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Medical Review

Seeing the Unseen

Clinical advances and future directions of SMI

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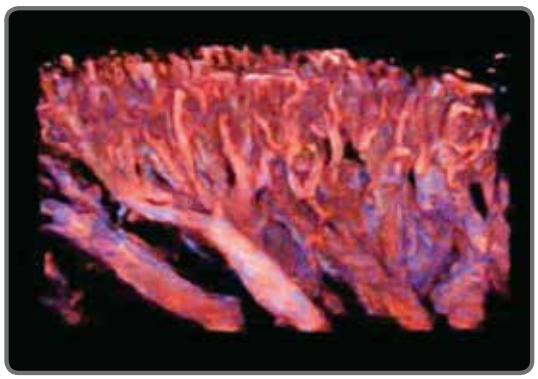

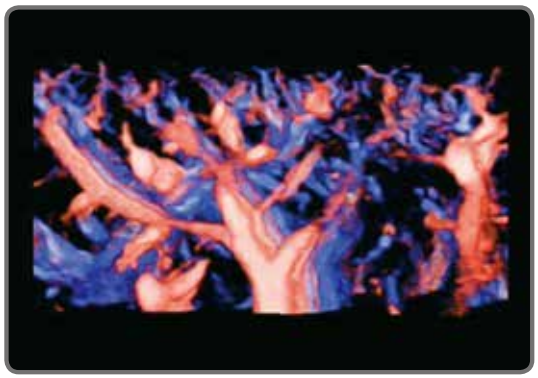

Seeing the Unseen
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Introduction

Superb Micro-Vascular Imaging (SMI) is a novel ultrasound Doppler technique available only on the Aplio™ Platinum Series. Compared with conventional Doppler methods, SMI has the advantages of high frame rates, high sensitivity (in particular in vessels with low velocities), high spatial resolution and low motion artefacts. SMI has clinical value in the evaluation of neoplastic diseases, inflammatory diseases and other disorders. SMI is extremely useful in the evaluation of the density and the shape of tumor vessels, assessment of activity in inflammatory diseases, diagnosis of ischemia or necrosis and monitoring chemotherapy response. The advantage of SMI over other imaging modalities is that even in a patient breathing freely, SMI can visualize the minute blood flow which shows the physiological change due to the respiratory cycle.

With the latest update on SMI, 3D SMI images can be constructed from 2D images obtained with SMI. 3D SMI images provide high resolution, three dimensional mappings of vascular structures and vessel branching, which enable more effective and accurate diagnosis, surgical planning and treatment evaluation.

Neoplasms

SMI has demonstrated significant clinical value for evaluating the density and shape of tumor vessels.

Submucosal Tumor (SMT)-like Gall Bladder Cancer

The grayscale images from a 71 year old woman (Fig. 3a) showed the presence of cholesterol polyps in the gall bladder. A solid component resembling biliary sludge was also found (Fig. 3b). Even with a higher frequency transducer, one cannot confirm whether this was a malignant tumor as the surface was smooth. The contrast enhanced ultrasound with time arrival parametric imaging (Fig. 3c) revealed rich perfusion inside the solid component, suggesting the presence of cancer. Also, SMI showed abundant tumor vessels (Fig. 3d). The patient was diagnosed with gall bladder cancer, which was proven by pathological examination (Fig. 3e). This was a unique cancer presentation because it looked like a submucosal tumor (SMT) but SMI was useful for making the correct diagnosis.

Gall Bladder Cancer

The following case is another example of gall bladder cancer. The suspicious area at the bottom of the gall bladder was observed in grayscale (Fig. 4a), but the diagnosis could not be confirmed by the grayscale image alone. However, the 3D SMI image showed the entire vascular structure inside this tiny tumor (Fig. 4b). Therefore, SMI is extremely sensitive for delineating tumor vessels and it can increase diagnostic confidence.

Pancreas Head Cancer

SMI is not only able to detect tumors with increased vascularity but can detect hypovascular tumors as

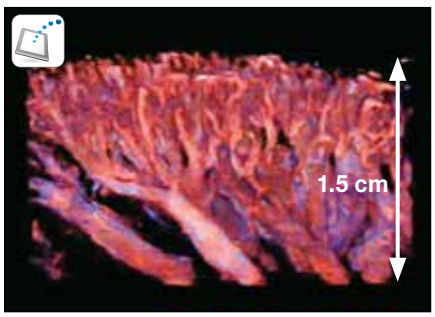

Figure 1. 3D SMI image of normal kidney
This looks like a 3D image created by CT angiography, but it is impossible to delineate each of these small vessels separately on a CT. The scale on the right side indicates the high spatial resolution of SMI.

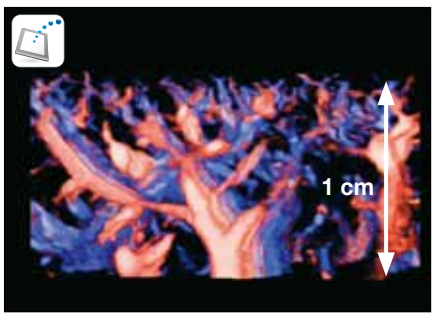

Figure 2. 3D SMI image of normal liver
This shows the fine vascular structure of a normal liver. This resembles a real specimen taken from the real liver, but it is impossible to make molds of these tiny vessels because they are so fragile. 3D SMI enables a delineation of vascular structure at a specimen level.

well, as demonstrated by this case of pancreatic cancer. On grayscale (Fig. 5a), the localization or even the presence of a tumor could not be confirmed. However, with cSMI, a hypovascular area in the pancreas was visible, strongly suggesting the presence of pancreatic cancer, which is commonly found to be hypovascular (Fig. 5b). After fine needle aspiration, the diagnosis was confirmed by surgical dissection (Fig. 5c). The distribution of cancer upon gross examination resembled the shape visualized noninvasively by SMI.

SMI enables the delineation of normal vascular structures and hypovascular areas inside the pancreas. In comparison, conventional color Doppler is inferior in visualizing the presence of the hypovascular areas in the pancreas.

Ovarian Cancer

A 33 year-old female presented with complaints of abdominal fullness. On grayscale, a large cystic tumor was observed in the abdominal cavity (Fig. 6a). There were a few solid components inside the cystic area but it could not be confirmed whether this was a tumor or sediments caused by infection or hemorrhage. cSMI clearly showed the rich vascular structure inside this solid component (Fig. 6b) and 3D SMI enabled a clear understanding of the entire vascular structure of this tumor (Fig. 6c). The diagnosis was ovarian cancer, which was later confirmed by pathological examination of the resected specimen.

Inflammation

SMI is particularly useful for evaluating disease activity, including inflammation, because of its high sensitivity to low velocity blood flow.

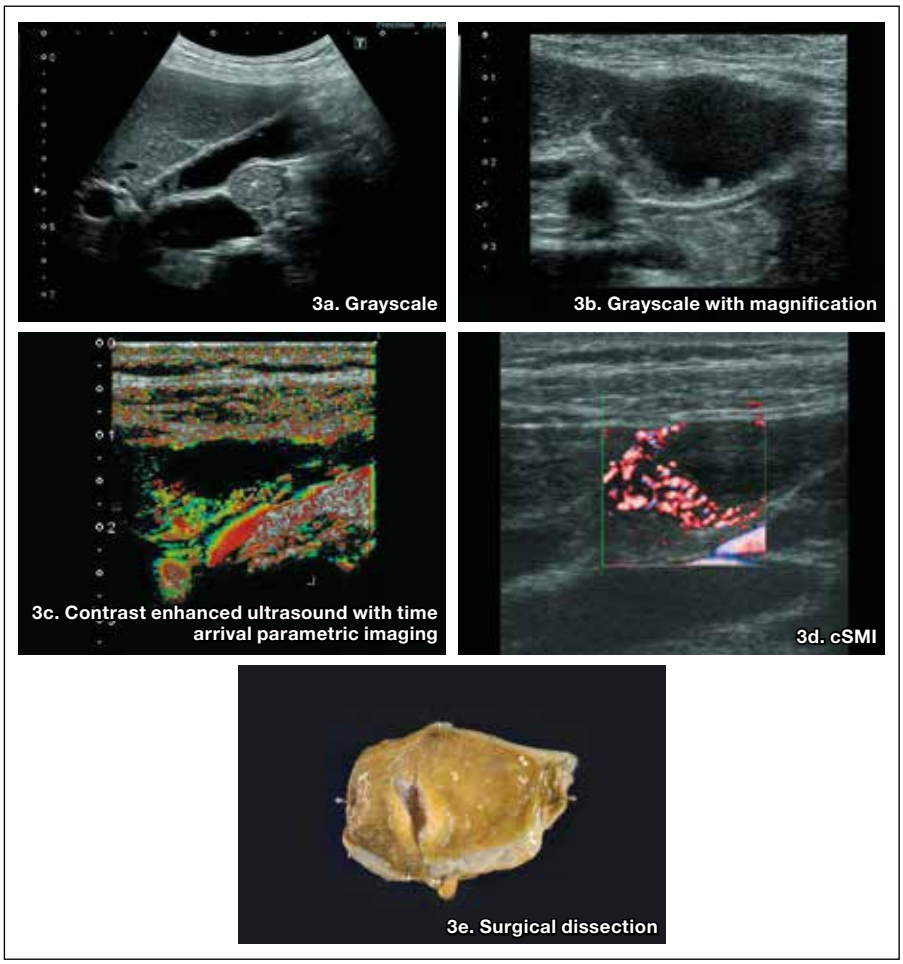

Figure 3. Submucosal tumor (SMT)-like gall bladder cancer

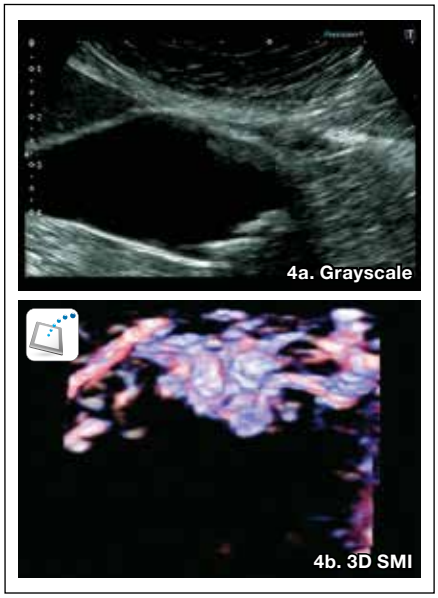

Figure 4. Gall bladder cancer

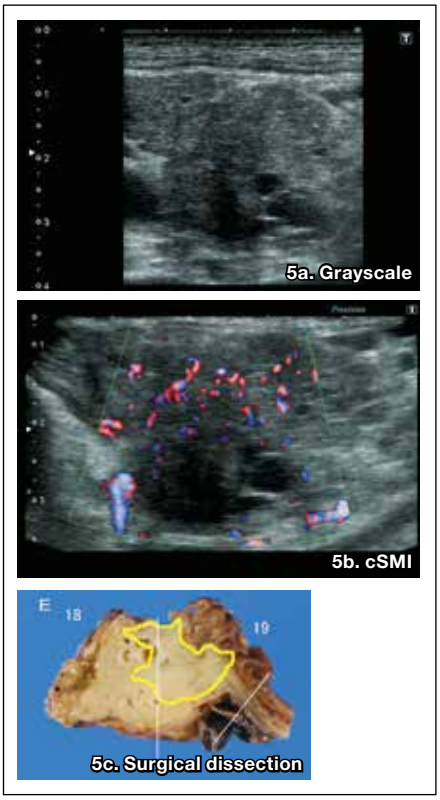

Figure 5. Pancreas head cancer

Acute Epididymitis

A 12 year-old boy presented with complaints of scrotal pain. On grayscale, the diagnosis of acute epididymitis was expected because there was swelling of the epididymis at the patient's right testis (Fig. 7a). This suspicion was confirmed by using SMI, which demonstrated hyperemia of the epididymis, representing severe inflammation (Fig. 7b, 7c). In patients with acute scrotal pain, the differentiation between testicular torsion and acute epididymitis is very important because the clinical courses of treatment are different. The diagnosis of acute epididymitis can be easily confirmed by using SMI based on its strong ability to delineate tiny blood vessels.

Other

SMI is effective in the diagnosis of ischemia or necrosis.

Traumatic Renal Injury

A 22 year-old man complained of left flank pain after badly hitting his left flank. On grayscale (Fig. 8a), there were some suspicious areas adjacent to his left kidney but the injury site could not be confirmed. By using cSMI, an avascular defect was detected (Fig. 8b) and confirmed by CEUS (Fig. 8c). 3D SMI clearly showed the entire area of vascular defect (Fig. 8d), which enabled a quick and accurate diagnosis. Appropriate treatment was successfully performed before the condition of the patient worsened.

Cavernous Transformation of the Portal Vein

On the grayscale images from a 17 year-old boy a portal vein deformity was observed but the abnormality was not clearly delineated by using conventional color Doppler due to overpainting (Fig. 9a). cSMI revealed the portal vein was composed of several small vessels instead of

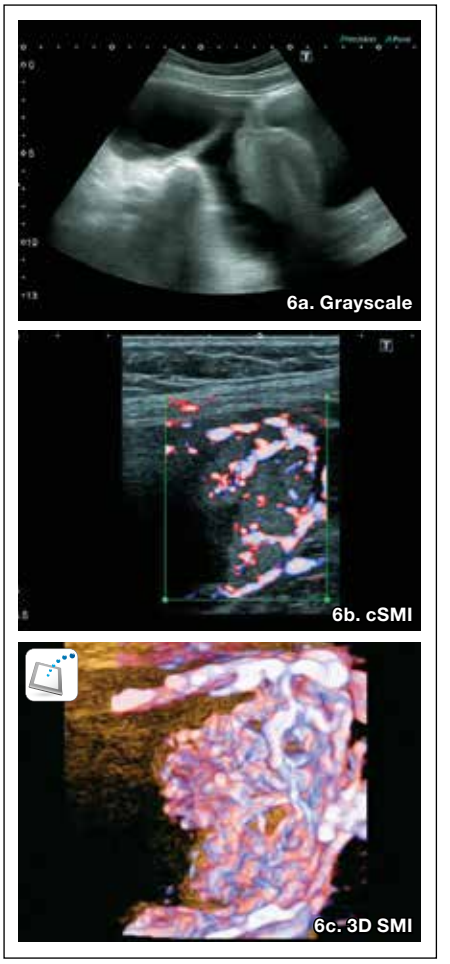

Figure 6. Ovarian cancer

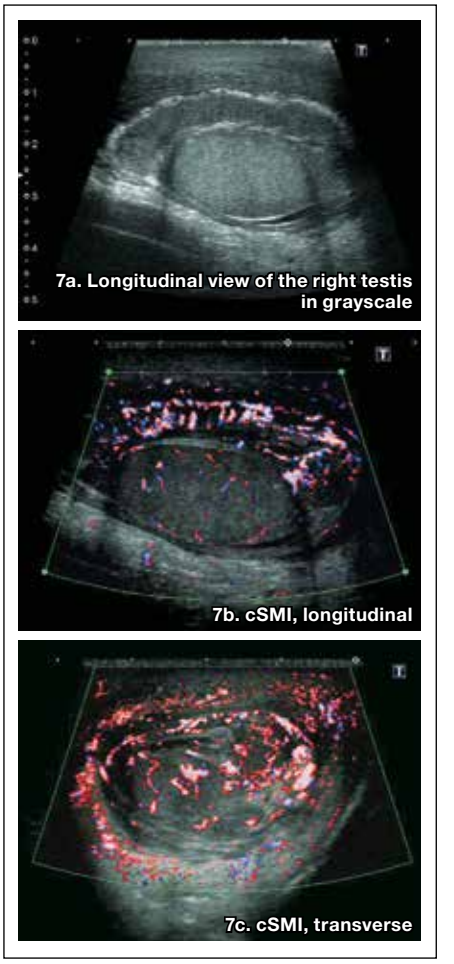

Figure 7. Acute epididymitis

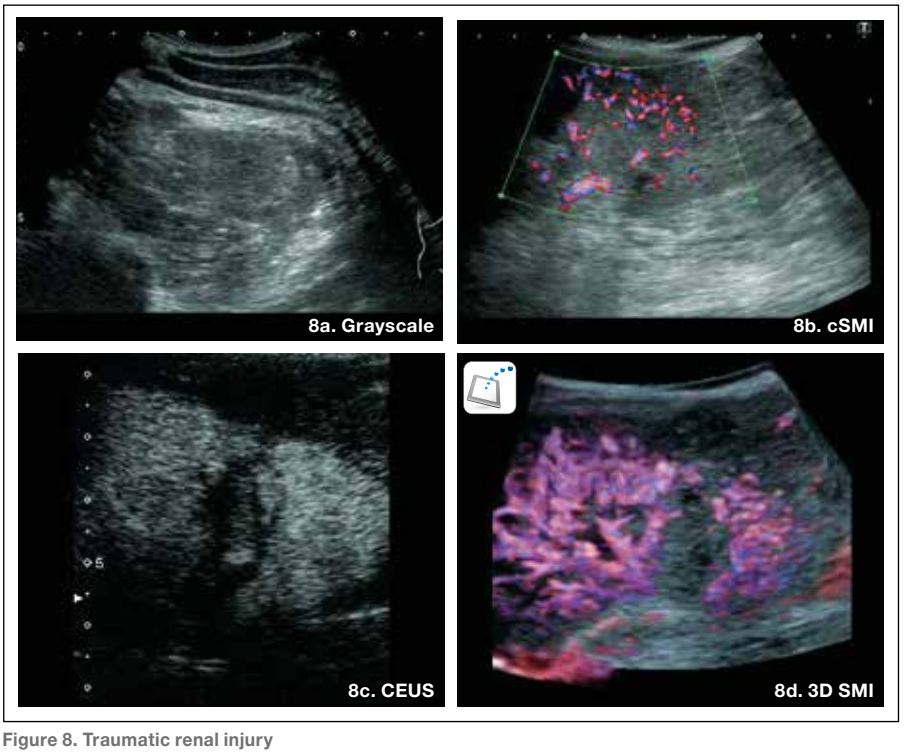

Figure 8. Traumatic renal injury

one portal vein (Fig. 9b). By using monochrome SMI (mSMI) with a higher frequency transducer (Fig. 9c), tiny vessels composing the portal vein were delineated. In addition, 3D SMI (Fig. 9d) clearly showed the cavernous transformation of the portal vein.

Conclusion

There are several options for using ultrasound to evaluate vascular structures. With conventional color Doppler, large diameter vessels and high velocity blood flow can be visualized, including display of the flow direction. SMI can detect low velocity, minute vessels, resulting in a more accurate and confident diagnosis. With 3D SMI, the entire vascular structure in an area of interest can be visualized, potentially allowing more effective surgical planning and treatment evaluation.

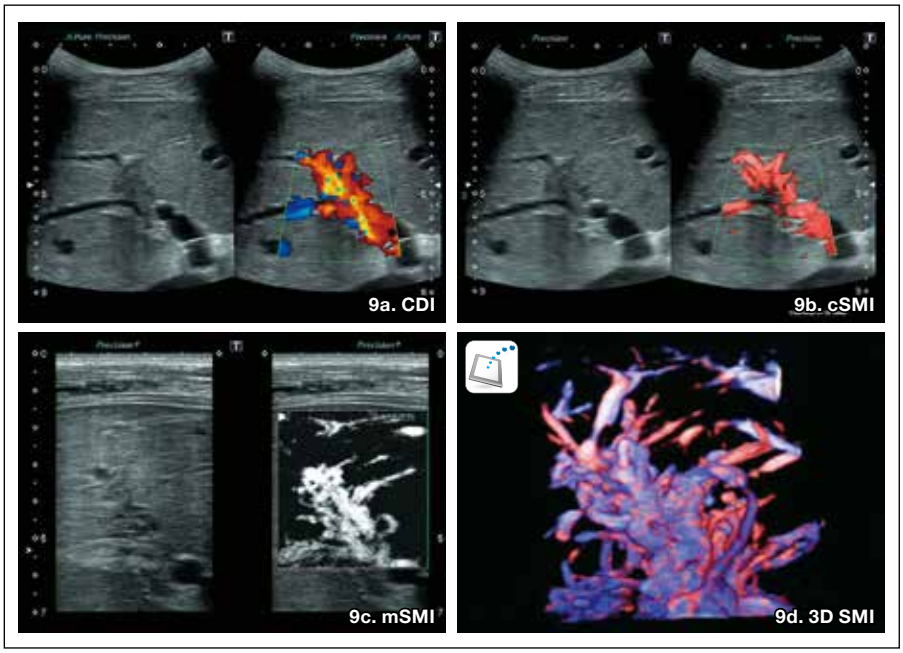

Figure 9. Cavernous transformation of the portal vein

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