Ultrasound / White paper

Clinical neurosonology: State of the art and perspectives

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Introduction

In recent years, neurosonology has presented a continuous evolution, shifting from a purely vascular technique to a brain ultrasound investigation technique. This strong transition, solely due to the development of ultrasound techniques, has contributed to the development of clinical neurosonology. As a dynamic examination, this approach lends itself very well to being firmly incorporated within the clinic, which changes over time, not just for mere vascular problems.

Transcranial Color Coded Doppler (TCCD)

The different aspects on the study of acute ischemic vascular disease are well known, only one technique is able to stepwise monitor[1-3] a dynamic evaluation of an intracranial stenosis or the activation of compensation and organ reactivity, i.e. vasomotility (reactivity that varies greatly from one individual to the next).

The treatment of occlusions of the major cerebral arteries with endovascular revascularization (EVT) techniques, which are increasingly used, requires assessment of the vessel using Transcranial Color Coded Doppler (TCCD) both before and after EVT; however, TCCD is a gold standard in the subsequent monitoring of the recanalized artery over time. The vascular's fields of application include:

- Diagnosis and monitoring of cerebral stroke: cerebral stenosis and recanalizations
- Post-endovascular treatment monitoring
- Vascular assessment of intracranial compensation
- Study of the posterior circulation for steno-occlusive pathologies of the posterior circulation / central vertigo
- Investigation for cardiopulmonary shunt (PFO)
- Diagnosis and monitoring of cerebral venous thrombosis
- Assessment and monitoring of subarachnoid hemorrhage
- Assessment and monitoring of the increase in vascular resistance in patients in a state of coma / brain death

Transcranial B-mode sonography

The use of B-mode at the cerebral level is certainly an area undergoing great development and gives the clinician a dynamic evaluation of the event, which may be the study of the optic nerve sheath in intracranial hypertension, the possibility of evaluating the third ventricle and forms of hydrocephalus, assessing increases in echogenicity such as in deep or subdural hemorrhages or evaluations in chronic diseases such as degenerative forms, Parkinson's and Parkinsonisms. The development of B-mode investigations has also made it possible to correctly identify the technique as transcranial B-mode sonography (TCBS). Fields of application in B-mode:

- Intracranial hypertension study
- Ophthalmic window
- Expanded masses (tumours, parenchymal hemorrhages)
- Study of the midline and midline shift
- Subdural hematomas
- Parkinson's and Parkinsonisms
- Hydrocephalus

B-Mode

One area of excellence is the ultrasound measurement of the optic nerve sheath diameter (ONSD), which is already well-known in neurology but is increasingly establishing itself as an indispensable technique in intensive care and resuscitation. Furthermore, the technique – which uses 7-8 MHz probes or superficial probes with much higher frequencies – can study both the posterior and anterior chamber of the eye as well as the retrobulbar structures, such as the ONSD, the ophthalmic artery (useful when assessing situations involving extra-intracranial steno-occlusions), the central artery and vein of the retina and the ciliary arteries, giving rise to neuro-ophthalmosonology. Embryologically, the retina is an eversion of the diencephalon and the optic nerve (ON) is enveloped by the same sheaths as the brain, namely the pia mater, the

arachnoid mater and the dura mater. On this basis, knowing that the cerebrospinal fluid circulates in the subarachnoid space, it is intuitive that in all clinical situations in which the latter varies, there is also a reflection on the sheath of the eye itself, causing an increase and / or a decrease in thickness:

1. Secondary intracranial hypertension
2. Idiopathic intracranial hypertension
3. Hydrocephalus
4. Cardiac arrest
5. Pregnancy, to predict the development of pre-eclampsia and eclampsia
6. Posterior reversible encephalopathy syndrome (PRES)
7. Intraoperative complications, in the field of laparoscopic surgery
8. Inflammatory disorder of the optic nerve
9. Acute altitude sickness
10. Intracranial hypotension
11. Cerebral ischemia and cerebral hemorrhages with intracranial hypertension

Papilloedema and an increase in diameter at the level of the ON sheaths are indirect signs of increased intracranial pressure, in relation to massive acute cerebral ischemia, hemorrhage or head trauma. As early as 1966, Helmke and Hansen[4] evaluated the possibility of studying the pupil with ultrasound. The investigation is currently performed using a linear multi-frequency probe from 5-12 MHz. In relation to potential thermal effects on the eye structures, the mechanical index (MI) must be reduced to 0.26 (ALARA criteria)[5-6]. This is in accordance with the US FDA Guidelines. Papilloedema is detected in cases of intracranial hypertension – easily and immediately simply by placing the probe on the patient's eyelid using a good amount of gel (rapid learning curve)[10-11] – as a domed prominence of the optic disc that projects into the eyeball. Its measurement is obtained by evaluating its bulging impact on the retina. A 1 mm cut-off has a sensitivity of 73% and a specificity of 100%[7]. It is also possible to study, independently of the protrusion, the presence of optic disc drusen or other calcified formations. The ON appears as a hypoechoic, ribbon-like structure located behind the eyeball / retina, surrounded by a hyperechoic halo. The ONSD is measured along the axial plane, with a frozen, enlarged image, which allows us to evaluate the thickness of the ON defined by the hyperechogenicity of the arachnoid mater up to the edge of the dura mater, applied 3 mm from the retina. In healthy volunteers the mean values are 5.4 mm+ / -0.6 mm[8-9].

Case Study 1

Patient with presence of papilloedema (1.3 mm), with ONSD>6.8 mm. The clinical picture of intracranial hypertension is completed by studying the midline shift, which highlights a clear disorientation of the brain: 73.5 – 57.3 = 16.2/2 = 8.1 (Fig. 1)

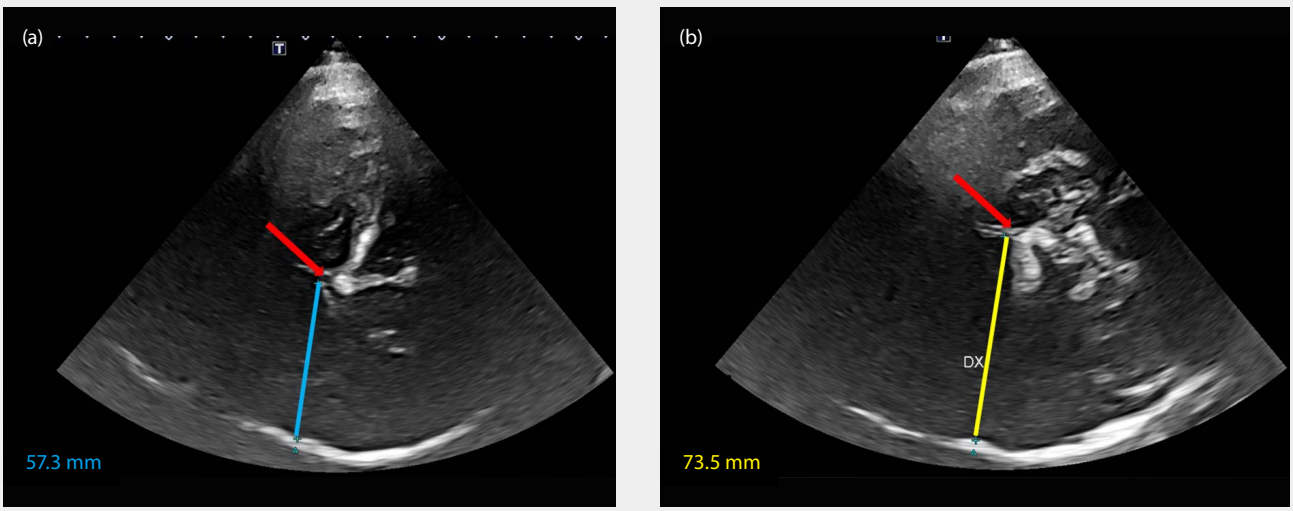

Figure 1 Ultrasound application conclusion in the clinic: This patient's work-up was conservative so ultrasound can monitor morphological changes.
(a) Insonation through right temporal window to measure left hemisphere.
(b) Insonation through left temporal window to measure right hemisphere.

Midline and midline shift

The study to evaluate the third ventricle is very easy and quick. Conclusions may be drawn from this, both in the acute phase and during monitoring in all neurological situations that occupy space creating hypertension, as in the case presented here.

Midline shift (MLS) = (A-B)/2

This rapid technique is also very useful in patients undergoing craniectomy and in particular during their monitoring in intensive care.

Hydrocephalus

The study of hydrocephalus often requires complex investigation techniques (MRI with flow dynamics, lumbar puncture), also because the mechanisms that induce this clinical picture are many and varied:

- Production of excessive liquor
- Resorption deficiency
- Impediments to drainage

But above all, the use of the ultrasound investigation can find its validation in the different presentation of the pathology, which can be:

- Acute, (in which case an external CSF (cerebrospinal fluid) shunt and / or endoscopic ventriculocisternostomy is required)
- Chronic, the average age of onset of chronic hydrocephalus is around 70

Case Study 2

Patient with achondroplasia, with clear clinical worsening, difficulty walking, with clear retropulsion, urinary incontinence. The question posed to the clinician could be, "Is normotensive or hypertensive hydrocephalus present?"
The ultrasound investigations show:

1. No presence of papilloedema
2. Increase of the third ventricle by 20.5 mm
3. Both in the axial and coronal temporal window access, large lateral ventricles which can be measured and controlled overtime through ultrasound studies (Fig. 2b)

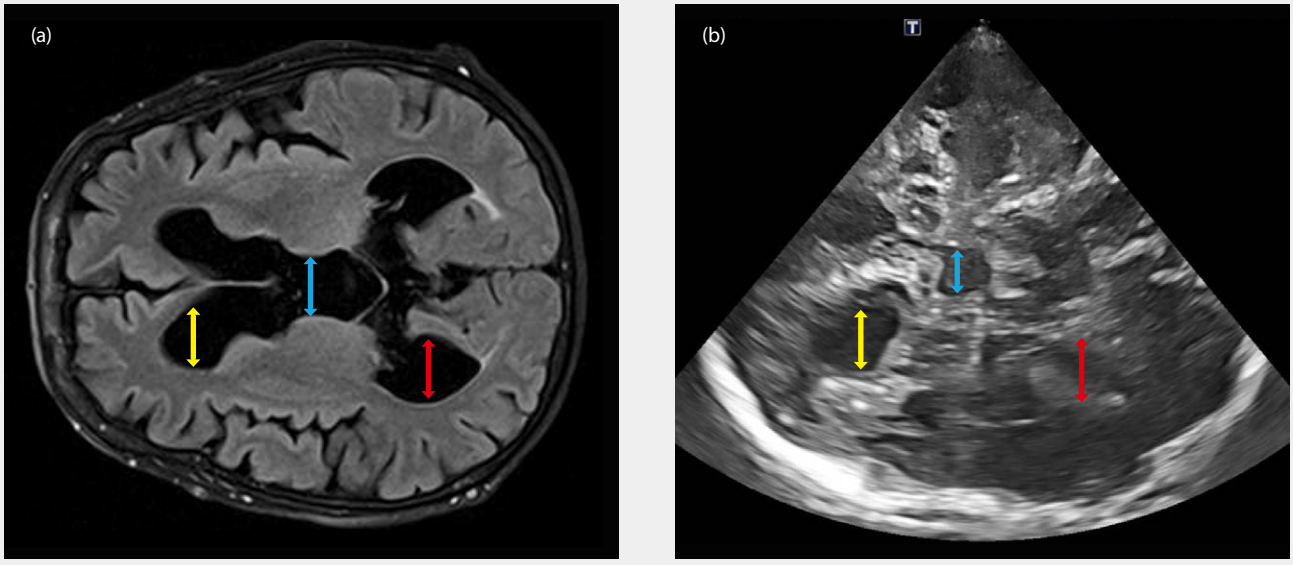

Figure 2 Ultrasound application conclusion in the clinic: Regardless of the future work-up, whether it is conservative or with Hakim's test and subsequent treatment, ultrasound can monitor progress without resorting to continuous neurological investigations.
Yellow arrow: enlarged anterior lateral cerebral ventricle
Blue arrow: enlarged third ventricle
Red arrow: enlarged posterior lateral cerebral ventricle

Color Doppler and ADF

The problem of color is inherent in the technique and produces distorting effects on the image, because it is affected by background noise. Background noise that until now has only been partially eliminated by means of low-pass filters. As you can see in this case (Fig. 4), the morphological diameter of the image in the Color and Power Doppler technique is not represented by the morphological investigation in B-mode (Fig. 3). The development of B-mode investigations has also made it possible to correctly identify the technique as TCBS.

Advanced Dynamic Flow imaging

Advanced Dynamic Flow (ADF) by Canon, which is available on the Canon's ultrasound systems, constructs a high-resolution color image that allows clinicians to identify particularly blood flow in small vessels and complex, circuitous blood flow paths. ADF offers spatial resolution at high frame rates to accurately represent flow with directional information in small vessels. ADF adds superior spatial resolution to Color Doppler analysis to reveal thin, distal flow patterns with increased accuracy and detail, while maintaining full B-mode image quality.

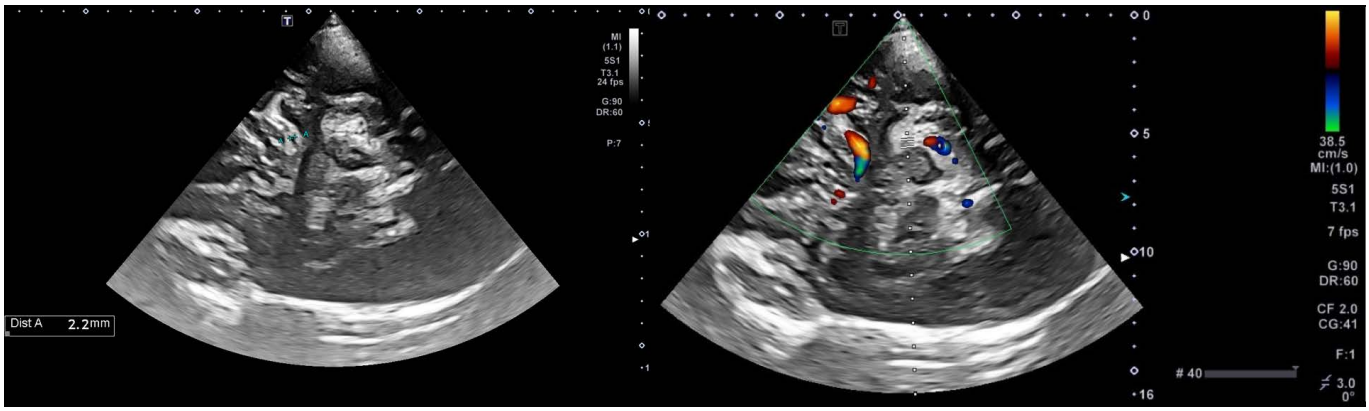

Figure 3

Figure 4

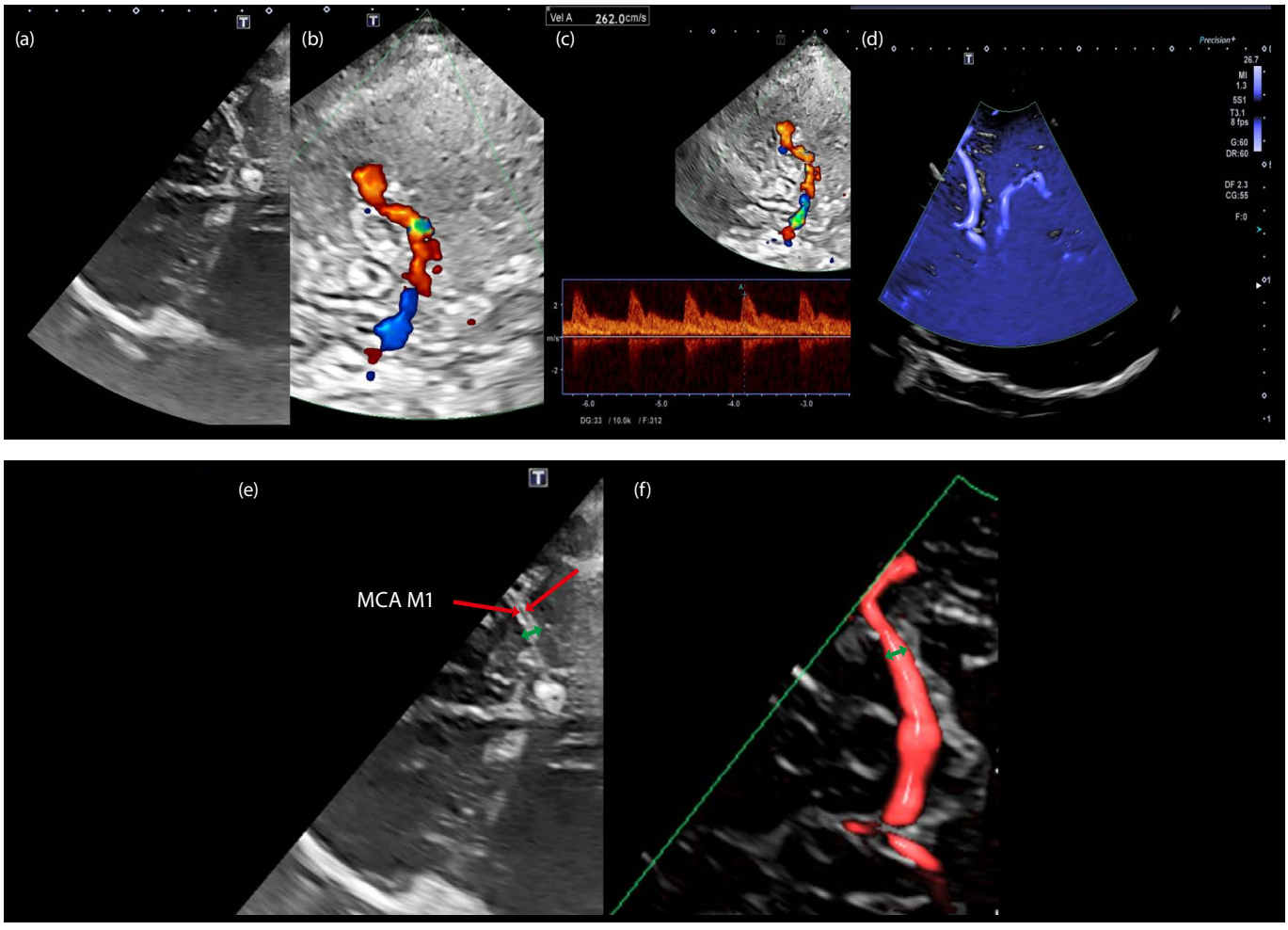

Figure 5 Intracranial stenosis studied with B-mode and color technique; in the middle distal segment of M1 there is a focal point of aliasing (Fig. 5b) where an acceleration of 260 cm / sec. is detected (Fig. 5c). In this case, it does not provide a morphology picture showing a stenosis of less than 5 mm (Figs. 5a and 5e). A working hypothesis could be the ADF, to overcome the limits described (Figs. 5d and 5f).

Conclusion

The use of ultrasound in daily clinical practice allows you to:

1. Retrieve the morphology.
2. Free the stenosis from velocitometry criteria (these criteria are no longer satisfied for stenoses>94%).
3. Differentiate stenoses>5 mm (which have ictal effects) from <5 mm.
4. Improve study accuracy in patients undergoing EVT, and intracranial stent placements.
5. Enable the assessment of distal circulations (pre-insular / insular and posterior circulations, P3 segment of the posterior cerebral arteries).
6. Guarantee the study's accuracy in the work-up, among other investigations, of cerebral aneurysms (evaluations of spectral accelerations or drops at the site of the aneurysm).

Aplio a-series offers a high-quality B-mode image, both at the level of the TSA (supra-aortic trunks) and the cranial base. The increased sensitivity when detecting the spectrum, allowing efficient steering and angle management, always enables the study to be performed with correct criteria.

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Results may vary due to clinical setting, patient presentation and other factors.

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