Child's Nerv Syst (1985) 1:341–345

Child's Nervous System CNS

Ultrasonographic evaluation of infantile hydrocephalus before and after shunting

A study in 20 children

Hélio R. Machado *, J. Cassiano Machado, J. Domingos Contrera, João A. Assirati, Jr., Nelson Martelli and Benedicto O. Colli

Hospital das Clínicas and Hospital São Francisco, (Division of Neurological Surgery), Rua Rui Barbosa, 1746, 14.100 Ribeirão Preto, São Paulo, Brazil

Abstract. The authors present the results of a prospective study of 20 children with congenital or acquired hydrocephalus of nontumoral etiology and submitted to ventriculo- (or cyst-) peritoneal shunting with valve. The diagnosis was established by B-mode or real-time brain sonography, in association with another neuroradiological procedure (computed tomography, ventriculography with air or Dimer-X, cerebral angiography). Among the proposed measurements (cortical thickness, lateral ventricle height, III ventricle width and ventricular ratio) for pre- and postoperative comparison, the cortical thickness and the lateral ventricle height were the ones that changed significantly when analyzed by sonography. The routine use of brain sonography allowed the visualization of the ventricular catheter position and the diagnosis of complications, such as subdural collection, progressive enlargement of cysts, isolated IV ventricle, etc, even before symptoms arise. The authors conclude that sonography is easily performed, inexpensive and innocuous, and should be used routinely during the follow-up of children with hydrocephalus.

Key words: Hydrocephalus – Brain sonography – Shunts in hydrocephalus.

The ventriculoperitoneal shunt has become the favored method for the surgical treatment of infantile hydrocephalus [12, 15]. Although the surgical technique is well known, the complications related to surgery, either mechanical or infectious, increase the morbidity of the procedure; frequently, an average of three or more surgical procedures per patient are required [12, 15, 19]. For this reason, all children submitted to this type of surgery should be followed regularly by trained personnel, establishing a real "shunt service" within each neurosurgical service [17].

Diagnosis of the complications related to the shunt implants has routinely been made by computed tomography (CT) [6, 11, 15]. Few publications have referred specifically to the role of brain sonography in the diagnosis and postoperative follow-up of hydrocephalus [3, 14, 22].

The present study was undertaken to assess the use of sonography as a diagnostic procedure, in view of its general availability, its harmlessness, and the recent interest in cerebral pathology with this technique.

* To whom offprint requests should be addressed

Materials and methods

The sonographic examinations were performed in B-mode with a sonodiagnostic B-52 Unit (Philips), or in real-time with a MK-500 Unit (ATL–Advanced Technology Laboratories, Bellevue, Wash.). No sedation was required and the technique consisted of applying the 3 or 5 MHz transducer on the anterior fontanelle (coronal, sagittal or oblique planes) or on the temporal region (axial plane). After complete visualization of the ventricular system, measures were obtained in coronal section at the level of the foramen of Monro III of cortical thickness and third ventricle width (Fig. 1 B, D). The ventricular ratio was obtained as the ratio between the lateral ventricle width and the cerebral hemisphere width in the medial coronal position. The lateral ventricle height was then obtained (the major distance between the anterior border of the foramen of Monro and the frontal ventricle wall) in the sagittal position (Fig. 1 A). In the axial plane, the ventricular ratio (ratio between the lateral ventricular width and the cerebral hemisphere width) was obtained (Fig. 1 C, D).

Between March 1982 and November 1983, we studied 20 consecutive patients admitted for treatment at the Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto, University of São Paulo. Fifteen were male and 5 female; their ages varied from 1–10 months, and they all had hydrocephalus of nontumoral etiology (Arnold-Chiari, myelodisplasia, 7 patients; diencephalic cyst, 1; Dandy-Walker, 1; postmeningitis, 2; aqueductal stenosis, 1; idiopathic, 7; neonatal hemorrhage, 1). The diagnosis was established by brain sonography together with one or more of the following investigations: computed tomography, ventriculography with air or Dimer-X, and cerebral angiography. All patients were submitted to ventriculoperitoneal shunting. The patient with a diencephalic cyst was initially submitted to a ventriculoperitoneal shunting, and later a catheter with a "Y" connector was inserted, joining the cyst with the shunting system. The patient with a Dandy-Walker cyst was submitted to cyst-peritoneal shunting. All patients were regularly followed with multiple sonographic examinations (78 in 20 patients) for a period up to 12 months after the initial surgery. Seven patients developed complications (mechanical complications, 5; infections, 3; subdural effusion, 1; skin necrosis over the valve, 4; cyst-peritoneal shunt revision, 1; death, 1). These complications required 34

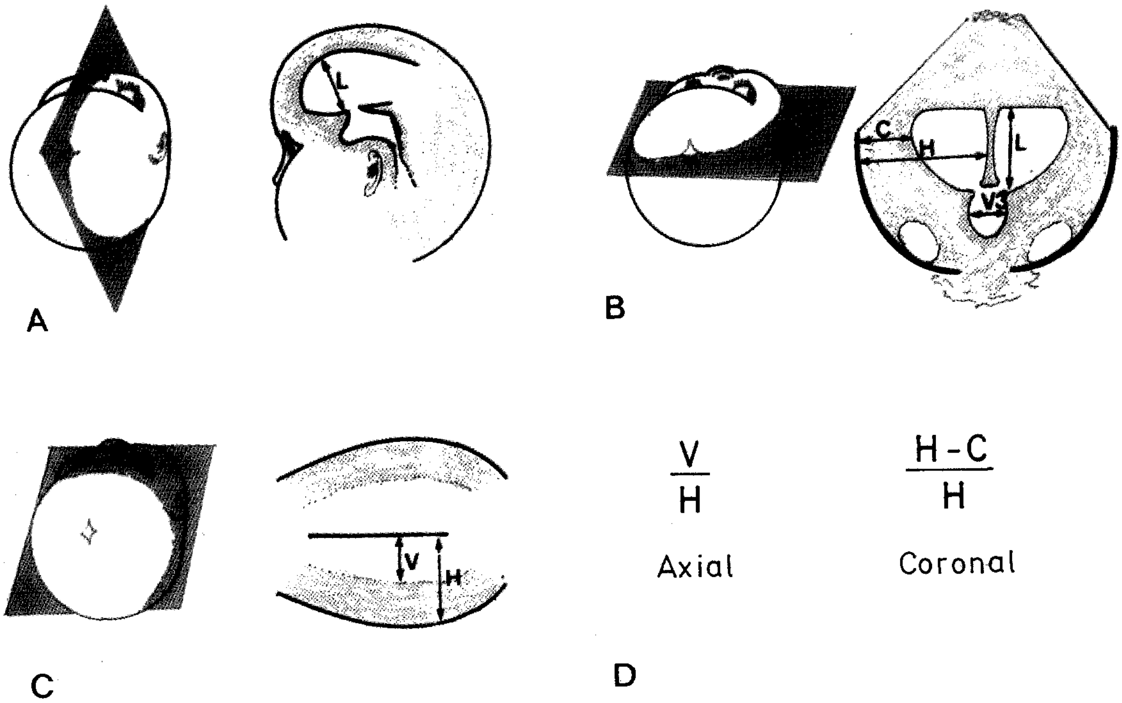

Fig. 1A–D. Measurements used in ultrasonographic follow-up of hydrocephalus. In the sagittal plane (**A**), the height of the lateral ventricle (*L*). In the coronal plane (**B**) at the level of the foramen of Monro, the cortical mantle thickness (*C*) the hemisphere width (*H*), the lateral ventricle height (*L*) and the III ventricle width (V_3). In the axial plane (**C**), the lateral ventricle width (*V*) and the cerebral hemisphere width (*H*). The lateral ventricle ratio (**D**) can be obtained either in the axial plane (*V/H*) or in coronal plane (*H–C/H*)

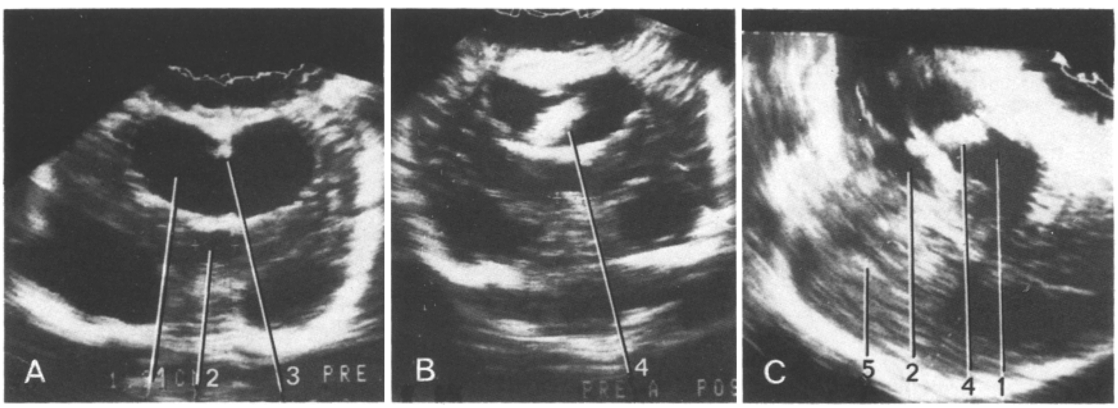

Fig. 2A–C. B-mode brain sonography, transfontanelle, in coronal (**A, B**) and sagittal (**C**) planes in the pre- (**A**) and postoperative (**B, C**) phases. Lateral ventricles (*1*); III ventricle (*2*); septum (*3*); ventricular catheter (*4*); IV ventricle (*5*)

surgical procedures in 20 patients (1.7 procedures per patient) and occurred within the first 2 months after the initial surgery in 93% of the procedures.

Results

Diagnosis of hydrocephalus

The progressive ventricular dilatation can be seen easily by ultrasonography: the rounding of the angles (Fig. 2A), and the distention of the ventricles can be quickly detected. When these changes are gross, the basal ganglia appear to "fluctuate" in the cerebrospinal fluid, sometimes making the differential diagnosis with hydranencephaly very difficult (Fig. 3A, C). The ventricular septum can be fenestrated or absent and the massa intermedia stretched (Figs. 2A, 4A). The III ventricle enlargement is limited by basal structures of gray matter and dilatation is variable (Figs. 2A, 3A, C, 4A). The IV ventricle is not always well visualized (Figs. 2C, 4C). The presence of a Dandy-Walker cyst can be well studied by ultrasonography (Fig. 6), as can diencephalic cysts (Fig. 5) and intraventricular hemorrhages (Fig. 4).

Correlation with other investigations

Eight patients underwent ventriculography with air or Dimer-X, and in four of them the ventricular ratio was

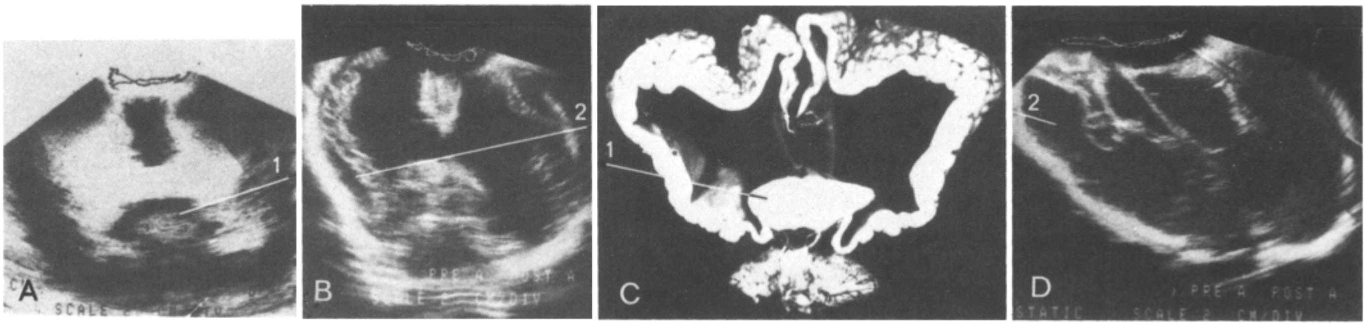

Fig. 3A–D. B-mode brain sonography transfontanelle in coronal plane (**A, B, D**) in a patient with maximum hydrocephalus (brain coronal section in **C**). Basal ganglia (*1*); subdural collection (*2*)

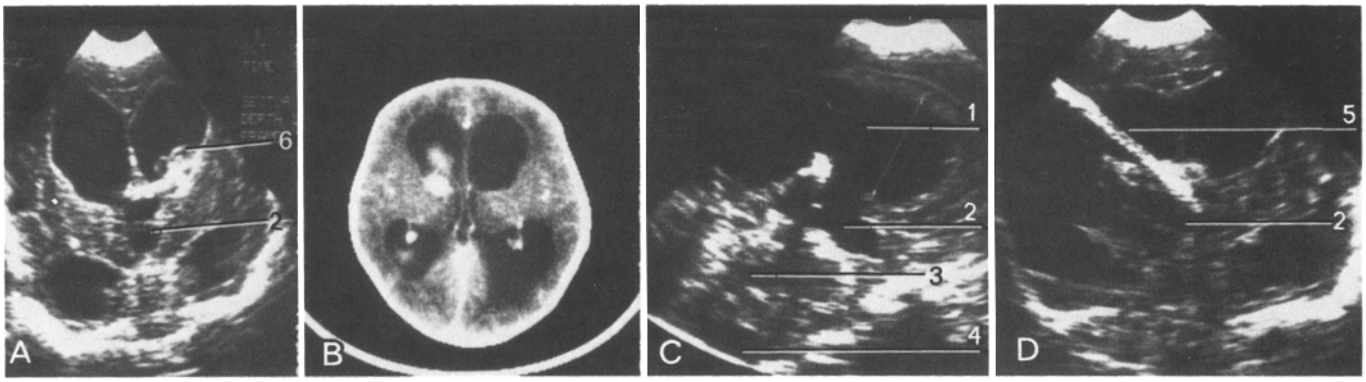

Fig. 4A–D. Real-time brain sonography transfontanelle in coronal plane pre- (**A**) and postoperative (**D**) and sagittal plane (**C**). Computed tomogram of the same patient shown in (**B**). Premature patient with hydrocephalus caused by ventricular hemorrhage. Lateral ventricle (*1*); third ventricle (*2*); fourth ventricle (*3*); cisterna magna (*4*); ventricular catheter (*5*); ventricular hemorrhage (*6*)

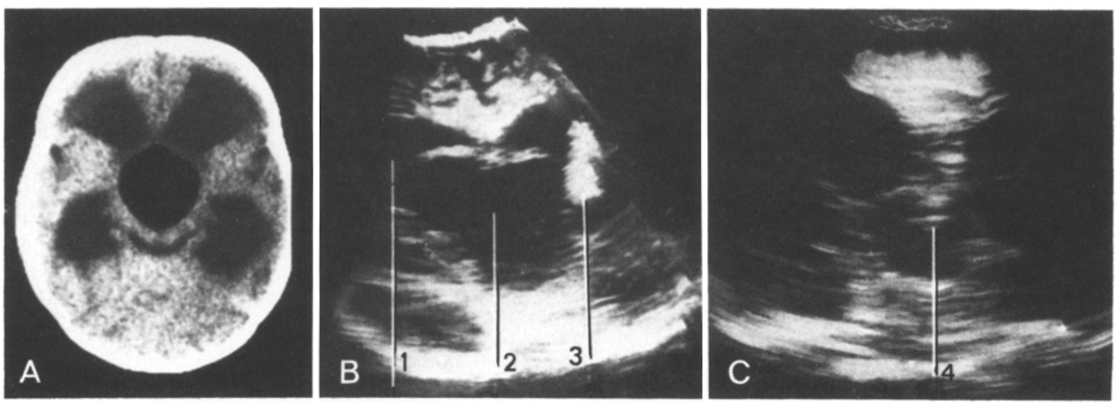

Fig. 5A–C. Computed tomogram (**A**). B-mode brain sonography transfontanelle in coronal plane in a hydrocephalic patient with a diencephalic cyst after ventriculoperitoneal shunt showing enlargement of diencephalic cyst (**B**). Same patient with reduction of the diencephalic cyst after "Y" cyst peritoneal shunting (**C**). Lateral ventricle (*1*); diencephalic cyst (*2*); ventricular catheter (*3*); intracyst catheter (*4*)

measured and compared with those obtained by sonography: good correlation between the methods ($r = 0.71$) was demonstrated by Pearson's correlation coefficient.

CT was performed in 8 patients and both CT and sonography revealed similar images (Figs. 4–6). In seven patients the correlation between the ventricular ratio obtained by these exams was excellent ($r = 0.99$, Pearson's correlation coefficient).

Only one patient underwent cerebral angiography to differentiate between gross hydrocephalus and hydranencephaly.

Measurements before and after shunting

Cortical thickness. The measurements obtained during the pre- and postoperative period in 12 patients with uncom-

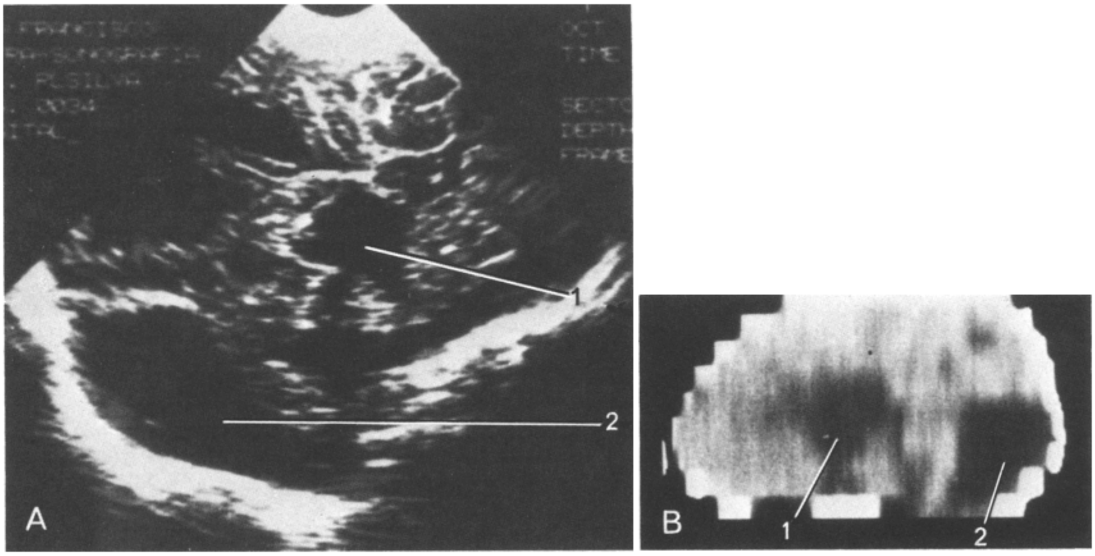

Fig. 6 A, B. Real-time brain sonography, transfontanelle in sagittal plane (**A**) and computed tomography (**B**) in a patient with a Dandy-Walker cyst. Third ventricle (*1*); Dandy-Walker cyst (*2*)

plicated clinical course were submitted to the Wilcoxon test. This analysis showed that the increase of the cortical thickness was significant when studied by sonography (significance level of 5%).

Lateral ventricle height. The lateral ventricle height measured in coronal or sagittal plane was obtained in 12 patients with an uncomplicated clinical course, and those values were submitted to the Wilcoxon test for the last measurement before and after the operation. This analysis showed that the reduction of height was significant (significance level of 5%).

Third ventricle width and ventricular ratio. The comparison of the data obtained during the pre- and postoperative period of 12 patients with uncomplicated hydrocephalus showed no significant difference either in the III ventricle width or in the ventricular index (Wilcoxon's test, significance level of 5%).

Ventricular catheter position. The strong echos from the ventricular catheter allow it to be followed by sonography from its passage through the skull to its tip in the lateral ventricle, III ventricle, cysts, or in the brain parenchyma (Figs. 2 B, C, 4 D, 5 B, C). One patient was submitted to a double shunting (ventricular and diencephalic cyst), and both catheters could be seen (Fig. 5 B, C).

Other data. Brain sonography also allows the diagnosis of several complications related to the shunting procedures including simple ventricular asymmetries, isolated IV ventricle, subdural collections, and expanding cysts (Figs. 3 B, D, 5 B, C).

Discussion

Although the use of CT makes it possible to treat hydrocephalus without any other investigation [16], repeated examination may expose the incompletely developed brain to excessive radiation [20].

According to Post and Page [18], CT examination during the postoperative period will give the following information:

1. Ventricular catheter position

2. Ventricular size determination

3. Diagnosis of septations and multiloculation of the ventricles

4. Shunt-related complications, such as subdural, intraparenchymal and/or intraventricular hematomas, ventriculitis, and localized encephalomalacia

5. Other causes for the rise of intracranial pressure not related to shunting complications (expanding subarachnoid cysts, tumors, or inflammatory lesions)

Among these items, the only one for which CT is by far superior to brain sonography is in the diagnosis of tumors responsible for hydrocephalus. In all the others, both sonography and CT are comparable [3, 10, 20–22]. Sonography and ventriculography also give comparable images [8].

Among the proposed measurements obtained by sonography the lateral ventricle height and the cortical mantle thickness revealed data that altered significantly during the pre- and postoperative period. A larger number of cases will be necessary to allow definite conclusions.

However, the utilization of those measurements will prevent the use of imprecise terms to evaluate ventricular dilation such as "moderate," "small," and "large," which are commonly used with CT [1, 11]. These measurements can also help in the diagnosis of shunting malfunction or in studies related to cognitive functions and cortical mantle thickness whose importance has already been demonstrated by others [4, 13].

Ventricular measurements of mainly the lateral ventricles are routinely used for the diagnosis of both prenatal [2] and postnatal hydrocephalus [7, 9]. Smith et al. [22] studied 26 hydrocephalic patients during the pre- and postoperative period and came to the conclusion that 74% of the reduction of the ventricular size occurs during the first 6 days after surgery. However, it is not necessary for the ventricles to reach normal size for a satisfactory result [11]. Epstein [5] observed a certain degree of ventricular dilatation in patients with arrested hydrocephalus. Nevertheless, progressive ventricular enlargement certainly indicates shunting malfunction [11].

The diagnosis of some complications in the treatment of hydrocephalus, such as subdural effusion, ventricular and parenchymal cysts and loculations, and isolated IV ventricle, can be obtained easily with the routine use of brain sonography even before serious symptoms of decompensation arise. For this reason, other authors also recommend the use of sonography in the follow-up hydrocephalus, even without ventricular measurements [3, 14].

The use of sonography in neurosurgery provides a unique opportunity: it makes it possible to follow the evaluation of a pathological process, with a simple procedure that is harmless, easy to interpret and of low cost, and which can be repeated whenever necessary.

References

1. Carrillo R, Nombela L, Salazar AR (1982) Computerized tomography and shunts. Monogr Neural Sci 8: 114–147
2. Denkhaus H, Winsberg F (1979) Ultrasonic measurements of the fetal ventricular system. Radiology 131:781 – 787
3. Edwards MK, Brown DL (1982) Hydrocephalus and shunts function. Semin Ultrasound 3:242 – 248
4. Eisenberg HM, Thompson M, Levin HS (1982) Outcome in shunted hydrocephalic patients. Monogr Neural Sci 8: 130 – 133
5. Epstein F (1982) Diagnosis and management of arrested hydrocephalus. Monogr Neural Sci 8:105 – 197
6. Epstein F, Maidich T, Kricheff L, Chase N, Lin J, Ransohoff J (1977) Role of computerized axial tomography in diagnosis, treatment and follow-up of hydrocephalus. Preliminary communication. Child's Brain 3:91 – 100
7. Fiske CF, Filly RA, Callen PW (1981) Sonographic measurement of lateral ventricular width in early ventricular dilation. J Clin Ultrasound 9:303 – 307
8. Garrett WJ, Kossoff G, Jones RFC (1975) Ultrasonic cross-sectional visualization of hydrocephalus in infants. Neuroradiology 8:279 – 288
9. Garrett WJ, Kossoff G, Warren P (1980) Cerebral ventricular size in children. Radiology 136:711 – 715
10. Grant EG, Borts FT, Schellinger D, McCullough DC, Silvasubramanian KN, Smith Y (1981) Real-time ultrasonography of neonatal intraventricular hemorrhage and comparison with computed tomography. Radiology 139:687 – 691
11. Harwood-Nash DC (1982) Radiology of shunt complication in childhood hydrocephalus. Monogr Neural Sci 8:26 – 33
12. Hoffman HJ, Hendrick EB, Humphreys RP (1982) Management of hydrocephalus. Monogr Neural Sci 8:21 – 25
13. Kato M (1982) Relationship between ventricular configuration and intelligence after surgery in infantile hydrocephalus. Neurol Med Chir (Tokyo) 22:849 – 854
14. McLaurin RL (1982) Clinician's viewpoint. Indications and uses. Semin Ultrasound 3:231 – 241
15. Milhorat TH (1982) Hydrocephalus: historical notes, etiology and clinical diagnosis. In: Pediatric Section of the American Association of Neurological Surgeons (ed) Pediatric neurosurgery. Surgery of the developing nervous system. Grune & Stratton, New York, pp 197–210
16. Naidich TP, Epstein F, Lin JP, Kricheff II, Hochwald GM (1976) Evaluation of pediatric hydrocephalus by computed tomography. Radiology 119:337–345
17. Nulsen FE, Rekate HL (1982) Results of treatment for hydrocephalus as a guide to future management. In: Pediatric Section of the American Association of Neurological Surgeons (ed) Pediatric neurosurgery. Surgery of the developing nervous system. Grune & Stratton, New York, pp 229–241
18. Post MJD, Page LK (1982) Value of CT in the shunted pediatric patient. Monogr Neural Sci 8:48
19. Robinson JS, Kawamura K, Raimondi AJ (1977) Complications of ventriculoperitoneal shunting procedures. In: McLaurin RL (ed) Myelomeningocele. Grune & Stratton, New York, pp 283–311
20. Shkolnich ML, Rosenbaum AE, Matzuk RT, Guthkelch AN, Heinz ER (1979) Detection of dilated cerebral ventricles in infants: a correlative study between ultrasound and computerized tomography. Radiology 131:447–451
21. Silverboard G, Horder MH, Ahmann PA, Lazzara A, Schwartz JF (1980) Reliability of ultrasound in diagnosis of intracerebral hemorrhage and post hemorrhage hydrocephalus: comparison with computed tomography. Pediatrics 66:607–614
22. Smith JRL, Haber K, Reynolds AF, Weinstein PR (1982) Ultrasonic evaluation of post ventricular shunt dynamics in infants and young children. Radiology 145:133–138