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The Use of B-Flow and other Vascular Techniques in the Assessment of **Vulnerable Carotid Plaque**



Introduction

For several years digital subtraction angiography was considered the gold standard method for the evaluation of carotid artery stenosis secondary to atherosclerotic disease. However, it has become increasingly clear that the degree of luminal stenosis alone is not the best predictor of stroke risk and the morphology- composition of the plaque plays a more crucial role.

Based on histopathological studies it is evident that vulnerable (unstable) plaques are those that are more prone to rupture and local thrombosis with a consequent increase in risk of ischemic symptoms.

Current research in carotid imaging is therefore focused on identifying characteristics that determine the unstable carotid plaque.

Recent studies have shown that vulnerable plaques are those with a thin or ruptured fibrotic cap, with a large lipid rich necrotic core, intraplaque hemorrhage or thrombus, presence of ulcer and signs of inflammation as well intraplaque neovascularization.



Ultrasound imaging has enjoyed tremendous success as a real time imaging modality for bedside diagnosis of carotid disease and has the potential not only to anatomically describe tissues and plaque morphology but also to assess physiology by evaluating blood flow characteristics in real time and assess the degree of carotid stenosis accurately.

The technique's role is significantly strengthened not only by the improvement and technological advance of modern ultrasonographic devices but also with the introduction of technologies such as B-Flow, Radiantflow™, Microvascular Imaging (MVI), Elastography and Contrast-Enhanced Ultrasound (CEUS).

Multiparametric ultrasound evaluations of atherosclerotic carotid plaques with the use of novel ultrasound methods and conventional US may represent the future of bed side and non-invasive identification of unstable carotid plaque before the development of symptoms of catastrophic ischemic stroke.

New Solutions for Vascular Ultrasound Investigations

To address the wide-ranging clinical needs in Vascular studies, GE Healthcare has made a variety of flow technologies available on the LOGIQ™ E10 Series ultrasound systems.

- **Color Flow Imaging (CF)**
- **Power Doppler Imaging (PDI)**
- **Microvascular Imaging (MVI)**
- **Radiantflow™**
- **B-Flow Imaging**

The new cSound imageformer gives to these flow modes even more sensitivity and uniformity.

COLOR FLOW (CF) IMAGING

The color flow (CF) mode allows the visualization of flow direction and velocity information within the region of interest (ROI), or color box, defined by the operator. The Doppler shifts of returning ultrasound waves within the ROI are color-coded based on average velocity and direction.

Compared with other flow modes, CF imaging has the following advantages:

- Displays flow velocity for both small and large vessels at different depths»
- Penetrates more to show flow information at deep depths
- Shows artery and vein flows with clear large vessels separations

In Vascular Imaging, CF may be useful in:

- Detection of high velocity areas in the carotid or lower extremity arteries.

POWER DOPPLER IMAGING (PDI)

Unlike CF, Power Doppler Imaging (PDI) is independent of velocity and direction of flow, and does not have any signal aliasing issue. Therefore, it allows detection of lower velocities than CF. In general, PDI has higher sensitivity than CF, which makes a trade-off with flash noise artifacts.

Compared with other flow modes, PDI has the following advantages:

- Shows high flow sensitivity, especially for small vessels at shallow depths
- No aliasing as compared with CF
- Displays intensity information and can show directional information with Directional PDI Maps.

MICROVASCULAR IMAGING (MVI)

There has long been a clinical need for detection of slow flow states especially in areas where assessment of vascularity is crucial to diagnosis and follow-up treatments. Traditional flow modes are limited in detecting very slow flow especially in small vessels. The Micro Vascular Imaging (MVI) technique has the potential to fill this role.

RADIANTFLOW™

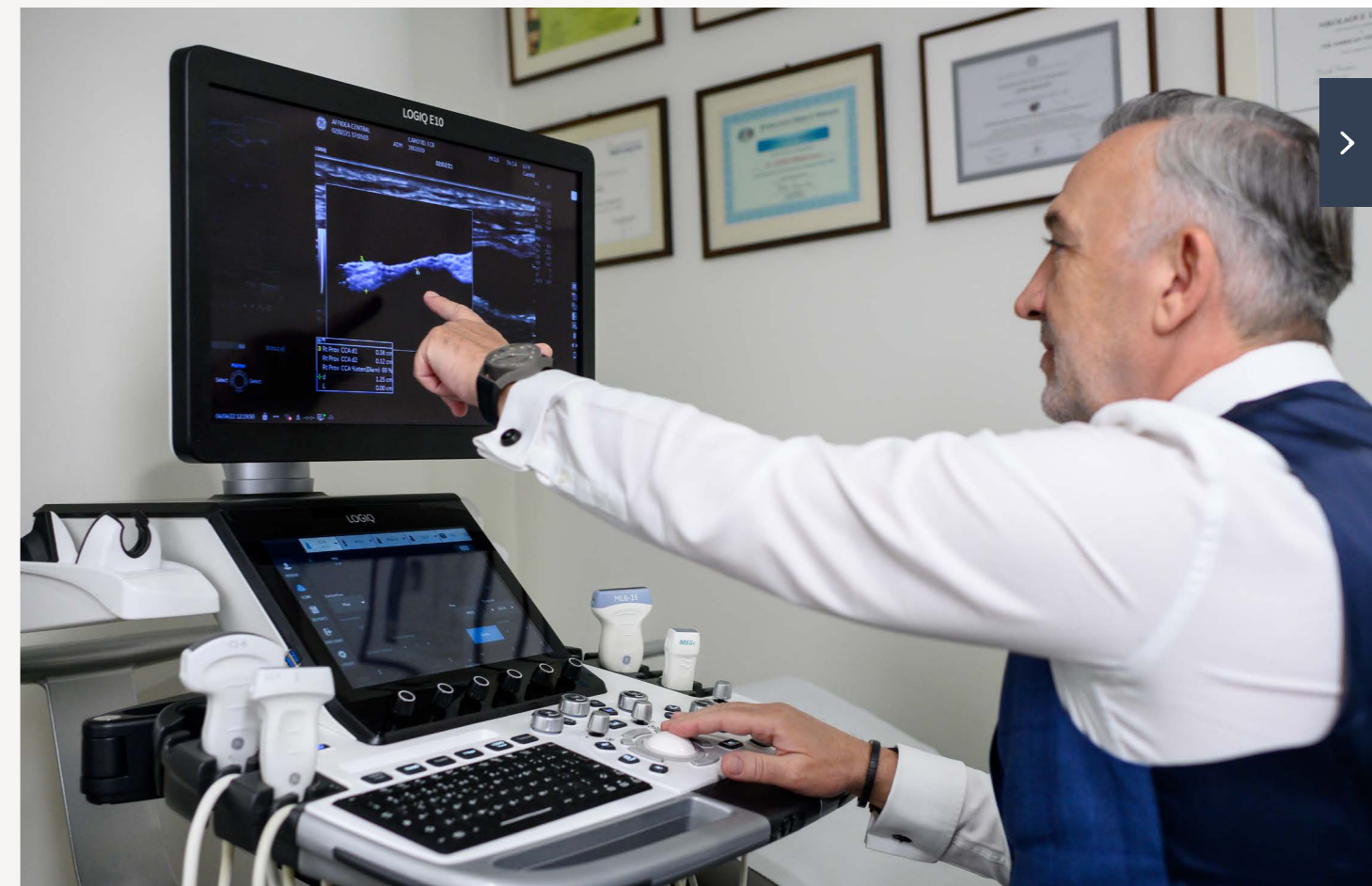
Radiantflow™ algorithms add height and depth information to Color Flow, Power Doppler Imaging or Microvascular Imaging signals to provide a 3D-like appearance. It provides clearer separation of the signal and background and assists in identifying slow flow in small vessels that at times can be hard to detect with traditional visualization techniques.

B-FLOW IMAGING

B-Flow Imaging is a unique flow mode that directly images blood reflectors and tissue information simultaneously, providing an accurate morphologic display of the intraluminal blood flow throughout the entire field of view.

In vascular investigation, B-Flow may be useful in:

- Assessing high grade stenosis in arteries
- Visualizing flow around an area of soft plaque.



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Clinical Cases



CASE 01 PLAQUE NEOANGIOGENESIS

PATIENT'S HISTORY

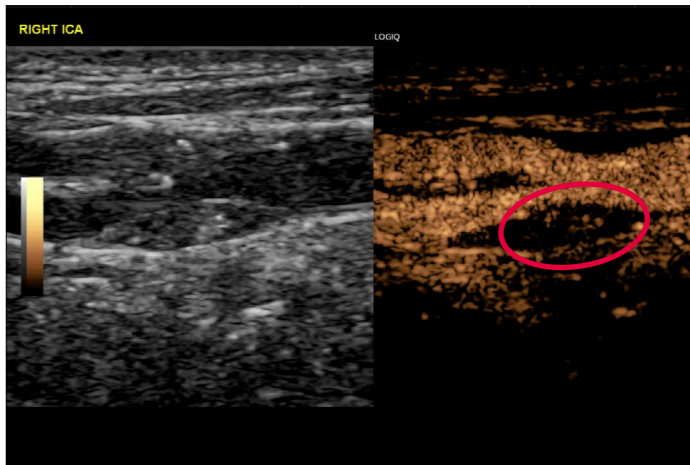
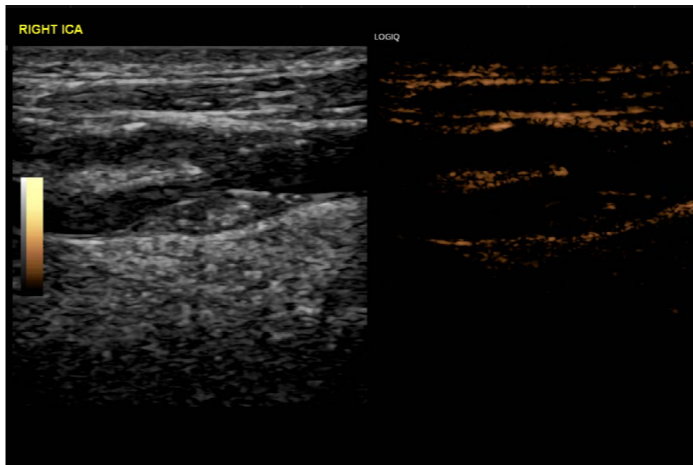
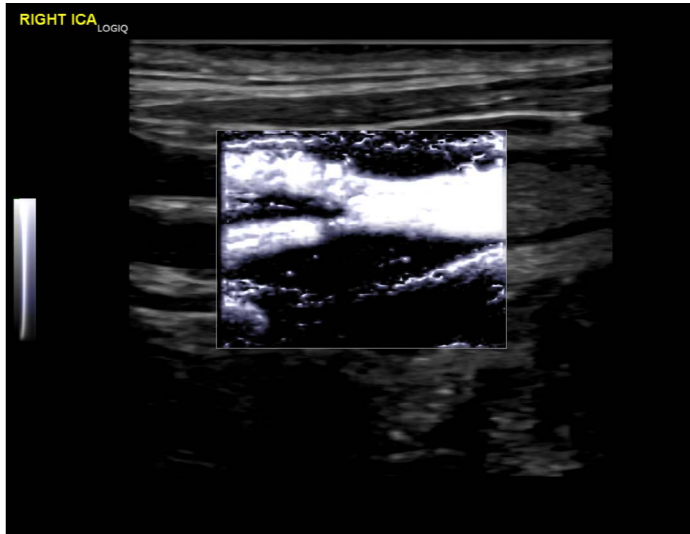
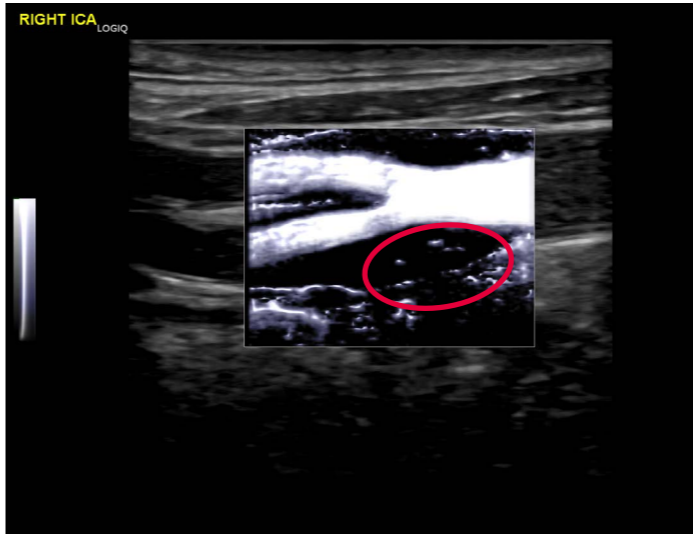
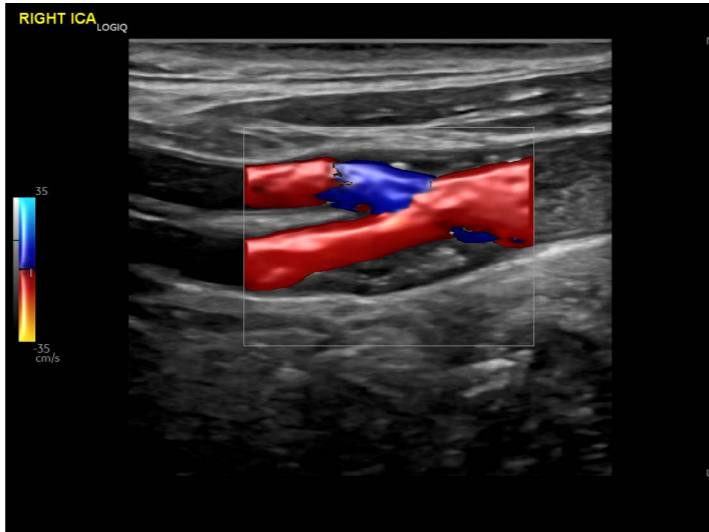
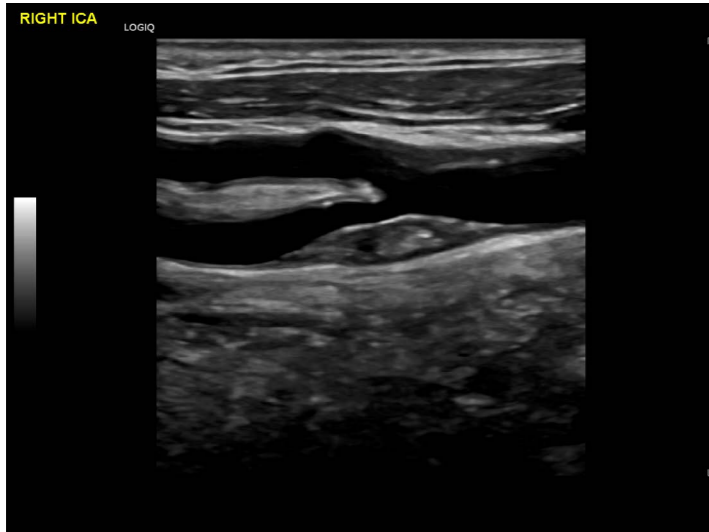


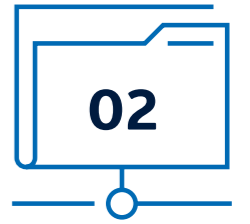
Male 58 years old presenting with TIA and mild symptoms on the left arm and leg and difficulty to speak clearly.

DIAGNOSIS



B-Mode image with clear delineation of the surface and fibrous cap of a predominantly echogenic atherosclerotic plaque. Image with gradient color flow without overlapping and obscuration of the plaque by color flow. Images with MVI reveal some very tiny vessels (neoangiogenesis) at the proximal part of the plaque (shoulder). Images before and after intravenous injection of 2,5 ml contrast agent (Sonovue) showing microbubbles indicating neoangiogenesis in the same position as MVI.





CASE 02 STENOSIS OF THE LEFT ICA-MVI ANGIOGENESIS (1/2)

PATIENT'S HISTORY

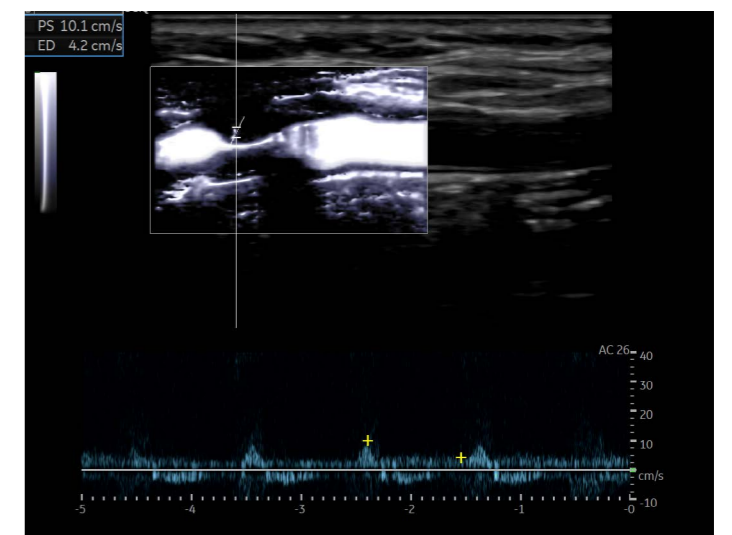
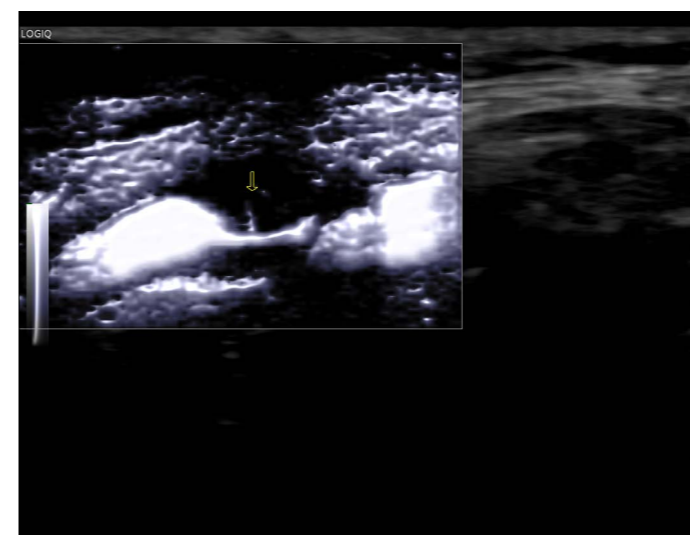
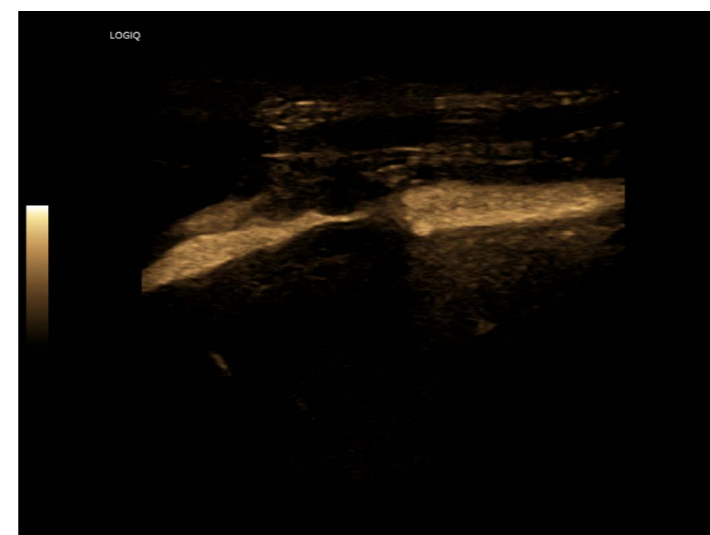
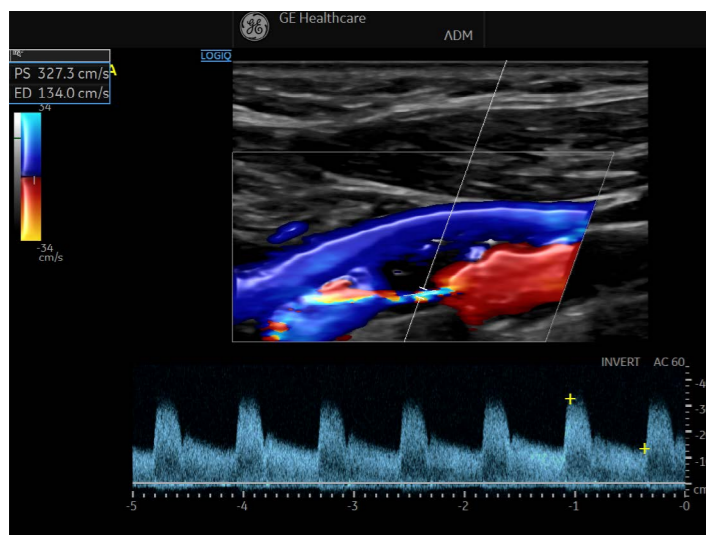
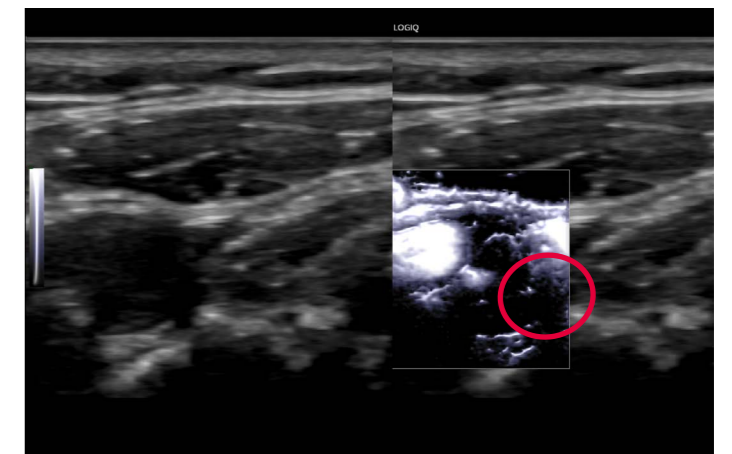
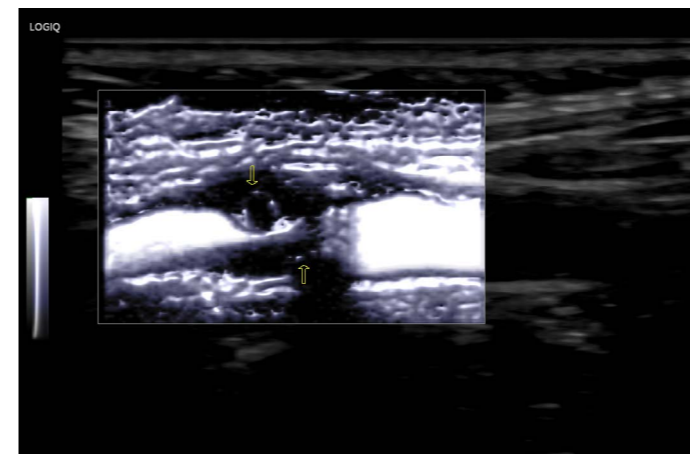
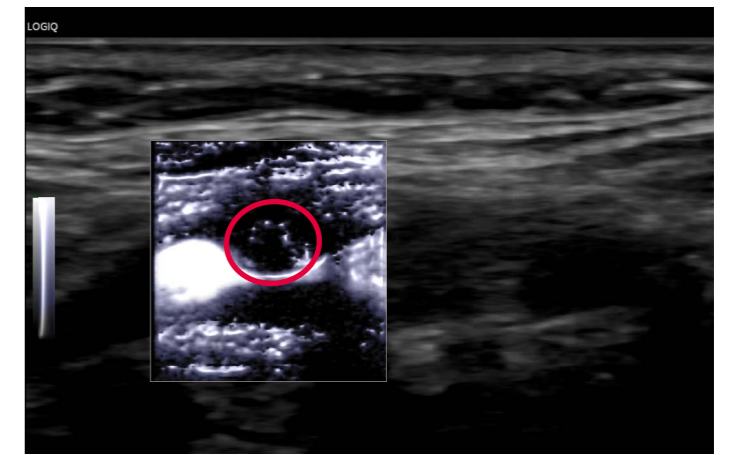
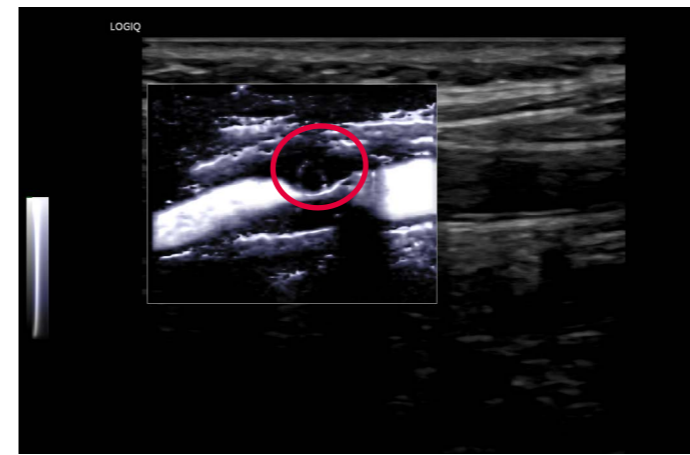
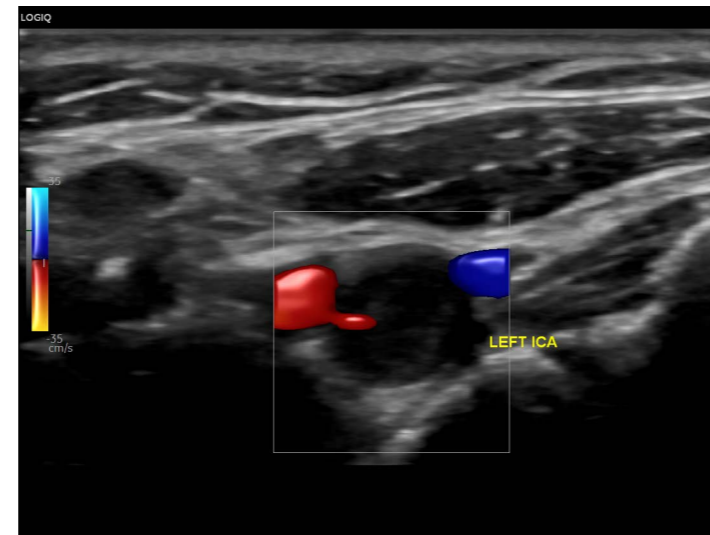
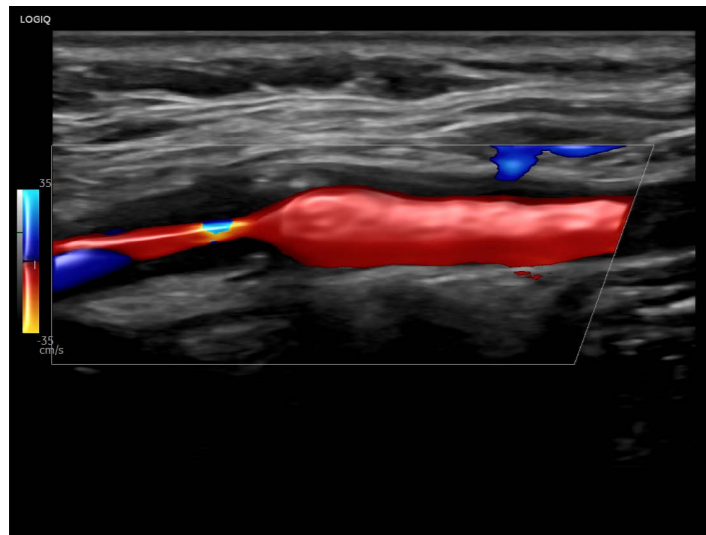


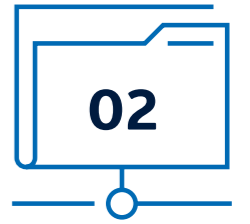
A young female 50 years old presenting with amaurosis fugax on the right eye lasting for 15-20 min several days ago.

DIAGNOSIS

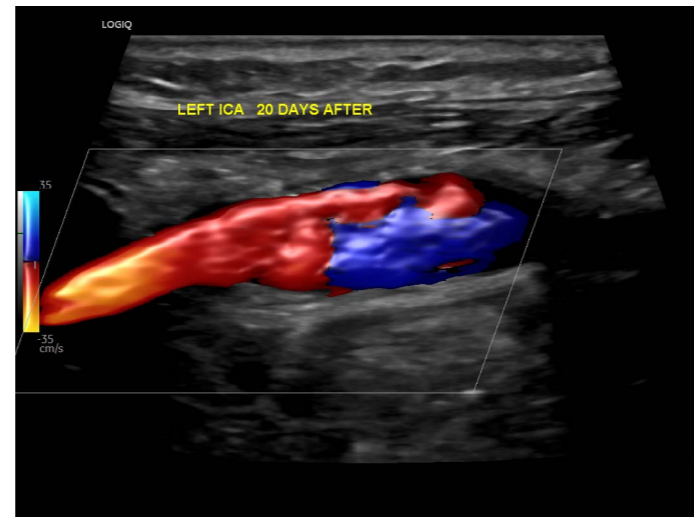
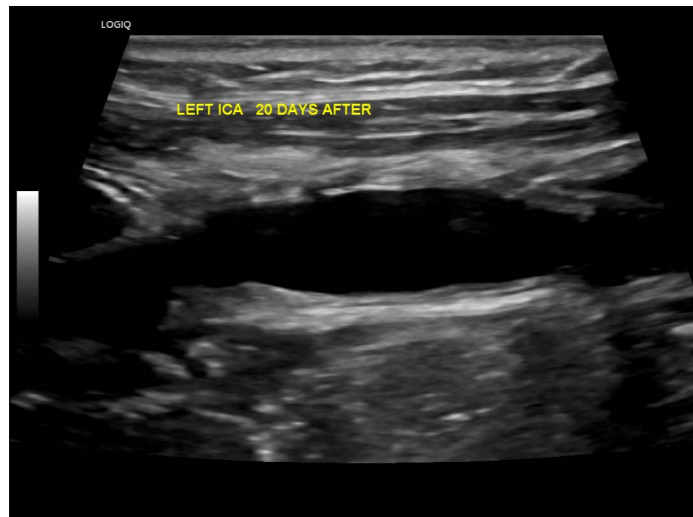


Using all techniques, a high-grade carotid stenosis is confirmed and MVI shows neoangiogenesis, more prominent inside the plaque proximal to the front wall. It is worth to mention that spectral Doppler detects signal with very low velocities from one very tiny vessel inside the plaque (bottom).

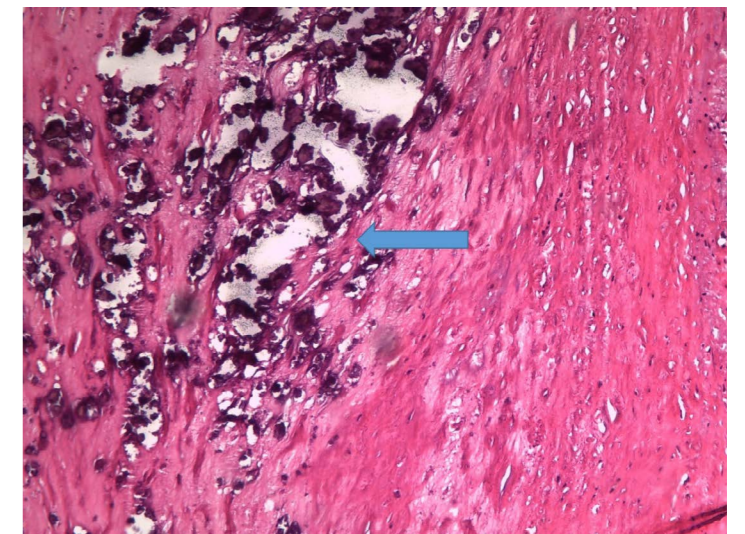
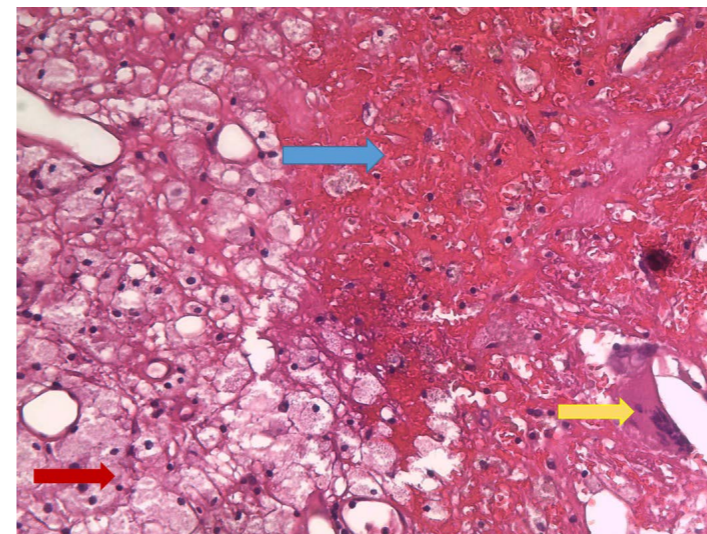


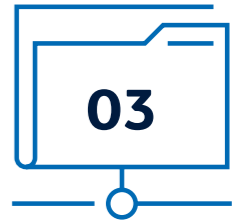


CASE 02 STENOSIS OF THE LEFT ICA-MVI ANGIOGENESIS (2/2)



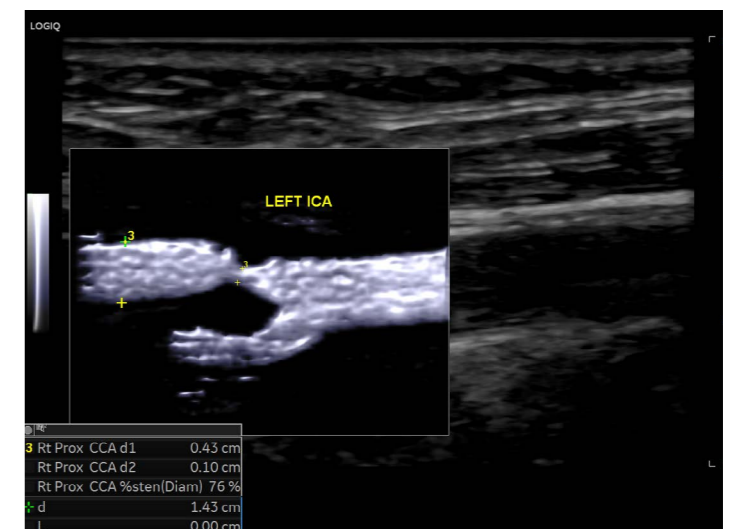
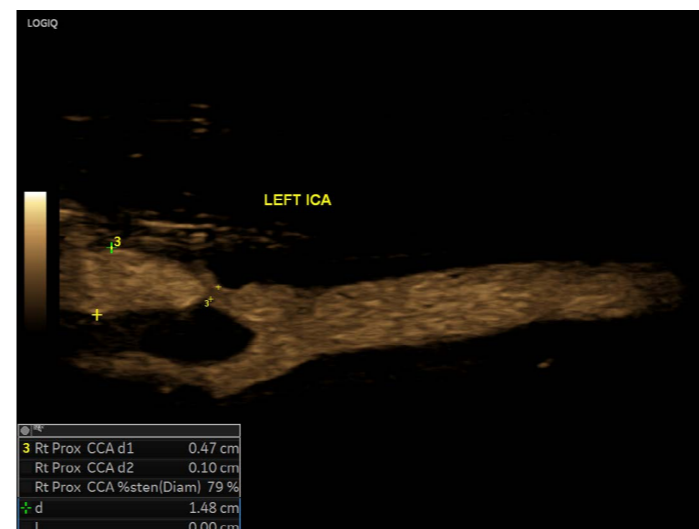
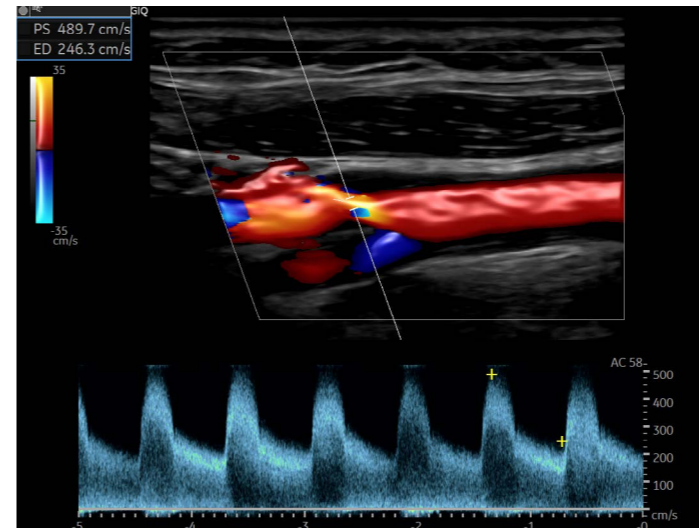
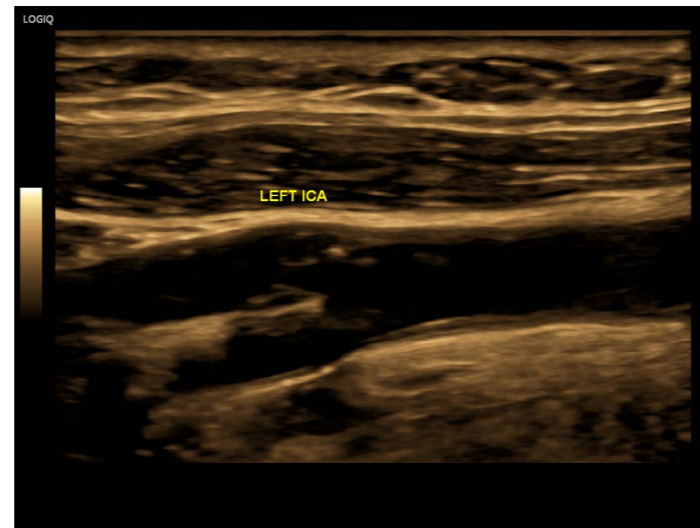
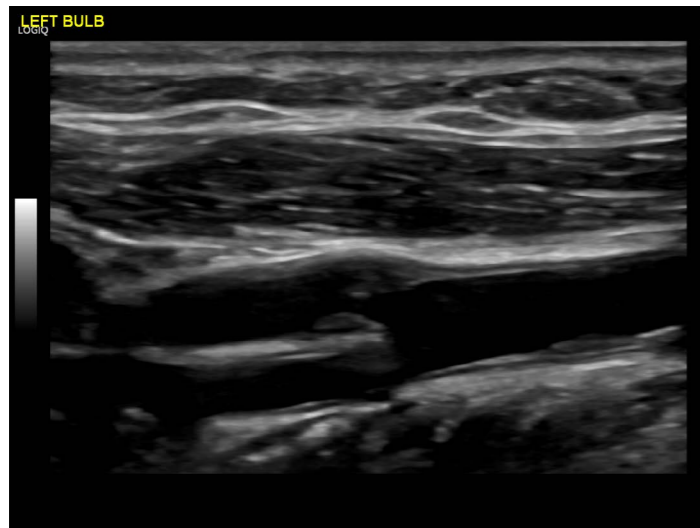
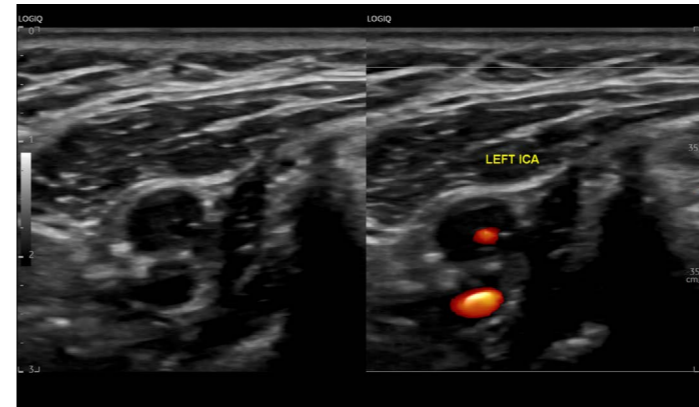
Images post endarterectomy and histopathology of the plaque showing vasa vasorum and some calcifications which were also seen in the US study. Pathology shows neovascularization (blue arrow); intraplaque hemorrhage (black area of the plaque); foam cells (histiocytes) (red arrow) and multinucleated giant cells of foreign body type (yellow arrow).





CASE 03 STENOSIS >80% IN THE LEFT ICA WITH NEW TECHNIQUES

A short time ago we initiated a prospective study for evaluating the grading of stenosis based on the comparison between the established Doppler criteria, B-Flow Imaging, Radiantflow™, MVI, DSA and CTA. The preliminary results obtained using the NASCET method in B-Mode, MVI, B-Flow and Radiantflow™ indicate a very good correlation of the different methods with the percentage of stenosis on DSA and CTA.





CASE 04 SIGNIFICANT STENOSIS OF LEFT ICA & OCCLUDED RIGHT ICA

PATIENT'S HISTORY

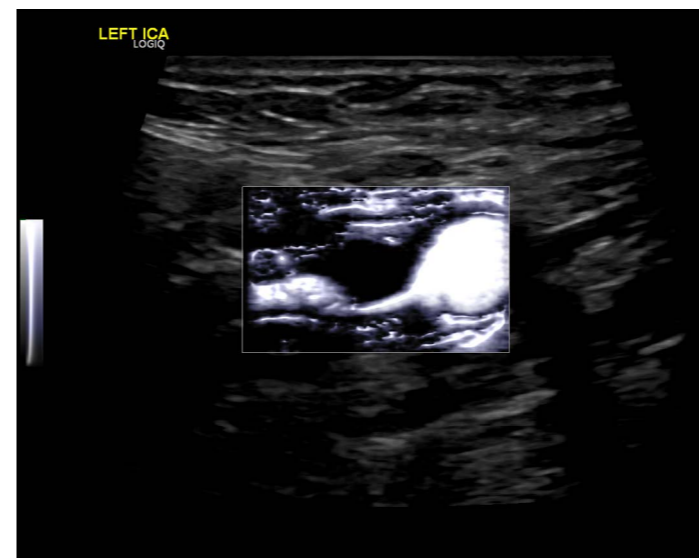
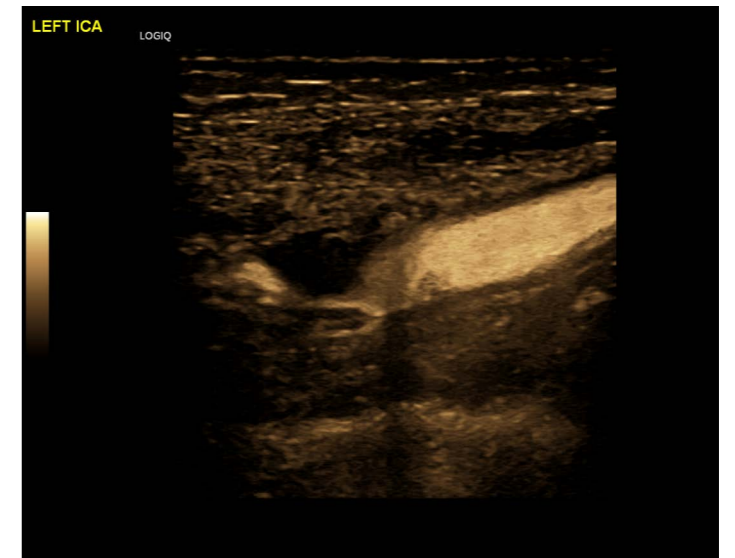
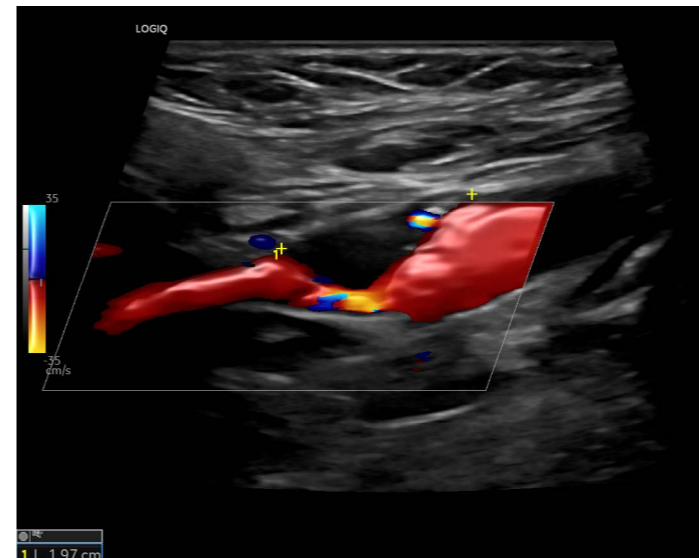
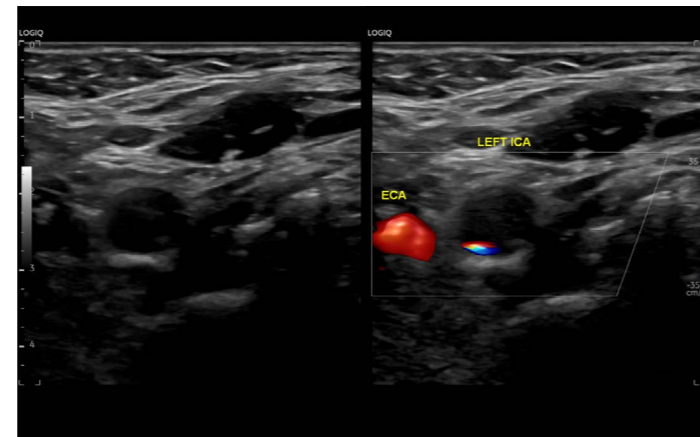
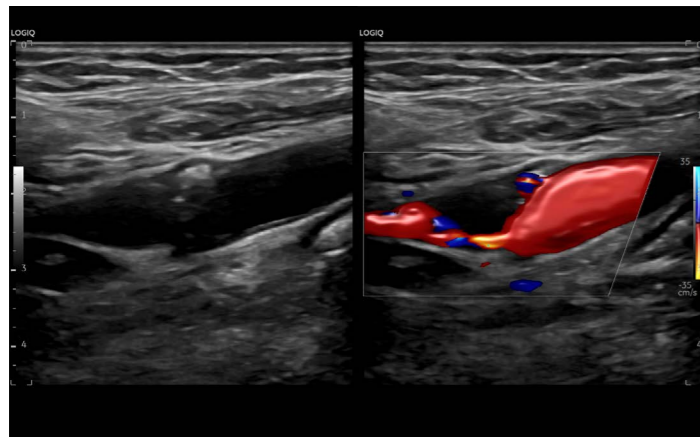


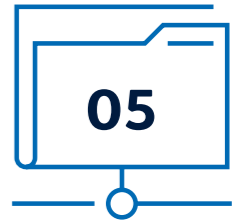
Male 65 years old suffered from a stroke with paralysis (hemiplegia) on the right side.

DIAGNOSIS



The US study using all the new techniques reveals occlusion of the right ICA and very significant stenosis (90-95%) on the left ICA. The plaque is predominantly echolucent, type II and the residual lumen can be visualized with Color Doppler combined with Radiantflow™, with B-Flow or MVI. Significantly elevated Doppler velocities are calculated at the site of stenosis. It is worth mentioning that distally to a severe stenosis PSV is very low (below 20cm/sec in this case) and acceleration time in the Doppler waveform is increased.





CASE 05 PARTIAL DISTAL DISSECTION OF LEFT ICA

PATIENT'S HISTORY

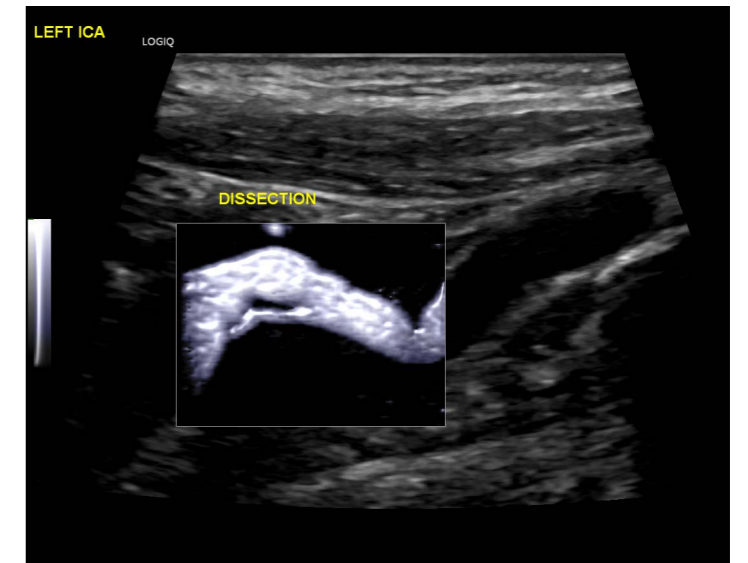
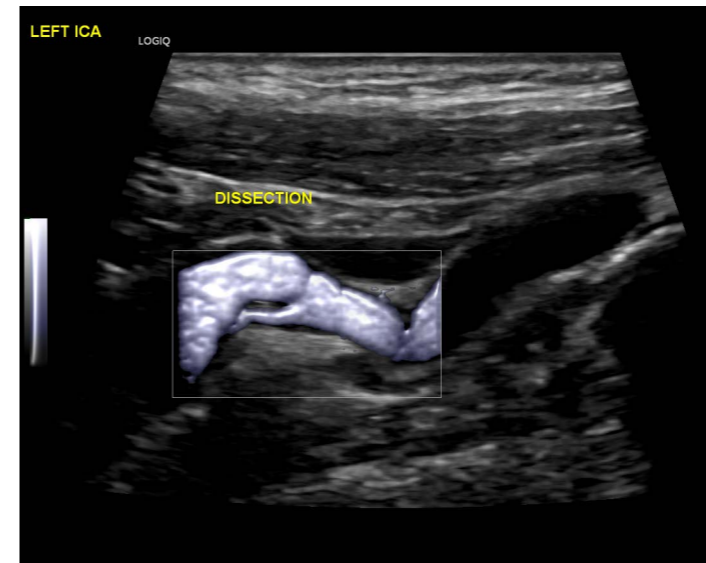
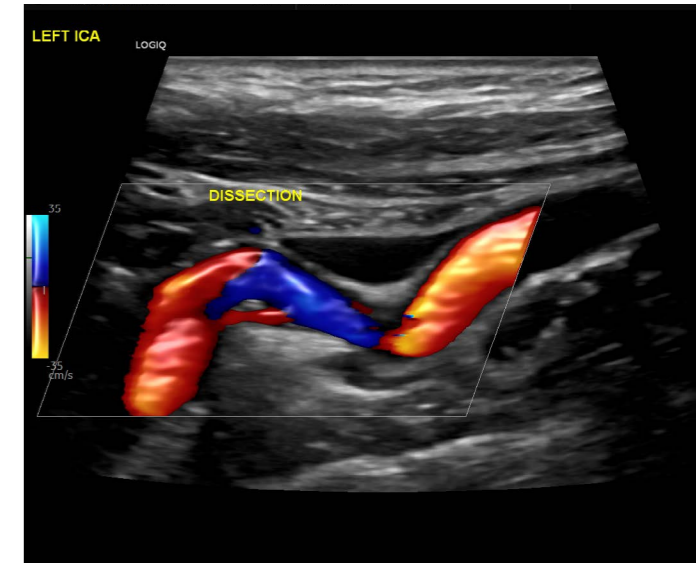


Female 38 years old complained about nausea and some visual defects on the left side.

DIAGNOSIS



B-Mode images show an echogenic lesion resembling a very small atherosclerotic plaque or potentially a small flap mostly because of its position in the very distal part of the left ICA. Using Color Doppler combined with Radiantflow™, B-Flow and MVI a diagnosis of a small-length partial dissection of the distal left ICA can be safely and easily reached.





CASE 06 ULCER

PATIENT'S HISTORY



Female 70 years old with an episode of dysarthria.

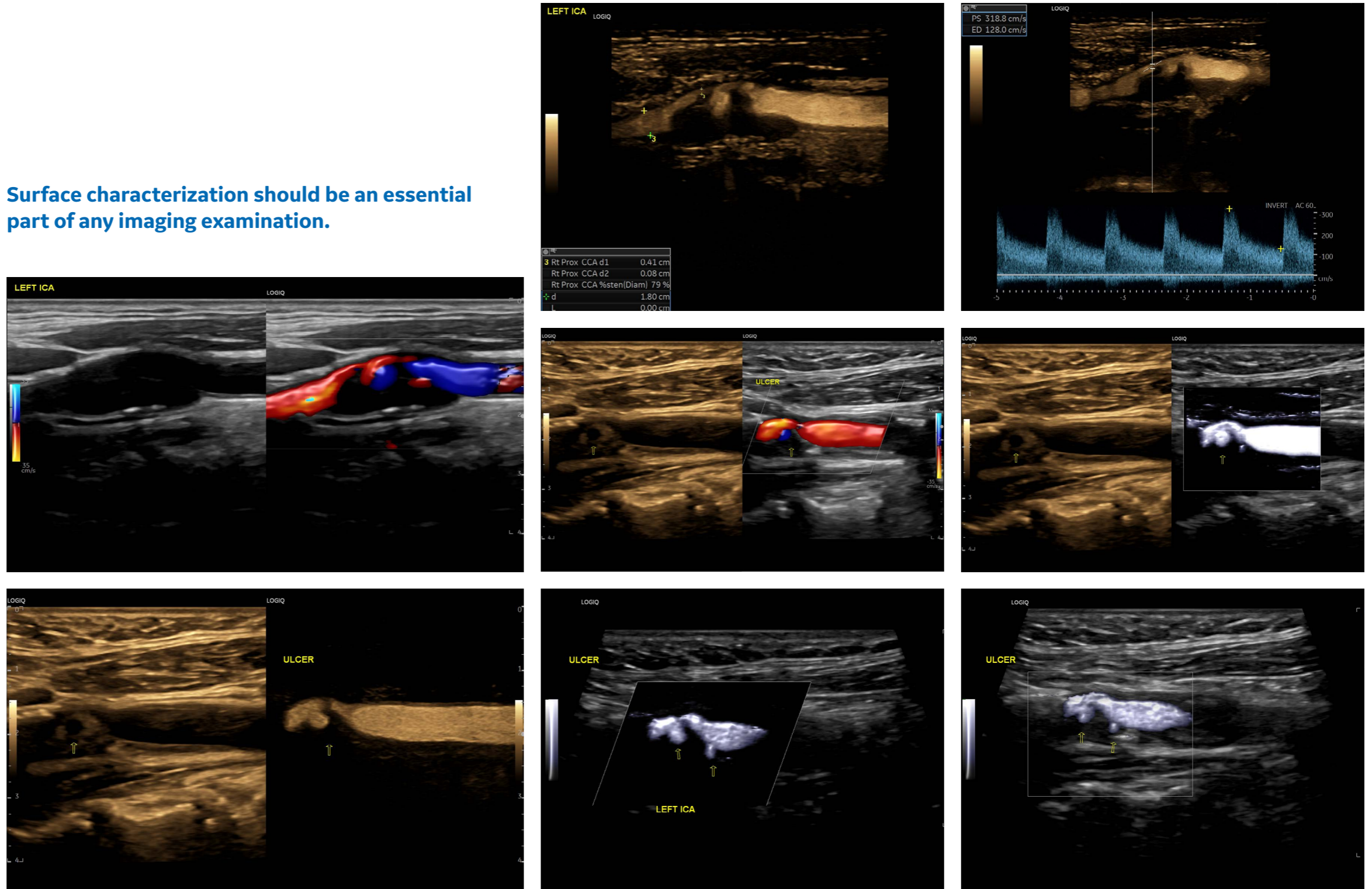
DIAGNOSIS



The B-Flow imaging was simply astonishing, providing images without overlapping of the plaque and its boundaries by color (blooming effect) in contrast with the color Doppler technique. A clear view of the residual lumen and also the presence of an ulcer are provided by the B-Flow technique without the need to use CEUS.

B-Flow imaging is sensitive to highlight the presence of an ulcer. Regarding plaque ulceration, literature shows that it is an essential feature of plaque vulnerability, being associated with the occurrence of stroke. In this case, using B-Flow imaging to calculate stenosis using the NASCET method the percentage of stenosis is 80%, and using Doppler velocity criteria stenosis is 80-85%. MVI revealed a second smaller ulcer which was not seen with color Doppler or B-Flow.

Surface characterization should be an essential part of any imaging examination.





CASE 07 THROMBOSIS - RECANALIZATION

We published in 2006 a case report of late spontaneous recanalization of an occluded extracranial internal carotid artery (ICA)* which has been infrequently described. Consequently, there were more cases of carotid recanalization reported in the literature. Using the new techniques recanalization after thrombosis of ICA can be evaluated.

PATIENT'S HISTORY

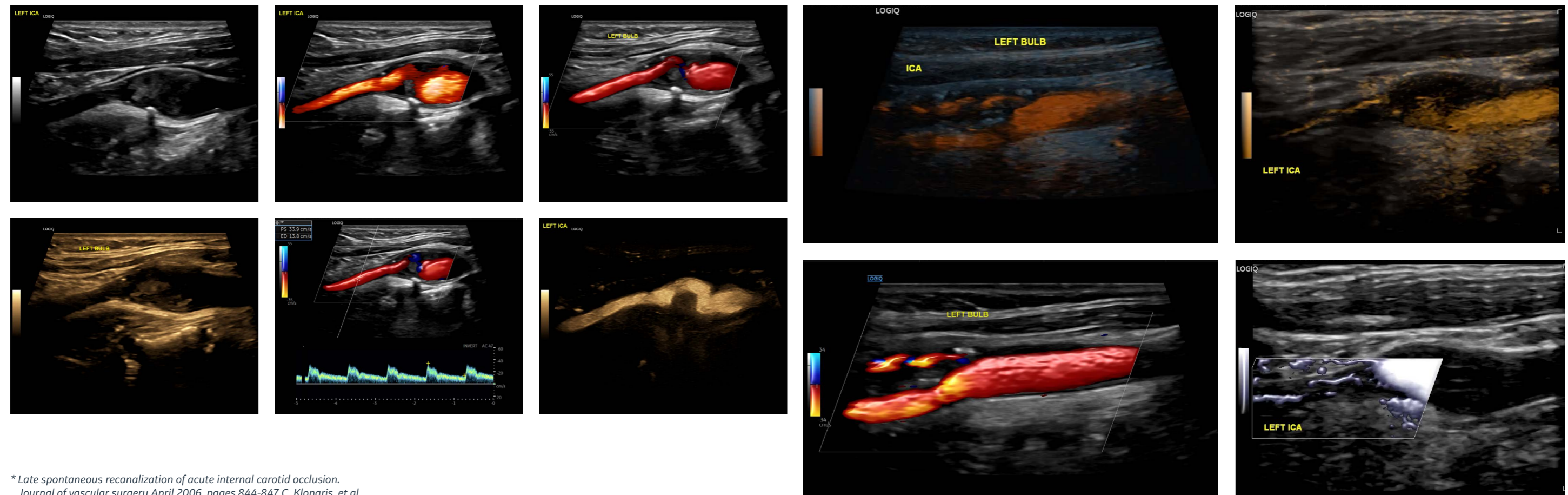
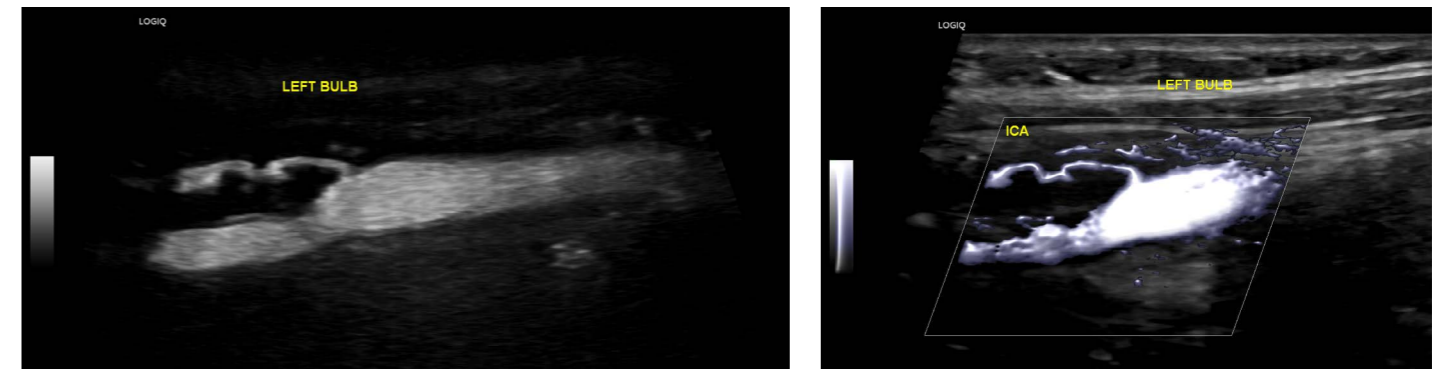
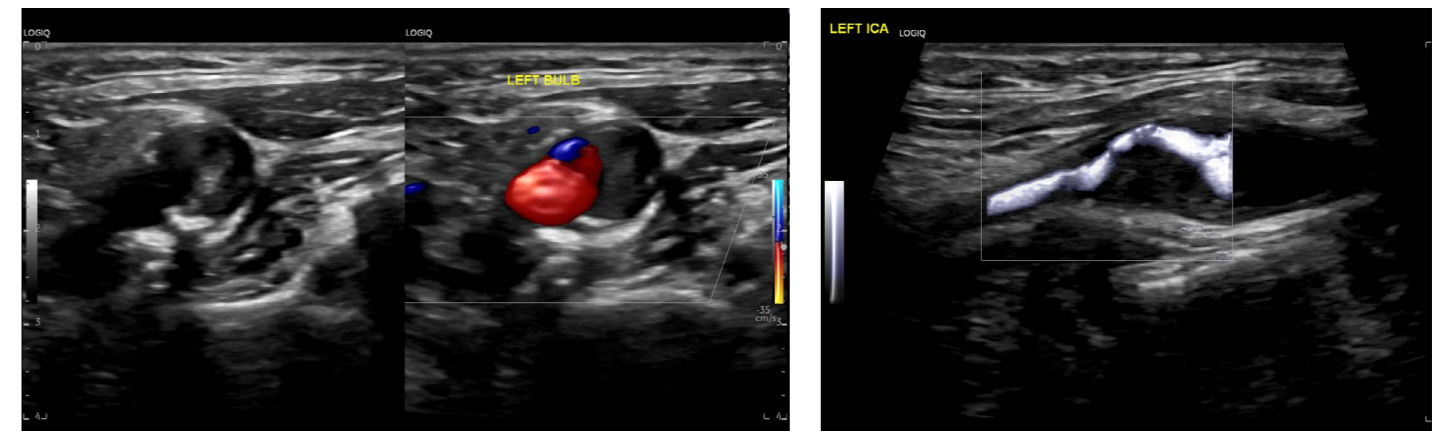


The patient was on clopidogrel treatment.

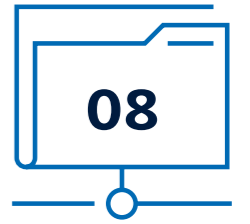
DIAGNOSIS



After 10 months (initially having total thrombosis of the L ICA) there is quite significant recanalization of the lumen. Endoluminal thrombus and the residual lumen can be clearly seen in B-Mode and PDI, B-Flow and, MVI. Spectral Doppler shows, very low velocities (PSV=34cm/sec).



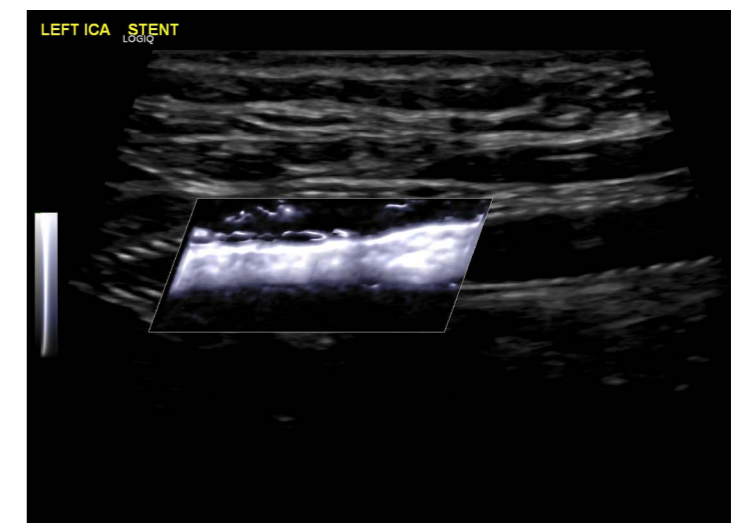
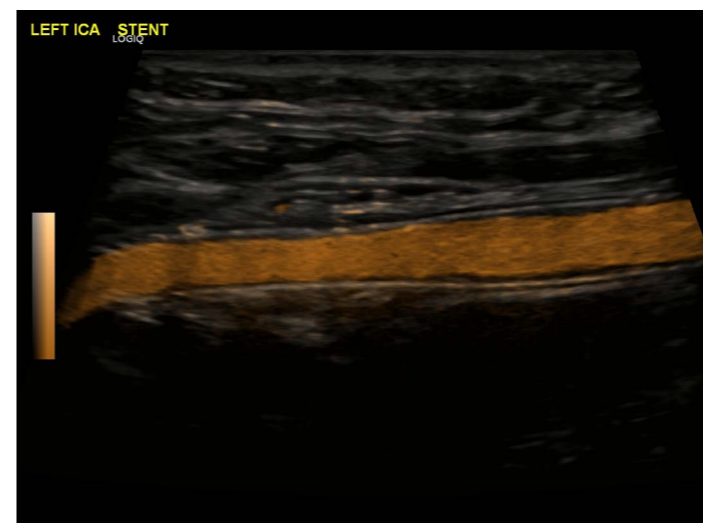
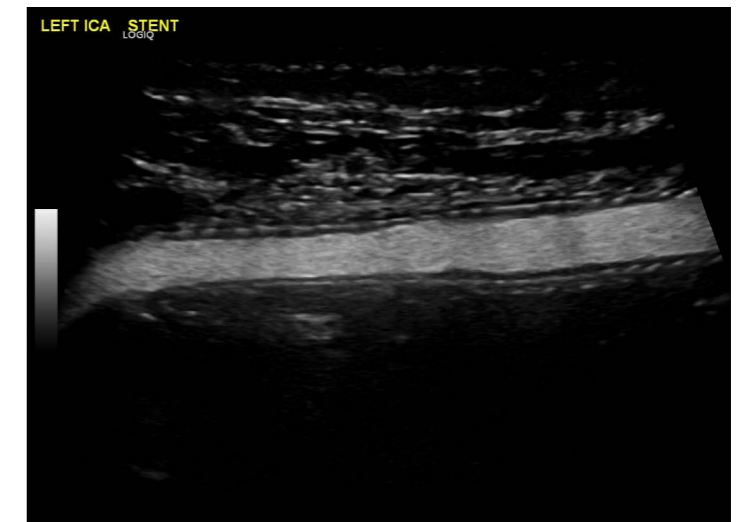
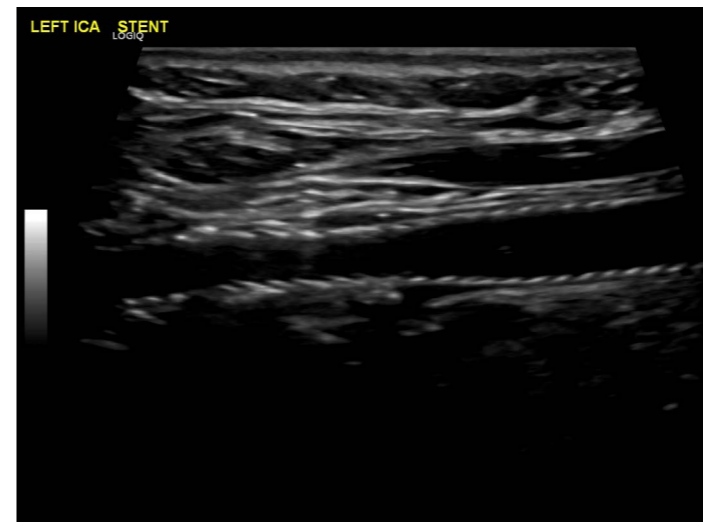
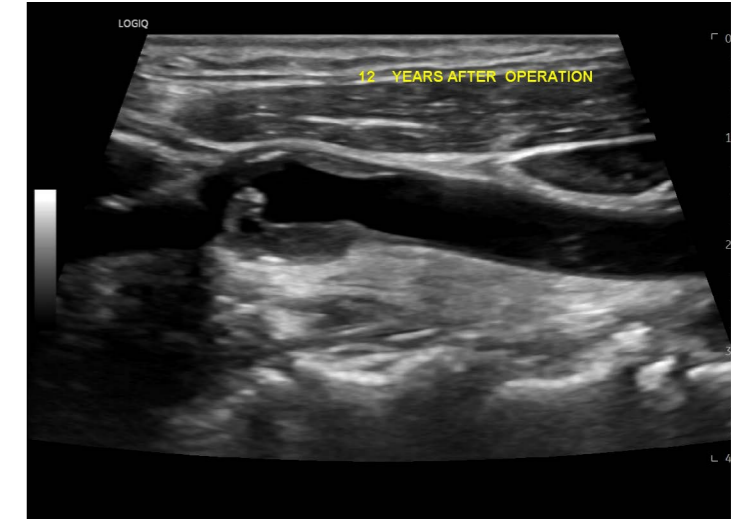
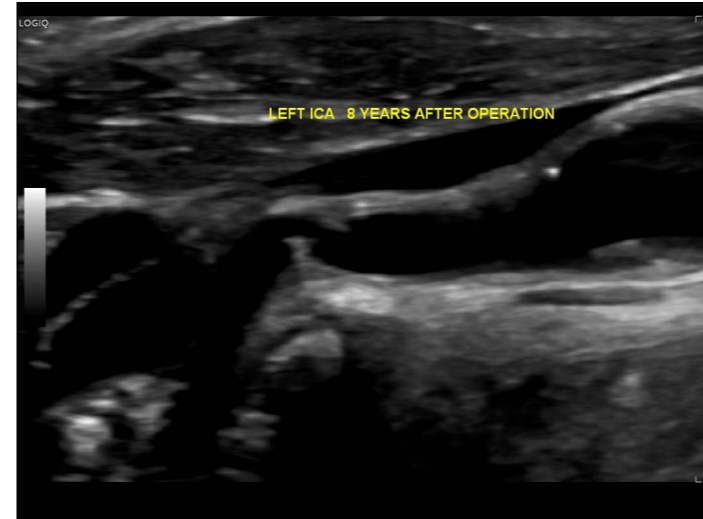
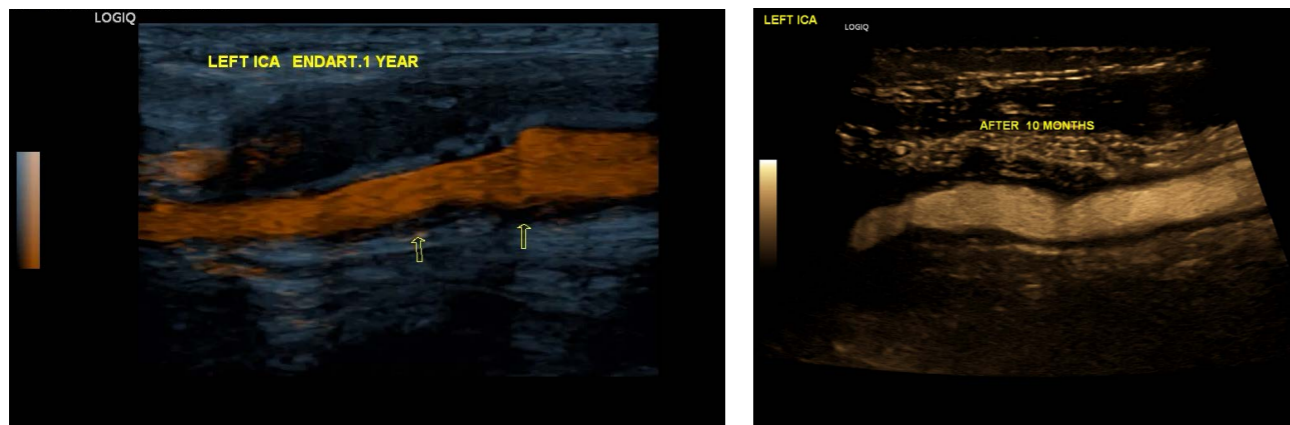
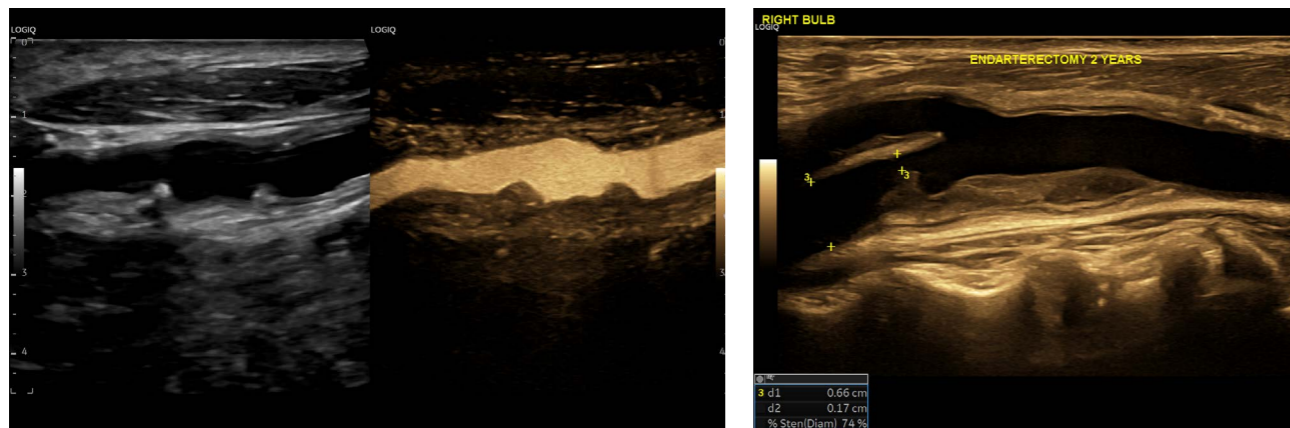
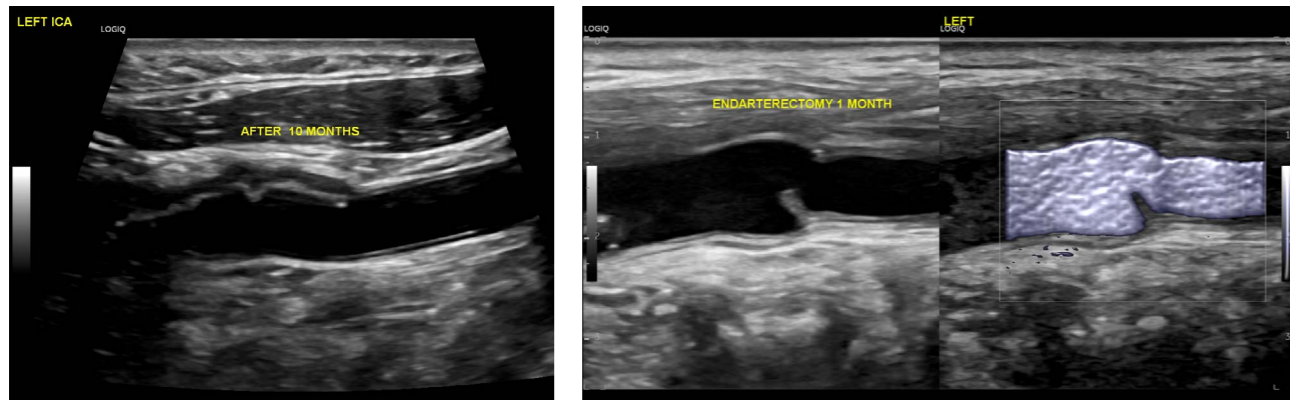
* Late spontaneous recanalization of acute internal carotid occlusion. *Journal of vascular surgery* April 2006, pages 844-847 C. Klonaris, et al.



CASE 08 CAROTID ENDARTERECTOMY-STENTING (CAS)

Ultrasonography is an ideal method for the follow up of patients who have undergone carotid endarterectomy with or without patch angioplasty.

Early restenosis is typically secondary to myointimal hyperplasia which can be easily evaluated using B-Flow imaging. B-Flow is an accurate technique for non-invasive follow-up after carotid stenting. The current risk of restenosis after stenting is 5% to 15% at 6 to 12 months.



Conclusion

Ultrasound is an ideal, unique, and inexpensive technique for carotid imaging. It not only reveals the geometry of the artery, but it also provides information about plaque morphology. It is highly accurate in the diagnosis of severe stenosis (70-95%).

With the implementation of Multiparametric Ultrasound in routine carotid imaging the need for the advanced imaging modalities for identification of vulnerable plaque could be reduced.

Further prospective studies on large patients' populations are required to establish the utility of ultrasound elastography, CEUS 3D Ultrasound, and assess correlation between these indices and plaque histopathology.



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Recently, he started investigating the role of Elastography at the assessment of the plaque vulnerability and thrombus recurrence.



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JB00159AFG