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Initial Experience Performing Percutaneous Ultrasound Examination with Real-Time Virtual Sonography with Color Display

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Key Words

SYNAPSE VINCENT · Real-time virtual sonography · Hepatocellular carcinoma

Abstract

Purpose: We report the efficacy of percutaneous ultrasound (US) examination using a novel real-time virtual sonography (RVS) method that collates multiple Digital Imaging and Communications in Medicine (DICOM) data sources and displays reference images in color. ***Materials and Methods:*** A total of 7 patients with 9 hepatocellular carcinomas were evaluated. Using the SYNAPSE VINCENT volume analyzer, DICOM data of the portal vein, hepatic vein, tumor, and hepatic segment were isolated from contrast-enhanced computed tomography DICOM data. Each portion of DICOM data was uploaded into an US scanner (HI VISION Ascendus, Hitachi Aloka Medical Ltd., Tokyo, Japan) and unified on a US platform to create a single reference image. Each uploaded portion of DICOM data was assigned a different color. Further, conventional RVS was performed using this information. ***Results:*** The maximal tumoral diameter ranged from 6.4 to 15 mm (mean ± SD, 11.0 ± 2.8). DICOM data could be isolated, enabling the display of color RVS in all patients. Color RVS facilitated superior visibility compared with conventional grayscale RVS and facilitated the comprehension of spatial positioning. ***Conclusion:*** RVS with color display demonstrates utility in increasing operator comprehension of spatial and positional relationships during percutaneous US examination.

Introduction

Abdominal ultrasound (US) is a noninvasive examination method that is recommended as a first-line screening tool for hepatocellular carcinoma (HCC) [1–6]. However, US is particularly operator-dependent and less objective compared with computed tomography (CT) [7] or magnetic resonance imaging (MRI) [8]. To overcome these disadvantages, the first US navigation system real-time virtual sonography (RVS) was developed by Hitachi Aloka Medical (Tokyo, Japan) in 2003 [9]. Various imaging software products using multiplanar reconstruction are available for the diagnosis of HCC and guiding treatment decisions [10–12]. Navigation systems are able to increase operator comprehension of the 3D relationship between the liver vasculature and tumors. Therefore, several other companies have subsequently developed navi-

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gation systems such as V-NAVI (GE, Fairfield, Conn., USA) and Smart Fusion (Toshiba Medical Systems, Tochigi, Japan). These technologies are used in clinical settings to identify tumors during patient screening and demonstrate utility as supportive modalities in radiofrequency ablation (RFA) therapy [13–17]. RVS is an innovative imaging technique that can produce reconstructed images based on real-time US imaging using Digital Imaging and Communications in Medicine (DICOM) data from CT and/or MRI. RVS allows the practitioner to easily comprehend spatial and positional relationships because the reconstructed reference screen image using DICOM data of CT and/or MRI is synchronized with the actual movements of the US probe. Although discrepancies between the reference and the real-time US image may be observed on the US monitor during RVS, the thick portal vein and hepatic venous vasculature represent good landmarks for adjustment and can easily be synchronized by rematching. Although the RVS system allows positions to be matched using thick blood vessels as markers, in cases where positions are matched according to thin blood vessels to identify peripheral lesions, it is often difficult for the practitioner to be confident that the blood vessel observed on the grayscale reference screen is the same as the thin blood vessel observed on the real-time US image.

In the present study, we evaluated a novel RVS method that displays the reference screen in color (color RVS).

Materials and Methods

Patients

A total of 7 patients with 9 HCCs were evaluated in this study. All patients were diagnosed with ≥1 ≤15-mm HCC nodules by dynamic CT and/or contrast-enhanced MRI using gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid (Gd-EOB-DTPA-MRI) prior to US examination with color RVS. CT during hepatic arteriography and CT during arterial portography (CTAP) were performed in all patients within 1 week of color RVS to increase the reliability of diagnoses [18]. All patients were scheduled to undergo RFA. To evaluate the utility of color RVS, DICOM volume data of CTAP were transferred to the RVS. It was technically difficult to identify and confirm tumoral positions using conventional US alone in all patients included in this study.

Equipment

A local area network system was connected to a computer with SYNAPSE VINCENT (Fujifilm Medical Co., Tokyo, Japan), a medical imaging and information management system, at Takamatsu Red Cross Hospital. B-mode sonographic scans were obtained using a HI VISION Ascendus (Hitachi Aloka Medical Systems) with a 1- to 5-MHz convex probe (EUP C715).

CT was performed using a 64-slice multidetector row CT scanner (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan) with the following scan parameters: reconstructed slice thickness, 1 mm; rotation time, 0.5 s; helical pitch, 23.0; pitch factor, 0.791, and X-ray tube parameters, 120 kV, 300–400 mA. Triple-phase contrast-enhanced CT was performed at 40, 70, and 180 s after initiating the injection of contrast media to obtain hepatic arterial, portal venous, and equilibrium phase images, respectively. A total of 100 ml of nonionic contrast material containing 300 mg of iodine per milliliter (Iopamidol, Bayer Yakuhin, Osaka, Japan) was intravenously injected at a rate of 3 ml/s using an automatic power injector.

Evaluation

DICOM data from CTAP were analyzed by uploading data into the 3D image volume analyzer SYNAPSE VINCENT (Fujifilm Medical Co.) [12]. Liver analysis software, a specific application of SYNAPSE VINCENT, was utilized and liver tumor, portal vein, and hepatic vein data were isolated using the same method as for simulations performed before conventional liver resection. Next, data from the portal and hepatic veins adjacent to the liver tumor were separately extracted from other data related to the portal and hepatic veins, with each portion of DICOM data saved separately. These data were then transferred onto DVD or USB media. Extracted DICOM data were uploaded into a US scanner (HI VISION Ascendus). DICOM data were then integrated on the US platform to create a single reference image (fig. 1). The US scanner software, Ascendus, was then used to assign different colors to each portion of uploaded DICOM data enabling the display of color reference images. Then, US examination by color RVS was performed using the same method as for conventional RVS (fig. 2a, b). For each patient, DICOM data for segment areas adjacent to the tumor were also extracted and used to perform color RVS with each segment area displayed in color.

Results

The maximum tumoral diameter ranged from 6.4 to 15 mm (mean ± SD, 11.0 ± 2.8). DICOM data regarding the tumor, portal vein, portal vein adjacent to the tumor, hepatic vein, and hepatic vein adjacent to the tumor were successfully extracted for all patients. In 3 of the 7 patients, DICOM data per segment adjacent to the tumor were extracted to increase the understanding of segment positional relationships. Data were successfully identified for all patients without difficulty. Color RVS was then performed using information from the colored segment area. All 9 nodules examined via conventional US sonography were difficult to detect with certainty because of unclear boundaries with the surrounding normal liver (6 were isoechoic, 2 nodules were isoechoic to hypoechoic, and 1 nodule was isoechoic to hyperechoic). Although it was difficult to identify and confirm tumoral locations via conventional US sonography alone, using color RVS fa-

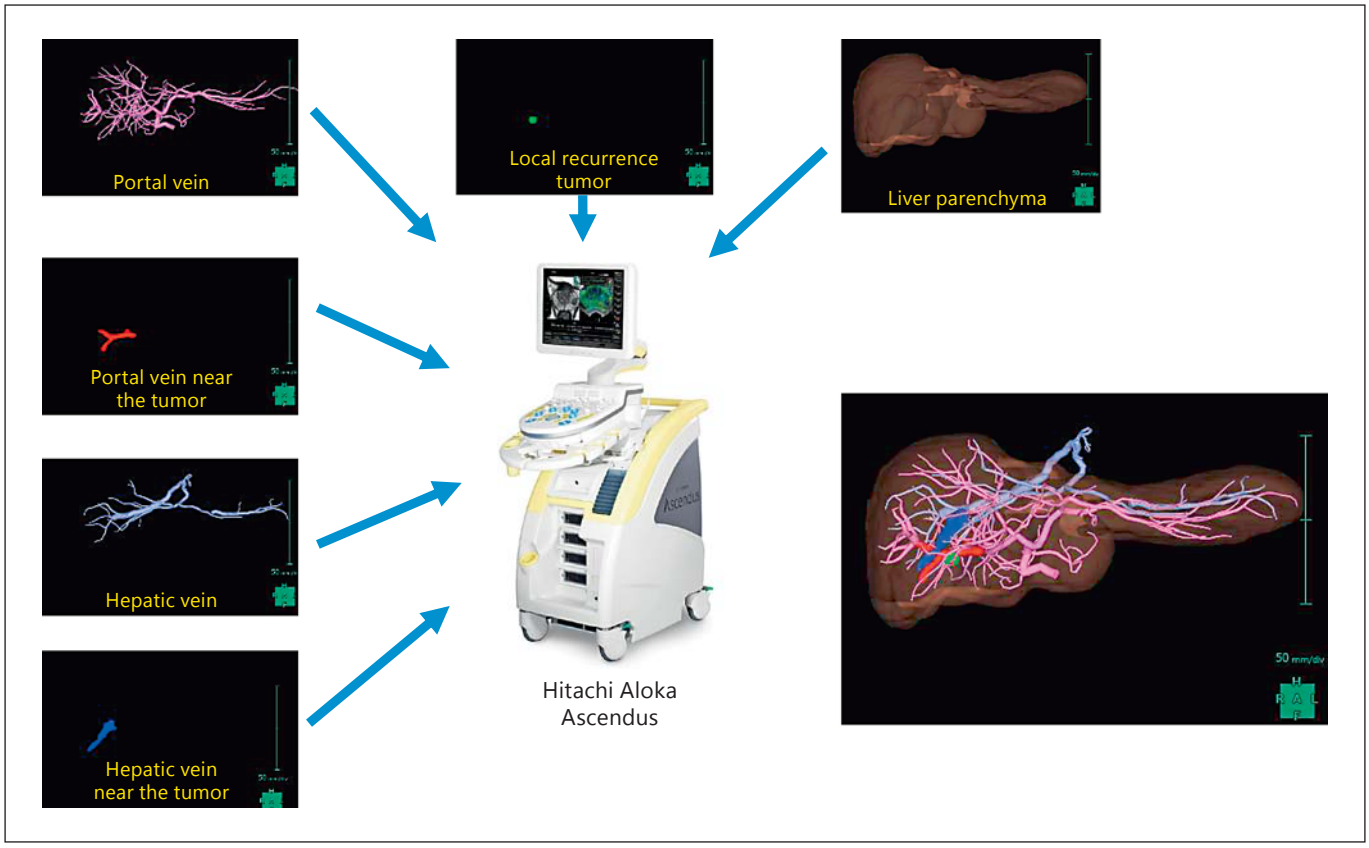

Fig. 1. Using the SYNAPSE VINCENT volume analyzer, DICOM data from CTAP were isolated, and a maximum of 8 segments of DICOM data can be uploaded onto an US platform and integrated to create a single reference image.

cilitated tumor identification and confirmation in all patients. Three of the 9 nodules were cases of local recurrence following RFA with unclear post-RFA borders at the recurrence site. By displaying a real-time US screen in color Doppler imaging (CDI), thin peripheral blood vessels on the reference screen and on real-time US could be displayed in color (fig. 2c). Using this method, operators could confidently conduct evaluations to easily identify the portal or hepatic vein with thin peripheral blood vessels. All patients then underwent successful RFA therapy in single sessions.

Discussion

RVS is a revolutional US technology that enables the use of CT or MRI data to easily determine spatial and positional relationships between lesions and blood vessels. In addition, because RVS synchronizes CT or MRI images on the US screen according to the movements of the US probe, RVS is considered to have an important role in guiding clinical treatments. In addition, numerous studies have demonstrated the utility of RVS as a supportive modality for RFA treatment [13–15]. However, the RVS reference image is constructed from one DICOM data image extracted from pretested contrast-enhanced CT or contrast-enhanced MRI and is displayed in grayscale. Thus, it is often difficult to instantaneously determine whether a thin blood vessel shown on the grayscale reference image and a thin blood vessel shown on the real-time US screen are the same vessel. Establishing whether the target thin blood vessel is the portal or hepatic vein requires continuous confirmation of the target blood vessel to its source. However, this identification can be difficult to confirm because of the presence of thick central blood vessels outside of the area rendered on US, which is dependent on probe direction. If positional alignment is accidentally performed with a neigh-

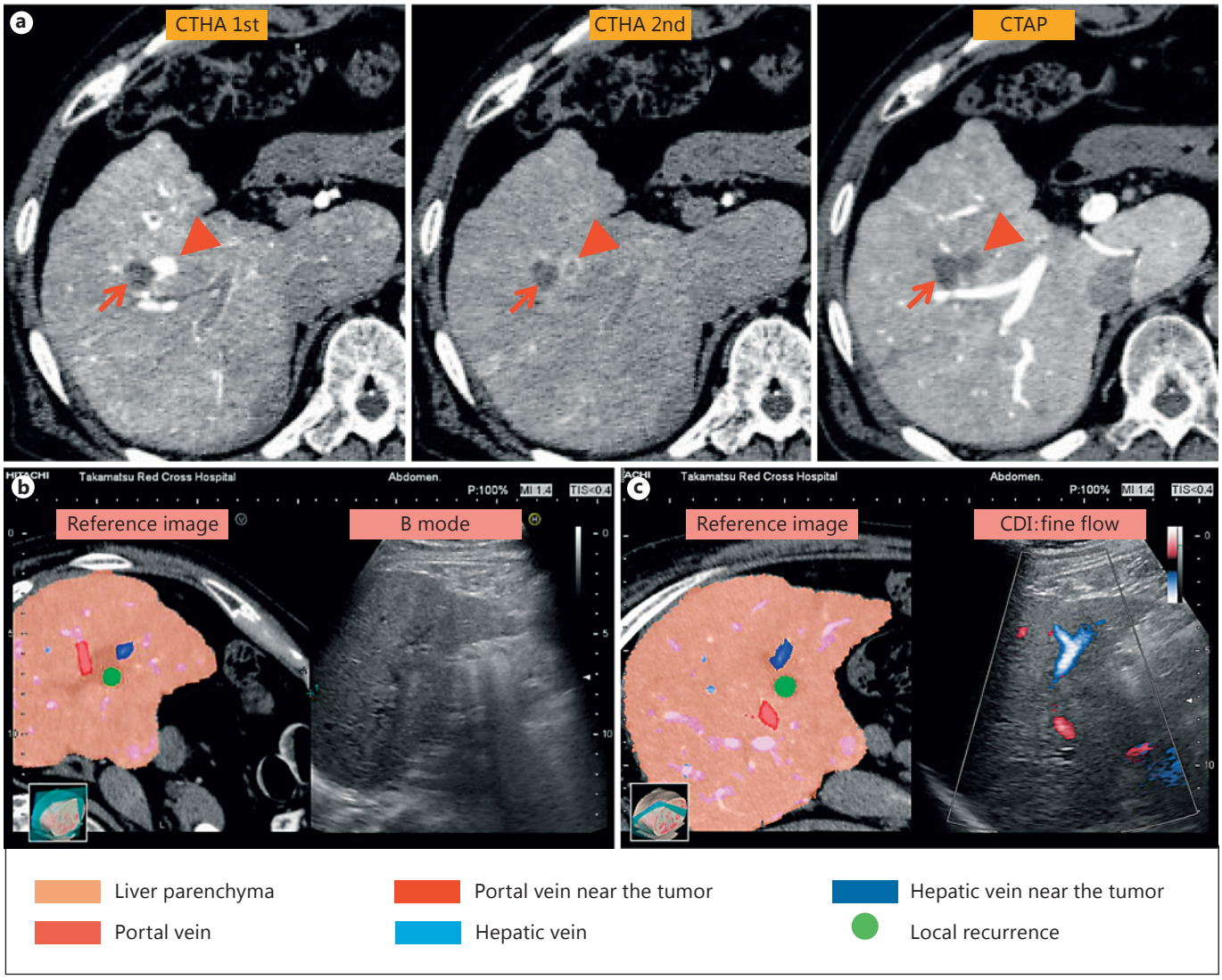

Fig. 2. Representative case of an 81-year-old man with a 9-mm local recurrence following RFA. **a** CT during hepatic arteriography (CTHA) and CTAP revealed a 9-mm local recurrence (arrowheads) and a post-RFA lesion (arrows) in liver segment VI. **b** The reference image could be displayed in color, and the examination using this information was performed with the same method as for conventional RVS. **c** By displaying the real-time US screen in CDI, the operator was able to identify vessels with greater confidence.

boring blood vessel, the positional discrepancy will increase, further necessitating repeat alignments and resulting in a time-consuming examination procedure. Therefore, a method to easily identify thin blood vessels is required. In particular, when identifying extremely small tumors of approximately 10 mm with isoechoic nodule density, alignment using thin blood vessels as markers must be performed to distinguish lesions from the normal liver background.

In recent years, the utility and sensitivity of Gd-EOB-DTPA-MRI in detecting early HCCs has been reported [5, 8, 19, 20]. This technology has enabled the identification of extremely small malignant nodules, increasing the frequency of situations in which practitioners are required to identify the position of tumors on RVS using thin peripheral blood vessels as markers. In cases of liver cirrhosis type B and alcoholic cirrhosis, multiple other small hepatic regenerating nodules are occasionally present; therefore, it is difficult to identify small HCCs without alignment using thin peripheral blood vessels. However, blood vessels observed on the reference screen and on real-time US are often misidentified when alignment

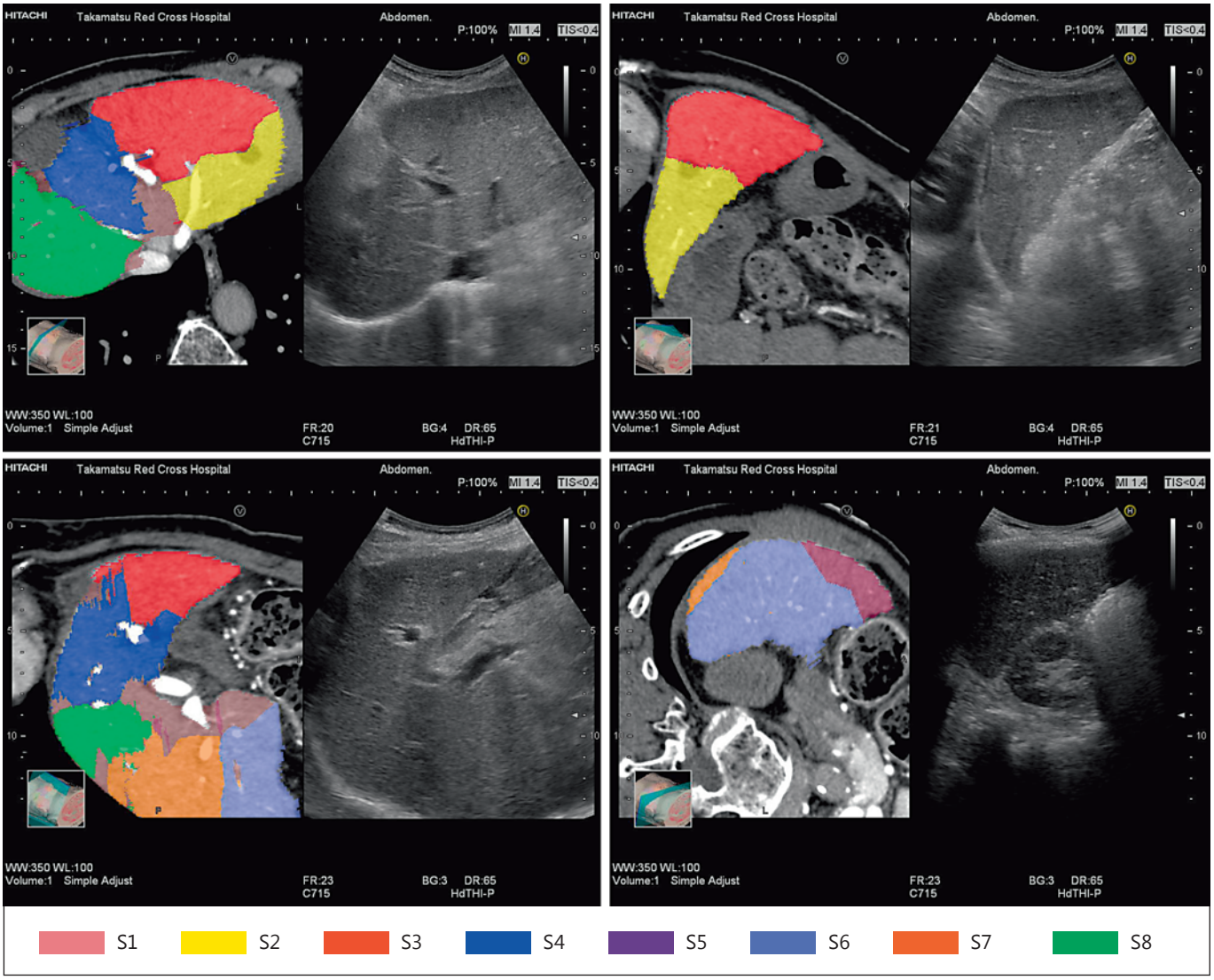

Fig. 3. Representative image of color RVS consisting of 8 segments assigned different colors. The comprehension and identification of segments during US examination is greatly increased.

is performed using vessels other than the thick central blood vessels.

To overcome this disadvantage, the epoch making colored RVS has demonstrated utility in identifying small liver tumors and as a supportive technology during treatment of HCCs by RFA. By integrating portal vein and hepatic vein DICOM data separated according to tumor proximity or central side location, and assigning different colors to each area, blood vessels adjacent to the tumor can be easily distinguished from either the portal or hepatic vein by color. Furthermore, because the portal and hepatic veins are shown in different colors, blood vessels adjacent to the tumor can be quickly detected when following blood vessels from the central to the peripheral region. Depending on tumoral locations, changing the B-mode screen CDI can increase the ease and simplicity of identifying target blood vessels. Color RVS facilitates superior visibility compared with conventional RVS, which displays images in grayscale only. Furthermore, by altering the color of blood vessels adjacent to tumors, tumors can be identified more quickly, facilitating increased operator comprehension of the spatial and positional relationships between tumors and blood vessels.

'Liver analysis software', a specific application of SYNAPSE VINCENT, can automatically isolate individual liver segments supplied by specific blood vessels. This

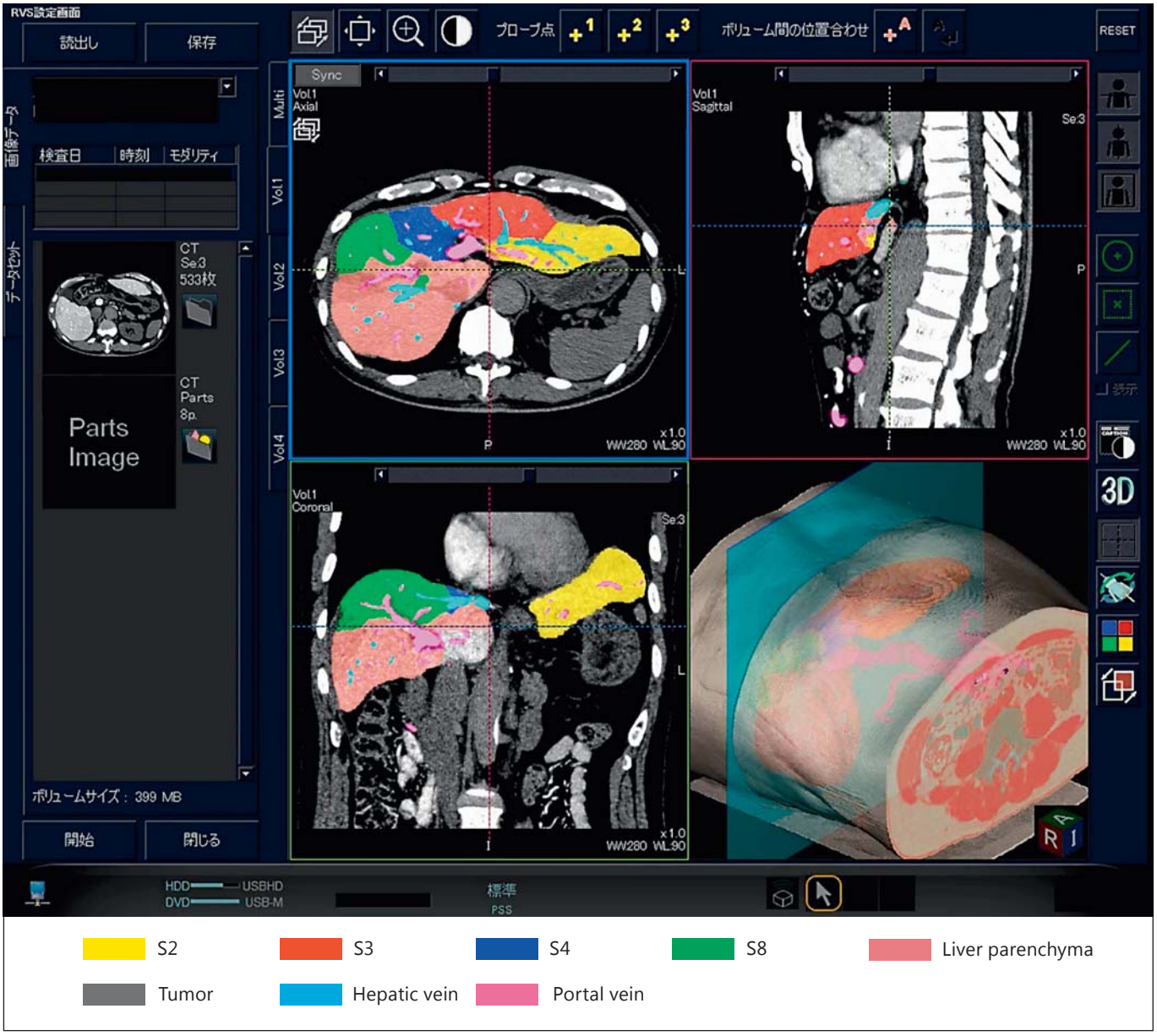

Fig. 4. Representative US display demonstrating the assignment of different colors to integrated DICOM data. By assigning a different color to each uploaded portion of DICOM data, the collated DICOM reference image could be displayed in color. DICOM data consisting of 4 segments (S2, S3, S4, and S8), the tumor, portal vein, hepatic vein, and liver parenchyma.

function is used in preoperative simulations prior to liver resection [21, 22] to determine resection ranges [23, 24]. By separately extracting all 8 segments as DICOM data using this function and uploading these segments into Ascendus, assigning different colors to each segment (fig. 3), and facilitating color RVS, the identification of segments during US examination is less technically challenging. Therefore, color RVS may represent a useful tool for educational and training purposes. With Ascendus, a maximum of 8 segments of DICOM data can be uploaded and integrated. Any combination is possible, e.g. DICOM data consisting of 4 segments (S2, S3, S4, and S8), the tumor, portal vein, hepatic vein, and liver parenchyma (fig. 4).

In recent years, there have been several reports regarding the utility of preoperative 3D simulation prior to liver resection, with various authors affirming the efficacy of preoperative 3D simulation using SYNAPSE VINCENT [24]. However, 3D simulation based on preoperative images is associated with issues such as inaccurate simulation because of factors including compression or distortion caused by intraoperative liver manipulations. Moreover, the liver must be returned to the orthotopic position to facilitate repeat alignments. In these settings, simulations using percutaneous US examination have been shown to be reproducible and extremely easy to operate because distortion due to liver positioning does not occur.

Color RVS has great utility in detecting small liver tumors and in contrast-enhanced US of small liver tumors and supporting RFA treatment. In the present study, all patients underwent CTAP. Therefore, we used DICOM data from CTAP for color RVS. However, DICOM data for color RVS can be extracted from conventional dynamic CT or MRI.

SYNAPSE VINCENT is the most widely used 3D image analysis system volume analyzer in the field of liver surgery in Japan and some other countries. Thus, there should be few obstacles to the introduction of color RVS at various facilities that would otherwise find it difficult to purchase new expensive, specialized software or equipment. Herein, we performed color RVS using the Ascendus US platform. However, color RVS can be performed using Preirus, which is manufactured by Hitachi Aloka Medical. With the SYNAPSE VINCENT server type, a liver analysis application can be used from a list of images on the normally employed chart PC. At our hospital, SYNAPSE VINCENT can be initiated not only in US rooms, but also on chart PCs located at over 100 stations including outpatient clinics, wards, and operating rooms. This widespread availability makes it possible to isolate DICOM data when physicians have spare time despite being in different locations. We believe this program could be universally introduced and are currently investigating the utility of color RVS in improving both percutaneous US examination and intraoperative US.

Conclusion

RVS with color display appears to have substantial utility in increasing the comprehension of spatial and positional relationships during percutaneous US examination.

Disclosure Statement

The authors declare that no financial or other conflicts of interest exist in relation to the content of this article.

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