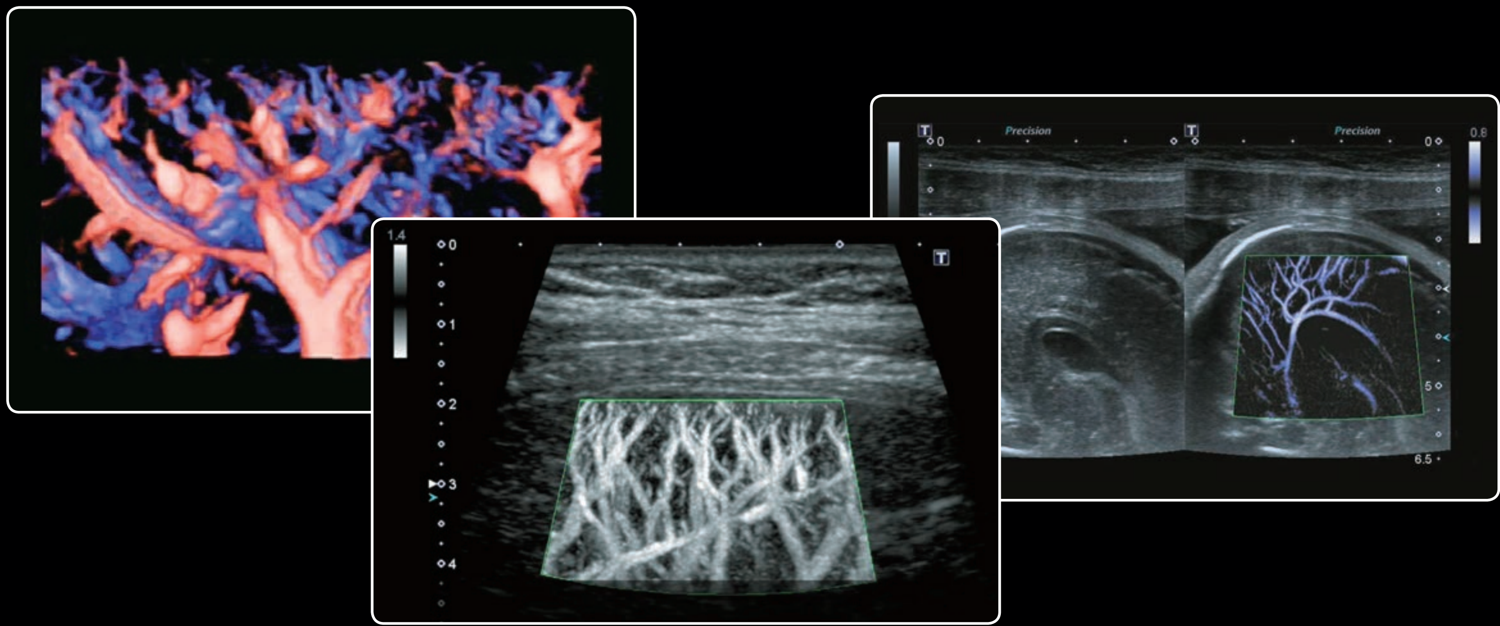
TOSHIBA MEDICAL

SMI

Superb Microvascular Imaging

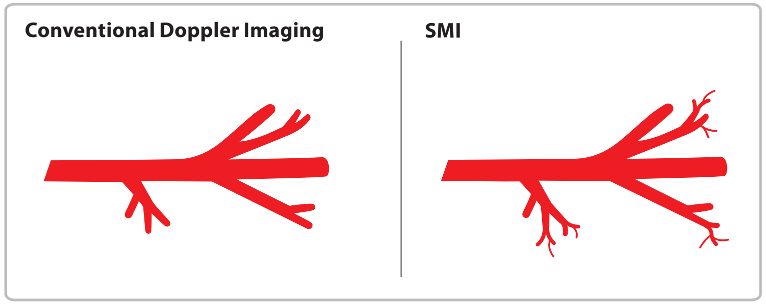
An essential ultrasound tool



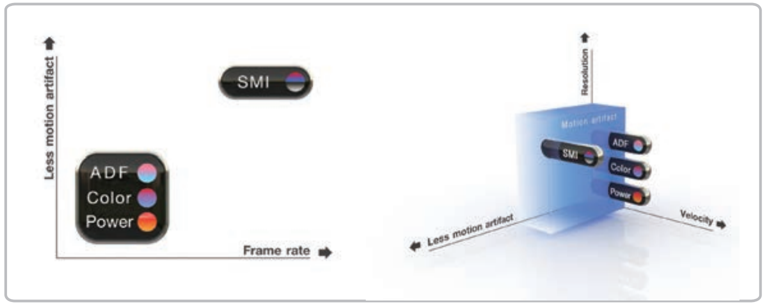
SEEING THE UNSEEN WITH SMI

Superb Microvascular Imaging (SMI)
SMI is a technology that expands the range of visible blood flow and provides visualization of low microvascular flow never seen before with ultrasound. Compared to conventional Doppler technologies, the advantages of SMI are high frame rates, high resolution, high sensitivity and fewer motion artifacts. This gives clinicians a new way to reveal minute vessels when evaluating lesions, cysts, inflammatory diseases and tumors. SMI offers an efficient tool for fetal assessment and patient monitoring during treatment phase.

Principle behind SMI
Traditional color and power Doppler technologies remove clutter by suppressing low velocity components. This suppression results in a loss of data, and subsequent lost visibility of flow in smaller vessels. SMI is a powerful and intelligent algorithm. Instead of suppressing these low flow signals, SMI separates these flow signals from overlaying tissue motion artifacts, while preserving low-flow components and providing detail and definition. SMI analyzes clutter motion and uses an adaptive algorithm to identify and remove tissue motion and reveal a more accurate blood flow depiction. This results in a high resolution ultrasound image in which minute vessels and low velocity flow can be demonstrated. All this can be done at high frame rates, not possible with any other Doppler technology.



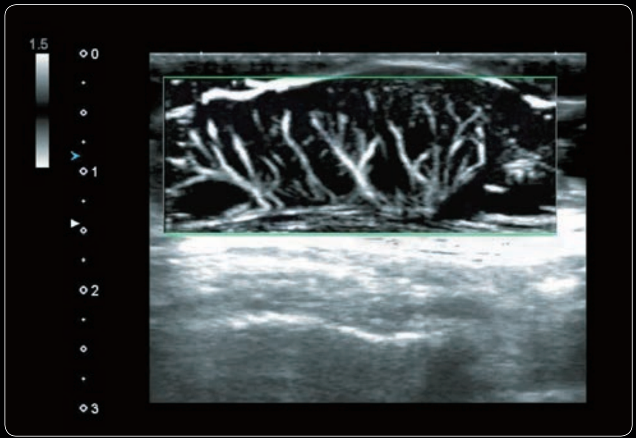
While conventional color Doppler (left) is unable to display flow in very small vessels which have very slow flow, SMI (right) can depict this microvascular flow.



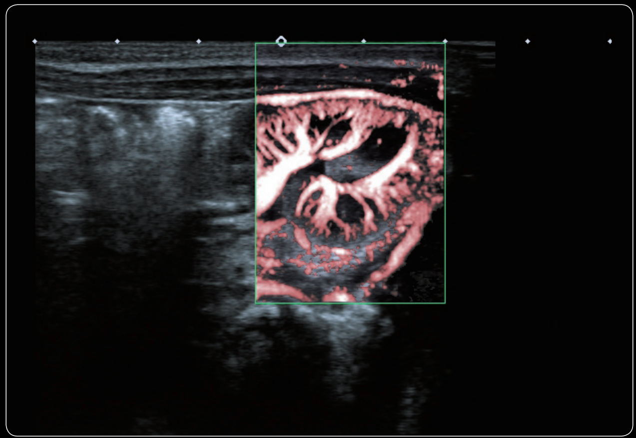
Difference between SMI and conventional Doppler techniques: SMI visualizes slow flow with a higher resolution and at higher frame rates while being less affected by motion artifacts.

Three modes of SMI

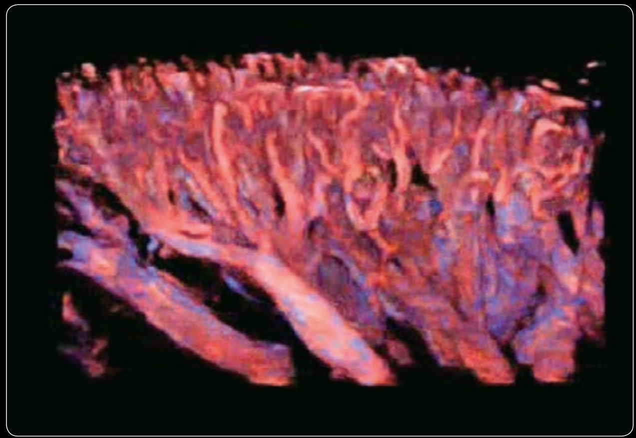
SMI currently has three modes available. The monochrome mode (mSMI) reveals fine vasculature with high sensitivity by removing anatomical background information.
Color-coded SMI (cSMI) demonstrates flow and greyscale information with high temporal and spatial resolution simultaneously.
With 3D SMI, the vascular structure and vessel branching relationships can be visualized.



Monochrome SMI (mSMI) visualizing squamous cell carcinoma underneath the facial skin surface.

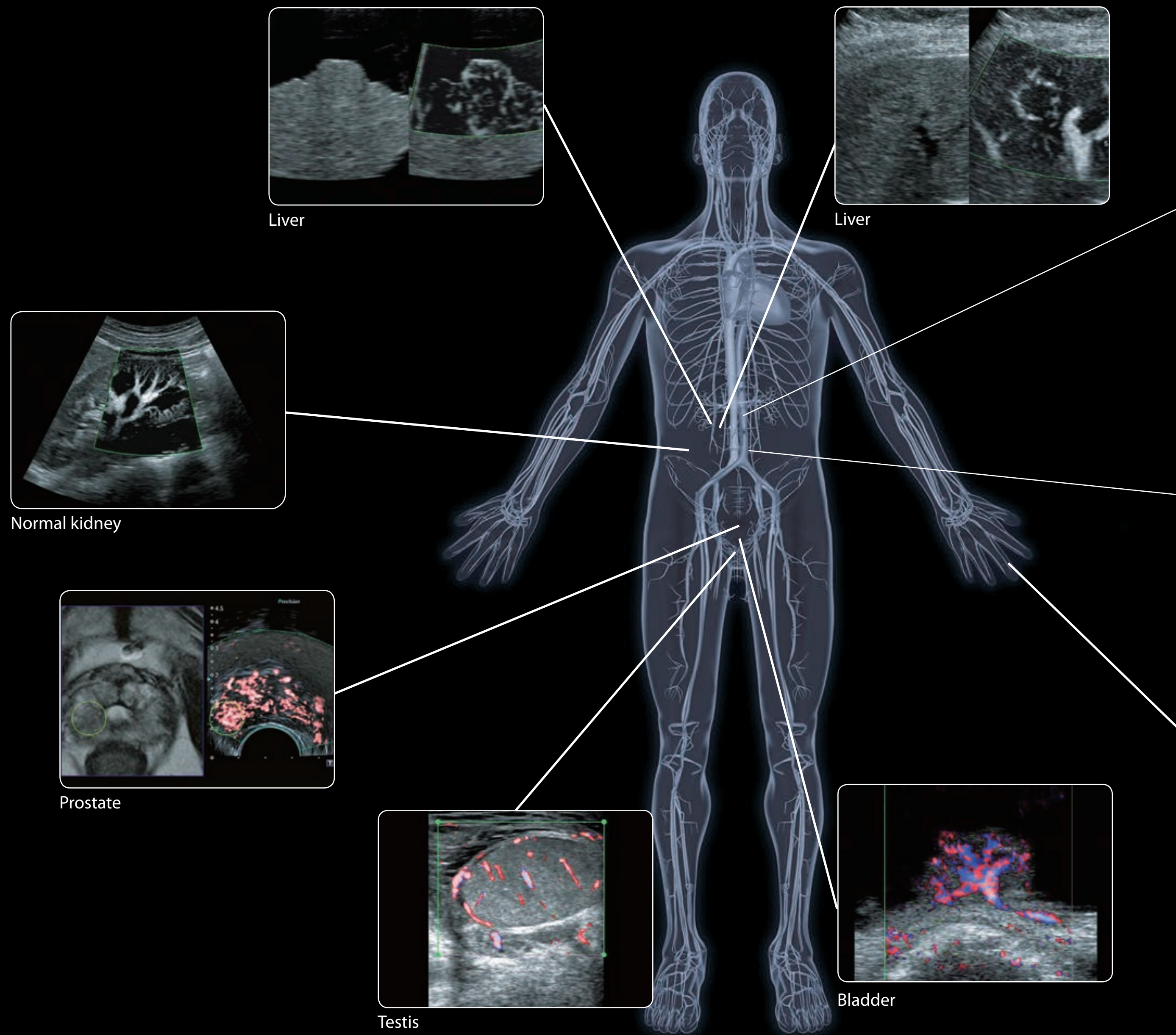


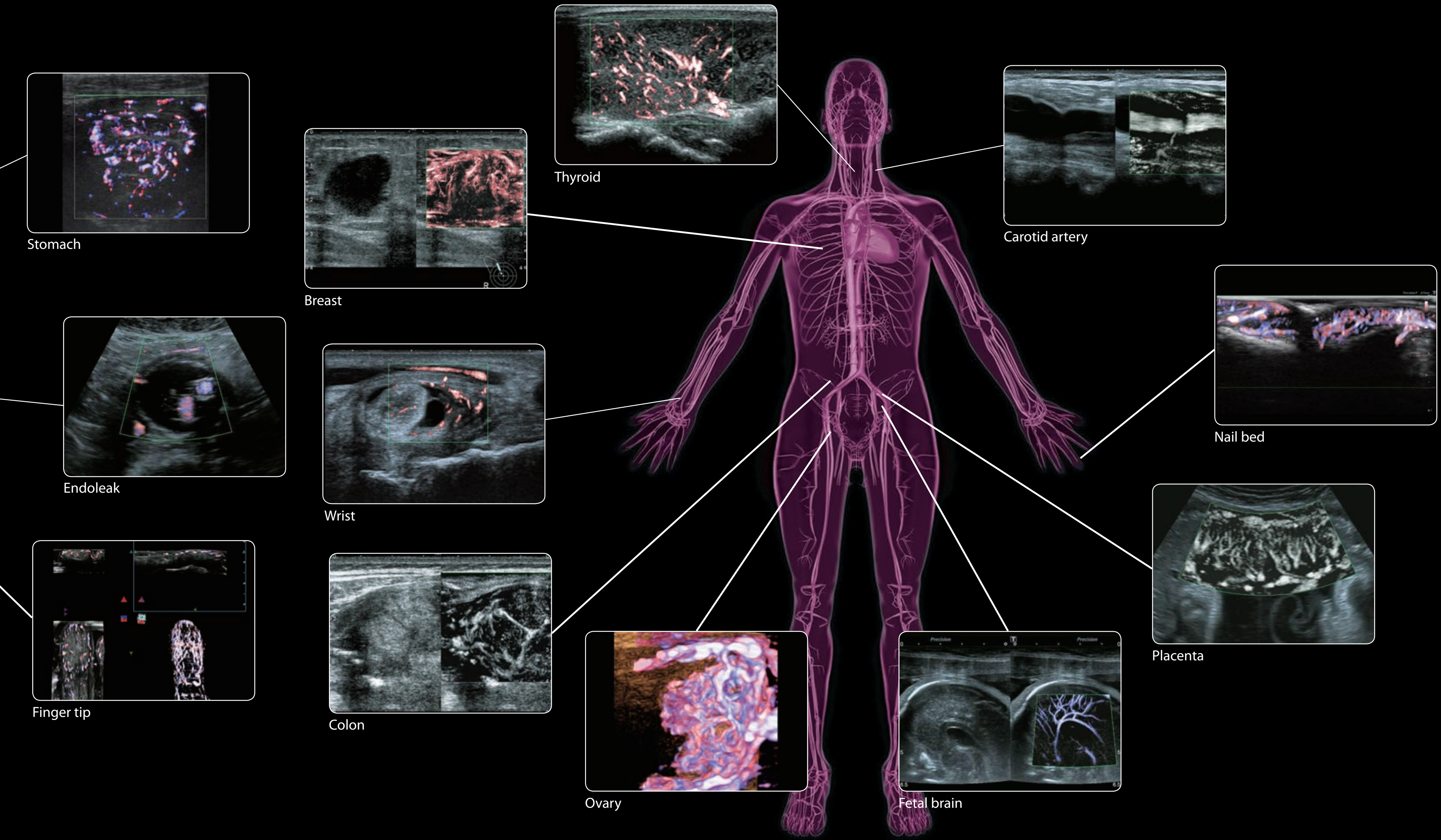
Color-coded SMI (cSMI) reveals minute blood flow inside the kidney of a baby.



3D SMI image of a normal kidney. Showing each of the vessels separately.

SMI IS USEFUL IN MANY CLINICAL APPLICATIONS AND ANATOMICAL REGIONS




Thyroid
Carotid artery
Stomach
Breast
Nail bed
Endoleak
Wrist
Placenta
Finger tip
Colon
Ovary
Fetal brain

Obstetrics *First Trimester Scan of the Fetal Heart*

In early stage pregnancy, SMI can already clearly visualize the filling of ventricles and the ventricular outflow tracts. SMI improves the confidence in assessing the fetal heart in the first trimester by a more precise visualization of cardiac structures such as the interventricular septum in the four chamber view (Figure 1), aorta (Figure 2) and branching of the pulmonary artery (Figure 3).

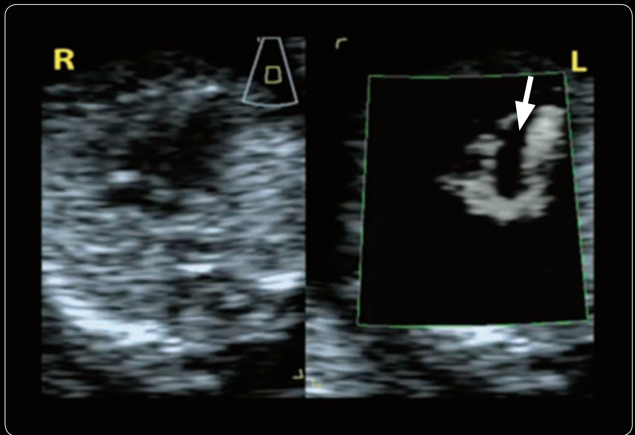


Figure 1. Interventricular septum in 4 chamber view

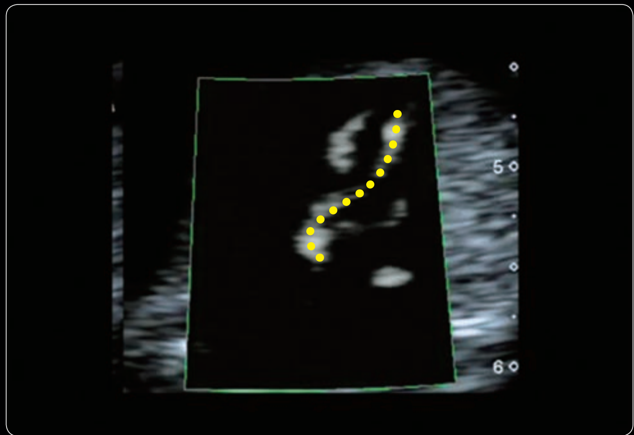


Figure 2. Aorta in 4 chamber view

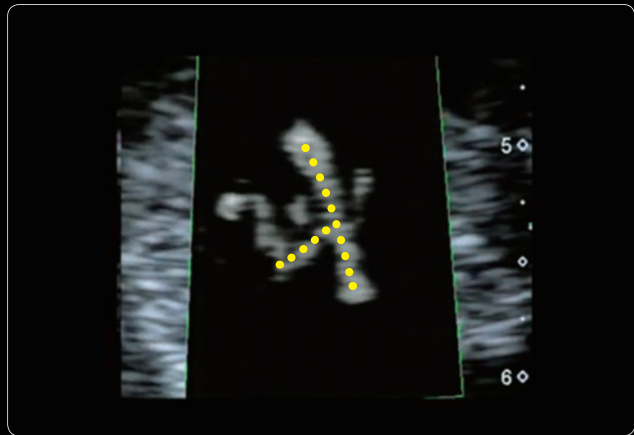


Figure 3. Pulmonary artery

> *“Assessment of the fetal heart in the first trimester is challenging, even for experienced doctors. For this reason it is important to find ways to improve the visualization of the cardiac structures. This is exactly what SMI does! It shows the cardiac structures in a more clear way.”*

Dr. Jader Cruz
Centro Hospitalar Lisboa Central, MAC, Portugal

Obstetrics

Evaluation of Placental Blood Flow

Low velocity placental flow is difficult to visualize using conventional Doppler techniques, due to artifacts caused by respiratory motion and fetal movement (Figure 1). SMI suppresses these motion artifacts – even at high frame rate – and thus is able to visualize minute placental flow (Figure 2).

In a normal placenta, 3D SMI shows high vascularity in the villous tree structure (Figure 3). In case of placental insufficiency, nutrients and oxygen supply is low, causing villous atrophy. This can also be confirmed with 3D SMI (Figure 4).

J. Hasegawa and N. Suzuki: SMI for imaging of placental infarction. Placenta. 2016; 47: 96-98.

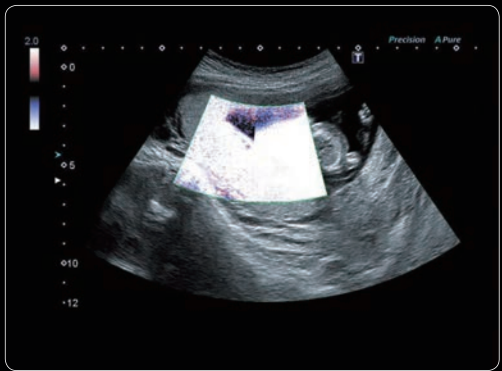


Figure 1. Conventional Doppler (5 fps)

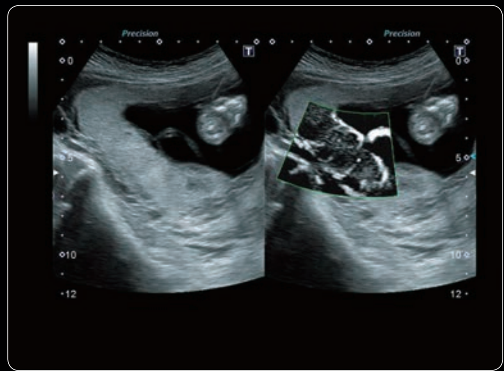


Figure 2. SMI (54 fps)

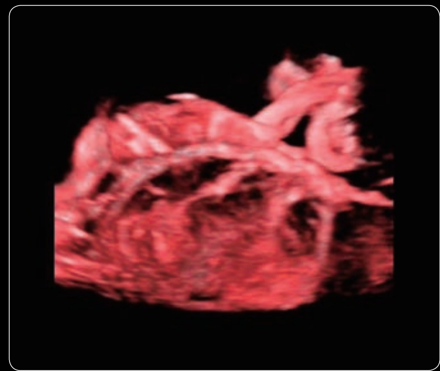


Figure 3. 3D SMI – Normal placenta (30 weeks)

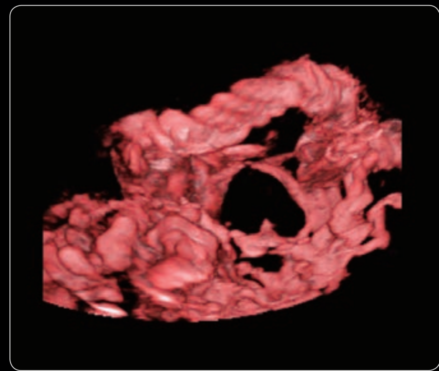


Figure 4. 3D SMI – Placental insufficiency (32 weeks)

> *“SMI is a new valuable tool for obstetrics. It can easily distinguish minute placental flow by suppressing motion artifacts that you would normally see. SMI has high potential in the evaluation of placental function and monitoring stunted growth.”*

Associate Professor Junichi Hasegawa
Department of Obstetrics and Gynecology, St. Marianna University School of Medicine, Japan

MSK *Detection of Low Grade Inflammation*

Power Doppler remains the gold standard for confirming the presence of an active synovitis in symptomatic patients with arthritides. However, in a proportion of clinically symptomatic joints, very slow vascular flow may not be detected. Owing to SMI's greater sensitivity to slow flow vessels, the presence of low grade activity can be more easily confirmed. This has potential to influence clinical management and treatment.

In a patient with metacarpophalangeal joint (MCPJ) showing synovial hypertrophy, the minute flow could not be depicted using Power Doppler (Figure 1a). However now with SMI, this can be clearly visualized (Figure 1b). In another patient with MCPJ synovitis, where there is mild equivocal flow detected on Power Doppler, SMI provides better visualization and resolution of the small neoangiogenic vessels (Figure 2a, b) confirming an active synovitis.

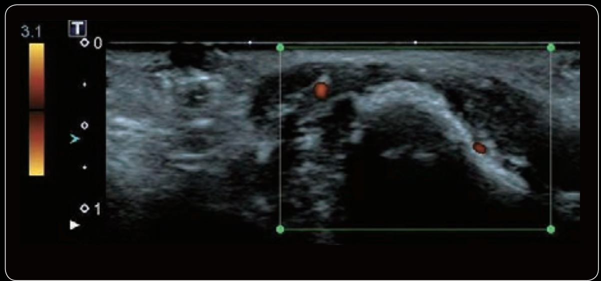


Figure 1a. MCPJ with Power Doppler

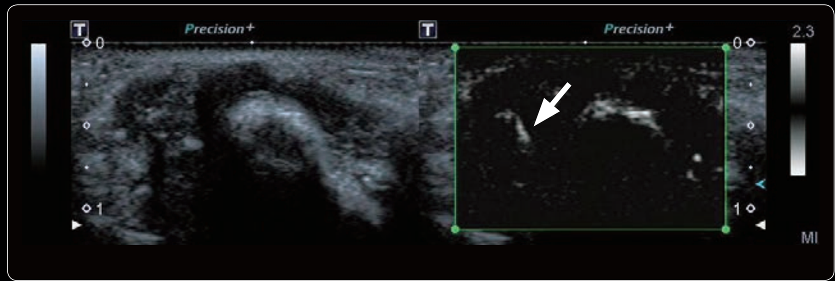


Figure 1b. MCPJ with SMI

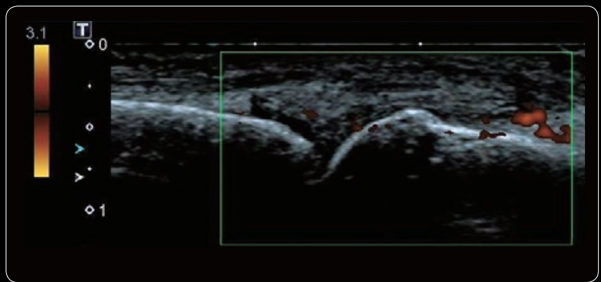


Figure 2a. MCPJ with Power Doppler

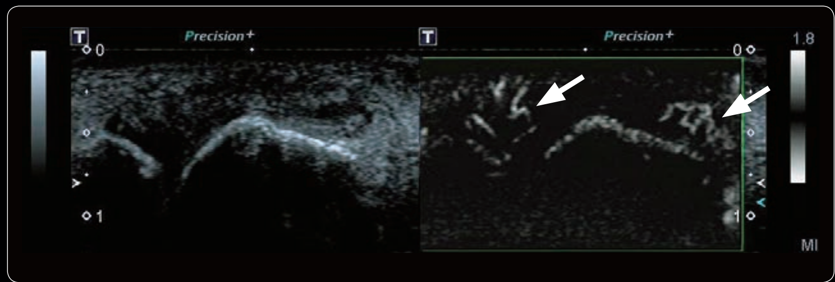


Figure 2b. MCPJ with SMI

> *SMI is a revolutionary Doppler technique which improves the visualization of the microvasculature, but it also allows detection of low grade inflammation in joints and tendons not previously seen with Power Doppler. This could have significant implications for Musculoskeletal Imaging.*

Professor Adrian Lim
Imaging Department, Imperial College and Healthcare NHS Trust, United Kingdom

Sports Medicine *Staging of Progression of Tendinosis*

Tendinosis has well recognized stages of progression and the presence of neovascularity is a defining factor confirming that it has progressed from the acute reactive phase into the proliferative phase. This has important implications for clinical management in terms of exercise load management and the use of anti-inflammatory medication.

SMI has advantages for low velocity blood flow as well as suppressing motion artifact, allowing the evaluation and staging of the progression of tendinosis (Figure 1). The healing process during the proliferative phase can be examined (Figure 2) and with "Hold" function, detailed vasculature can be constructed (Figure 3).

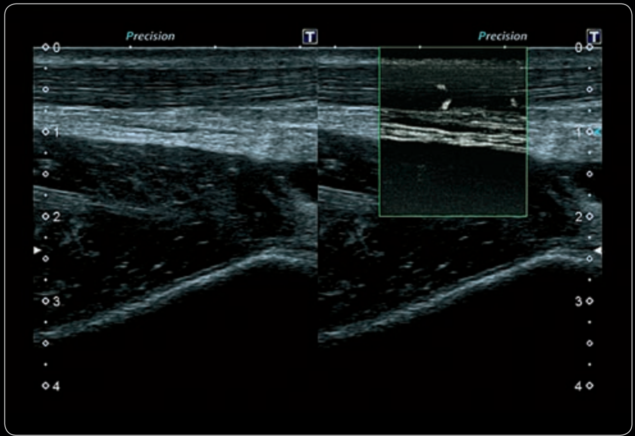


Figure 1. Subtle achilles tendinosis with mSMI

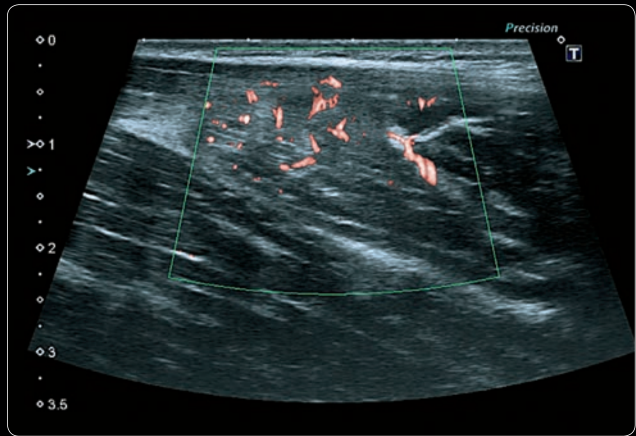


Figure 2. cSMI of healing patellar tendon with advanced proliferative proximal tendinosis

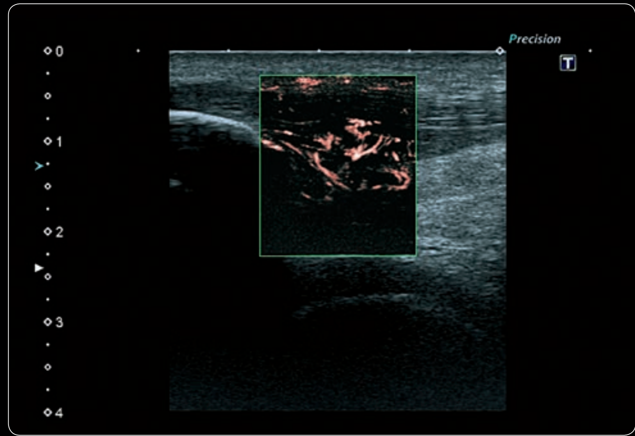


Figure 3. mSMI Hold image of patellar tendon with advanced proliferative proximal tendinosis

> *"SMI provides a much clearer and defined outline of the vascular pattern with less movement–related artefact and the facility to employ the "Hold" function allows the vascular tree to be constructed over several seconds whilst the operator holds the transducer in a static position. Building a library of sequential scans is a useful record of progress particularly when managing a chronic injury such as tendinitis."*

Dr. Steve McNally
Head of Football Medicine & Science, Manchester United, United Kingdom

Cardiovascular *Endovascular Aneurysm Repair of Abdominal Aortic Aneurysms*

The residual aneurysm sac and patency of the limbs of the stent graft were assessed with both color Doppler and SMI in both the transverse and longitudinal planes. Particular attention was paid to anechoic areas within the residual aneurysm sacs, looking for any potential endoleaks.

Figure 1 shows obvious endoleak with cSMI. Figure 2 shows the same endoleak with mSMI. The mSMI image demonstrates the endoleak more extensively than is seen with cSMI and it is more clearly depicted.

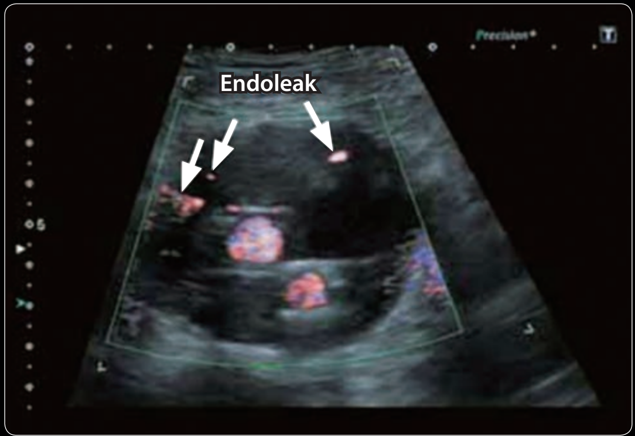


Figure 1. cSMI

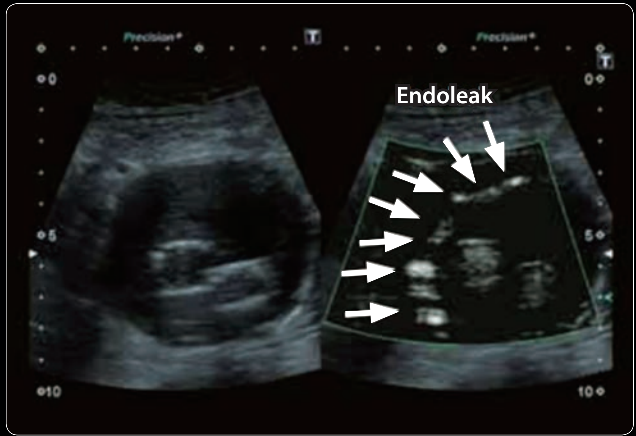


Figure 2. mSMI

> *SMI is an effective tool for the detection of endoleaks in an EVAR surveillance programme. SMI outperforms CDUS in the detection of endoleaks. It appears at least as sensitive as CTA in the detection of endoleaks and has several advantages over the use of CEUS. I believe SMI is a safe tool for use in EVAR surveillance and further studies are warranted to test the sensitivity of SMI compared with CEUS.*

Professor Neil Pugh
Cardiff and Vale University Health Board, United Kingdom

Cardiovascular *Carotid Plaque Neovascularization*

Neovascularization inside carotid plaque is now considered to be a cause of stroke via plaque hemorrhage and/or rupture. A pilot study investigated the ability of SMI to detect neovascularization in chronic, calcified carotid artery plaques (Figure 1). SMI detected intraplaque neovascularity in 22 out of 32 examined vessels, while conventional power Doppler detected flow in only nine, and CTA 0 ($p < 0.01$).

In one particular case, SMI detected flow in an internal carotid artery diagnosed by CTA and conventional ultrasound as being completely occluded (Figure 2a, b). The case indicated the capability of SMI to increase positive predictive value.

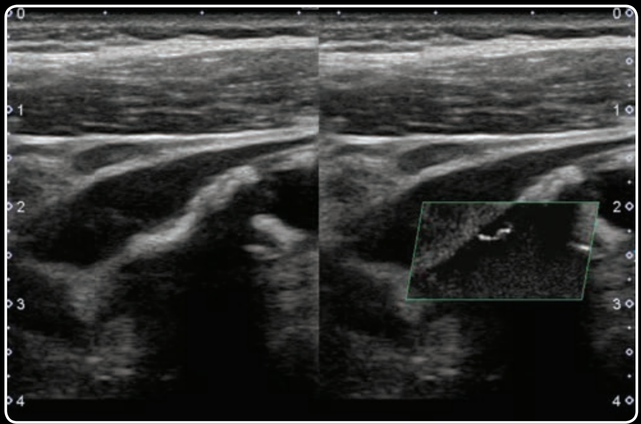


Figure 1. Neovascularization detected with SMI

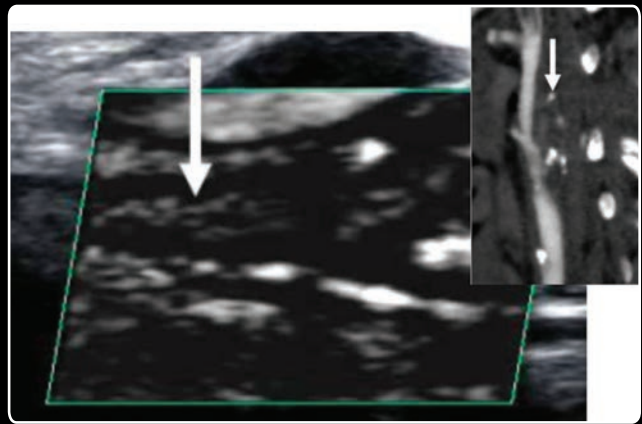


Figure 2. CTA image (small) displaying an occluded internal carotid artery while mSMI image detecting flow within the same vessel

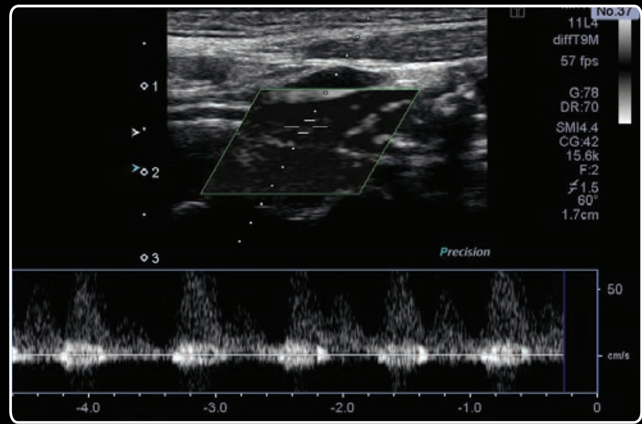


Figure 3. Flow can be confirmed by spectral Doppler in combination with cSMI

"SMI improves overall detection of flow and provides a contemporary and exciting look into flow hemodynamics. By improving our ability to obtain flow information, this application has the potential to alter the way we interrogate chronic calcified plaques and interpret hemodynamics."

Professor Flemming Forsberg
Department of Radiology, Thomas Jefferson University, U.S.A.

Abdomen *Lesion Characterization with Contrast-Enhanced Ultrasound (CEUS)*

An indeterminate, hypervascular liver mass was detected with CT/MRI examination in a young female patient. Conventional color Doppler (Figure 1) shows insufficient details for characterization. Even with CEUS, the vasculature inside the mass was not clear during the arterial phase (Figure 2). CEUS and SMI combined can acquire more sensitive images based on the increased signal from traveling microbubbles. A typical spoke-wheel pattern that indicates the present of a focal nodular hyperplasia (FNH) can now be clearly observed (Figure 3), even after the arterial phase. This eliminates the need to perform a biopsy or surgery.

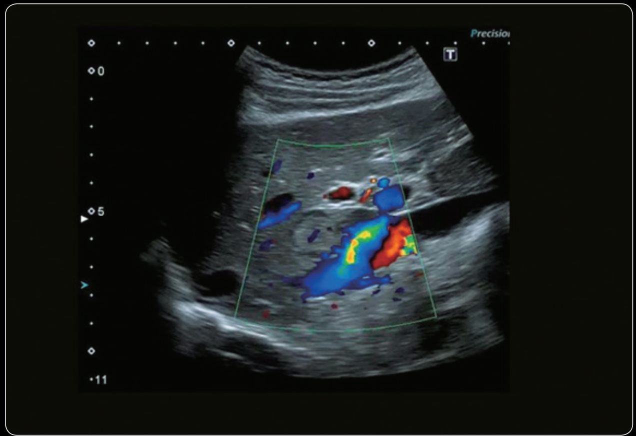


Figure 1. Conventional color Doppler

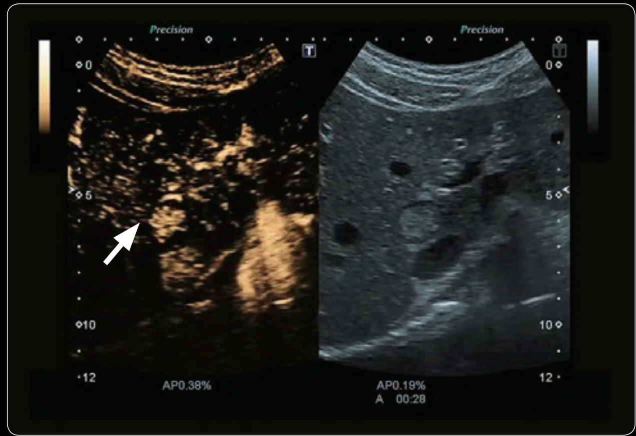


Figure 2. CEUS

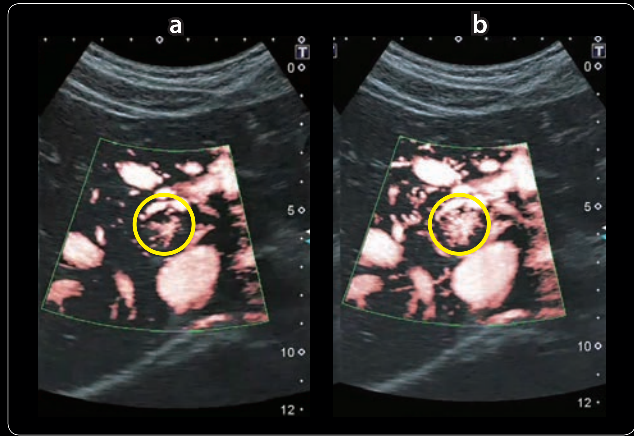


Figure 3. SMI with CEUS after 1min 48s (a) and 1min 50s (b)

> *"CEUS is an excellent method for liver tumor characterization. However, at late phase, the observation of vasculature becomes difficult due to perfusion in the parenchyma. With SMI we can now visualize each bubble traveling at low velocity inside minute vessels, but at the same time exclude perfusion in the parenchyma. SMI gives more confidence in making the right diagnosis."*

Professor Jean-Michel Correas
Department of Adult Radiology, Necker University Hospital, France

Abdomen *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 (Figure 1). cSMI revealed that the portal vein was composed of several small vessels instead of one portal vein (Figure 2). By using mSMI with a higher frequency transducer (Figure 3), tiny vessels composing the portal vein were delineated. In addition, 3D SMI (Figure 4) could clearly show the cavernous transformation of the portal vein.

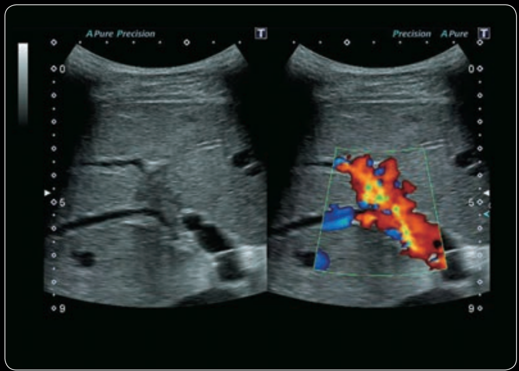


Figure 1. Conventional color Doppler

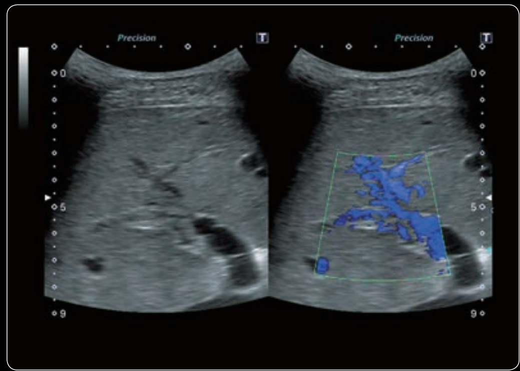


Figure 2. cSMI

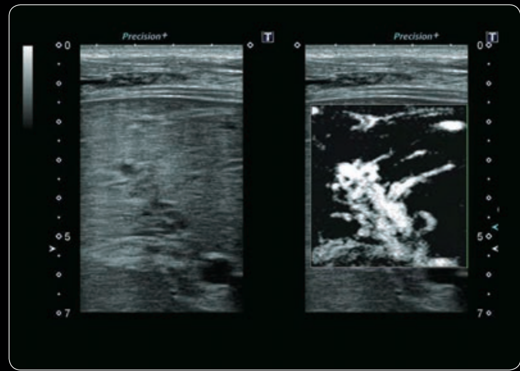


Figure 3. mSMI

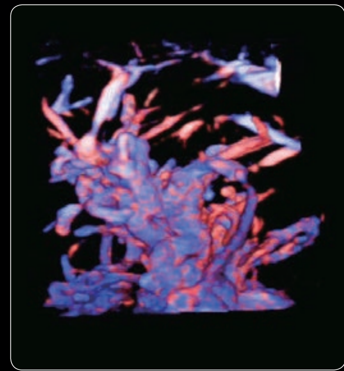


Figure 4. 3D SMI

“ *With conventional color Doppler, large diameter vessels and high velocity blood flow can be visualized, including display of flow direction. SMI can detect low velocity flow in minute vessels, resulting in a more accurate diagnosis. With 3D SMI, the entire structure in an area of interest can be visualized, potentially allowing more effective surgical planning and treatment evaluation.* ”

Professor Jiro Hata
Department of Endoscopy and Ultrasound, Kawasaki Medical School, Japan

Pediatrics *Vesicoureteral Reflux (VUR) in Children*

X-ray cystography is the common method to detect vesicoureteral reflux from the bladder into the kidney. Cystograms are frightening for children since bladder catheterization is invasive and sedation is generally not offered in order to see more physiologic voiding patterns.
Figure 1 shows an example of flow detected within the renal pelvis of a pediatric kidney using SMI. This case was a young patient being treated for a urinary tract infection (UTI). No anatomical anomalies were found to explain a predisposition to UTI, but SMI detected urinary flow in the renal pelvis toward the collecting system of the kidney, instead of into the bladder. Figure 2 demonstrates how SMI visualizes the reversed flow in the ureter. Figure 3 shows how the "swirl" sign in the renal pelvis can easily be observed using SMI.

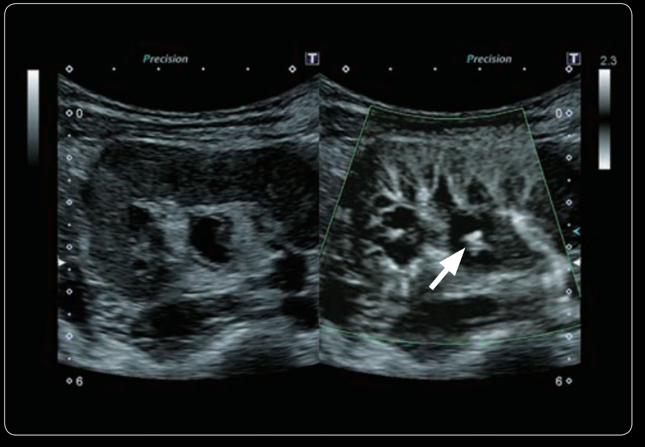


Figure 1. VUR detected within the renal pelvis

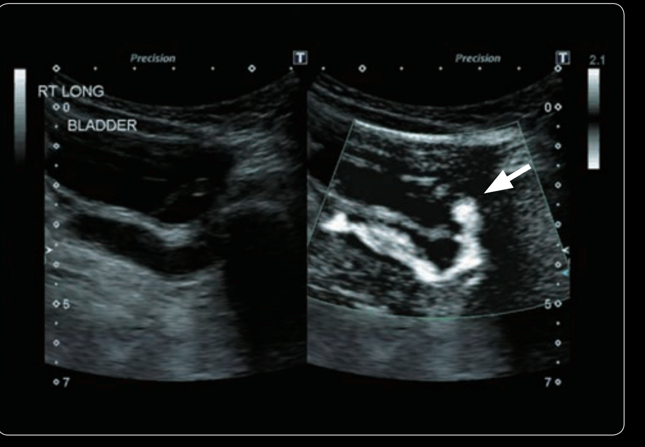


Figure 2. Reversed flow detected in the ureter

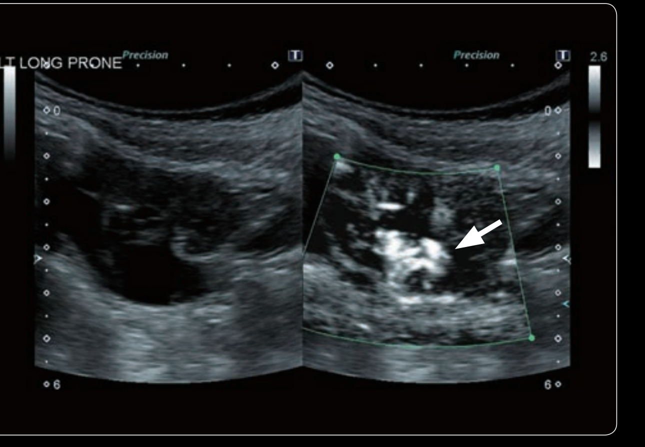


Figure 3. "Swirl" sign in renal pelvis

> *"SMI provides a non-invasive and pain-free method for detecting vesicoureteral reflux in young patients. In addition, SMI offered a more rapid diagnosis and does not require radiation exposure to young patients, as compared with cystography."*

Professor Sara M. O'Hara
Department of Radiology and Medical Imaging, Cincinnati Children's Hospital Medical Center, U.S.A.

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