Ultrasound / White paper

“Seeing the unseen” never stops! – What you can REALLY see by SMI Angio mode

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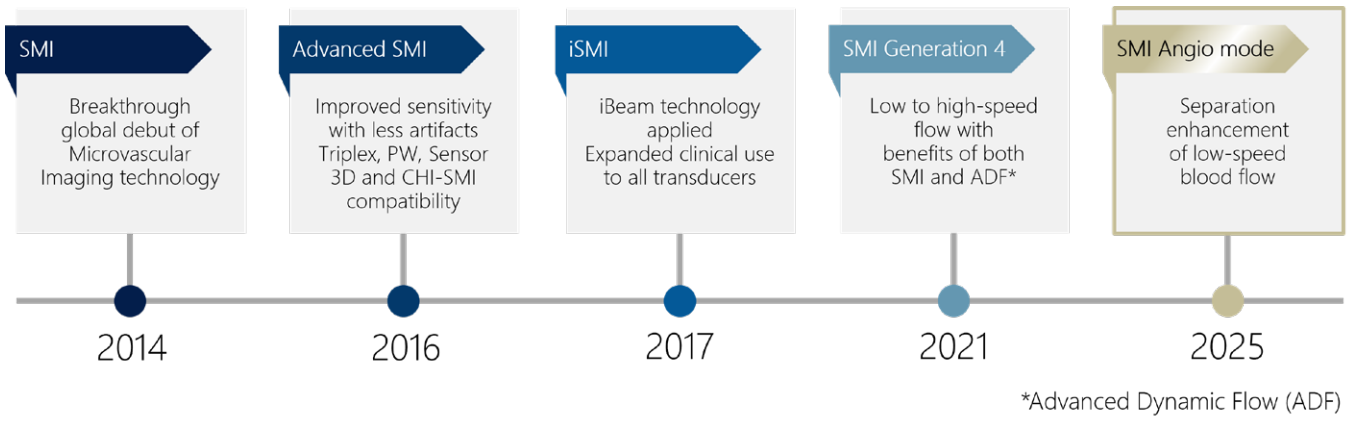
Evolution of SMI to date

Superb Micro-vascular Imaging (SMI), introduced in 2014, selectively reduces motion artifacts while preserving blood flow signals by analyzing tissue motion characteristics. This makes it possible to clearly visualize low-velocity blood flow, which can be challenging using conventional Doppler techniques. Furthermore, high frame rates can be achieved by optimizing the transmission sequence and signal processing and by overlapping the data used between display frames. An improved version known as iSMI was introduced in 2017. In iSMI, multiple received signals are processed simultaneously, allowing effective noise reduction and high frame rates to be maintained even when the ROI is expanded. This technology further evolved into SMI Generation 4 (SMI Gen 4) in 2021, which extended the flow velocity range from low to high velocities, allowing high-velocity motion artifacts to be reduced and expanding the application of SMI to the visualization of high-velocity blood flow. As outlined above, SMI has undergone several evolutionary developments over the years. But now in its 11th year, SMI has returned to its roots, with new advances in the visualization of low-velocity blood flow. This report introduces these technological advances.



*Advanced Dynamic Flow (ADF)

Introduction of SMI Angio mode technology

In areas containing large numbers of blood vessels, such as tumors and peripheral tissues, blood flow in adjacent vessels may be superimposed on each other, which can interfere with visualization. In SMI Angio mode, statistical analysis focusing on localized positional information in the blood flow signals is applied in the frame direction, and blood flow of adjacent vessels is depicted in finer, sharper and more clearly separated vessels by reducing background noise. In addition, sensitivity in the detection of weak blood flow is improved by the addition of a combined setting for persistence (with a longer analysis time than before) and statistical analysis. This function can be used in both non-contrast and contrast imaging and supports a wide variety of transducer types, and it is therefore expected to have a wide range of clinical applications.

Examples of the clinical applications of SMI Angio mode

As previously discussed, SMI Angio mode is superior to conventional SMI for clearly separating and visualizing overlapping blood flow. Furthermore, by adjusting the persistence setting, it is possible to clearly visualize blood flow patterns in fine vessels that cannot be depicted using conventional methods. This is expected to improve the diagnostic capabilities for a wide variety of diseases and lead to the identification of new pathological conditions. This report presents a number of clinical cases of tumors, inflammatory diseases, and other conditions to illustrate the clinical usefulness of SMI Angio mode.

1. Tumors

It is difficult to visualize low-velocity blood flow and blood flow with weak signals in the fine vessels inside tumors using conventional imaging methods, and there is a risk of misidentifying hypervascular tumors as hypovascular. Sufficiently detailed information concerning vascular morphology cannot be obtained in some cases.
SMI Angio mode is expected to overcome these problems. Several illustrative clinical images are presented below.

Figure 1a SMI image of hepatocellular carcinoma (PVI-475BX)
Blood flow signals are observed around the tumor, at the tumor margins, and inside the tumor.

Figure 1b SMI Angio mode image of the same tumor (PVI-475BX)
Blood flow inside and outside the tumor (which could not be seen in the conventional SMI image) is clearly visualized in this SMI Angio mode image.

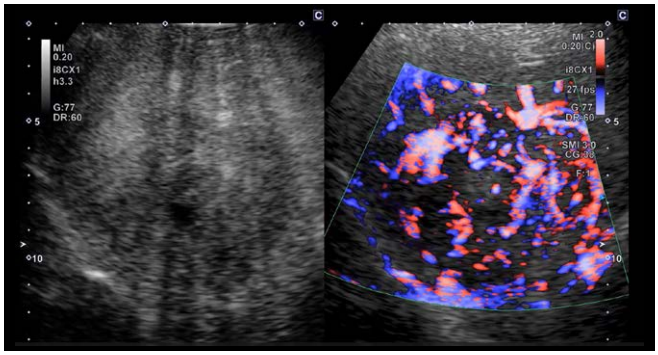


Figure 2a Contrast-enhanced SMI image of the same tumor (PVI-475BX)
Abundant blood flow is observed, but due to noise over the entire area, the vascular morphology is rather unclear.

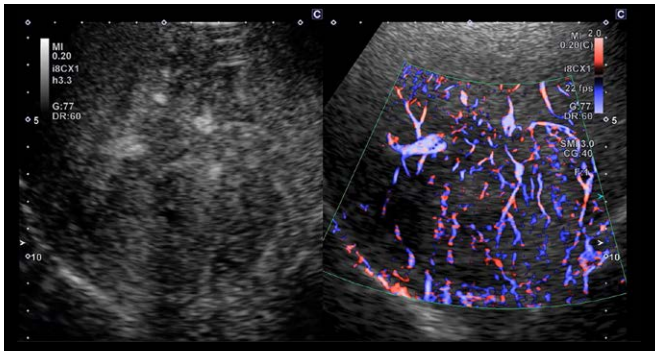


Figure 2b Contrast-enhanced SMI Angio mode image of the same tumor (PVI-475BX)
With reduced overall noise, the individual blood flow in tumor vessels is clearly visualized, reflecting high sensitivity for flow signal detection. This image clearly demonstrates the usefulness of SMI Angio mode as a contrast optimizing technique.

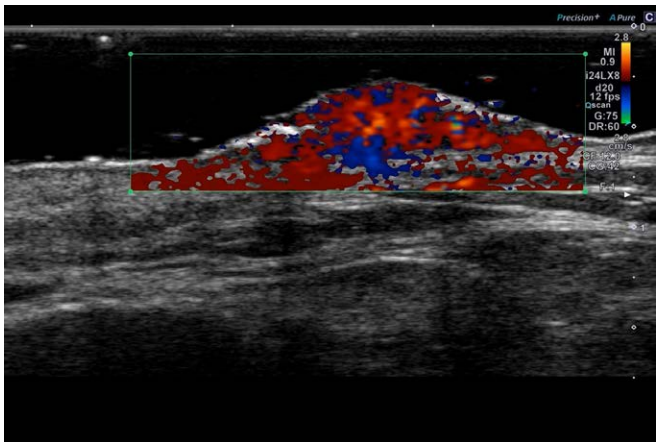


Figure 3a Color Doppler image of cutaneous squamous cell carcinoma (PLI-2004BX)
Blood flow in the tumor can be observed with a velocity display range of 2.8 cm/s, but artifacts are increased and the clarity of the image is poor.

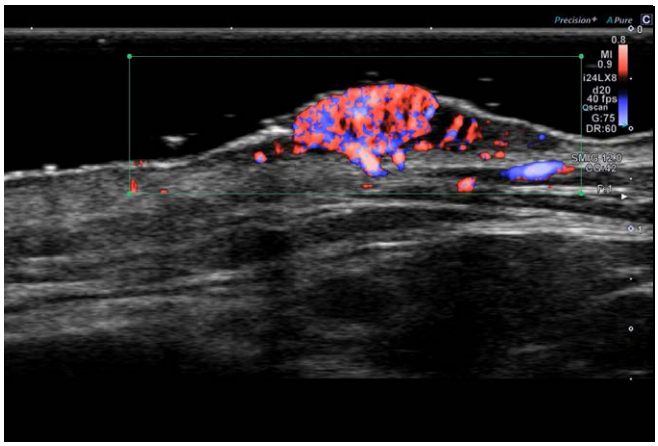


Figure 3b SMI image of the same tumor (PLI-2004BX)
Noise is suppressed and abundant blood flow inside the tumor can be clearly visualized. However, the individual tumor vessels are not clearly depicted and appear as bundles.

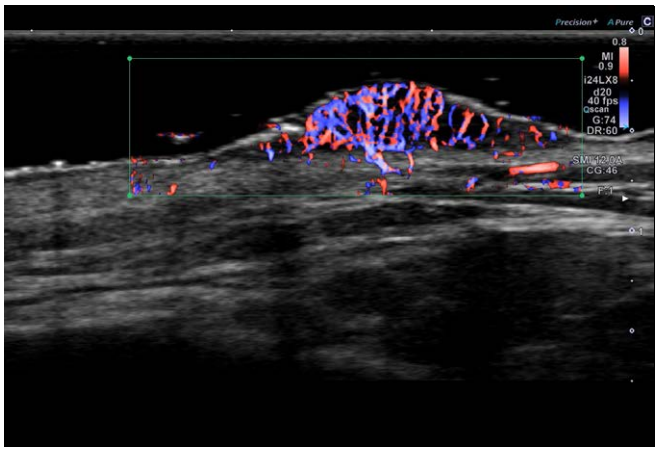


Figure 3c SMI Angio mode image of the same tumor (PLI-2004BX)
Individual blood flows are clearly visualized and can be precisely discriminated.

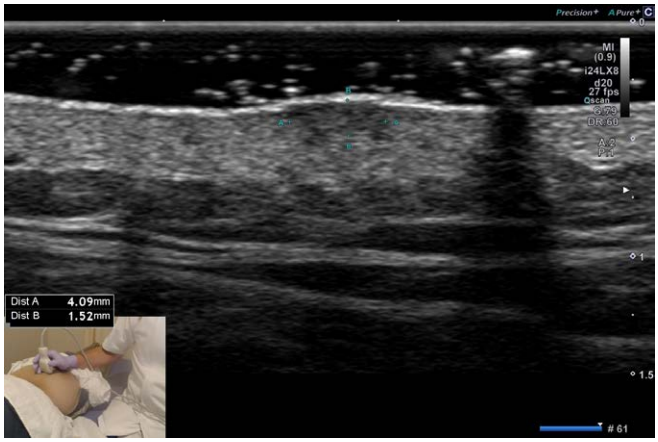


Figure 4a B-mode image of cutaneous T-cell lymphoma (PLI-2004BX)
A very small hypoechoic area measuring 4 x 1.5 mm is observed in the skin.

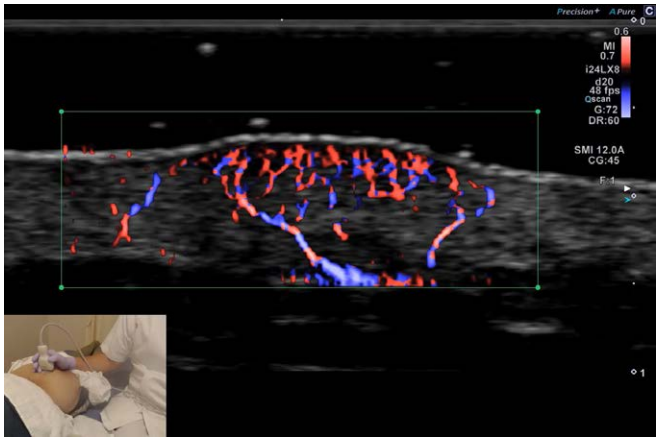


Figure 4b SMI Angio mode image of the same lesion (PLI-2004BX)
Abundant blood flow signals in the lesion are clearly visualized.

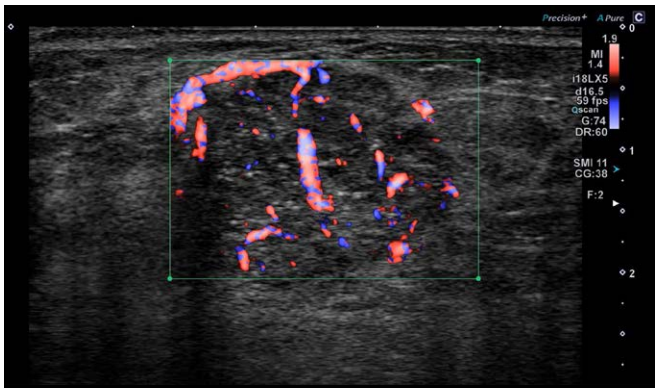


Figure 5a SMI image of mammary ductal carcinoma in situ (DCIS) (PLI-1205BX)
Blood flow signals can be observed to some degree in a tumor as small as 1.5 cm, but the vascular continuity is unclear.

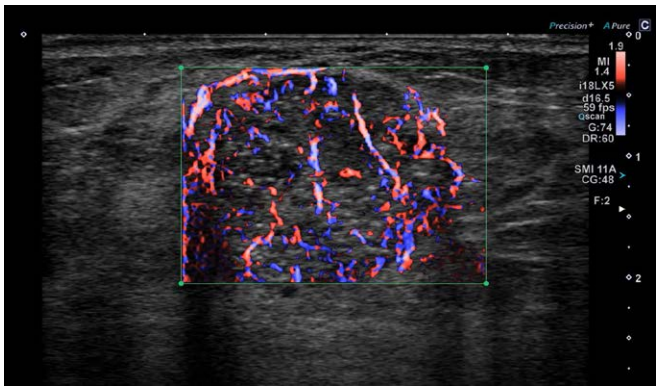


Figure 5b SMI Angio mode image of the same lesion (PLI-1205BX)
Even delicate blood flow patterns can be visualized with good continuity, clearly demonstrating the hypervascularity of the tumor.

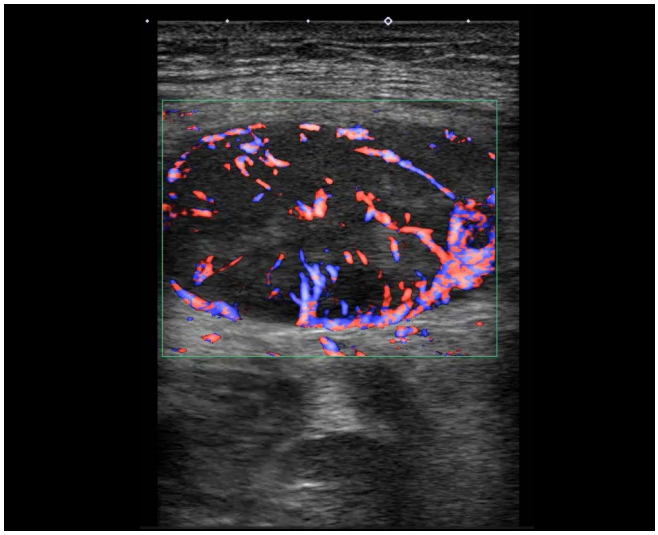


Figure 6a SMI image of abdominal lymph node metastasis of prostate cancer (PLI-705BX)
The hilum of the lymph node is disrupted and contains multiple inflow vessels.

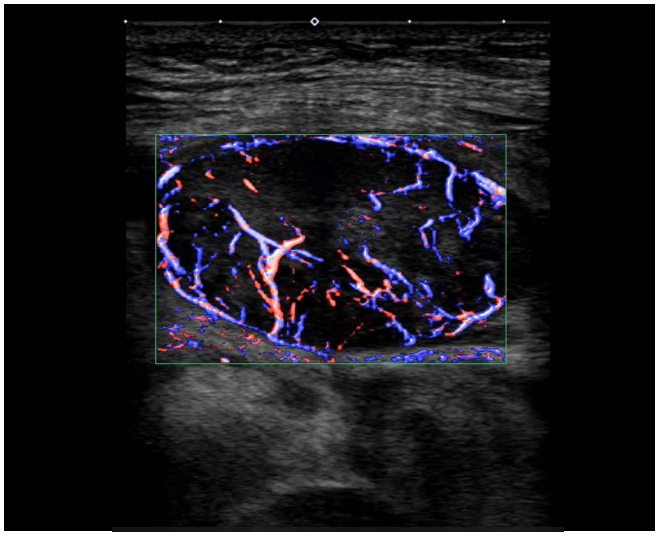


Figure 6b SMI Angio mode image of the same lesion (PLI-705BX)
Motion in the irregular vascular structures is clearly depicted with good continuity, allowing more precise diagnosis.

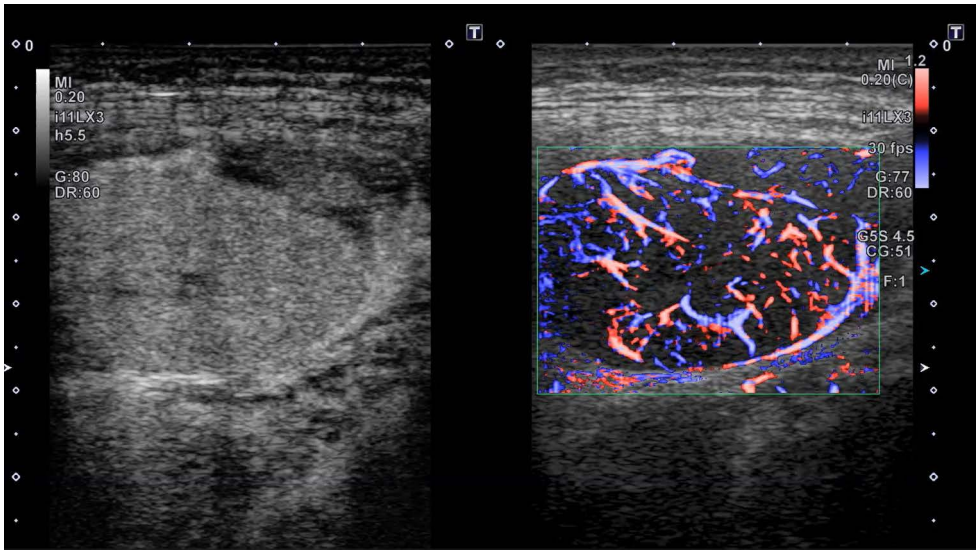


Figure 6c Contrast-enhanced SMI Angio mode image of the same lesion (PLI-705BX)
A much sharper, finer blood flow pattern is clearly depicted in Angio mode.

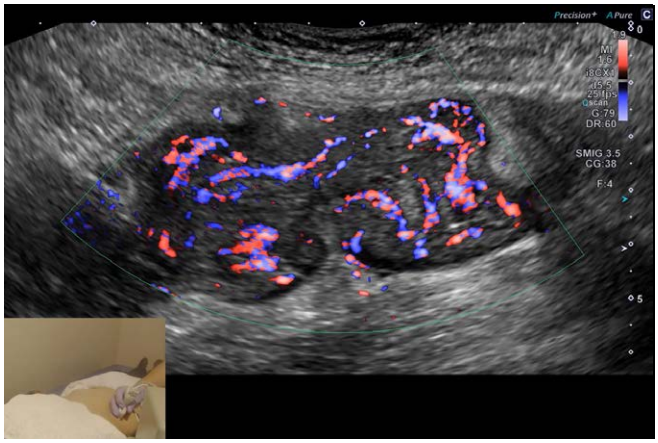


Figure 7a SMI image of colon cancer (PVI-475BX, Ultra Wide View)
Irregular flow is seen inside the tumor.

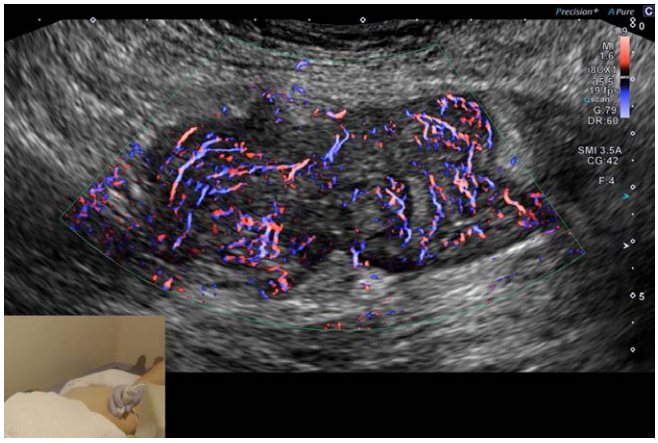


Figure 7b SMI Angio mode image of the same lesion (PVI-475BX, Ultra Wide View)
Flow in tumor vessels that were difficult to observe with conventional SMI are clearly visualized. As shown in this case, SMI Angio mode can be used in combination with Ultra Wide View.

2. Inflammatory diseases

Increased blood flow is a common sign of inflammation, and blood flow changes has become widely accepted internationally as a useful parameter for monitoring the local activity of chronic rheumatoid arthritis and inflammatory bowel disease. Although color or power Doppler is generally used, it goes without saying that SMI Angio mode is more useful for assessing disease activity because it allows blood flow to be visualized with greater clarity and detail. A number of illustrative clinical images are presented below.

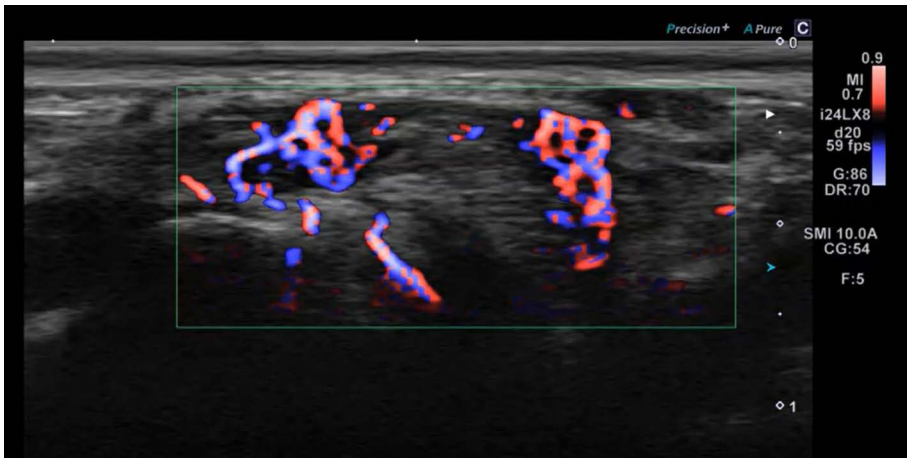


Figure 8 SMI Angio mode image of rheumatoid tenosynovitis (PLI-2004BX)
Significantly increased blood flow is clearly seen in the tendon sheath. High-frequency transducers such as a 24 MHz transducer are very useful for detecting and visualizing fine blood flow in such small structures.

Figure 9a Short axis SMI image of a Crohn's lesion in the ilium (PLI-705BX)
Blood flow signals are seen within the intestinal wall. These can be difficult to detect using conventional Doppler.

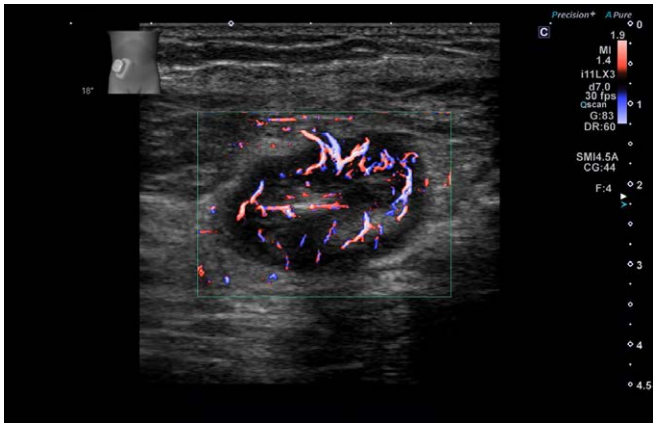


Figure 9b SMI Angio mode image of the same lesion (PLI-705BX)
Even finer blood flow is depicted in outstanding detail.

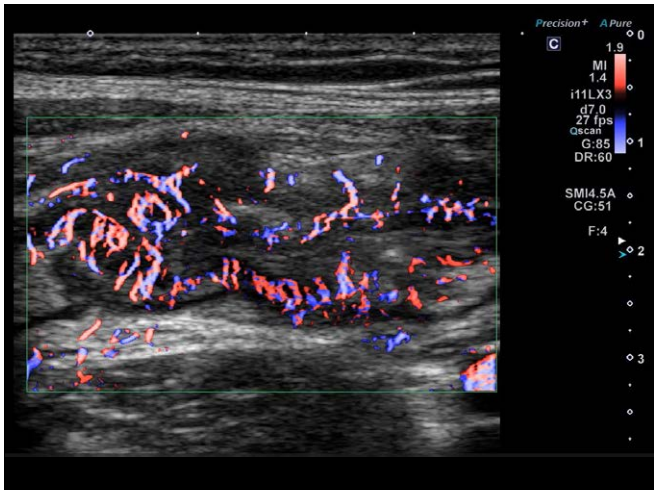


Figure 9c Long axis SMI Angio mode image of the same lesion (PLI-705BX)
Increased blood flow is seen in all layers and flow in each vessel can be clearly visualized and precisely differentiated. This function is expected to allow disease activity to be monitored with greater accuracy.

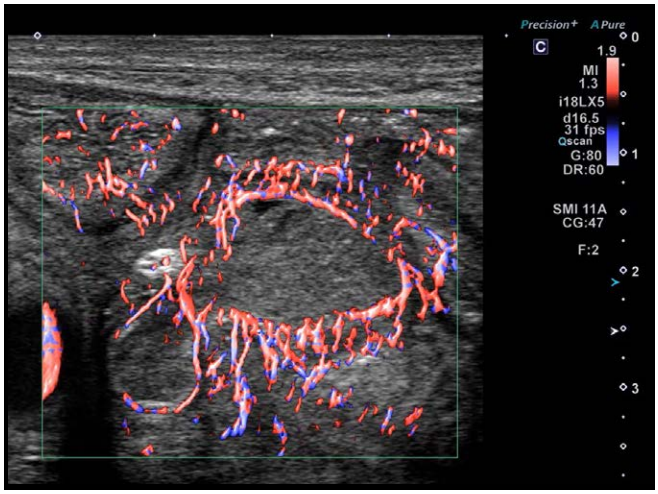


Figure 10 SMI Angio mode image of an abscess in complicated appendicitis (PLI-1205BX)
While the increased blood flow around the abscess is clearly visualized, the abscess itself is depicted as an avascular area. In this case, even contrast-enhanced ultrasound is unnecessary.

3. Other conditions

The evaluation of micro-blood flow using SMI Angio mode provides a clearer understanding of hemodynamics in vascular lesions and normal tissues and is expected to lead to new insights into various pathological conditions in the future.

Figure 11a B-mode image of multiple intrahepatic portal venous shunts (PVI-475BX)
This patient experienced persistent repeated episodes of disturbance of consciousness of unknown cause. The hepatic parenchyma shows an irregular distribution of hyperechoic and hypoechoic areas.

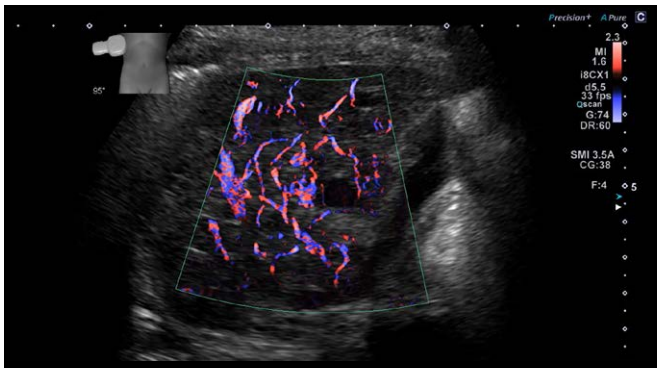


Figure 11b SMI Angio mode image of the same lesion (PVI-475BX)
Numerous small intrahepatic shunts are observed. These were judged to be the reason for the patient's disturbance of consciousness. Blood ammonia levels were elevated, and the patient's symptoms improved as ammonia levels decreased.

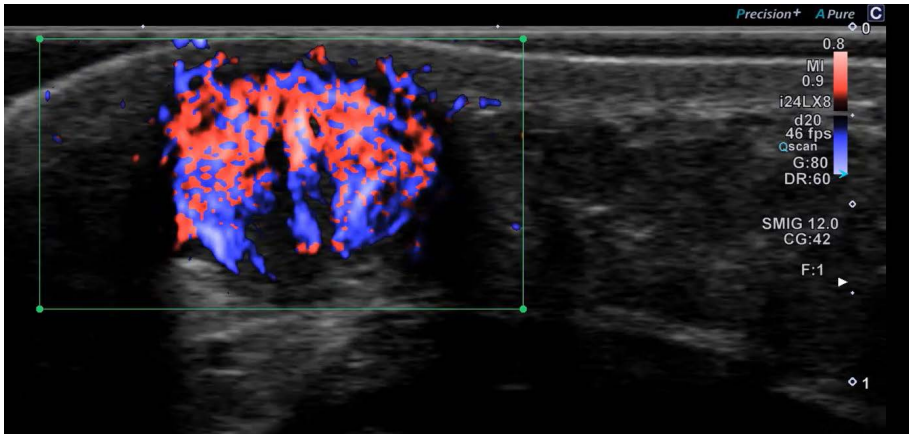


Figure 12a SMI image of a subcutaneous vascular malformation (PLI-2004BX)
This is a subcutaneous mass found in a 3-month-old female infant. SMI findings strongly suggest the presence of a vascular malformation.

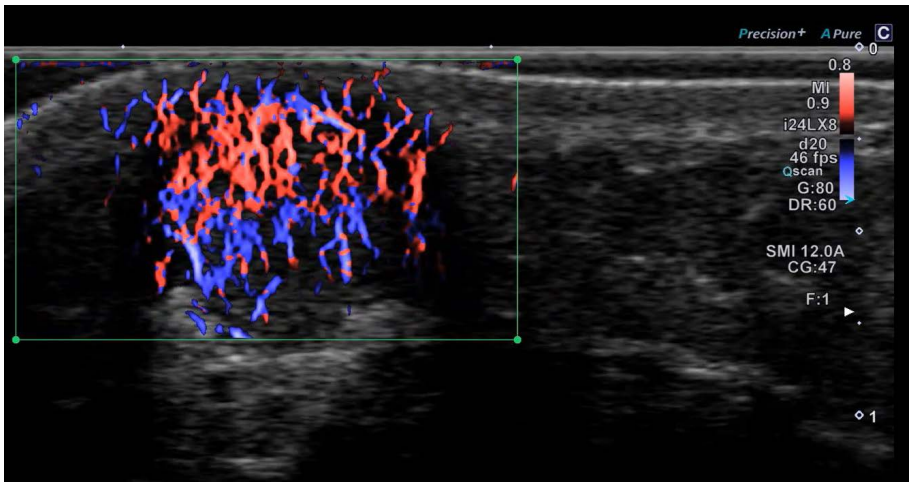


Figure 12b SMI Angio mode image of the same lesion (PLI-2004BX)
A dense focus of fine vascular flow is clearly depicted, providing further evidence of a vascular malformation.

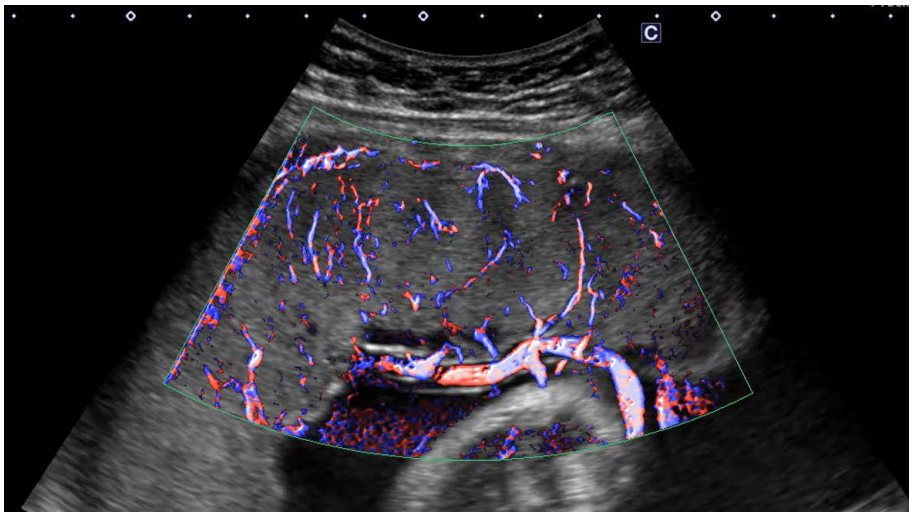


Figure 13 SMI Angio mode image of the normal placenta (PVI-475BX)
Evaluation of placental blood flow is important for monitoring normal pregnancy and for predicting the course of pregnancy and delivery. SMI Angio mode, which can be used to visualize placental micro-blood flow, is expected to be a valuable diagnostic method for the visual evaluation of placental hemodynamics.

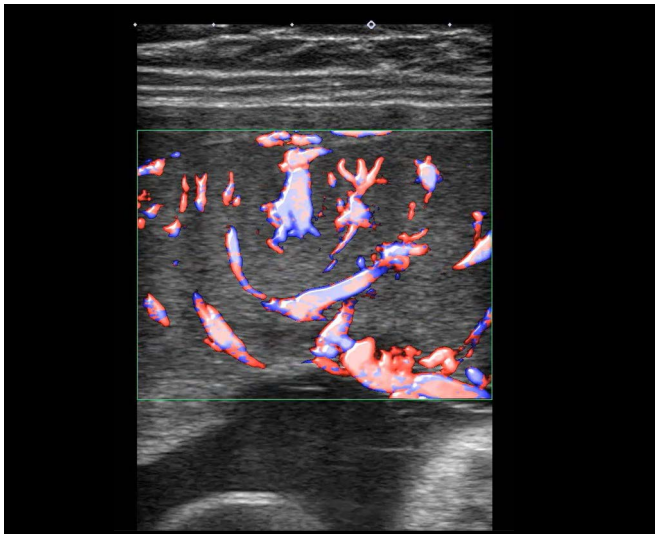


Figure 14a SMI image of the same region (PLI-705BX)
High-frequency waves have theoretical advantages for the evaluation of subtle blood flow, and the PLI-705BX transducer can be used to visualize fine flow, as demonstrated in this image.

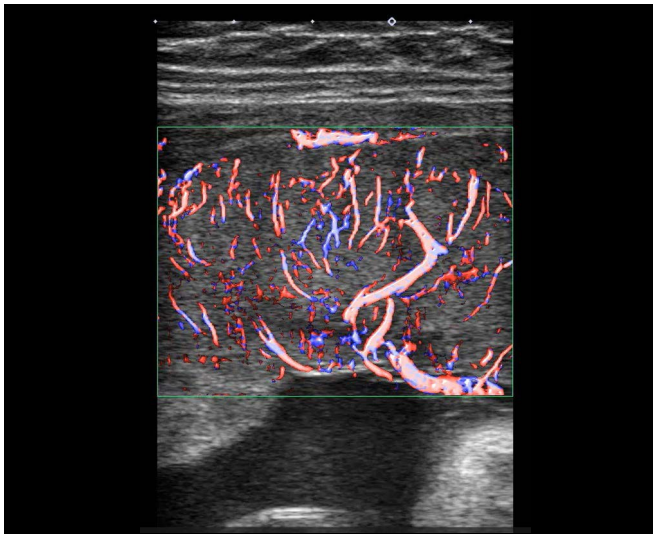


Figure 14b SMI Angio mode image of the same region (PLI-705BX)
The continuity of fine vascular structures is more clearly depicted with SMI Angio mode, demonstrating its superior imaging capabilities compared to conventional SMI.

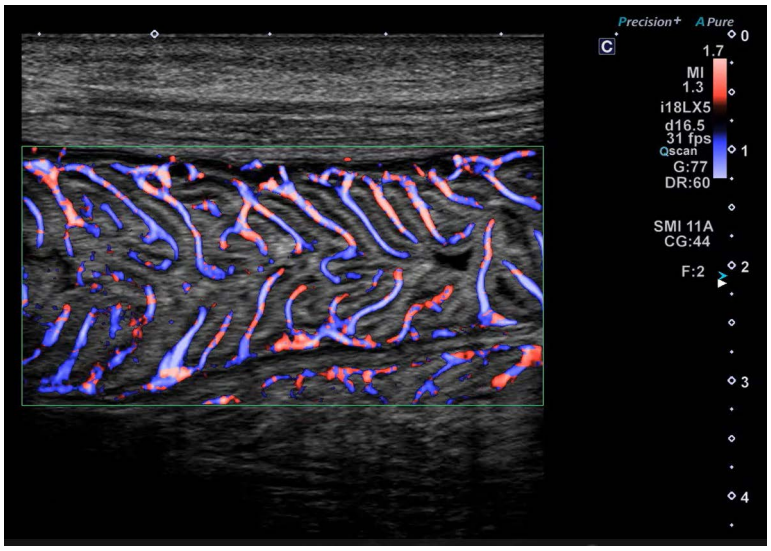


Figure 15 SMI Angio mode image of the normal jejunum (PLI-1205BX)
The blood flow running within the circular folds of the jejunum can be clearly visualized. The image is almost entirely free of artifacts related to peristaltic motion.

The above clinical images of actual cases have been presented to demonstrate the usefulness of SMI Angio mode. The capabilities of SMI Angio mode in visualizing blood flow in such fine detail are expected to provide new insights in the diagnosis and pathophysiological assessment of various medical conditions such as tumors and inflammatory diseases, as well as the evaluation of physiological changes within each organ across the parts of the body. It goes without saying that we cannot evaluate what we cannot see in the first place. We look forward to future advances in medical science and healthcare based on the continuing technological development of Aplio, which allows us to clearly see what was previously invisible.

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