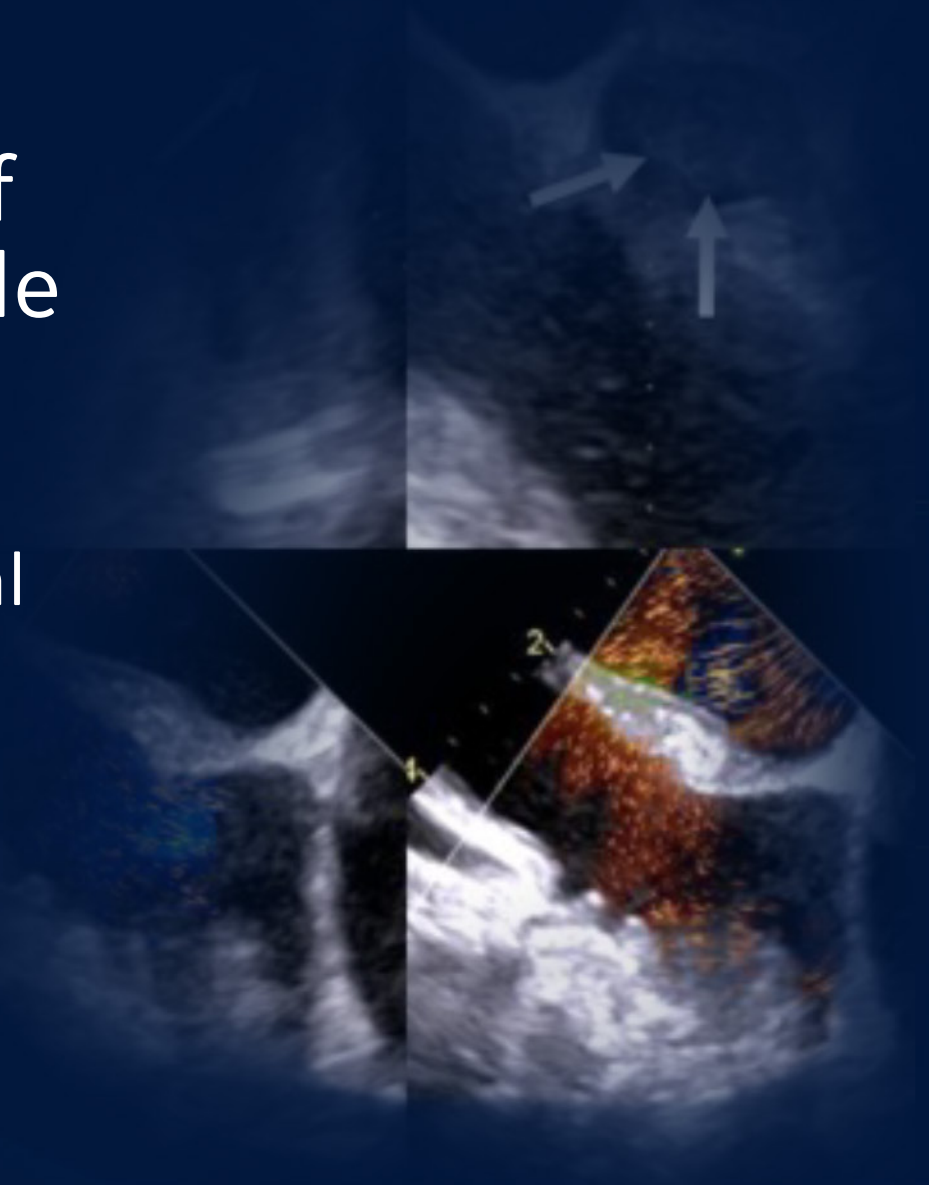
The Utility of Blood Speckle Imaging

for Assessment of the Left Atrial Appendage

Case Study



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Background

Transesophageal echocardiography (TEE) is performed regularly to exclude the presence of left atrial appendage (LAA) thrombus prior to cardioversion and LAA closure. However, in a subset of patients, differentiation between thrombus and normal anatomic structures (such as pectinate muscles), artifact, or spontaneous echo contrast (which is indicative of slow flow in the LAA) may be particularly difficult. Furthermore, LAA "sludge" which represents an intermediate state between spontaneous echo contrast and thrombus may further complicate this assessment. While Doppler imaging is essential in the evaluation of intra-cardiac blood flow and may aid in this assessment, Doppler is limited in its ability to understand complex flow patterns in cardiac chambers partially due to angle dependency. From a clinical standpoint, exclusion of left atrial thrombus prior to cardioversion and structural heart procedures is imperative to decrease the risk of subsequent stroke or thromboembolic events.

Blood speckle imaging (BSI) is a novel blood flow visualization technique utilizing ultrahigh frame rate acquisitions with plane wave ultrasound imaging in order to track speckles generated by moving blood. This technique has the potential to aid in the understanding of complex flow patterns in cardiac chambers (e.g., vortex flow), flow direction when Doppler is limited by angle dependency, and slow or absent intra-cardiac flow such as in the presence of an intra-cardiac thrombus. We hypothesized that BSI would be a beneficial adjunctive technique in the assessment of LAA spontaneous echo contrast, sludge and thrombus and present several novel cases utilizing this new technology in the understanding of blood flow in the LAA.

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Case 1:
Left Atrial Appendage with Prominent Pectinate Muscles

A 78-year-old male with a history of permanent atrial fibrillation presents for TEE-guided LAA closure. Two-dimensional (2D) and three-dimensional (3D) TEE imaging (figure 1) demonstrates prominent LAA pectinate muscles with deep recesses. While no thrombus was seen in the body of the appendage, excluding a very small thrombus in these deep recesses may be difficult even with optimal 2D and 3D imaging. With the application of BSI technology, moving blood cells can be tracked down to the very bottom of these recesses adding additional diagnostic confidence to the exclusion of thrombus in the LAA particularly in these difficult to visualize regions prior to cardioversion or LAA closure.

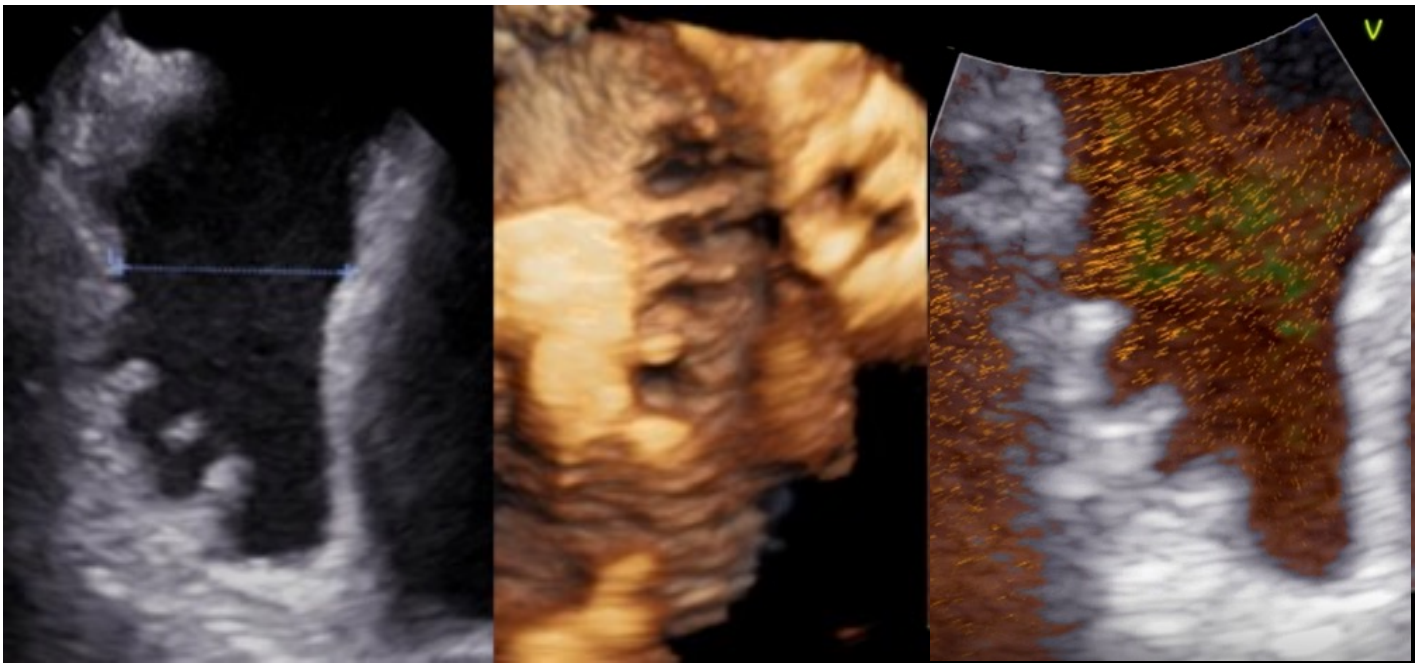

Figure 1. *Left atrial appendage with prominent pectinate muscles and deep recesses by 2D (left) and 3D (center) transesophageal echocardiographic imaging. Blood speckle imaging (right) confirms the presence of moving blood cells in these deep recesses.*

Case 2:
Thrombus-mimicking Reverberation Artifact

An 83-year-old male with a history of persistent atrial fibrillation presents for TEE-guided LAA closure. Two-dimensional imaging demonstrates a typical bi-lobed appendage with a prominent 'Coumadin' ridge (figure 2, left). A prominent 'Coumadin' ridge (which separates the left superior pulmonary vein from the LAA) can frequently make the assessment of LAA thrombus difficult due to the presence of thrombus-mimicking reverberation artifact[1] (figure 2, left, white arrow) which was seen in this case. The suspicion of thrombus, however, does not fit with the assessment of LAA flow velocities by pulsed-wave Doppler which are low-normal (figure 2, middle). However, with the application of BSI, vortex and LAA entrance flow was seen in the proximal portion of the LAA in the region of this suspicious echodensity confirming that this finding was, in fact, reverberation artifact and not thrombus. On the other hand, blood speckles appear to "respect" the prominent ridge separating the two lobes of the appendage (figure 2, right) and are seen traveling to the bottom of each lobe confirming lack of thrombus in these regions as well.

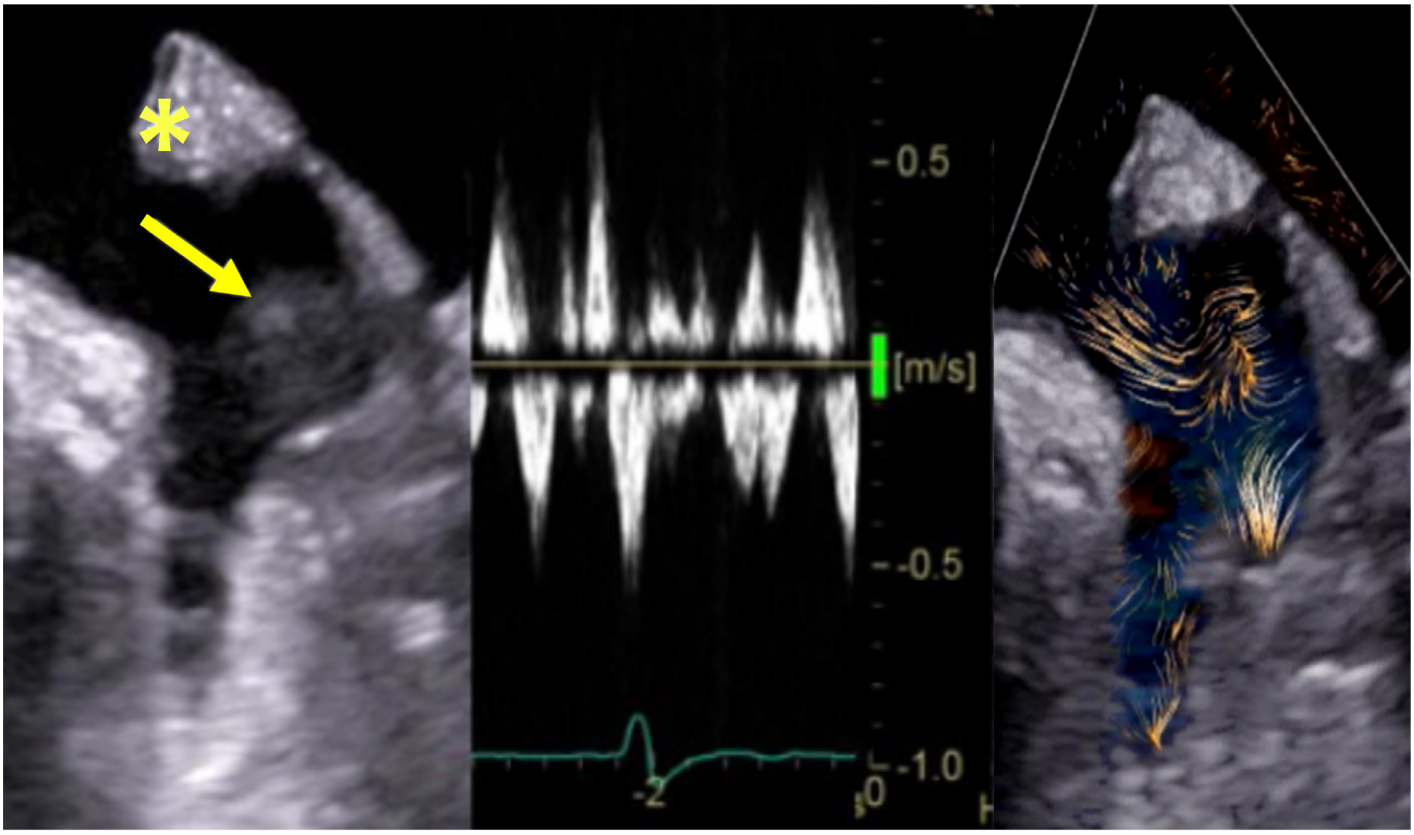

Figure 2. *Bi-lobed left atrial appendage with thrombus-mimicking reverberation artifact (left, arrow) from prominent Coumadin ridge (*) but with normal flow velocities by pulsed-wave Doppler (center). Blood speckle imaging shows normal blood flow in the region of the artifact as well as in both lobes of the appendage (right) suggesting the absence of thrombus.*

Case 3:
Dense Spontaneous Echo Contrast

An 87-year-old male with a history of paroxysmal atrial fibrillation and severe aortic stenosis presented for transcatheter aortic valve replacement (TAVR). Intraoperative TEE demonstrated dense spontaneous echo contrast with concern for possible LAA thrombus (figure 3, left). There was concern about proceeding with TAVR as there might be increased risk for perioperative stroke due to the presence of LAA thrombus. LAA flow velocities were markedly reduced as assessed by pulsed-wave Doppler (figure 3, right) indicating very slow flow in the LAA. BSI was performed to help with differentiation between slow flow and actual thrombus. As with color Doppler imaging, the BSI scale can be reduced in order to enhance the appearance of slow moving blood flow. Blood speckle directionality, however, can still be difficult to assess with very slow flow and a color Doppler overlay is provided to aid in understanding of speckle movement. With the application of BSI, blood speckles could be seen entering (figure 4, left) and exiting (figure 4, center) throughout the LAA suggesting that while there was slow flow, a discrete thrombus was not present. An ultrasound enhancing agent was also administered and low mechanical index imaging of the LAA was also performed (figure 4, right). Contrast was seen penetrating into the appendage and its recesses without evidence of a discrete filling defect confirming BSI findings that a LAA thrombus was not present. TAVR was successfully performed without any perioperative complications.

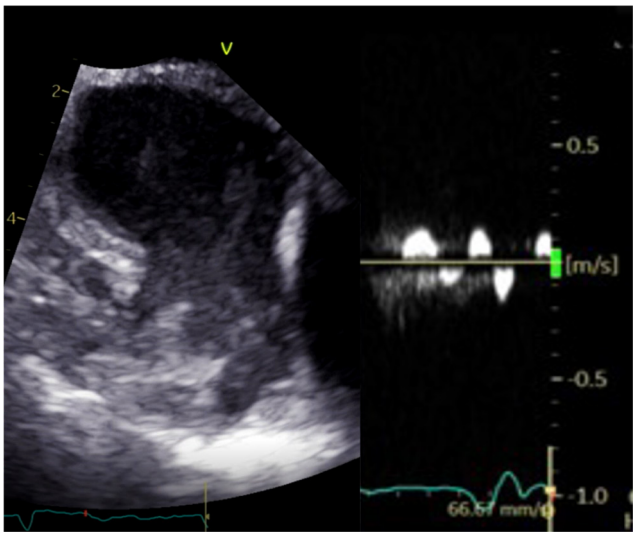

Figure 3. *Dense spontaneous echo contrast in the left atrial appendage with markedly decreased flow velocities by pulsed-wave Doppler.*

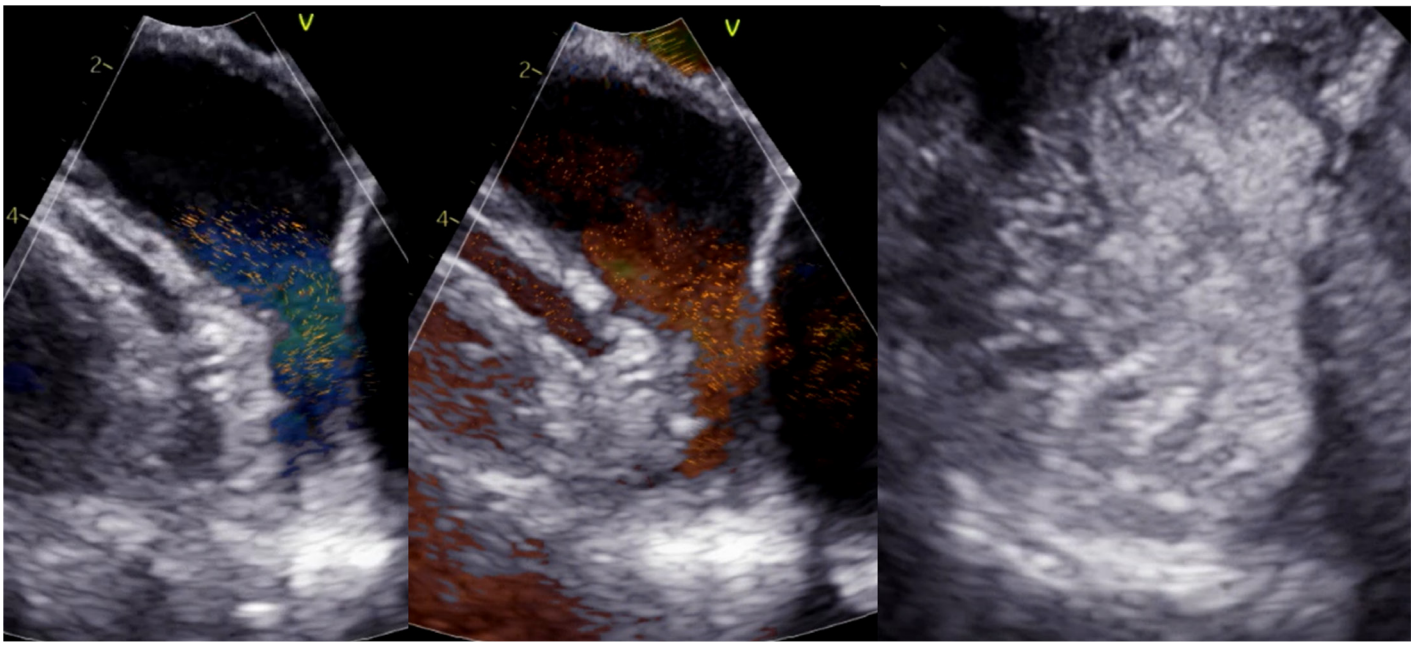

Figure 4. *Entrance flow (i.e., filling) into the LAA (left) and emptying flow during LAA contraction (center) is shown with BSI with color Doppler overlay in a patient with dense spontaneous echo contrast. Moving blood speckles are seen throughout the appendage suggesting absence of LAA thrombus. Ultrasound enhancing agent administration with low mechanical index imaging of the LAA was also performed demonstrating penetration of contrast into the entire LAA confirming the absence of thrombus (right). LAA=left atrial appendage.*

Case 4:
Left Atrial Appendage Thrombi

A 71-year-old male with a history of atrial fibrillation and frequent gastrointestinal bleeding was referred for LAA closure. Intraoperative TEE imaging demonstrates a multi-lobed appendage with two discrete, well-circumscribed thrombi. The application of BSI demonstrates flow in between the thrombi (where spontaneous echo contrast was also seen) but not in the region of the thrombi themselves. The LAA closure procedure was cancelled due to the TEE findings.

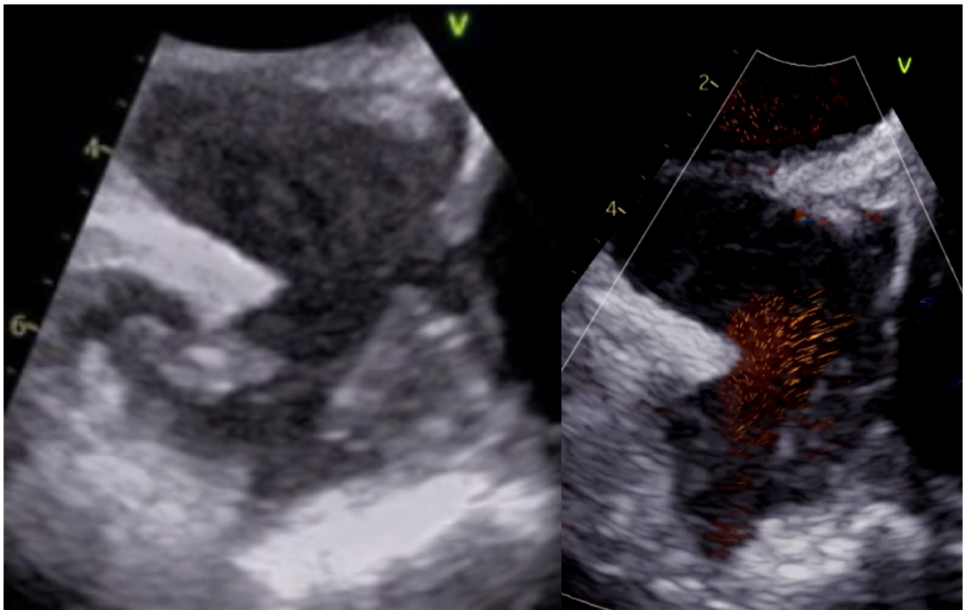

Figure 5. *Two thrombi are seen in the multi-lobed LAA. Blood speckles are seen exiting the LAA in between the thrombi in the region of the spontaneous echo contrast. The width of the emptying flow appears narrow as it traverses the space between the thrombi but widens as the flow exits the appendage. LAA=left atrial appendage.*

Conclusion

The accurate identification of LAA thrombus is critical prior to cardioversion, LAA closure and other structural heart procedures. However, differentiation of potential thrombus between spontaneous echo contrast, sludge, normal anatomic structures and/or artifact can be difficult even with conventional echocardiographic imaging techniques. BSI is an imaging technology available to cardiovascular specialists that can provide key information of flow patterns, not seen by traditional Doppler techniques, and may add confidence to this important assessment of flow in the left atrial appendage. BSI provides additional insight into the understanding of complex and dynamic intra-cardiac flow patterns and has the potential to improve diagnostic confidence when making these critical assessments for patients.

References:

1. Bertrand PB, Levine RA, Isselbacher EM, Vandervoort PM. Fact or Artifact in Two-Dimensional Echocardiography: Avoiding Misdiagnosis and Missed Diagnosis. *J Am Soc Echocardiogr.* 2016;29(5):381-391.