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The mastoid view: a different approach to the ultrasound exploration of neonatal brain

La fontanella mastoidea: una diversa finestra di esplorazione ecoencefalografica

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Summary

Objectives. We aimed to determine whether imaging through the mastoid fontanelle improves the accuracy of the standard sonographic examination, and evaluate for how long this approach is feasible after the first month of life.
Methods. Therefore, for 4 months, we performed a prospective study of 32 neonates admitted to our neonatal intensive care and of 33 outpatients evaluated during follow-up visits.
Results. We describe a cranial ultrasound scan approach that allows, by mastoid view, a detailed exploration of the posterior fossa structures and midbrain.
Conclusions. We describe several pathological findings detected with this approach and discuss some limitations of the technique.

Riassunto

Obiettivi. *Lo studio è stato condotto con lo scopo di verificare l'utilità dell'esame e la pervietà della fontanella mastoidea nel neonato e nel lattante.*
Metodi. *Sono stati studiati prospetticamente per 4 mesi 32 neonati ricoverati nel nostro reparto di terapia intensiva neonatale e 33 pazienti provenienti dall'esterno, che eseguivano l'esame nell'ambulatorio per il follow-up.*
Risultati. *L'esplorazione ecoencefalografica attraverso la fontanella mastoidea, recentemente proposta, consente di definire più accuratamente i dettagli della fossa posteriore e del mesencefalo rispetto all'accesso tradizionale dalla fontanella anteriore.*
Conclusioni. *Presentiamo alcune patologie esplorate attraverso l'accesso mastoideo, segnalando qualche limite incontrato con la metodica.*

Key words

Cranial ultrasound scan • Posterior fossa • Midbrain • Posthemorrhagic hydrocephalus

Parole chiave

Ecoencefalografia • Fossa posteriore • Mesencefalo • Idrocefalo postemorragico

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Introduction

The cranial sonography technique is commonly used by neonatologists and pediatricians to explore the neonatal brain. When performed during the first months of life it is able to easily detect most conditions affecting the central nervous system, thanks to the patency of the anterior fontanelle to ultrasound. Nevertheless, it is more difficult to detect midbrain and posterior fossa abnormalities, because of the relatively large distance between such structures and the ultrasound transducer. In the past others acoustic windows were used [1,2], and recently a mastoid approach has been proposed [3,4]. We show some affections of the midbrain and posterior fossa correctly detected by this technique. We believe that it may be useful to complete an infant's standard sonoghraphic evaluation by this acoustic window.

Materials and methods

This study was performed to determine 1) whether imaging through the mastoid fontanelle improves the accuracy of the standard sonographic examination and 2) to evaluate until what age this approach is applicable. Therefore, from June to September 2001, we performed a prospective study of 32 neonates admitted to our neonatal intensive care unit (5 term and 27 preterm newborns, aged between 24 and 36 weeks) and 33 out-patient infants aged between 2 and 8 months, evaluated during follow-up visits.

All images were performed using phased array multiple foci 5.0 or 7.0-MHz sector transducers (Acuson 128

Tab. I. Patency of the posterolateral fontanel and useful features obtained by the mastoid approach on the neonates examined.

Total number of examined infants	Patency of the fontanelle	Useful features	Confirm by MRI
Preterm babies	27/27	4/27	2/4
Term newborns	5/5	1/5	1/5
Infants	21/33	3/21	3/3

Tab. II A. Features of the newborns in whom the mastoid approach was able to detect abnormalities or gave uncertain results.

G.A. = gestational age; A.F. = features detected through the anterior fontanelle; PL.F. = features detected through the posterolateral fontanelle; U.R. = uncertain results; MRI = magnetic resonance imaging

N	Age (G.A.)	Affections	A.F.	PL.F.	U.R.	MRI
1	40 days (24 w)	Respiratory distress syndrome, mechanical ventilation, hyponatremia, intraventricular hemorrhage	Post hemorrhagic hydrocephalus	Detailed observation of the posterior fossa, explanation of the site of obstruction	/	Confirmed
2	2 days (24 w)	Prolonged rupture of membranes, respiratory distress syndrome, severe hypotonia	Massive intraventricular bleeding, poor representation of the posterior fossa	Detailed representation of cerebellum, severe fourth ventricle widening; depiction of blood flow within the ventricle	/	MRI not performed Post mortem confirmation (massive ventricular flooding)
3	31 days (32 w)	Hepatic hemangio-endothelioma, respiratory distress syndrome, prolonged mechanical ventilation and asphyxial attacks	Prolonged periventricular flare	Hyperechoic aspect of the cerebellar parenchima	Yes	Not confirmed (MRI performed after 45 days)
4	14 days (40 w)	Neonatal seizures and severe neurological damage (sulfite-oxyidase deficiency)	Widespread multicystic encephalo-malacia, undetailed cerebellar sizes	Obvious depiction of cerebellar hypoplasia	/	Confirmed
5	4 days (29 w)	Prolonged rupture of membranes, cardiogenic shock	Periventricular hemorrhagic infarcts (occipital and temporal zone)	Detailed representation of the extent of infarcts within posterior cerebral parenchyma	/	Confirmed

Tab. II B. Features of infants.

N°	Age	Affections	A.F.	PL.F.	U.R.	MRI
6)	3 months	Right cardiac heart failure, aneurysm of the Galeno vein	Aneurysm of the Galeno vein, supratentorial ventricular enlargement	More detailed study of the aneurysm, incomplete study of vascularization	Yes	Confirmed
7)	5 months	Preterm (34 weeks), intrauterine growth retardation	Moderate sopratentorial ventricular enlargement, external hydrocephalus	Subtentorial ventricular system sizes, fourth ventricle morphology	/	Confirmed
8)	32 days	Tremors, hyperexcitability	Suspected Dandy-Walker variant	Exclusion of cerebellar affections Suspected Megacisterna magna or posterior fossa subarachnoid hemorrhage	/	Confirmed mega cisterna magna

XP 10, Mountain View, CA). Scanning was performed through the anterior fontanelle by standard sagittal and coronal planes; each examination was concluded by observation through the mastoid (postero-lateral) fontanelle, performed placing the transducer approximately 1 cm posterior to the helix of the ear and 1 cm above the tragus (point of junction of posterior parietal, temporal and occipitals bones).

Standard sagittal and coronal planes through this fontanelle have not yet been well defined. We obtained the images by axial sonograms (placing the transducer parallel to the orbito-meatal line, angling it from the superior to inferior point) and coronal planes (right-angled with respect to the previous planes, from anterior to posterior points). Thus we observed the cerebral hemispheres and peduncles, the ventricular system and the posterior fossa in detail, including the large cisterns (predominantly anechoic spaces, containing cerebrospinal fluid) and smaller cisterns (predominantly hyperechoic spaces). We also observed the cerebellum, fourth ventricle, cerebral aqueduct, the Luschka and Magendie's foramina, the vallecula and midbrain. This examination requires very detailed knowledge of the region's anatomy [5], although the widening of ventricular system greatly facilitates the procedure.

Results

Table I shows the 32 newborns and 33 infants examined. The mastoid view improved the accuracy of the standard sonographic examination in 5/32 neonates (4 preterm and 1 term) and in 3/33 infants. Table II reports the subject's features, any abnormality detected through the anterior view (with respect to the postero-lateral fontanelle), and the diagnostic confirmation of the latter performed, whenever possible, by magnetic resonance imaging. In one case (number 2) the confirmation was obtained by post mortem examination.

The posterolateral fontanelles were patent in all neonates and the images were well-defined, especially in preterm babies; however only in 21/33 infants was the posterior fossa approachable, mostly in those younger than 4 months.

Figures 1A, 1B, 1C and 2 show the anatomical details in normal neonates; figures 1D, 1E and 1F compare the same structures observed through the anterior fontanel. Figure 2A shows the lateral ventricles scanned at the level of frontal and temporal horns, the fourth ventricle and cerebral aqueduct.

In case of ventricular obstructions (case number 1) the mastoid view is able to show in detail the patency of foramina and the obstruction sites (Fig. 3A). Figures 3B and 3C are, images of the same patient, viewed through the anterior fontanelle.

During massive intraventricular bleeding (case number 2) it is sometimes difficult to observe the subtentorial ventricular system (Figs. 4A and 4B); the mastoid view, obtained in this case by high frequency linear transducer (Fig. 4C), shows a widened fourth ventricle containing fine clots. The post mortem examination confirmed a massive intraventricular bleeding.

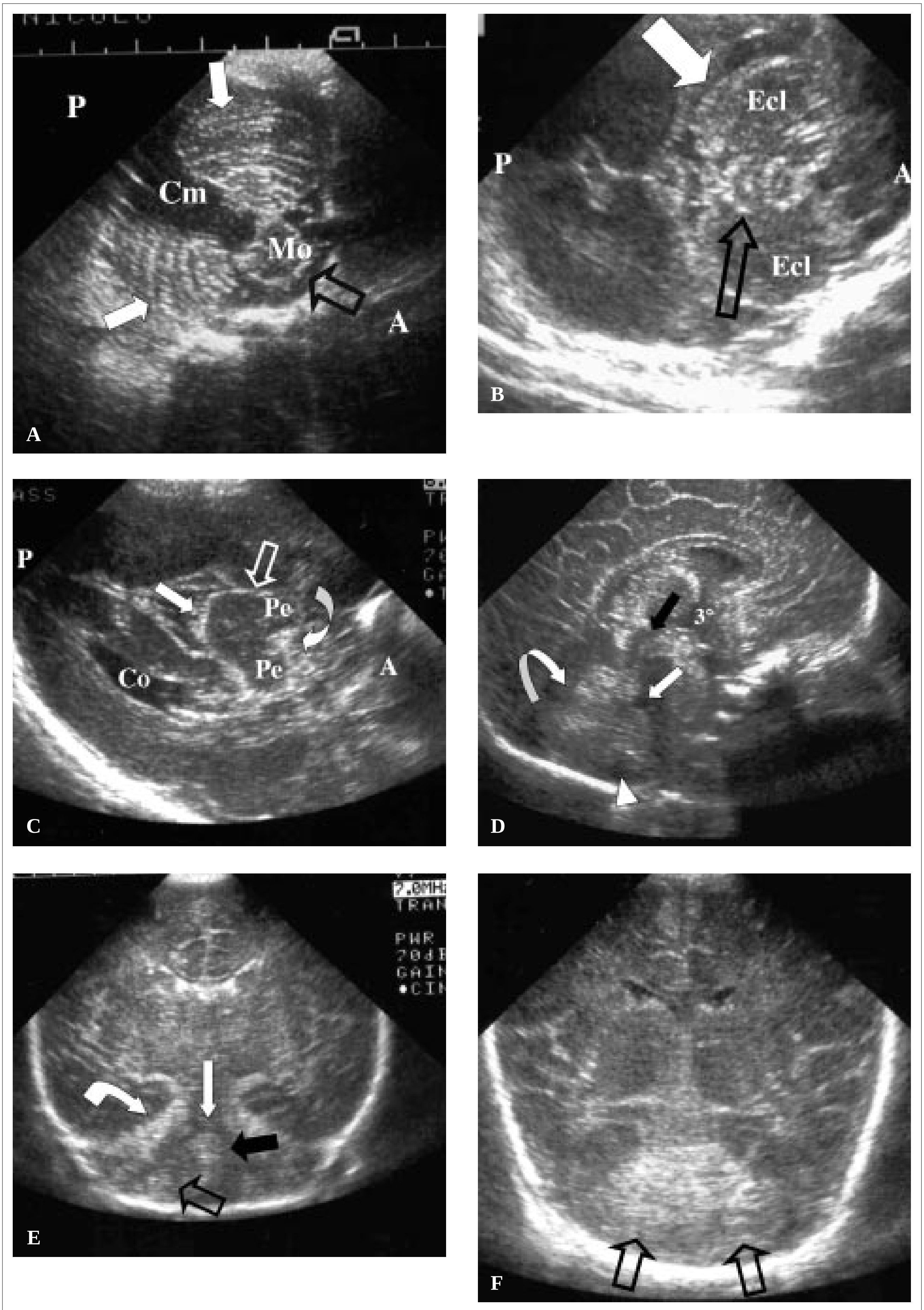
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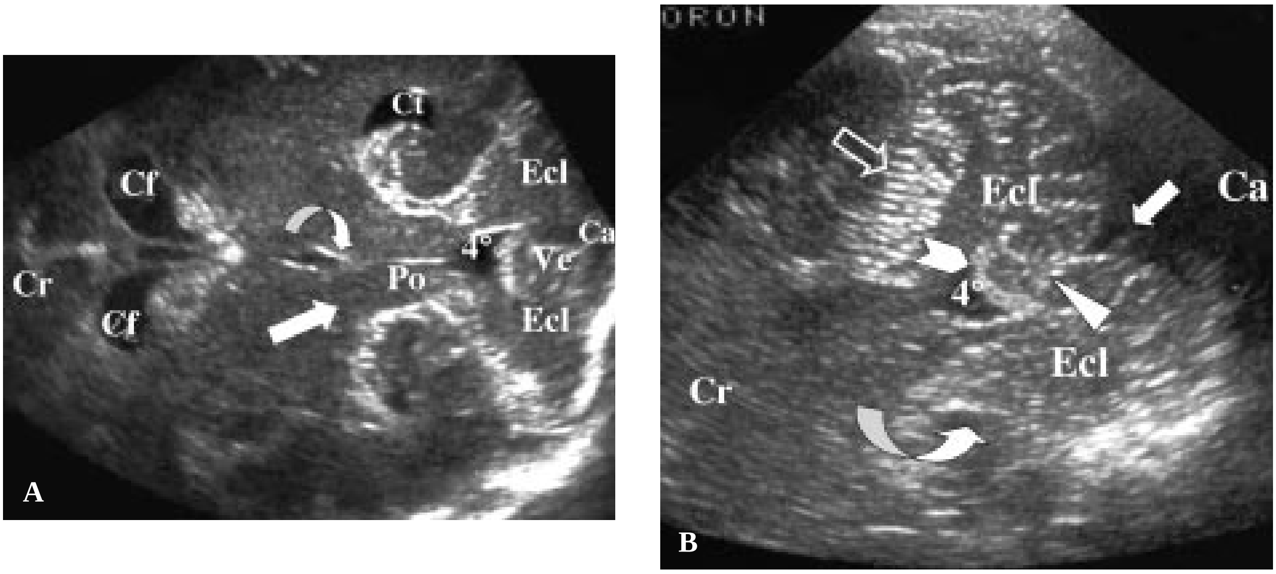
Fig. 1. Axial mastoid sonograms obtained placing the transducer parallel at the orbito-meatal line, angling it from the superior to the inferior point; A) lower surfaces of cerebellar hemispheres, divided from the medulla (Mo) on the inferior plane; anterior side (A), posterior side (P). Alternating bands of cerebellar fissure (hyperechoic) and folia (hypoechoic) (white arrows). In the preterm baby the spaces surrounding spinal cord (empty arrow) and cisterna magna (Cm) are broader than in term newborns. B) Intermediate plane: cerebellar hemispheres (Ecl), posterocerebellar cistern (white arrows), vermis (empty arrows). C) Superior plane: midbrain and perimesencephalic cistern (empty arrow), occipital horn of the lateral ventricle (Co), cerebral peduncles (Pe), quadrigeminal lamina cistern (straight arrow), interpeduncular fossae (curved arrow). D) Midsagittal sonogram through the anterior fontanelle: cerebellar vermis (curved arrow), fourth ventricle (white arrow), third ventricle (3°), cerebral aqueduct (black arrow), cerebellomedullary cistern (white triangle). E) and F) Posterior coronal sonograms through the anterior fontanelle: ambient cistern (curved arrow) fourth ventricle (straight white arrow), vertebral body (black arrow), cerebellar hemispheres (empty arrows).

Fig. 2. Coronal mastoid sonograms A) Depiction of the whole ventricular system: frontal horn of the lateral ventricle (Cf) and small hemorrhagic area in subependymal zone; temporal horn (Ct). Passageway between the third ventricle and the aqueduct (curved arrow), cerebral peduncles (straight arrow), basilar pons (Po) bounded by ambient cistern, cerebellar vermis (Ve), cerebellar hemisphere (Ecl), fourth ventricle (4°), upper side (Cr) and lower side (Ca) B) Cerebellar sonogram: cisterna magna ed cerebellar inferior fissure (full arrow). On the cerebellar surface (empty arrow) alternating bands of sulchi and laminae; hyperechoic appearance of cerebellar sulchi located proximally to the transducer (empty arrow). Fourth ventricle (4°) and choroid plexus (stripe), cerebellar vermis (arrowhead).



Posterior fossa abnormalities, as in the Dandy-Walker or megacisterna magna, are better depicted by the posterolateral fontanelle. In the megacisterna magna (case number 8, Fig. 5), it was possible to define in detail the size of the cerebellum and fourth ventricle (Fig. 5C), to exclude possible Dandy-Walker malformations, despite the unclear images obtained through the anterior fontanelle (Figs. 5A and B).

After severe hypoxia the cerebellar parenchima is obviously inhomogeneous and extensively hyperechoic (case number 3), although this condition is not visible by observing the cerebellum through the anterior fontanelle (Figs. 6A and 6B). Magnetic resonance images, performed after 45 days failed to show any cerebellar lesion.

In sulfite-oxydase deficiency (case number 4) the sizes and morphology of the cerebellum are not clearly assessable through the anterior fontanelle (Figs. 7A and B), but the mastoid view correctly showed cerebellar hypoplasia (Fig. 7C). In our case, the diagnosis was confirmed by magnetic resonance imaging.

Discussion

Cranial ultrasound scanning has been used in infants and newborns for over 20 years. It is not expensive, simple and can be performed directly at the patient's bedside. Despite some limitations, it enables an easy diagnosis of hemorrhagic, ischemic and infectious affections of the central nervous system [6]. However, its result depends on the patency of the anterior fontanelle, which decreases with age. Moreover, it is difficult to explore posterior fossa structures [7], as they are relatively distant from the ultrasound transducer. Subarachnoid hemorrhage is not always clearly detectable [8] and posterior fossa hemorrhage, frequently observed during extracorporeal membrane oxygenation (ECMO) therapy [7], traumatic delivery or coagulation abnormalities [9] may remain undetected [10 11]. The real incidence of such affections is unknown, but it is probably higher than previously estimated: as a matter of fact, cerebellar hemorrhage had been recently found in premature babies without apparent clinical symptoms and not as-

Fig. 3. Posthemorrhagic hydrocephalus: A) Mastoid coronal sonogram. Depiction of the whole ventricular system: frontal horn of the lateral ventricle (Cf), temporal horn (Ct) cerebellar hemisphere (Ecl) and cerebral aqueduct (straight arrow), clot within the interventricular foramen (curved arrow); B) Same child observed through the anterior fontanelle (midcoronal sonogram): lateral ventricles (VL) interventricular foramen (white arrow), temporal horn of the lateral ventricle (CT); C) Midsagittal sonogram through the anterior fontanelle: widening of third and fourth ventricles (black arrows); note the poor visualization of posterior fossa structures, very well depicted in A).

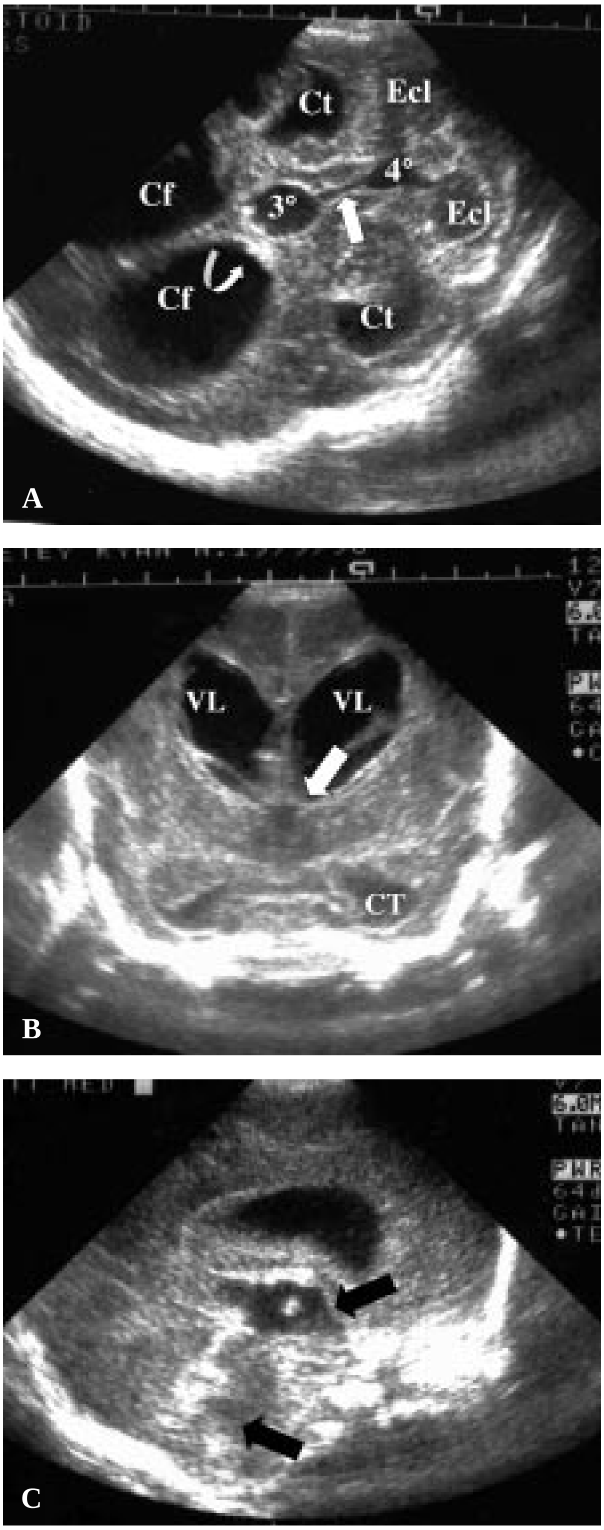
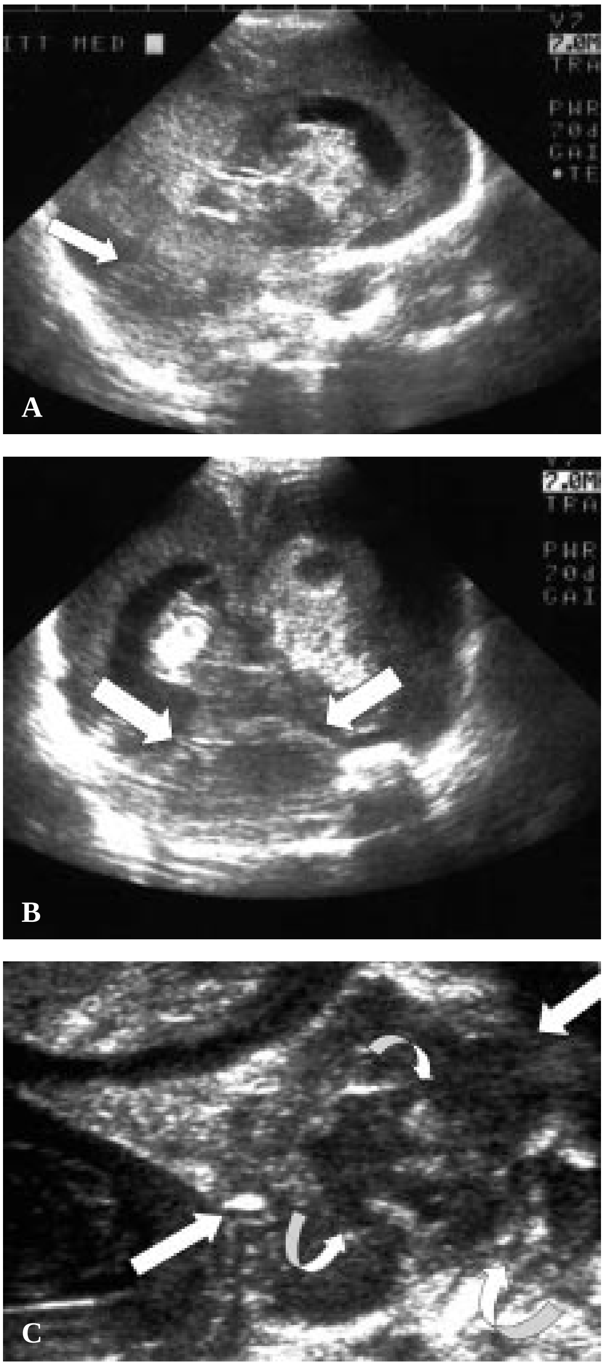
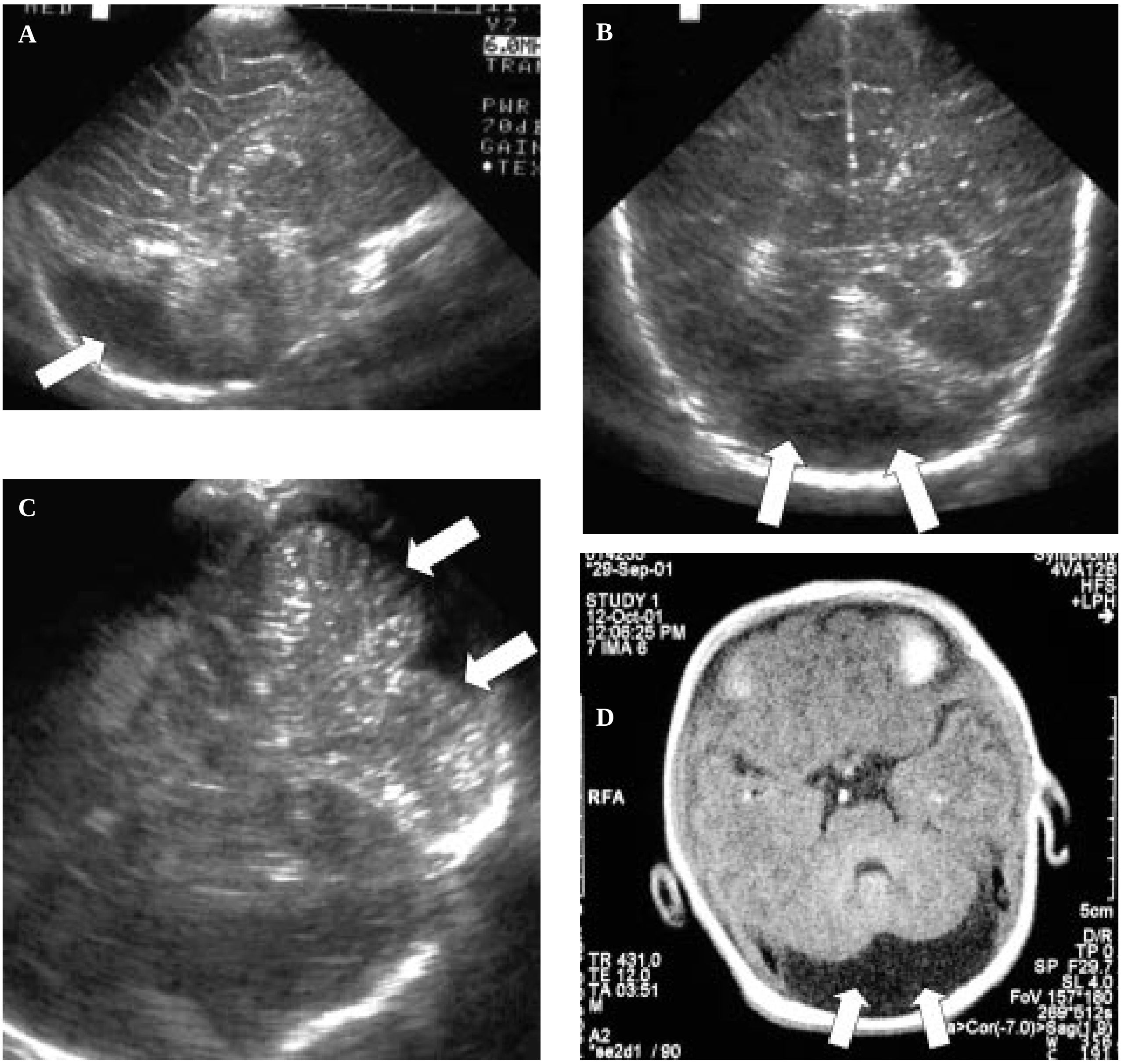


Fig. 4. Intraventricular massive flooding. Through the anterior fontanelle, in midsagittal (A) and posterior coronal sonograms (B): poor definition of cerebellar borders (straight arrows). With linear high frequency transducer (C), through the mastoid fontanelle, high cerebellar definition (straight arrows). Fine clots are observed within the fourth ventricle, widening of the lateral recesses of the fourth ventricle (curved arrows).



sociated with massive supratentorial hemorrhage [11]. Other acoustic windows, such as the posterior fontanelle [1 12] and the squamous sutures wich are closer to the posterior fossa, have been employed with the aim to improve the exactness of ultrasound scan examinations. However, these are sometimes small or not well

Fig. 5. Megacisterna magna. Through the anterior fontanelle, in midsagittal (A) and posterior coronal sonograms (B): wide retrocerebellar hypoechoic space (white arrows). Mastoid view (C) and magnetic resonance image (D) show normal sizes of cerebellum, vermis and fourth ventricle, with broad retrocerebellar space, consistent with diagnosis of megacisterna magna.



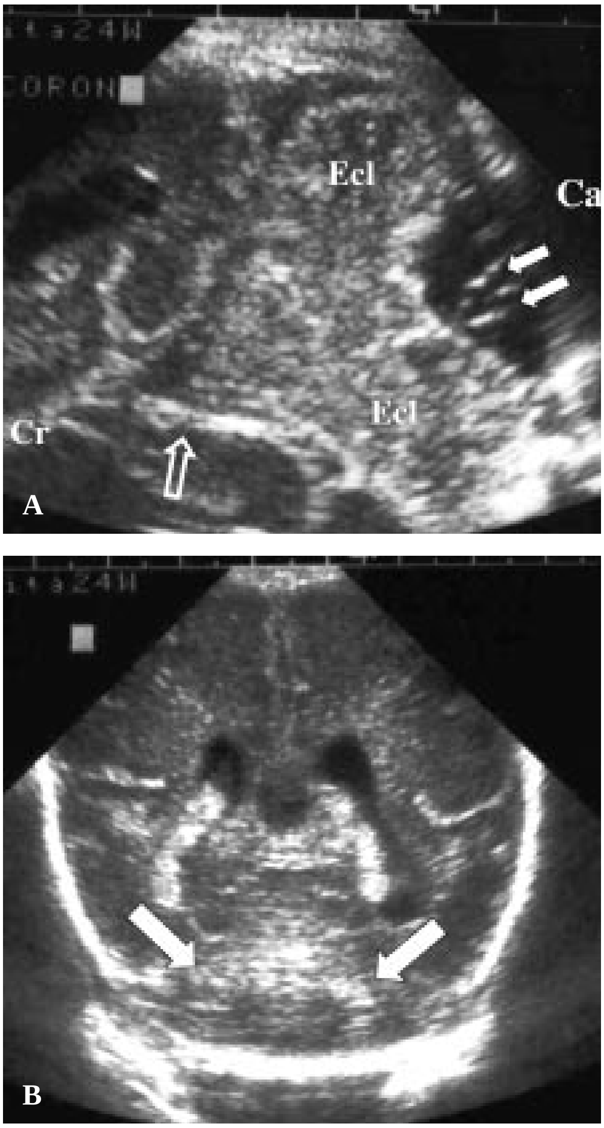
approachable, due to the presence of infusion lines. An approach through the foramen magnum [2] and recently also through the mastoid fontanelle has been proposed, that allow the best exploration of those structures [3 4]. A morphological examination can be concluded by performing a Doppler study, to detect blood flow in the cerebral vessels of the posterior fossa (posterior cerebral arteries, transversus venous sinus).

Our cases shows that the mastoid approach is useful to observe the posterior fossa in neonates, but is less helpful after the third month of life, for the reduced patency of the posterolateral fontanelle. However it is able to easily detect posthemorragic hydrocephalus and cerebellar hemorrages [13] in the newborn; moreover, it is probably helpful in detecting hyperechoic lesions of the cerebral parenchyma when the images obtained through the anterior fontanelle are not well defined. Several malformations are often clearly detectable, but subtle abnormalities of the cerebellar vermis or type II Arnold-Chiari malformations may be misdiagnosed with this approach [14].

Moreover, we have sometimes observed in preterm babies with severe asphyxia a pattern of diffuse cerebellar hyperechogenicity (case number 3). Several weeks later magnetic resonance imagings were quite normal.

As a consequence, we are unable to safely interpret the meaning of such pattern, and understand whether is an unnatural effect, a parenchymal lesion or simply a re-

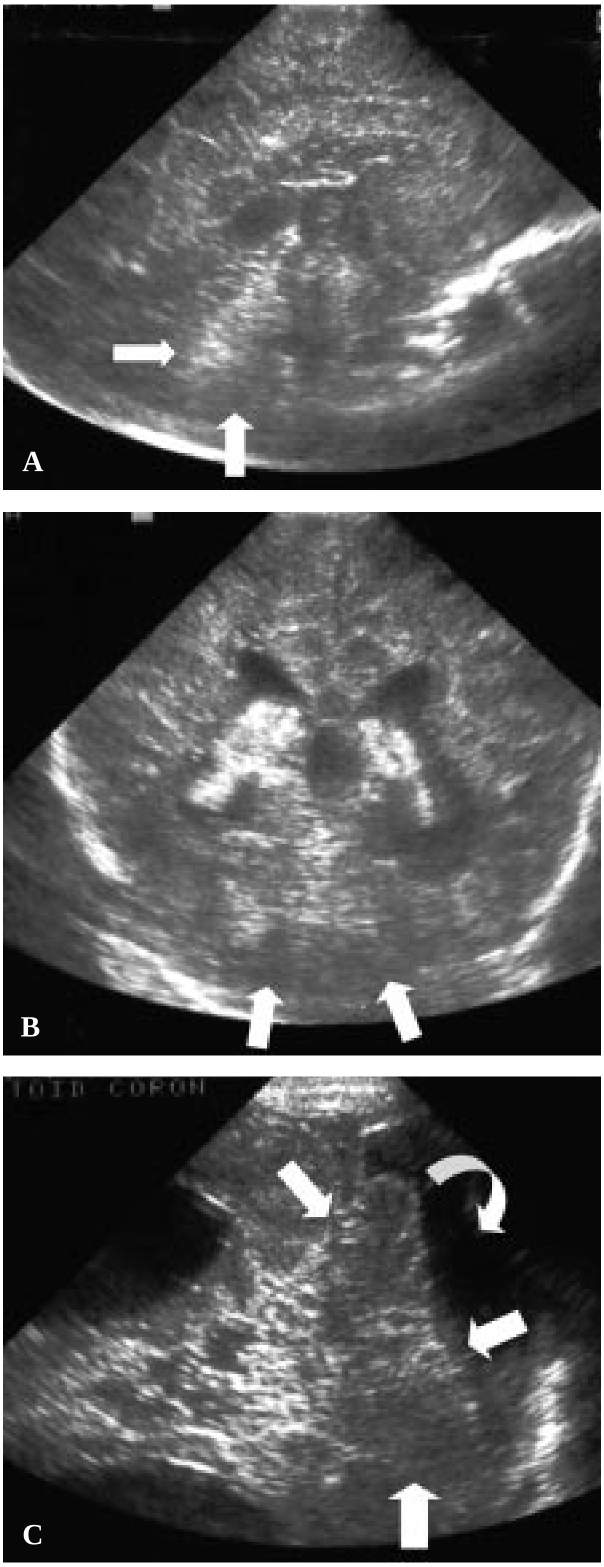
Fig. 6. Widespread hyperechoic aspect of the cerebellar parenchima. After severe asphyxia, by mastoid sonogram A) hyperechoic cerebellar hemispheres (Ecl). Thin linear stranding (white arrows) within the cistern. B) Coronal sonogram: instead, the hyperechoic appearance is not well defined through the anterior fontanelle (white arrows).



versible edema. Comparing ultrasound scan images and post mortem examinations in the future will probably allow us to clarify the nature of such pattern.

It is important to remember that post mortem examinations were able to detect parenchymal cerebellar hemorrhages in 13-25% of very low birth weight neonates [15-17]. In these infants the pathogenesis is similar to that observed during intraventricular hemorrhage. On the other hand, in term babies cerebellar hemorrhage is less frequently detected and abitually follows a traumatic delivery [18]. Computed tomography, which was performed in the past for the diagnosis, probably underdetects the real incidence of cerebellar hemorrhages in preterm babies [19]. Such condition is

Fig. 7. Sulfite-oxydase deficiency, cerebellar hypoplasia. Through the anterior fontanelle, midsagittal (A) and posterior coronal sonograms (B): poor visualization of cerebellar boundary zones (straight arrows). Mastoid coronal sonogram (C) shows cerebellar hypoplasia, confirmed by magnetic resonance images. Note the «triangular» morphology, the high definition of cerebellar (white arrows) and cisterna magna boundaries (curved arrow), with poor representation of cerebellar sulchi and laminae.



likely more frequent than previously considered by studies «in vivo» [18], and post mortem studies seems to confirm that feeling.

Therefore cerebellar lesions may be associated with lesions occurring in the more common sites, thus contributing to a worse prognosis. Instead, scarce attention has been so far given to this problem, except in case of large lesions, which are clearly detectable through the anterior fontanelle. It would be interesting to perform a long-term development follow-up of premature babies with ascertained cerebellar lesions, which were undetected before the introduction of the mastoid approach.

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