EC EMERGENCY MEDICINE AND CRITICAL CARE
Review Article

Brain Ultrasound and Transcranial Doppler in Critically Ill Patients

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Abstract

In the last years, Critical Care U/S has become an essential branch of critical care Medicine and has gained general acceptance. Its use, both as a diagnostic tool and for hemodynamic monitoring, has increased markedly, greatly influencing contemporary cardiorespiratory management. The RUSH Protocol for undifferentiated shock, the BLUE- protocol for the management of acute respiratory failure. Moreover, as judged by the American College of Radiology Appropriateness Criteria, renal Doppler ultrasonography is the most appropriate imaging test in the evaluation of AKI and has the highest level of recommendation. However, brain imaging by brain U/S is still not used in general intensive care setting.

There are 2 types of brain U/S, TCD and TCCD. In contrast to TCD which was introduced in clinical practice approximately 40 years ago, TCCD identifies the cerebral arteries "blindly" based on arterial depth, direction and waveform analysis and is mainly a spectral Doppler. Trans cranial color-coded duplex (TCCD) is better than the conventional TCD examination because it shows the images of the intracranial anatomy by 2D image and arteries by duplex B-mode, while still having the capacity to measure the blood flow velocity. TCCD is not used frequently in intensive care setting, moreover, it is not included in both European [EDEC] and American [CCEeXAM] certification for advanced critical care Echo.

MRI and CT- Brain are the gold standard to diagnose important diseases in ICU setting like CVS, but recently, especially in COVID-19 era, there was a large number of patients who are on high setting mechanical ventilator and cannot be transferred to radiology department. Thus, nowadays we need to decrease mobilization of infected patients between departments so, brain U/S could be an alternative for the patients who cannot be mobilized safely to radiology department.

The main obstacle to brain U/S is due to absence of temporal window, in 12- 20% of the patients especially elderly females, but, with improvement of technology of U/S machines and the appearance of new mode [Harmonic], it is expected to decrease the number of failed studies due to absence temporal window.

Brain ultrasonography can be used to evaluate cerebral anatomy and pathology, as well as cerebral circulation through analysis of blood flow velocities. Trans cranial color-coded duplex sonography is a generally safe, repeatable, non-invasive, bedside technique that has a strong potential in neurocritical care patients in many clinical scenarios.

In this review we will discuss the value of TCCD in ICU daily practice. In the first section, we will illustrate the clinical applications as Doppler mode, and in the second part will enumerate the different uses as B-mode to assess the brain tissues and ventricles.

Keywords: *TCCD; CVS; Brain U/S; ICU*

Abbreviations

PI: Pulsatility Index; MCA: Middle Cerebral Artery; ACA: Anterior Cerebral Artery; PCA: Posterior Cerebral Artery; BA: Basilar Artery; VA: Vertebral Artery; LE: Lindegaard Equation; TCD: Trans Cranial Doppler; MLS: Midline Shift

Introduction

Transcranial Doppler (TCD) ultrasonography, first described in 1982 by Aaslid., *et al*. is a readily available, noninvasive, and reproducible technique used to evaluate cerebral blood flow hemodynamics through the insonation of the basal cerebral arteries.

MRI and CT- Brain are the gold standard to diagnose important diseases in ICU setting like CVS, but, recently, especially in COVID-19 era, there was a large number of patients who are on high setting mechanical ventilator and cannot be transferred to radiology department. Nowadays, we need to decrease mobilization of infected patients between departments. Brain U/S could be an alternative for the patients who cannot be mobilized safely to radiology department.

Brain U/S can be used as Duplex-B mode to diagnose hydrocephalus [1], intracranial hematoma [2] and midline shift [3,4].

Brain U/S can be used as Doppler mode to measure the velocity, and direction of blood flow in basal cerebral arteries to diagnose spasm, stenosis, and complete occlusion.

We use phase array probe with 2 MHz for complete penetration, depth will be adjusted to 12 - 15 cm in temporal window to see the opposite side of skull, and focus will be at the midline. Temporal window is located at the thin temporal bone, in the area between the tragus of the ear and the angle of the eye above zygomatic bone. We use it to localize the midbrain, third ventricle, and lateral ventricle, where we look at acute intracranial hematomas, hydrocephalus, and midline shift.

In Doppler study we use three windows. First, the temporal window to localize the MCA, ACA, and PCA. Second, the subcostal window, the dimple between the edge of the foramen magnum and spinous process of the axis to localize the VA and BA. Third, the orbital window to localize the ophthalmic artery.

In this review, we will cover the important applications, and the suggested protocol of Brain U/S and TCD in ICU daily practice.

Brain U/S as a doppler mode

Cerebral circulation is a low resistance circulation with prominent diastolic flow because brain is a vital organ, and all vital organs receive blood during systole and diastole in contrast to non-vital organs which receive blood only in systole.

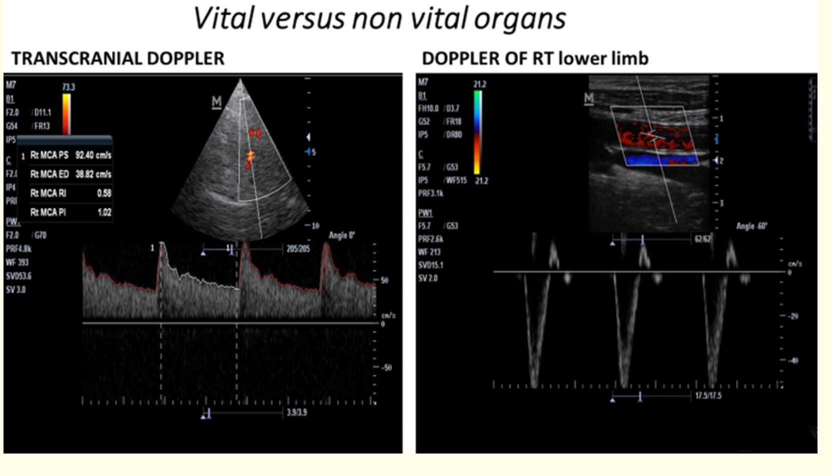


***Figure 1:** Comparison between vital and non-vital circulation [MCA TCD with prominent diastolic flow in comparison of LL Doppler with reversed diastolic flow].*

Here is a suggested protocol and clinical applications of TCCD as Doppler mode in ICU daily practice.

First, look at diastolic flow:

- Alteration of diastolic flow in case of marked increase of ICP. E.g. circulatory arrest of brain death.
- TCD has very high sensitivity (96.5%) and specificity (100%) in the diagnosis of cerebral circulatory arrest, but the possibility of temporary arrest should be excluded by having the systolic blood pressure > 70 mm Hg during the TCD assessment [5,6].

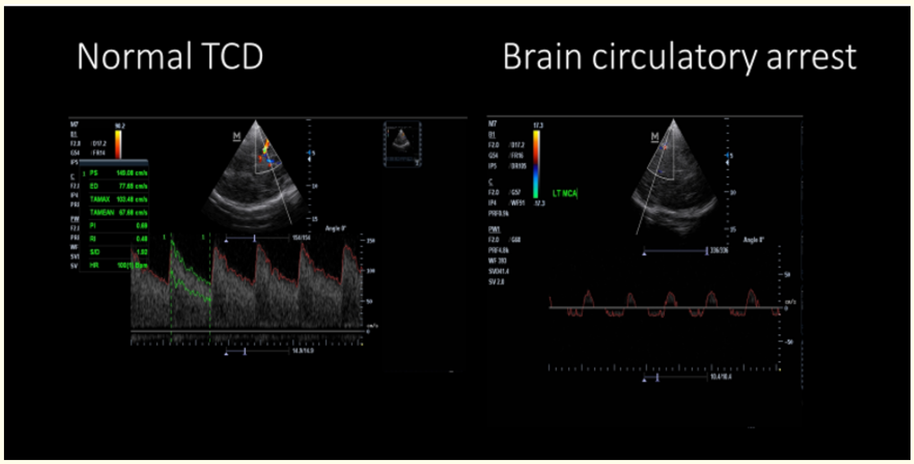


Figure 2: *Normal MCA TCD showing prominent diastolic flow in comparison with reversed diastolic flow in brain circulatory arrest.*

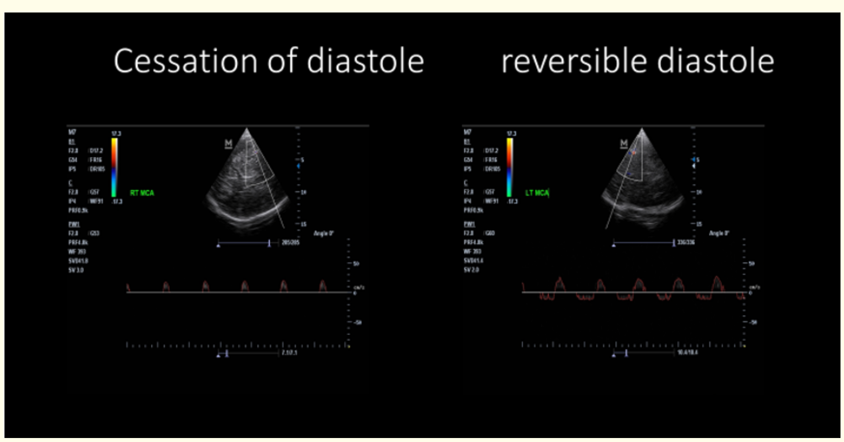


Figure 3: *Diagram showing doppler signs of brain circulatory arrest [systolic spikes and reverberating flow].*

Second, measure PI:

PI which is equal to the peak systolic velocity- end diastolic velocity/mean velocity, the most important application is:

- Prognosis of head trauma, more than 1.25 bad prognosis.
- In special circumstances It may be a surrogate of ICP [7,8].

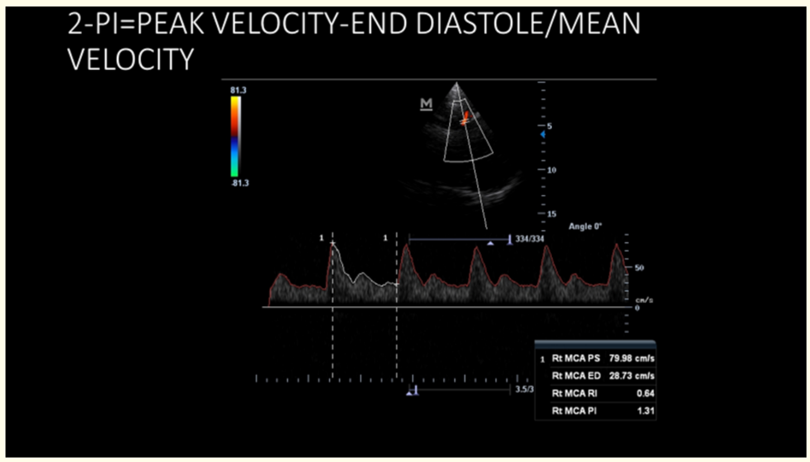
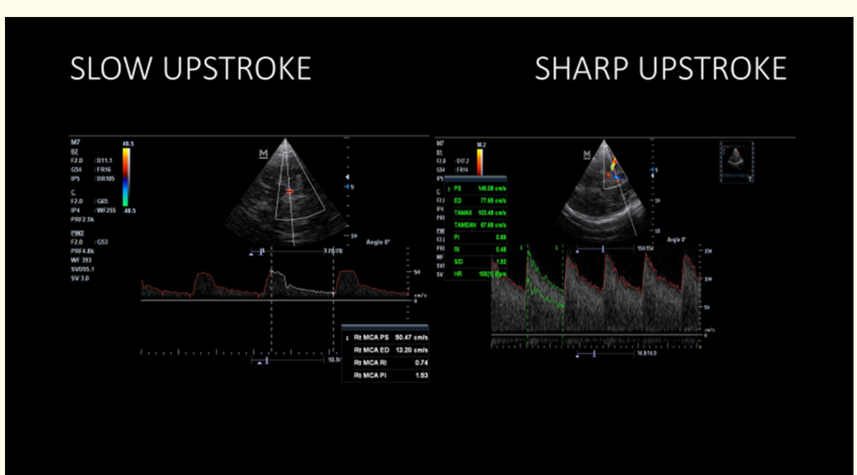


Figure 4

Third, systolic upstroke:

- Slow dull Systolic upstroke denoting proximal obstruction in case of focal lesion or systemic low flow state in case of diffuse lesion [9].



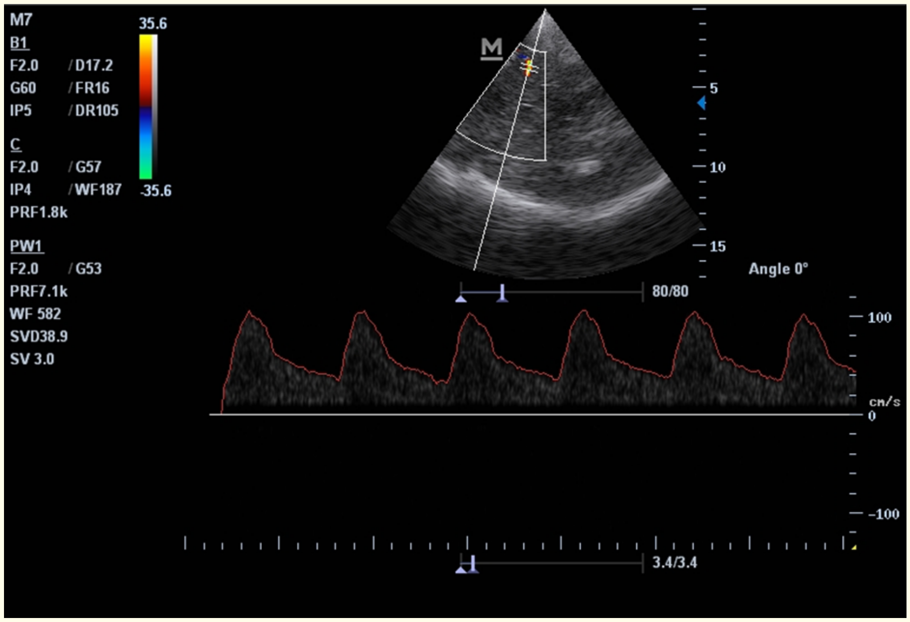


Figure 5: *Slow upstroke in LT MCA due to cerebral atherosclerosis.*

Fourth, flow velocity:

Increase in case of spasm and stenosis, it is focal in stenosis and diffuse in spasm.

To differentiate between the spasm and hyperemia due to triple therapy in subarachnoid hemorrhage, we measure Lindeegard equation which is the MFV of cerebral artery/MFV of the feeding proximal artery, for example LE of MCA equal MFV MCA/MFV ICA. If the ratio is high it is vasospasm and if low it is hyperemia [10]:

- Transcranial doppler is reasonable to monitor for the development of arterial vasospasm (Class IIa; Level of evidence B) (New recommendation).
- Guidelines for management of aneurysmal subarachnoid hemorrhage AHA/ASA 2012.

Cutoff value for diagnosing vasospasm in intracranial arteries are:

- MCA, MFV > 120 cm/s mild, > 130 cm/s mod, > 200 severe, Lindeegard > 3 mild, > 6 severe.
- BA, MFV > 60 mild, > 80 moderate, > 115 cm/s severe, Lindeegard > 3 severe.
- VA, MFV > 60 cm/s mild, >80 cm/s moderate-severe [11-13].

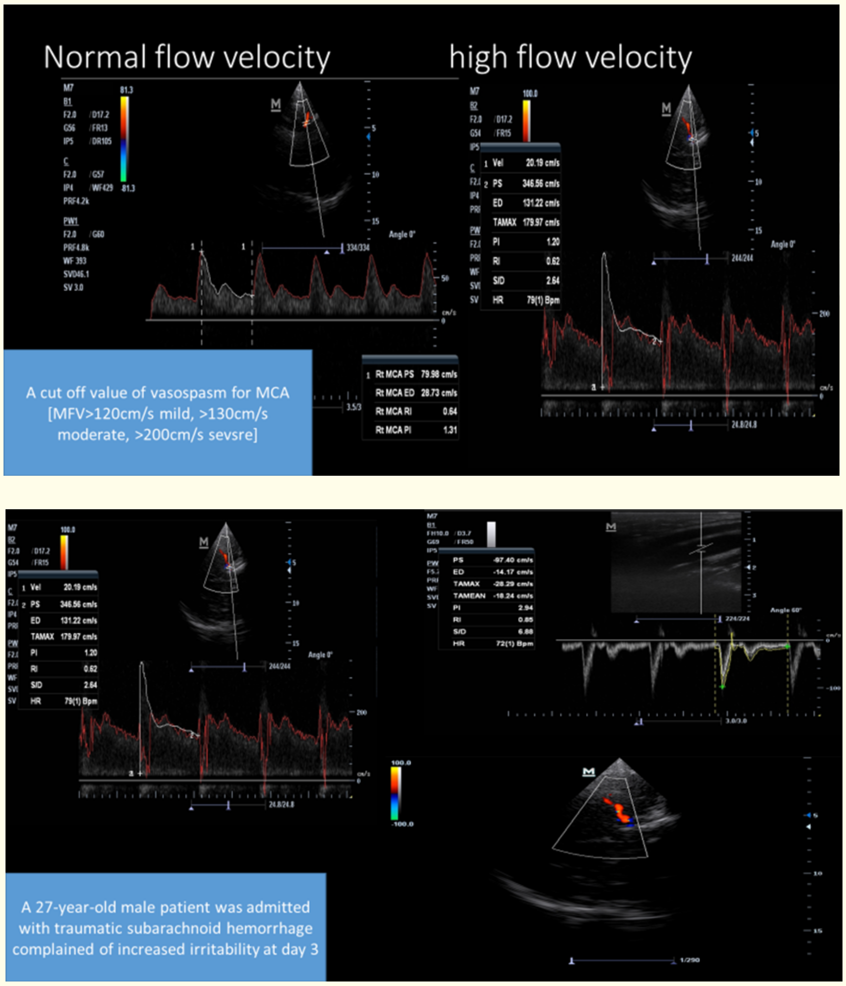


Figure 6: *A Case of traumatic subarachnoid hemorrhage with aliasing flow of RT MCA with high flow velocity and Lindeegard index.*

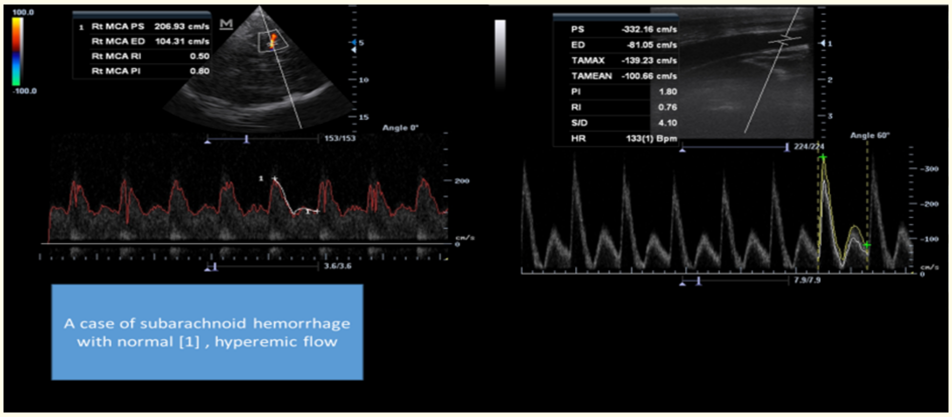


Figure 7: *A Case of traumatic subarachnoid hemorrhage with increased flow velocity in both RT MCA and RT ICA denoting hyperemia.*

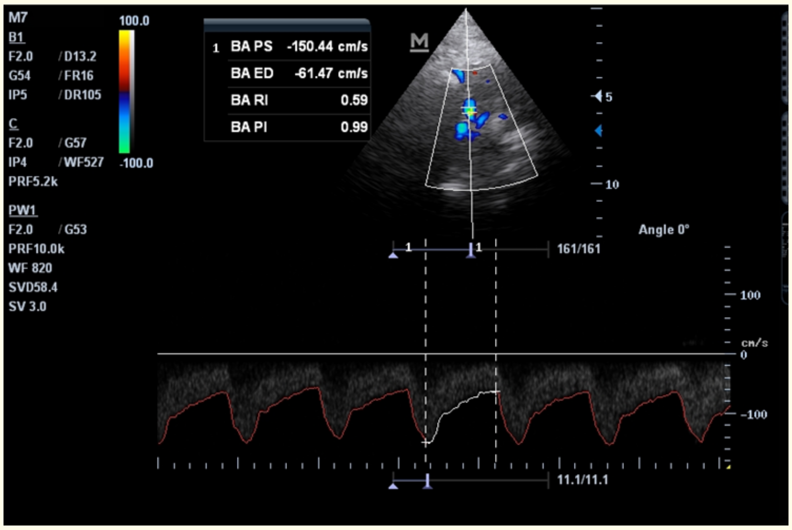


Figure 8: *A case with increase flow in the basilar artery with slow upstroke due to focal stenosis of atherosclerosis.*

Fifth, look for absence of flow:

Cessation of flow and F/U recanalization in acute ischemic stroke:

- TCD is very important in management and prognosis of CVS by properly confirming recanalization with very good accuracy.
- TCD can detect acute MCA occlusions with high (> 90%) sensitivity, specificity, and positive and negative predictive values [14].

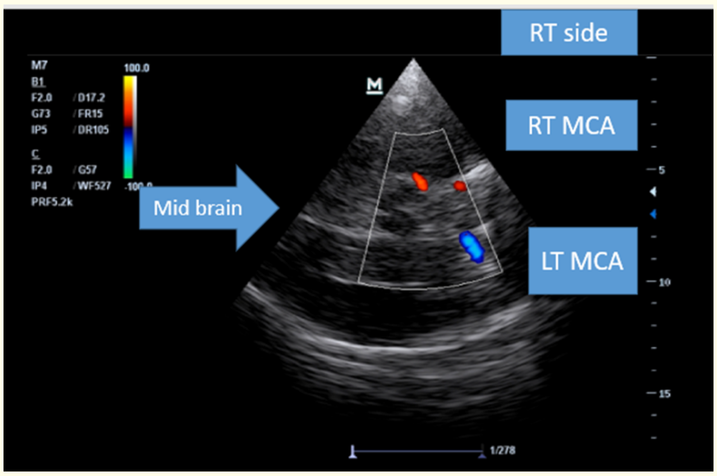


Figure 9: *A case of RT MCA complete occlusion on day 1.*

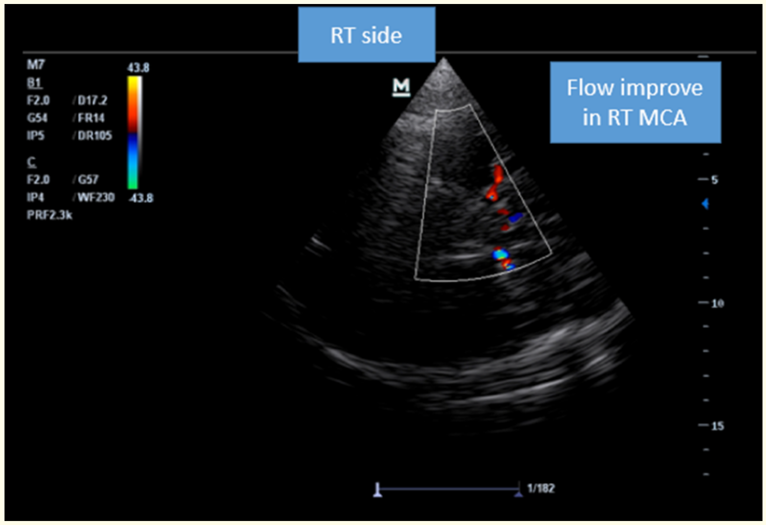


Figure 10: *Resumption of flow due to recanalization.*

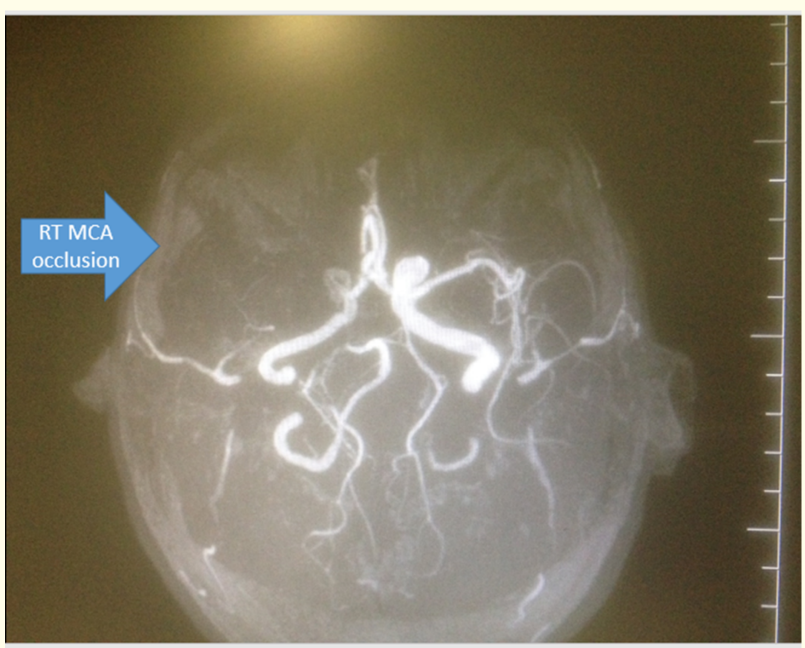


Figure 11: *CT cerebral angiography of the same patient revealing complete RT MCA occlusion.*

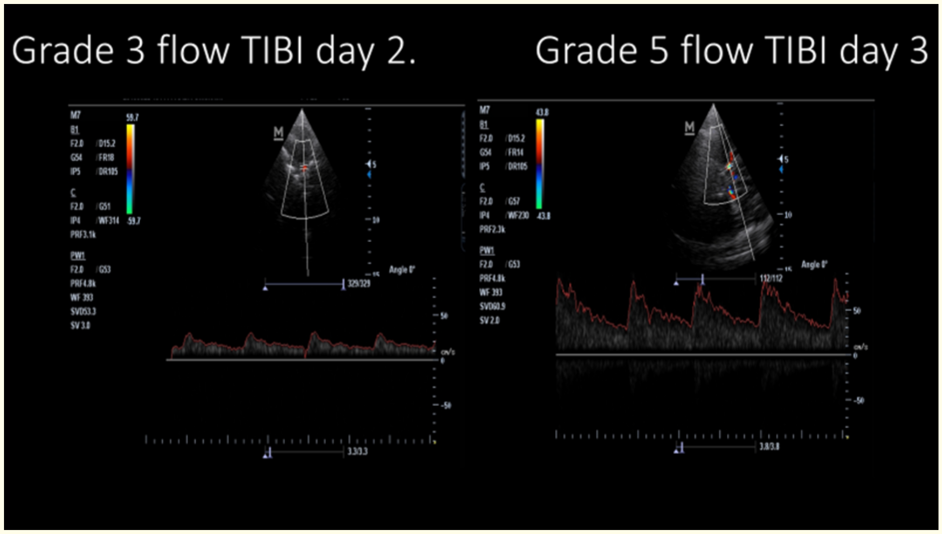


Figure 12: *Spectral doppler of the same patient revealing improved blood flow in thrombolysis in brain ischemia [TIBI] grade due to recanalization.*

Sixth, great role of brain U/S as bubbles test and for micro emboli detection

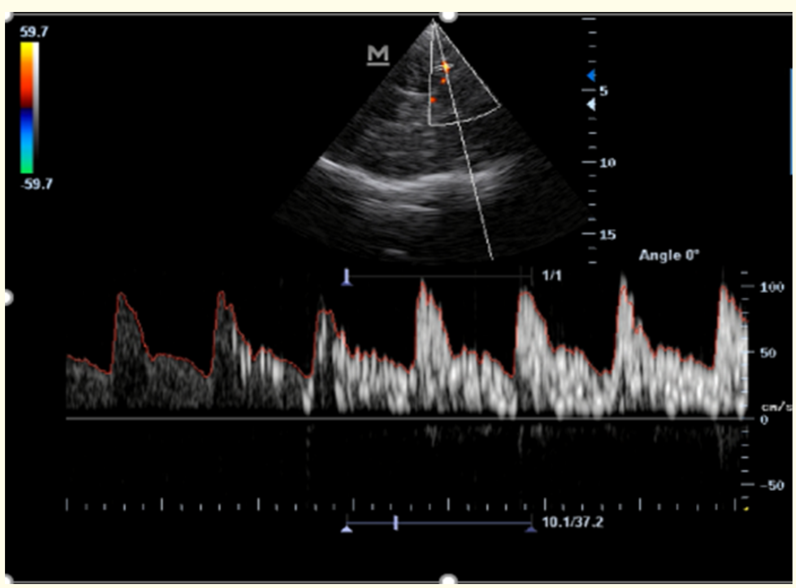


Figure 13: *High intensity in the RT MCA flow after injection of agitated saline [positive bubble test due to RT to LT shunt].*

Seventh, look for microemboli:

- TCD is the only medical device that can detect circulating cerebral microemboli which can affect the management as in CARESS trail when dual antiplatelets were better than aspirin alone in decreasing embolic events in symptomatic patients with > 50% carotid stenosis in presence of microemboli in TCD.

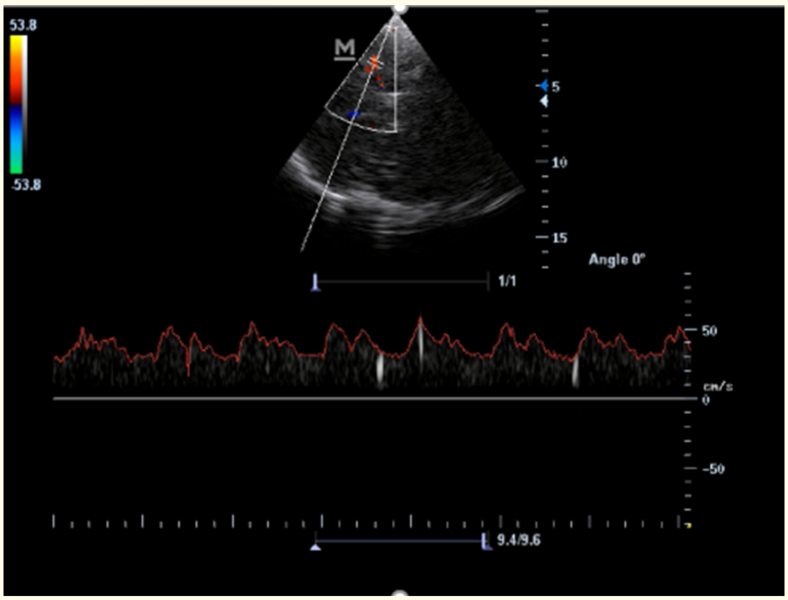


Figure 14: *High intensity signals of fat emboli of a SCD patient with systemic fat embolization syndrome.*

Conclusion

Brain ultrasonography, used to assess brain parenchyma and cerebral blood flow (CBF), is a generally safe, non-invasive and relatively low-cost neuromonitoring method that is easily applicable at the bedside. TCCD is a portable, and sensitive imaging tool which can assess and follow up the brain in different disease states which are common in ICU setting especially in case of unsafe to mobilize the patient to radiology Department because of high ventilatory setting or increasing inopressor dose.

It could provide crucially important information in the early detection and monitoring of neurological diseases, and to allow bedside assessment of cerebral haemodynamics in critically ill patients.

It has a role in diagnosis and follow up CVS and its complications [hemorrhagic transformation, MLS], vasospasm of cerebral arteries in subarachnoid hemorrhage, and microthrombi. It can diagnose RT to LT shunt and has a crucial role in diagnosis of cerebral circulatory arrest.

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