REVIEW ARTICLE

Point of care B mode ultrasound in Neurological Emergencies

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Abstract

Bedside ultrasound allows diagnostic, therapeutic and monitoring approaches in critically ill patients. Currently ultrasound enables to perform a scan almost of all body regions in both adult and pediatric populations.

Head and especially central nervous system, have traditionally been excluded, based on the idea that access to the brain is not possible given the limitation of the skull, Therefore in adults, the main ultrasound applications in central nervous system assessment have been limited to the transcranial Doppler and the measurement of the optic nerve sheath as a subrogate finding of intracranial hypertension.

Nonetheless, through the temporal bone window it is possible to visualize the midline (third ventricle), nuclei basal ganglia, the mesencephalon and the lateral ventricles: the basic structures for the brain ultrasound

Although the Gold standard for the initial assessment of many neurological pathologies in the emergency department is computed tomography; the ultrasonography allows an approximation to the midline shift and acute bleeding, combined with transcranial doppler some hemodynamics estimations can be acceded, this allow the diagnosis or follow-up of increased intracranial pressure which could favor pharmacological treatments and follow the therapeutic effect.

In this review, basic B mode neurosonology for the emergency physician is explored and future directions discussed.

Key words: Point of care ultrasound, B mode, Brain ultrasound, neuro emergencies.

Introduction

Bedside ultrasound allows diagnostic, therapeutic and monitoring approaches in critically ill patients (1). Currently, ultrasound enables to perform almost a scan of all body regions in both adult and pediatric populations (2,3).

Head, and especially central nervous system, have traditionally been excluded, based on the idea that access to the brain is not possible given the limitation of the skull which insufficient acoustic penetration; consequently, up to 15% of patients will not allow a good window to cerebral parenchyma (4). Therefore, in adults, the main ultrasound applications in central nervous system assessment have been limited to the transcranial Doppler (5) and the measurement of the optic nerve sheath as a subrogate finding of intracranial hypertension (6-8). In neonates where the sutures are still separated and in subjects with craniotomies the cerebral parenchyma is totally accessible by ultrasound (9,10).

Nonetheless, through the temporal bone window, it is possible to visualize the midline, the third ventricle, the mesencephalon and the lateral ventricles; this allow measure midline shift, it is also feasible to detect acute intracerebral and extra-axial hemorrhages, transcranial Doppler complement access to estimation about cerebral hemodynamics.

Here, the basics about the scan of the brain parenchyma especially the midline structures are presented and future directions discussed.

Access to the brain the basic planes.

Initially the probe is located in the same anatomical landmarks as in transcranial Doppler, low frequency 2-5mghz probe in the squamous portion of temporal bone are located, the preferred is phased array but convex can be used if b mode images is the only information need it. Transcranial Doppler software is not necessary if only assessment of anatomical structures is required

Evaluate adequate window usually depicting the contralateral bone on the ultrasound screen (hyper echogenic inner border) then adjust the scanning depth according to this bone, in adults usually 16 centimeters

This analysis is performed using 3 visualization planes according to the transducer position with respect to the temporal bone and its relation with the anatomical structures.

1) First plane mesencephalic: Through this plane you access the midbrain, transducer is located in squamous portion of temporal bone, without inclination (0 degrees in the horizontal plane), the probe mark towards patient nose. Mesencephalon usually is recognized by its “butterfly” shape in the center of the monitor (11) (figure 1). Pineal gland calcification can be a depicted as hyperechoic round structure anterior to the mesencephalon in certain individuals.
2) The second plane is obtained by tilting in a cephalic way the transducer 10 degrees, to obtain a view of the third ventricle; seeing as a “double line” structure. (figure 2)
3) The third plane is attained with 30 degrees inclination to observe lateral ventricles (12). Sometimes ventricles can be seen positioning the probe in the temporal bone over the ear. (figure 3)

These three planes are named mesencephalic, diencephalic and ventricle. (11, 12)

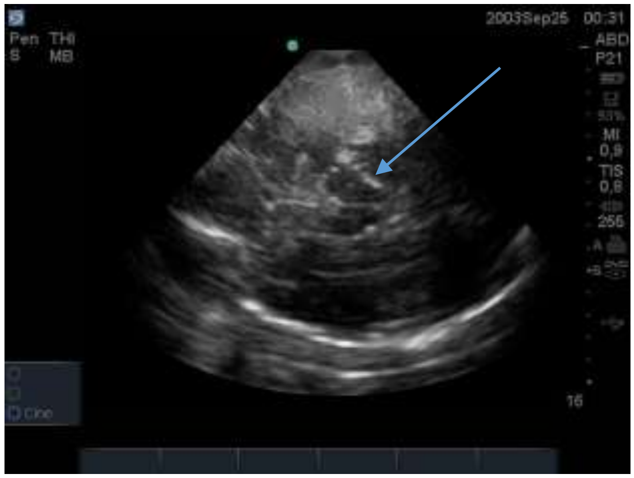

Figure 1 the mesencephalon in mesencephalic plane. Recognized as "butterfly" image (blue arrow), note this image as An abdomen software, not transcranial doppler software.

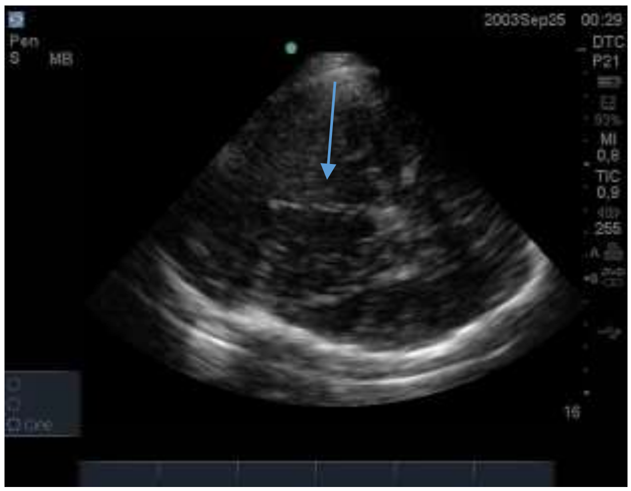

Figure 2 the midline (blue arrow), structure as double line, tilt up 10 degrees. The transducer once the mesencephalon is insonated.

Figure 3 lateral ventricles (blue arrow), tilting up 30 degrees the transducer from. The initial position. (image depicted with abdomen software)

Assesment the midline

The midline is depicted through the diencephalic plane (10 degrees tilting up once the mesencephalon is visualized), the midline is a small hyperechoic double line which represents the 3rd ventricle (12), through this plane , the displacement is measured initially calculating the distance from the image of the transducer skin contact (top of the screen) to the center of third ventricle in both sides (figure 4),(scan one side, then scan the opposite) Distance A – Distance B divided two is the midline displacement, this is the proposed approach to the suspicion of space occupying and mass effect over the midline. (13-15)

Figure 4 midline measurement: from the top of the image to the center midline (dotted line) Scan one side then the opposite, distance A – Distance b divided 2 is the midline shift

Acute bleeding

Acute stage of bleeding (<5 days) is described as a hyperechoic, homogenous, sharply demarcated image (16-18),(contrary to the FAST protocol that is anechoic) this pattern can be visualized in intra and extraxial hematoma (19-20) (figures 5 and 6) which must be contextualized according to the patient scenario, since arteriovenous malformations, tumors and calcified lesions also can be visualized hyperechoic. This visualization also allows the calculation hematoma volume and growth (21- 23)

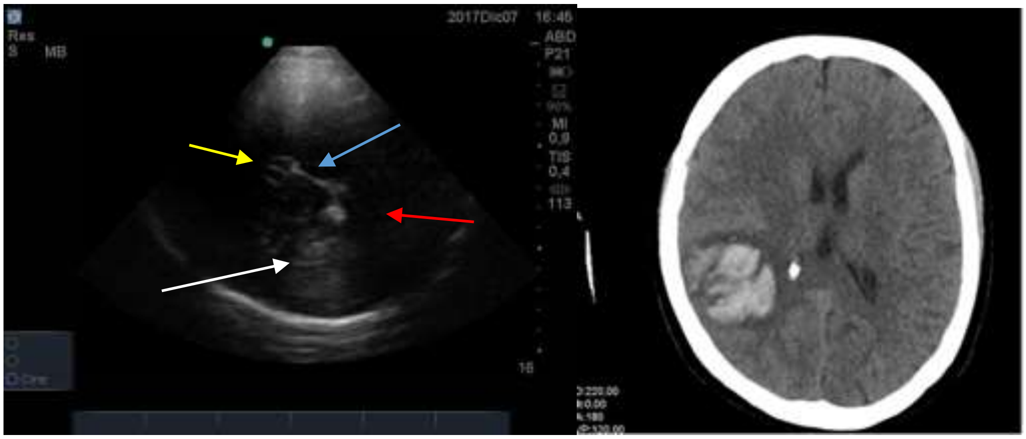

Figure 5 Left image Intracerebral hemorrhage ultrasound, white arrow hyperechoic image suggesting acute blood, red arrow choroid plexus calcification, blue arrow midline, yellow arrow ventricles, right image corresponding ct scan.

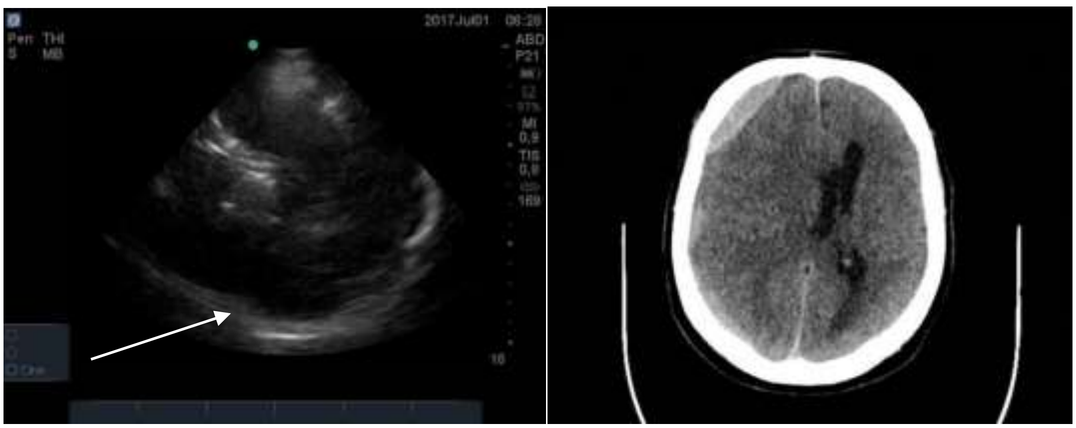

Figure 6 left image acute extraxial bleeding (white arrow), right: corresponding ct scan.

Generally after 5 days intraparenchymal blood become hypoechoic with a peripheral hyperechoic halo; This is explained by early degradation of red blood cells in the central area of the hematoma (23)

Optic nerve sheath diameter. (ONSD)

Up to now, Critical Care and Emergency Medicine recognize the usefulness of ultrasound of the optic nerve sheath as screening for increased intracranial pressure,(ICP) (24) as a non-invasive tool, repeatable, bedside and easy learn technique (25,26) the ultrasonography plays an important role in the evaluation of these patients.

Direct measurement of intracranial pressure is complex on Emergency department where devices to invasively measure frequently are not available, that is why non-invasive estimation of ICP is interesting.

ONSD measurement has an anatomic basis: Optic nerve is enveloped by arachnoids and there is subarachnoid space between these two structures, then Intra Cranial Pressures changes generate diametrical changes between the sheath that cover the optic nerve from side to side and that are measured by ultrasound (27)

Measurement of the optic nerve sheath diameter through the ocular window may be used as ancillary test for detection of intracranial hypertension, changes are greater in the anterior portion of the nerve sheath, just behind the eyeball, an area that is easily accessible by ultrasound. (28)

How to measure the optic nerve sheath:
A high-frequency (7–10 MHz) linear transducer is required. Set to visualize structures up to 5–6cm deep. The transducer is placed over the closed eyelid after generous gel application. The optic nerve is identified as the hypoechoic structure along a regular course behind the eyeball. (Figure 7)

Figure 7 optic nerve (white arrow): Recognized as an anechoic structure behind the eyeball

For measurement, a vertical line is drawn from the junction between the optic nerve and the eyeball, This line serves just as a reference and must be 3mm long (figure 8A); Once the 3mm length is established, a horizontal line is drawn across the optic nerve sheath.(figure 8B) This second line provides the measurement of the optic nerve in millimeters.(29)

The normal value is between 5 and 5.8mm, due there is heterogeneity in the reports of different studies (30-32), possibly the normal value to exclude intracranial hypertension should be adapted to specific population groups, since normal values of up to 4.9 mm have been reported in Asian adults. (33) but usually 6mm is considered elevated and compatible with IPC. (30-32)

Figures 8, Figure 8A left, a 3mm vertical line is drawn as a standard, Figure 8B right, after the 3mm line an horizontal line across the end of the vertical one and through the optic nerve sheath from outer border to outer border, this is optic nerve sheath measurement.

Even so, there are proposals to quantify this hypertension non-invasively through mathematical formulas such as nICPONSD = ONSD x 3.7242 / 0.128 where nICPONSD means Non-invasive intra cranial pressure optic nerve sheath diameter, and ONSD means optic nerve sheath diameter (34)

Monitoring
Ultrasonography can also monitor patients with neurological pathology, monitoring volume and grow of intracerebral hemorrhage, the deviation from the midline in stroke and stroke complications (21,35-36), neuroinfections (37-38), and therapeutic effectiveness (39-41)
There are also reports of ultrasound as a prognostic tool in different acute neuro emergencies as in intracerebral hemorrhage, (42-44) and in post cardiac arrest (45), a better understanding of the pathophysiology of the patient is achieved if B mode is complemented with Doppler (46 -48).

Ultrasound and Brain Ct
The characterization of non-traumatic intracerebral bleedings and the deviation of the midline has been in comparison with the skull tomography, although meta-analysis has not yet been obtained if it has been reported that compared to ct scan ultrasound it has a good correlation with the volumes and monitoring the hematoma growth as high as 97% (55) ; the limitation is found in patients who do not have a good acoustic window and small hemorraghes (less than 2 cms volume) (4), midline shift has a correlation of 0.88 (56)

Training
In current acep guidelines (54), ultrasound of the central nervous system is limited to the optic nerve as a surrogate for intracranial hypertension; some suggest a curve of 20 ultrasound as training of optic nerve sheath measurement technique.(53)
Recently, a consensus is proposed for the skills and competences in brain ultrasound, with a division into 4 levels, the measurement of the optic nerve sheath and the midline are proposed as a basic plus level. (50)

DISCUSSION
Ultrasound evaluation of midline structures in the central nervous system initiated in the early 90s´, demonstrating that midline shift through the third ventricle could be measured (4, 11-12). During the same decade, case series began, in which it was possible to visualize intracranial hemorrhage, as well as stroke hemorrhagic transformations in association with patient outcome (22,35).
Images can be obtained through convex or phased array transducers without requiring transcranial Doppler software since only static structures B mode images are needed; Doppler requires appropriate software and training (50) there is a need to standardize point of care ultrasound training in neurological applications beyond the measurement of the optic nerve sheath and define the place of the doppler in the emergency room
Promoting B-mode ultrasound evaluation of the central nervous system anatomy, complemented with optic nerve sheath assessment, can be combined to estimate parenchymal abnormalities, intracerebral hypertension screening or optic never sheath ICP quantification (34)
Point of care brain sonography can be used in situations where clinically suspected intracranial hemorrhage (traumatic, spontaneous or post- thrombolysis) and real-time midline shift is need to visualize since ultrasound can be compared with ct scan in some situations (50-51), point of care ultrasound can be an alternative in situations where there is no CT scan access,

such as: prehospital scenarios , delayed transfers to the imaging room or in patients with hemodynamic deterioration in whom their transfer could worsen their clinical situation.

Future directions

Transcranial Mode B point of care ultrasound can be complemented with Doppler to evaluate brain hemodynamics, Doppler mathematical formulas can estimate intracranial pressure, also evaluate vasospasm, cerebral autoregulation and brain arrest (46-49) Thus, the association of cerebral hemodynamics with visualization of the parenchyma should contribute more precisely to understand the patient pathophysiology in acute conditions in the emergency department and help to follow the effect of therapies that are started while the patient is located in definitive treatment units.

Since emergency departments are crowding units, ultrasonography could help triage high-risk patients such as some red flag headaches and non-traumatic alterations in consciousness; Common conditions that pose challenges when the initial evaluation is only clinical and performed in resource-limited settings.

There is an urgent need for investigation of point of care applications in the emergency department and their role in the algorithms of patients with neuro emergencies.

Conclusions

Point of care ultrasound is a growing field in emergency medicine; central nervous system assessment is a relatively new application with two components B mode and Doppler, b mode allows intracranial pressure screening and calculation through the measurement of the optic nerve sheath, but it is also possible to infer the possibility of a space-occupying lesion that deviates the midline, it is possible to visualize intra or extraxial bleeding.

The interrelation of effects of space-occupying injuries on the midline and inferring their effect on intracranial pressure becomes an attractive non-invasive tool for emergency physicians, Ultrasound is less time consuming when compared with other neuroimaging studies, and eliminates the need to transfer critically ill patients, Moreover, it offers the possibility of assessing response to treatment by means of serial measurements, the complement with the Doppler allows access to hemodynamic variables that could be targeted in the emergency department, especially in those who have time-sensitive pathologies.

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