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CASE SERIES

Contrast-enhanced Ultrasound of Kidneys in Children with Renal Failure

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Ultrasound (US) has been an important tool for evaluating and imaging renal pathology in children. Development of US contrast agents and dedicated software for the detection of microbubbles has given this radiological investigation a new dimension, especially in children with renal impairment. Application of contrast-enhanced US (CEUS) brings US into the domain historically occupied by computed tomography and magnetic resonance imaging. We retrospectively studied nine children who had undergone CEUS (age range 3—16 years). This pictorial essay draws on our experience and illustrates the safety and accurate depiction of enhancement pattern of focal renal lesions.

Introduction

Conventional ultrasound (US) has been the mainstay of the imaging renal system and abdominal organs in clinical practice, especially in the pediatric age group. With its advantages of being a nonradiating modality and real-time imaging, US has become essential in radiological evaluation in children. The advent of microbubble contrast-enhanced US (CEUS) has added a new dimension to this essential role and has the potential of offering insights to enhancing patterns of organs and masses similar to, if not better than, conventional computed tomography (CT) and magnetic resonance imaging (MRI) [1]. We provide an overview of the use of CEUS for assessment of renal diseases in children in our hospital.

As US contrast agents consist of microbubbles, and thus are blood pool agents, implying that they do not leave the blood vessels and are not subjected to normal renal filtration nor excretion, they essentially behave like vascular tracers.

The risk of water-soluble, contrast-induced nephrotoxicity and nephrogenic systemic fibrosis with gadolinium in patients with renal compromise (estimated glomerular filtration rate $<$ 30mmol/L) has essentially limited the role of contrast-enhanced CT and MRI in such patients. A conventional US kidney is often suboptimal in assessment of

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renal lesion characteristics [2]. Therefore, US contrast agents, with their relative safety and low incidence of side effects, offer a unique perspective to renal imaging. They are not nephrotoxic or cardiotoxic and are excreted in the lungs, and thus, their use does not require renal function tests to be performed prior to administration [1,3]. Riccabano and Darge et al and Riccabano and Avni et al all have found ultrasound contrast agents to be quite safe in use of children [4,5]. A large retrospective analysis showed that SonoVue has a good safety profile in abdominal applications, with an adverse event rate lower than or similar to that reported for radiological and magnetic resonance contrast agents [4,5].

SonoVue (sulfur hexafluoride by Bracco, Milan, Italy) is the only sonographic contrast available in our hospital and was used in these studies. SonoVue is phospholipid-encapsulated sulfur hexafluoride microbubbles with an average bubble diameter of 2.5 μm. Five milliliters of normal saline was added to SonoVue powder to form a suspension, and 1.5 mL of microbubble suspension was quickly injected via a peripheral vein (in which a 20 G intravenous cannula had been earlier inserted), followed by rapid bolus injection of 5 mL normal saline. We typically injected up to two boluses of well-dispersed microbubble suspension at an interval of 10—15 minutes. We selected appropriate positions, depending on different needs to perform coronal, sagittal scans of the kidneys. Gray scale US was conducted to observe tumor size, shape, echo intensity, and demarcation from adjacent tissues while color Doppler was used to examine the blood flow within and outside of the tumors. CEUS was performed by fixing a probe targeted at the mass following selecting a suitable section.

US equipment used in this study was AS500 (Toshiba Medical, Tokyo, Japan) and IU22 (Philips Medical, Amsterdam, The Netherlands), with contrast imaging mode on these machines.

Renal lesions were compared with their corresponding normal renal cortex. Lesions with post SonoVue enhancement higher than, lower than, or equaling that of the cortical echogenicity were defined as hyperenhancing, hypoenhancing, and isoenhancing, respectively. The vascular phases were classified into cortical (from 8—15 seconds to 30—35 seconds after injection), corticomedullary (from 36—41 seconds to 120 seconds), and late phase (> 120 seconds to the disappearance of bubbles) [6—8]. The differences in initial enhancement, the enhancement extent, and pattern were compared between the lesion and the peripheral renal cortex. The enhancement extent was classified into hyperenhancement, isoenhancement, and hypoenhancement compared with the surrounding renal parenchyma. In addition, the time in which the contrast agent entered and exited the mass was also compared with that of the rest of the normal. "Fast in" and "fast out" means that inflow and outflow of the contrast agent into and from the mass is earlier than as compared to the rest of the renal cortex; "identical in" and "identical out" mean that the contrast agent enters and exits the mass and the normal renal cortex at the same time; and "slow in" and "slow out" mean that inflow and outflow of the contrast agent are later in the mass than in the normal cortex. According to CEUS features, comparisons between renal lesions and their surrounding tissues, the dynamic change patterns of lesions in kidney and bladder were divided into six types, that is, fast in and fast out (FIFO), fast in and slow out (FISO), identical in and fast out (IIFO), identical in and identical out (IIIO), fast in and identical out (FIIO), and slow in and slow out (SISO) [9].

We present a group of nine children who had undergone CEUS, age range 3—16 years. Written informed consent was obtained from the parents before the study and the referring clinician was present on site at the time of the study. All these children presented with deranged renal function (estimated glomerular filtration rate < 30 mmol/L) and had undergone other limited cross-sectional imaging examinations which were equivocal for underlying disease. As the use of SonoVue in children is not approved by the Singapore Health Authority, it was only used as the last viable option for these children with renal failure, for whom further contrast imaging with CT or MRI was not possible. The decision to perform CEUS was made as a prelude to possible surgical intervention and/or biopsy. No episode of allergic reaction or post procedure complication was encountered in any of the assessed patients.

Renal cysts

Characterization of complex renal cyst remains a common and sometimes difficult diagnostic dilemma for the referring urologist and radiologist. These are routinely found incidentally on radiological investigations. Whether a cyst enhances or not, is important in differentiating it from being a malignant lesion, as the chance of neoplasia increases to 40—80% when there is enhancement noted [8]. Although contrast CT/MRI is the gold standard, CEUS has given evaluation of complex renal cyst a new dimension. CEUS has the advantage of being able to visualize the thin fine septa better than CT [2,10]. Fig. 1 shows a simple cyst in the kidney, with no nodular enhancement of the cyst wall, and no internal septae or delayed washout. Fig. 2 shows a complex renal cyst, with mild enhancement of the internal septae. However, no nodular enhancement of the septa and no washout within the cyst or septae is seen, rendering it a Bosniack II cyst.

Renal angiomyolipoma

Renal angiomyolipoma shows filling in of the contrast agent starting from the periphery of the echogenic mass and slowly extend to the center of the lesion with iso- or hypoenhancement to the rest of the normal renal cortex. This is most likely due to the presence of malformed blood vessels with tortuous course and disorganization. These anatomical features associated with renal angiomyolipoma result in SISO of the contrast agent, thus the start of the inflow and outflow of the contrast agent is both later in the mass than in the renal cortex. Fig. 3 shows a typical renal angiomyolipoma, where the lesion is seen to be less enhancing than the adjacent normal renal parenchyma at all phases, that is, arterial, portal-venous, and delayed phases.