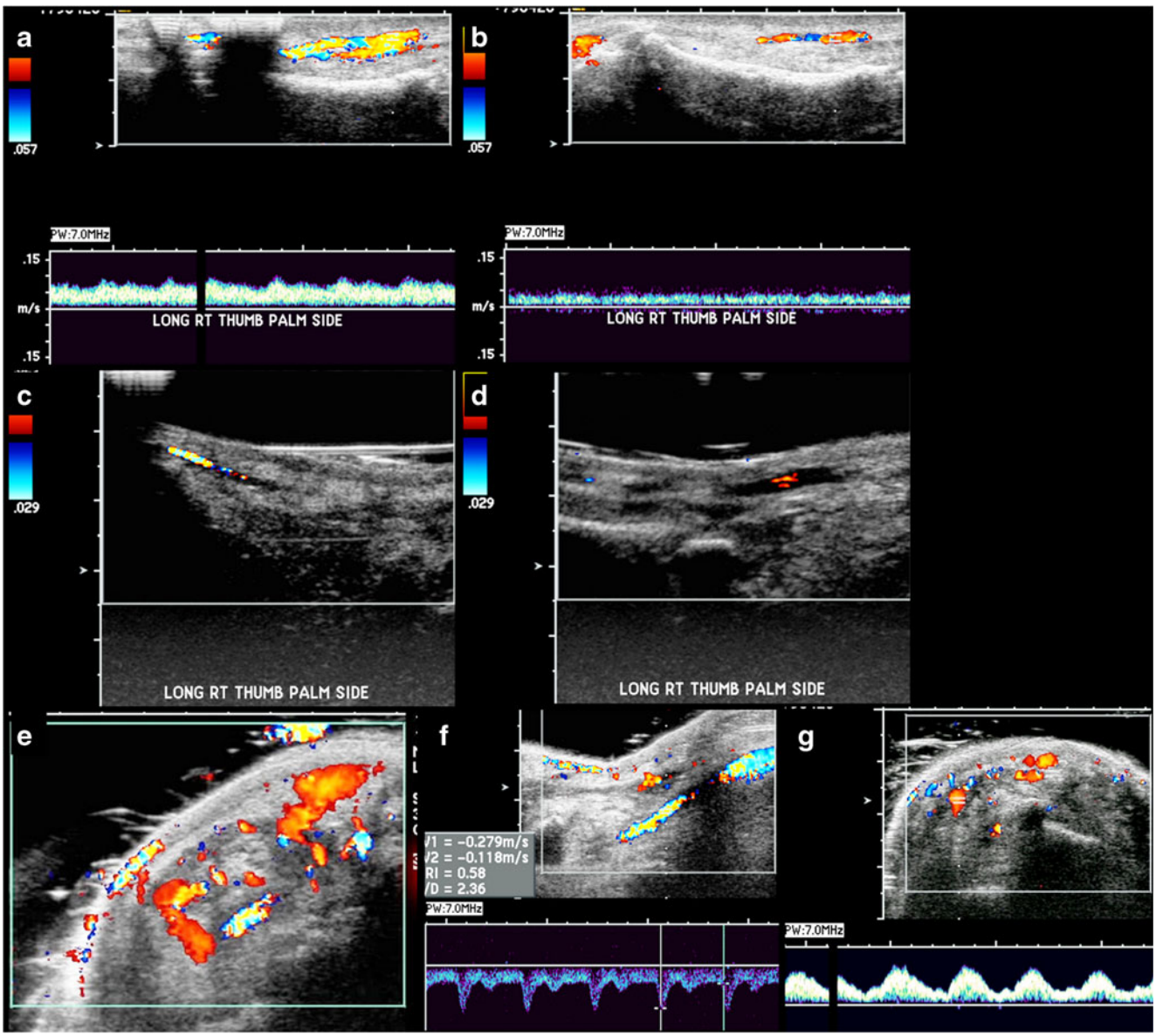

Fig. 3 Images of a subcutaneous AVM in a 9-year-old boy. The AVM manifested as a nonspecific swelling over the radial aspect of the wrist, without any associated warmth or palpable thrill. Conventional imaging using direct transducer contact over a gel mound shows a few prominent vessels with low-resistance arterial flow (**a**) and non-pulsatile venous flow (**b**), suggesting an inflammatory process. A stand-off pad was then used to obtain better detail but it resulted in nonvisualization of superficial vessels because of compression (**c**, **d**). The child's hand was then placed in a water bath; imaging performed without any contact with the skin revealed numerous tortuous vessels (**e**) with low-resistance arterial flow (**f**) and pulsatile high-velocity venous flow (**g**), consistent with an AVM

We found the following cases of change in diagnosis with water-bath technique:

1. A subcutaneous arteriovenous malformation (AVM) manifested as a nonspecific swelling over the radial aspect of the wrist (Fig. 3), without any associated warmth or palpable thrill. Conventional imaging using direct transducer contact over a gel mound showed a few prominent vessels with low-resistance arterial flow and nonpulsatile venous flow, suggesting an inflammatory process. A stand-off pad was then used to obtain better detail but resulted in nonvisualization of superficial vessels because of compression. The child's hand was then placed in a water bath, with imaging performed without any contact with the skin, revealing numerous tortuous vessels with low-resistance arterial flow and pulsatile high-velocity venous flow, consistent with an AVM. This was confirmed using a high temporal resolution time-resolved MR angiogram (Fig. 4), which demonstrated the nidus of a subcutaneous AVM fed by branches of the radial artery, with two early draining veins.
2. The second case was isolated subcutaneous soft-tissue thickening of the hand with pulsatile low-resistance arterial flow within several vessels using the standard technique. It was suspected to be an AVM, but the water-bath study was able to successfully interrogate the regional veins, which demonstrated nonpulsatile flow, thereby confirming a diagnosis of cellulitis.
3. The third case was an example of a subcutaneous sclerosing infantile hemangioma that had an atypical appearance because of partial fatty replacement with lack of significant blood flow on the standard technique, but the water-bath technique revealed its discrete margins with hypervascularity, confirming the diagnosis.

There are several reasons image quality is improved using water-bath technique.

1. The lack of contact of the transducer with the skin resulted in reduced patient discomfort and improved cooperation in the setting of painful inflammatory processes such as cellulitis, subcutaneous ulcer (Fig. 5), tenosynovitis (Fig. 6), osteomyelitis (Fig. 7), abscess and penetrating foreign body. Patient motion was substantially reduced resulting in improved image quality.
2. The water-bath technique provided a large field of view unaffected by contour of the extremity, often providing a view of the entire cross-section or the length of the affected region (Figs. 2 and 7), as opposed to the conventional technique, which allowed high-resolution imaging of only the area immediately in contact with the transducer. A benefit of the water-bath technique was easier identification of acoustic windows to assess deeper soft tissues.
3. Real-time dynamic evaluation of the affected tendons or joints was rendered a lot easier in the setting of tenosynovitis, ganglion cysts and ligamentous pathology (Fig. 8) because of an unhindered acoustic window

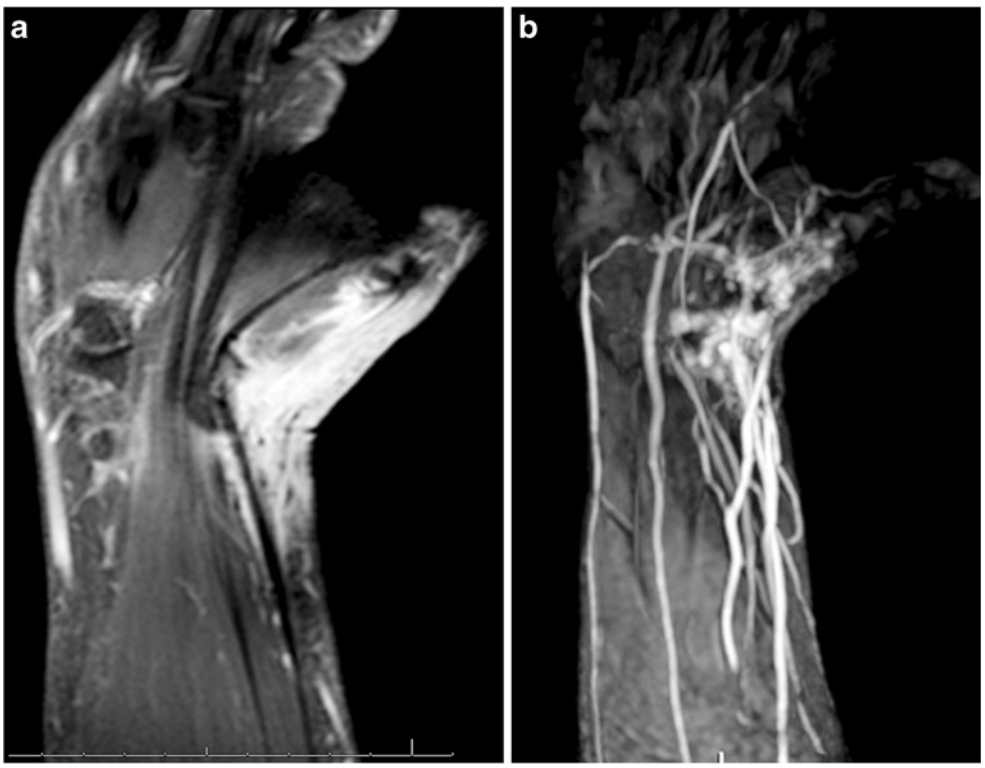

Fig. 4 Same patient as in Fig. 3. **a** Coronal STIR MR sequence shows abnormal soft-tissue thickening and increased STIR signal centered on the anatomical snuff-box of the right hand. The diagnosis was confirmed using a high temporal resolution time-resolved MR angiogram performed with a keyhole technique. **b** A maximum-intensity projection image from the MRA demonstrates the nidus of a subcutaneous AVM fed by branches of the radial artery, and two early draining veins

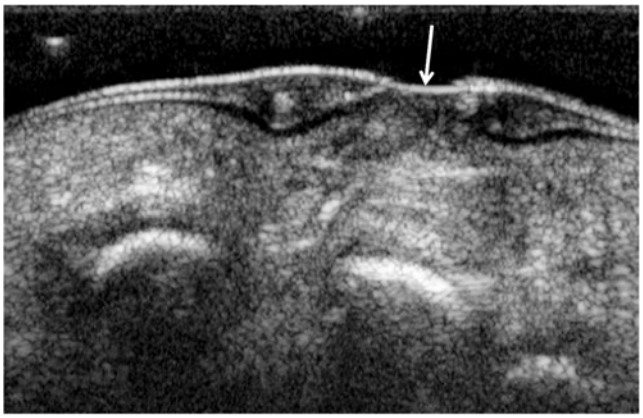

Fig. 5 The use of a water-bath technique to rule out an underlying abscess in a 10-year-old with a deep soft-tissue ulcer (*arrow*). The lack of direct contact with the inflamed pathology leads to better compliance and less motion, resulting in improved image quality

during motion, enabling the entire region to remain in the field of view across the dynamic maneuver.

Discussion

High-resolution US is often used as a first-line diagnostic modality for a wide variety of pathology involving the hands and feet [1–5]. It is portable, safe, inexpensive and widely available, provides excellent resolution for the superficial soft tissues and is conducive to dynamic evaluation. However, it is not without its limitations. Direct contact of the transducer with the skin of the affected region can be a source of discomfort for small children, resulting in lack of cooperation. The transducer head, with or without a stand-off pad, can compress important superficial structures, resulting in suboptimal delineation of pathology and in rare cases mischaracterization of pathology. The undulating surfaces and crevices of the small hands and feet of children and the limited sizes of high-resolution transducer heads often result in suboptimal contact of the probe with the region of interest, resulting in small fields of view and difficulty in rendering the big picture. The stand-off pad, in addition to causing compression of the structures, is thick, heavy and slippery. Some operators use a large amount of gel as an acoustic mound, with gentle placement of the probe head over the mound, to avoid compression of underlying structures. This technique, although effective for a focal abnormality, is usually not conducive to a comprehensive evaluation of the entire region of interest and depends on the cooperation of the child.

We have described a simple technique to enhance image quality of US examinations of the hands and feet in children by using a water bath. The technique uses simple and widely available material and has the potential to not only improve

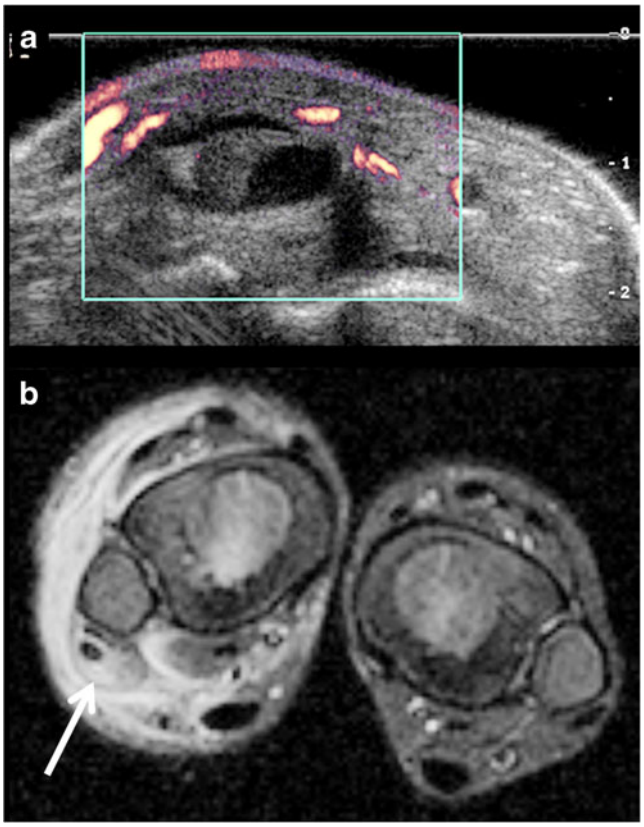

Fig. 6 The water-bath technique can also be used to image tendinous pathology around the ankle by using a deeper and wider receptacle, as in this adolescent girl with peroneus longus tenosynovitis (*arrow*) and adjacent cellulitis. **a** The water-bath method provided large field of view coverage of the entire lateral aspect of the ankle. **b** Subsequent post-gadolinium T1-weighted MRI was performed to rule out osteomyelitis

patient compliance and image quality in children but also diagnostic efficacy, as we demonstrated in our small series of cases.

The water-bath method has existed since the dawn of US imaging. A case report from 1981 describes a water-bath technique for imaging the thyroid gland [6]. Yamaguchi et al. [5] reported ultrasonic evaluation of pediatric superficial masses using a rubber balloon filled with water attached to the skin like a skin pad to bring the subject nearer to the focal distance and to obtain a wider and clearer image. Relatively recent publications used a water bath in the emergency room to improve characterization of lacerations, abscesses and tendon injuries [7–9].

The water-bath technique is based on the following principles:

1. Removal of direct contact between the transducer and skin results in decreased discomfort and improved patient cooperation. In our series, this was the single most important factor responsible for improvement in image quality when compared with the standard technique. The destructive bony changes with subperiosteal abscess, cartilaginous

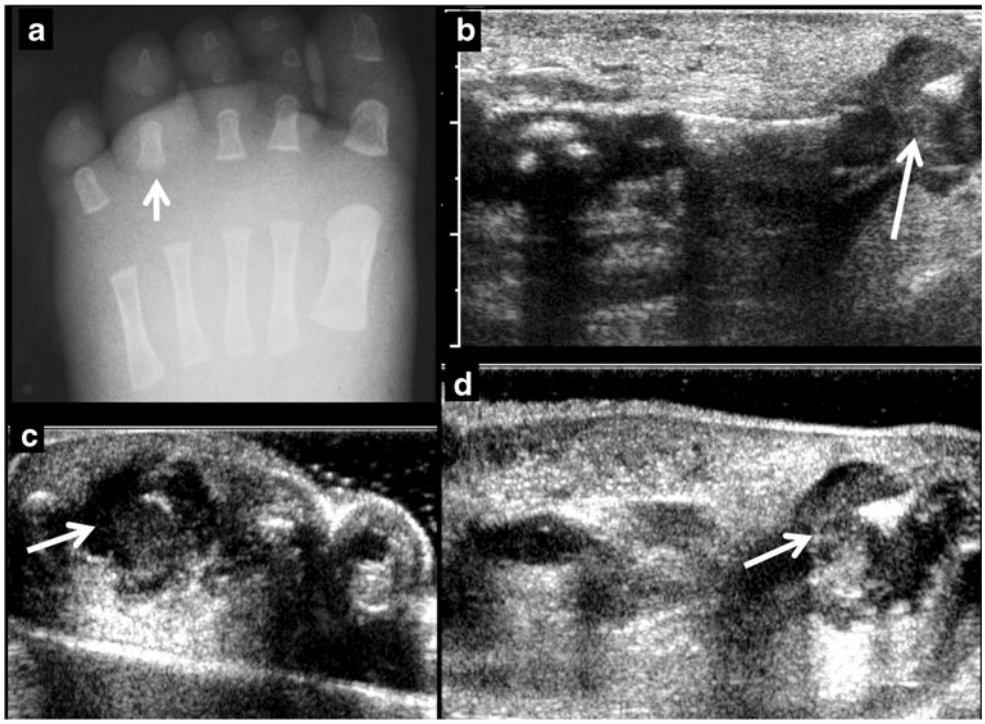

Fig. 7 Images of cellulitis of the foot in a 9-month-old boy. **a** Radiograph shows subtle loss of cortical sclerosis involving the proximal phalanx of the fourth digit (*arrow*), raising the possibility of osteomyelitis. **b** Conventional sonography with direct transducer contact was limited by significant tenderness but shows complex fluid collection surrounding the base of the proximal phalanx (*arrow*). Water-bath technique was then used, with short-axis (**c**) and long-axis (**d**) images of the fourth digit showing a large abscess (*arrow*) surrounding the base of the proximal phalanx, with secondary involvement of the metatarsophalangeal joint. Note the ability of the water-bath technique to show the entire foot in cross-section, similar to an MRI. The diagnosis of osteomyelitis and metatarsophalangeal joint septic arthritis was confirmed surgically

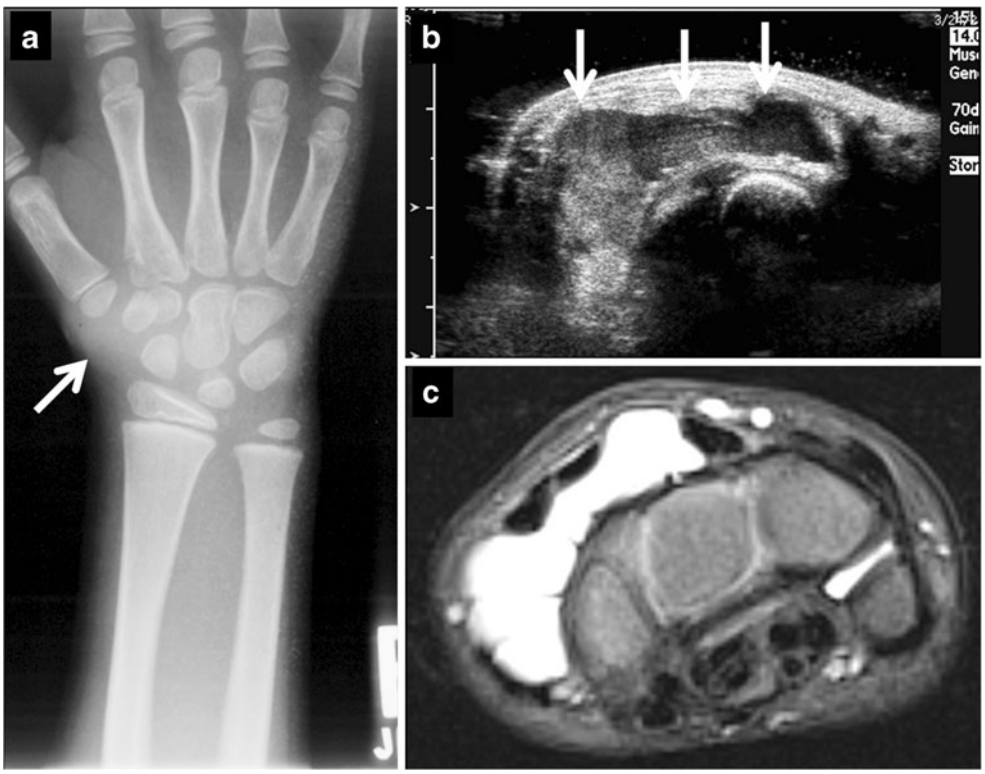

Fig. 8 Images in a 6-year-old girl with a mass on the radial aspect of the wrist noted on conventional radiography (**a**) and confirmed at surgery to be a dorsal intercarpal ganglion cyst. Transverse images from water-bath US (**b**) and MRI (**c**) show comparable anatomy, with location of the cyst (*arrows*) between the extensor tendons and underlying carpal bones

and joint involvement accompanying osteomyelitis of the digit was well demonstrated without making direct contact with the affected digit (Fig. 7). Similarly, screening for a penetrating foreign body is more successful because of enhanced patient cooperation.

2. This technique improves acoustic windows and provides an unhindered, large field of view that rivals MRI in comprehensive cross-sectional coverage and soft-tissue resolution in addition to providing flow characterization and dynamic real-time information. The technique overcomes limitations of the standard technique related to lack of transducer contact in the web spaces of the digits and in scanning over bony projections that are abundant in the hands and feet. Although an experienced operator can obtain the necessary information from standard US techniques, the big picture provided by the water-bath technique could improve communication with the referring physician and the patients.
3. Removal of compression of superficial structures and vessels results in improved characterization of the tissues and vasculature in their native state. This factor was responsible for the change in diagnosis in three cases in this series. In the setting of a low-grade AVM, the standard technique masked pulsatile flow in the draining veins by compressing the nidus and did not recognize the characteristic blood flow within a sclerosing infantile hemangioma. The water-bath technique allowed for accurate characterization of these lesions.

There are a few limitations to this study. It is observational, involved only one reader and included diverse pathology of the extremities. However, the primary purpose was not to validate the water-bath technique in any specific disease but to describe our technique of performing such studies. The technique itself is not without limitations. Positioning the foot to image its plantar aspect can be difficult in the absence of a broad water bath. Fixed supination of the hand in the water bath to image its palmar aspect can be uncomfortable for children. Children have to cooperate with placement of the extremity in the water, which can be challenging to accomplish with very young children.

Conclusion

The water-bath technique overcomes important limitations of conventional sonography in evaluation of superficial structures in the extremities of children, thereby improving diagnostic accuracy and image quality. The small parts of the hands and feet, especially, lend themselves to exploitation by this technique, and we recommend widespread adoption of this safe and simple method.

Disclaimer The authors have no financial interests, investigational or off-label uses to disclose.

References

1. Blankstein A, Cohen I, Heiman Z et al (2001) Ultrasonography as a diagnostic modality and therapeutic adjuvant in the management of soft tissue foreign bodies in the lower extremities. Isr Med Assoc J 3:411–413
2. Schumacher R, von Klingmuller, Reither M (1981) Ultrasound investigations of superficial structures during childhood. Rofo 135:635–640
3. Riebel TW, Nasir R, Nazarenko O (1996) The value of sonography in the detection of osteomyelitis. Pediatr Radiol 26: 291–297
4. Orlinsky M, Knittel P, Feit T et al (2000) The comparison accuracy of radiolucent foreign-body detection using ultrasonography. Am J Emerg Med 8:401–413
5. Yamaguchi M, Takeuchi S, Matsuo S (1987) Ultrasonic evaluation of pediatric superficial masses. J Clin Ultrasound 15: 107–113
6. Berger LA, Lister A, Lilley AC (1981) A water bath for thyroid scanning with ultrasound. Br J Radiol 54:630–631
7. Blaivas M, Lyon M, Brannam L et al (2004) Water bath evaluation technique for emergency ultrasound of painful superficial structures. Am J Emerg Med 22:589–593
8. Sierzenski PR, Leech SJ, Gukhool J et al (2003) Ultrasound evaluation of the index flexor tendon: a comparison of water-bath evaluation technique (WET) versus direct contact ultrasound. Acad Emerg Med 10:573
9. Sierzenski PR, Leech SJ, Blaivas M et al (2003) Water-bath vs. direct contact ultrasound: a randomized, controlled, blinded image review. Acad Emerg Med 10:573–574