CASE REPORT

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Potency of real-time virtual sonography for the preoperative evaluation of invasion in nephroblastoma

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ABSTRACT

Fusion with a real-time virtual sonography system is an ultrasonography fusion technology with magnetic position navigation. We present a case of a left nephroblastoma successfully resected using real-time virtual sonography for tumor margin assessment and excision boundary determination. A 2-year-old girl presented with fever and abdominal distension. Contrast-enhanced computed tomography revealed a large heterogeneous mass (90 × 75 × 125 mm^3) in the left kidney. Needle biopsy confirmed nephroblastoma. Chemotherapy with vincristine and actinomycin was initiated according to the International Society of Pediatric Oncology Wilms Tumor 2001 guidelines. Subsequent computed tomography revealed that the tumor size decreased to 45 × 25 × 63 mm^3; however, margins with adjacent muscles remained unclear, indicating potential invasion beyond Gerota's fascia. Real-time virtual sonography evaluation revealed a single fat layer separating the tumor from the muscle groups, showing tumor regression to the medial side of Gerota's fascia, with visible respiratory movements on ultrasonography. Left nephrectomy, including Gerota's fascia, was performed, preserving the abdominal wall muscles. Pathology confirmed that the tumor had penetrated the renal capsule but was completely resected with clear margins. The postoperative diagnosis was high-risk stage II blastemal type nephroblastoma, prompting chemotherapy on postoperative day 12. During the 5-year follow-up, no recurrence was observed. Real-time virtual sonography is a valuable adjunct for detailed preoperative evaluation when computed tomography alone is inadequate, facilitating precise tumor margin assessment and successful surgical outcomes.

Keywords: nephroblastoma, real-time virtual sonography, Wilms tumor

Abbreviations:
RVS: real-time virtual sonography
US: ultrasonography
CT: computed tomography

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INTRODUCTION

Fusion with a real-time virtual sonography (RVS) system is an ultrasonography (US) fusion technology with magnetic position navigation developed in Japan by Fujifilm Healthcare.[1,2] The RVS system comprises a transmitter and a magnetic sensor that detects the sonographic probe position. The transmitter is fixed to the US, and a magnetic sensor is applied to the sonographic probe. RVS enables the synchronization of real-time US and multiplanar reconstruction (MPR) of magnetic resonance imaging (MRI) or contrast-enhanced computed tomography (CT) images and provides the same cross-sectional MPR images as US images on the same monitor screen in real time, using Digital Imaging and Communication in Medicine (DICOM) volume data.[3] To date, it is widely used in various domains, including the liver, and its efficacy has been documented.[1-5] We here present a case of left nephroblastoma successfully resected by assessing the tumor margins and determining the appropriate excision boundaries using RVS.

CASE PRESENTATION

A 2-year-old girl presenting with fever, abdominal pain, and abdominal distension was referred to our department. She underwent contrast-enhanced CT, which revealed a large heterogeneous mass (90 × 75 × 125 mm^3) in the left kidney (Figs. 1 and 2). Enlarged para-aortic lymph nodes (10 mm) increased the suspicion of a metastasis. Blood tests revealed the following results: lactate dehydrogenase, 1,044 IU/L; blood urea nitrogen, 11 mg/dL; creatinine, 0.26 mg/dL; and C-reactive protein, 2.27 mg/dL. Furthermore, the diagnosis of nephroblastoma was confirmed using transretroperitoneal needle biopsy. Chemotherapy with vincristine (VCR) and actinomycin (ACT) was initiated (VCR 1.0 mg/m^2/week for 4 weeks and ACT 30 μg/kg in weeks 1 and 3) following the International Society of Pediatric Oncology Wilms Tumor 2001 guidelines, with two-thirds of the original dose based on the patient's body weight (11.3 kg). Subsequent CT revealed a reduced tumor size of 45 × 25 × 63 mm^3 (Fig. 3). However, the tumor bordered the quadratus lumborum and transversus abdominis muscles, and its boundaries were indistinct; therefore, completely ruling out tumor invasion beyond Gerota's fascia was not feasible. Therefore, to evaluate the suspected infiltrated areas, RVS was performed. RVS with CT revealed a single layer of fat separating the tumor from the muscle groups, indicating that the tumor border was on the medial side of Gerota's fascia (Fig. 4A). Additionally, another cross-sectional image revealed it (Fig. 4B). Moreover, at the same site, sliding with respiratory movements of the fascia and muscle groups was visible on the US screen. Conducting a more accurate assessment of ambiguous areas on CT was feasible. Left nephrectomy, including Gerota's fascia, and sampling of the para-aortic lymph nodes were performed; the abdominal wall muscles were preserved. Postoperatively, the lymphorrhea was complicated and improved with conservative management. Pathology confirmed that the tumor had penetrated the renal capsule into the perirenal fat and was completely resected with clear margins (Fig. 5). The postoperative diagnosis was high-risk stage II blastemal type nephroblastoma, prompting the initiation of chemotherapy on postoperative day 12 following the postoperative protocols. Cyclophosphamide (300 mg/m^2) for 3 consecutive days with doxorubicin (33.3 mg/m^2) on day 1 of this course (a total of six courses) at a 6-week interval was initiated. Etoposide (100 mg/m^2) for 3 consecutive days and carboplatin (133 mg/m^2) for 3 consecutive days (six courses) were administered at 6-week intervals starting from week 4. These courses were alternated. During the 5-year follow-up, no recurrence was observed.

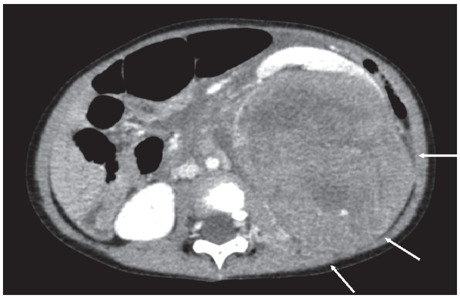

Fig. 1 Axial view of the contrast-enhanced computed tomography before chemotherapy
Imaging reveals a large heterogeneous pathological mass in the left kidney (white arrows).

Fig. 2 Coronal view of the contrast-enhanced computed tomography before chemotherapy
The tumor compresses the intestine (white arrows).

Fig. 3 Computed tomography finding after chemotherapy
The image reveals a reduced tumor size (white arrows).

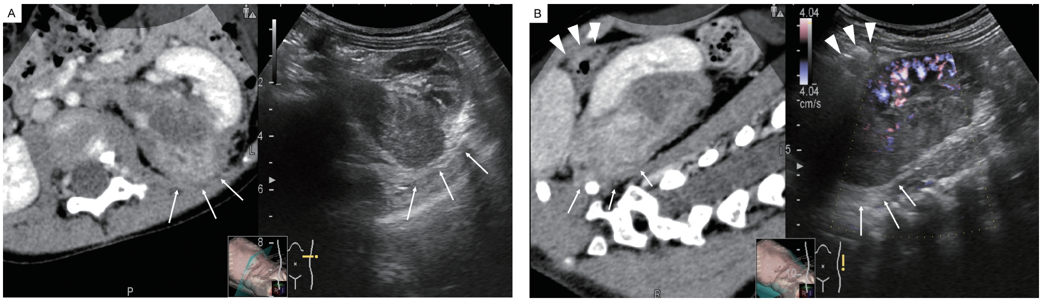

Fig. 4 Real-time virtual sonography with computed tomography findings after chemotherapy

Fig. 4A: A single layer of fat is noted between the tumor and the muscle group initially suspected of invasion on computed tomography (white arrows).

Fig. 4B: Real-time virtual sonography generates cross-sectional multiplanar reconstruction images identical to those produced using ultrasonography imaging. A single fat layer is observed between the tumor and muscle group (white arrows). Although gastrointestinal gas artifacts are revealed (white arrowheads), the fusion with computed tomography images facilitates orientation.

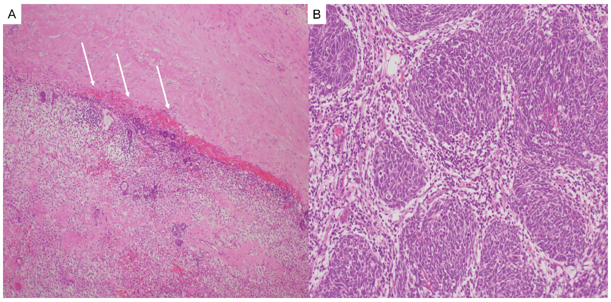

Fig. 5 Histopathological findings

Fig. 5A: Hematoxylin and eosin staining (×100). The tumor penetrates the renal capsule but does not extend beyond Gerota's fascia (white arrows).

Fig. 5B: Hematoxylin and eosin staining (×400); 70% of the viable tumor comprises a blastema.

DISCUSSION

The US offers the following advantages: it features minimal invasiveness and simplicity, includes no radiation exposure, and has good beam permeability into the abdominal cavity. This imaging modality is ideally suited for children possessing minimal subcutaneous and visceral fat.[6] It is typically more advantageous than CT in discerning intricate imaging details and the interrelationships with adjacent structures.[7] Although the US excels in dynamic and qualitative assessments, it is a generally subjective examination and lacks objectivity, particularly in malignant tumor staging. Although CT remains invaluable for preoperative anatomical evaluation, it provides qualitative tissue assessment and objective organ positioning. Regarding Wilms tumor, CT is superior in terms of assessing neoplastic invasion (rupture of the renal capsule and pelvic, ureter, and renal vein invasion) and plays a notable role in diagnosing the disease.[8,9] The reasons for the inferiority of US include challenges in reproducibility because of artifacts including gastrointestinal gas, and difficulties in visualizing large tumors in their entirety, compromising objectivity.[10] Although CT may be less precise than US for detailed evaluation, and assessment of tumor invasion into adjacent organs can occasionally prove challenging.[7,10] Reportedly, US is beneficial for assessing vascular extension,[8] confirming the presence of invasion by respiratory shifts in the fascia. Therefore, RVS, which integrates US and CT, mitigates the respective limitations of these modalities, thereby enabling high-quality image evaluation. Integrating CT objectivity into voluntary US enables the understanding of positional relationships between the lesion, the surrounding organs and vasculature, and the lesion's intrinsic structure.

RVS accuracy depends on the precise synchronization of US and CT, for which establishing reference points is critical. An experienced sonographer is preferable for ensuring accurate fixed-point positioning. However, for abdominal RVS, using the hepatic or portal vein bifurcation as a reference point is common; this can be reproducibly identified by several sonographers and physicians. The presence of metallic implants, which can generate artifacts, may compromise RVS accuracy. In CT imaging, metallic implants frequently generate circumferential artifacts, obscuring the surrounding anatomical structures. In contrast, US imaging, owing to its specific detection properties, frequently presents an acoustic shadow only on the dorsal side of the implant. Therefore, RVS can offer a reliable evaluation by offsetting the weaknesses of individual imaging modalities, particularly in cases involving metallic implants. Herein, the RVS from Fuji-film Healthcare was utilized; however, the RVS system was ready for use once the US scanner, magnetic sensor, and RVS software have been installed.[11] Furthermore, various companies have recently launched synchronous fusion US/CT products available in clinical practice. Reportedly, RVS is widely employed in adult population for various organs, including the breast, liver, and prostate.[1-5,11] Excluding the thoracic cavity, in which US is considered ineffective, RVS demonstrates high versatility. Although no studies have been conducted on its use in areas with extensive adhesions, dynamic evaluation using US, in conjunction with CT, may complement its effectiveness. As previously mentioned, no reports regarding the use of RVS in pediatric cases or in those with complications, including adhesions, have been conducted. Therefore, to assess its efficacy in such contexts, further case reports are warranted.

In this patient with nephroblastoma for whom CT suggested potential infiltration beyond Gerota's fascia, RVS enabled detailed US evaluation of the suspected region. At the same site, the absence of tumors reaching the fascia and the confirmation of respiratory shifts in the fascia demonstrated the high-resolution capability of RVS. Although the US alone can assess invasion, the evaluation of tumor invasion in the presence of gastrointestinal gas artifacts is challenging and widely considered inferior to CT.[10] However, RVS permits evaluation even in regions affected by artifacts using CT for orientation while performing US evaluation (Fig. 4B). Therefore, RVS enhances surgeons' confidence in the infiltration area in preoperative CT and offers remarkable advantages. Complete tumor resection evaluation is pivotal for subsequent therapeutic decision-making in Wilms tumor.[12] Several studies have suggested that employing RVS can facilitate lesion identification in synchronization with CT or MRI findings when US examinations are inadequate for identifying lesions.[4,5] However, the use of US with RVS when detailed evaluation is challenging with CT alone is conversely underscored in the present case, suggesting the broader potential of RVS. Furthermore, RVS compensates for the inherent limitations of US and CT, and providing more detailed information and making a more precise diagnosis become possible. Therefore, when CT cannot make judgments on the staging, RVS enables making a precise diagnosis.

Nevertheless, the RVS findings cannot be generalized without further validation in a larger cohort. Although RVS holds promise, additional studies are necessary for establishing its clinical utility. Moreover, considering this is a single case report, the potential for selection bias cannot be excluded. However, considering the established efficacy of US in breast and liver disease, similar outcomes may be anticipated in other patient populations, particularly in pediatric settings in which US demonstrates high reproducibility.

CONCLUSIONS

RVS is a valuable adjunct when detailed assessment is challenging with CT alone. By combining the objectivity of CT with the obscureness in the free scanning of the US, easy interpretation of the relationship between the lesions, surrounding organs, and position of vascular structures was possible. Notably, RVS could support preoperative assessment and enhance the surgeon's intraoperative judgment. Although RVS shows potential, conducting additional studies to confirm its effectiveness is preferred.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All procedures followed were in accordance with the ethical standards of the Helsinki Declaration of 1964, as revised in 2013. The publication of the present study was undertaken in accordance with the ethical standards of Shizuoka Children's Hospital (2024028). Informed consent was obtained from the patients and their families for the publication of this report.

AUTHOR CONTRIBUTIONS

Akiyoshi Nomura wrote the manuscript; Masaya Yamoto, Hideto Iwafuchi, Masashi Koyama, Kenichiro Watanabe, and Koji Fukumoto provided conceptual advice. All authors approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FUNDING SOURCE

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