Original Article

ISSN: 2675-3626

Anatomical Variations of the floor of the third ventricle in patients with hydrocephalus may affect the surgical outcome?

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Introduction: Anatomical variation of the floor membrane of the third ventricle can occurs in patients with hydrocephalus of any etiology and age and can affect the surgical outcome.

Methods: Images of the floor of the third ventricle were captured and analyzed from videos of 99 patients with hydrocephalus of different etiologies and ages who underwent endoscopic third ventriculostomy (ETV) with emphasis on the type of floor membrane.

Results: Based on the types of membranes of the floors of the third ventricle found in our study and the data described in the available literature, we can describe four "main types of membranes" with their common characteristics and "subdivisions of the main membranes" where they present common types of main membrane associated with details and/or abnormalities.

Conclusion: Anatomical variations of the floor of the third ventricle occur in patients with hydrocephalus of any etiology and age and their recognition is essential before the main surgical procedure (ETV), as they increase the risk of injuries that can affect the surgical outcome.

Keywords: Hydrocephalus, endoscopic third ventriculostomy, complications, third ventricle floor, anatomical variations, malformation.

INTRODUCTION

Hydrocephalus is a word of Greek origin, meaning "water in the brain" and was mentioned by "Hippocrates" in the 5th century B.C. [1,2]. It is a complex disorder, involves all ages, results from multiple etiologies, its genetic characteristics are already well documented in the literature, and it has a high global prevalence and incidence, especially in underdeveloped countries, being considered the most common disorder treated by pediatric neurosurgeons in daily practice [3,4,5,6,7]. In general, the development of hydrocephalus is due to an accumulation of cerebrospinal fluid (CSF) within the ventricular system, with consequent dilation and generally an increase in intracranial pressure [8,9]. Depending on the age of involvement or the form of presentation (acute or chronic), the compressive effect on the vascular and neural structures around the cerebral ventricle can cause permanent brain damage [10,11].

For just over 60 years, hydrocephalus has been treated by diverting CSF from the dilated cerebral ventricles to another part of the body (peritoneum as the most common location) through a system of valves. However, even with an improvement in the prognosis for patients, many complications were observed, with consequent high morbidity and mortality [12]. Due to complications resulting from the treatment of hydrocephalus with valve systems, a new treatment option (neuroendoscopy) has been gaining space, through endoscopic third ventriculostomy (EVT), which communicates the ventricular system with the subarachnoid space through perforation of the floor of the third ventricle (tuber cinereum), which has become the main treatment option for hydrocephalus in relation to the valve system [13].

From an anatomical point of view, the third ventricle is a small and narrow slit-shaped cavity, located below the lateral ventricles, above the pituitary gland and midbrain. It communicates with the lateral ventricle on its anterior/superior margin, through the interventricular foramen of Monro (FM), and inferiorly with the fourth ventricle, through the narrow cerebral aqueduct (CA). It is a complex anatomical region, which has multiple structures of great importance for endocrine and executive functions

Submitted: 05 May 2024
Accepted: 10 December 2024
Published: 01 January 2025

[14,15,16]. The tuber cinereum (TC) is in the anterior or diencephalic portion of the third ventricle, which extends from the optic chiasm (OC) anteriorly to the mammillary bodies (MB) posteriorly. The TC is bounded by the hypothalamus on each side and the basilar arterial complex just below (interpeduncular cistern), where the ETV occurs, as well as near the fornix, OC, and pituitary gland. The floor of the third ventricle is concave and trapezoidal from side to side, has a smooth glial structure and contains only hypothalamic nuclei [15].

In cases of hydrocephalus, the third ventricle distends, elongates and the floor presents a thin and transparent membrane [17]. Figure 1 below highlights the anatomical structures located in the anterior portion of the floor of the third ventricle, visible in front of the endoscope lens during the surgical procedure, which must be readily recognized by the surgical team as the optic chiasm (OC), dorsum sella (DS), tuber cinereum (TC), infundibular recess (IR), mammillary bodies (MB), lateral walls (LW) and premammillary recess (PR).

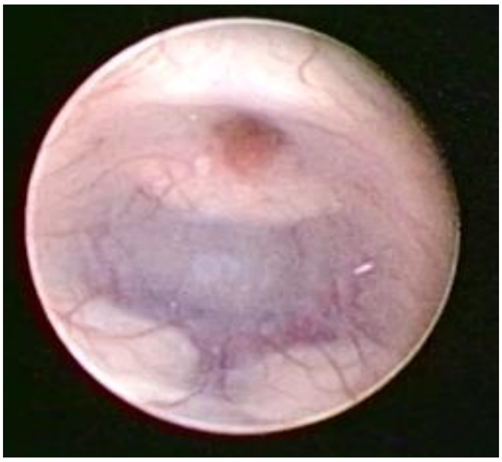


Figure.1 – Image captured from video during intraventricular endoscopic procedure on the floor of the third ventricle, showing all anatomical structures reference; optic chiasm (OC), dorsum sella (DS), tuber cinereum (TC), infundibular recess (RI), mammillary bodies (MB), premammillary recess (PR) and lateral walls (LW) (child, hydrocephalus due to obstruction of the fourth ventricle) (author's personal archive).

MATERIALS AND METHODS

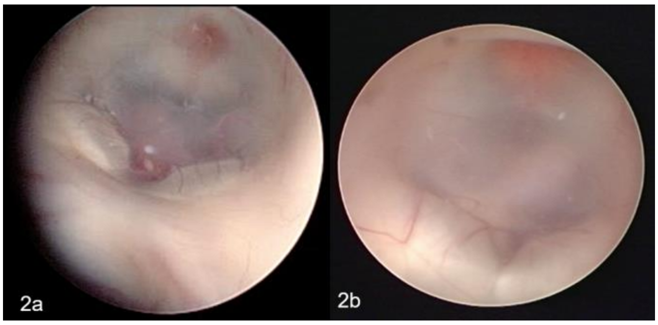
From a total of 310 videos of patients with hydrocephalus of different etiologies and ages undergoing ETV, we selected and captured images of 99 videos considered high definition of anatomical structures and mainly of the floor membrane of the third ventricle

RESULTS

Based on the type of membrane found in each floor of the third ventricle studied, we identify four common types of membranes - “main types of membranes” and “subdivisions of the main types of membranes” for the main membranes with certain details and anomalies and each type of membrane present a comment on how they may affect the surgical outcome:

Main types of membrane

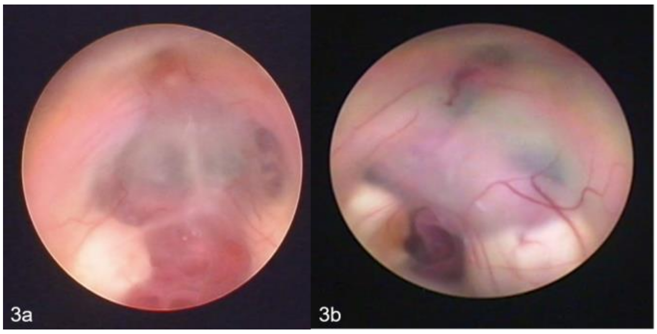
1) Transparent floor - This type of floor is characterized by a thin and transparent membrane, where it is possible to identify vascular contents inside the interpeduncular cistern (figs.2a,b). In our study, we found 24/99 cases with this type of floor. In the literature the transparent floor is described as “transparent floor” or “translucent floor or “delicate floor” and “thin floor” [16,17,18,19,20].



Figures .2a,b – Transparent floor. Vascular structure visible below the membrane. In 2a (child, hydrocephalus associated with retrocerebellar arachnoid cyst) and in 2b (adult, cerebellar pontine angle tumor) (Author's personal archive).

Subdivision of the main types of membrane

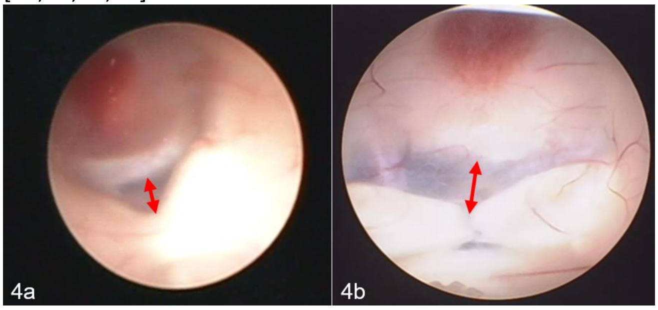
1a) Very vascularized transparent floor - This type of floor is characterized by a thin and transparent membrane and highly vascularized in different parts (figs.3a,b). In the study we found only 2/24 cases, and we did not find a description of this type of floor in the literature.



Figures.3a,b– Very vascularized transparent membrane (8a - adults with LOVA and 8b – adult with PNH) (Author's personal archive).

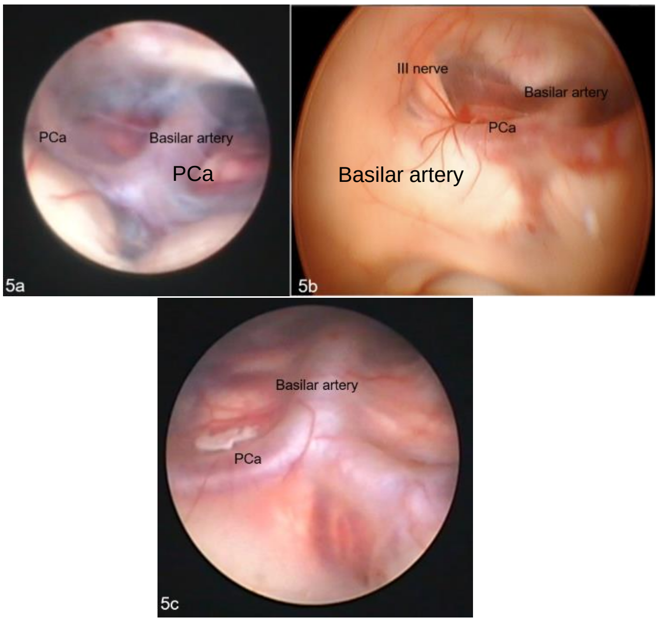
DOI: 10.46900/apn.v7i1.260

1b) Transparent floor with small prepontine space - This type of floor is characterized by a thin and transparent membrane located in a "small space" visible between the dorsum sellae (DS) and the mammillary bodies (CM) called prepontine space (figs.4a,b). In this type of floor, it is often possible to visualize the anatomical structures located inside the interpeduncular cistern, through a small transparent space. In the study, we found 8/24 cases. This type of floor is described in the literature with the same name [17,20,22,27].

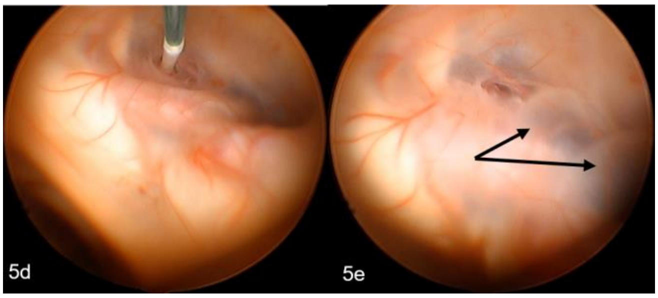


Figures.4a,b – Transparent floor with small prepontine space (red arrows). The presence of vascular structures and the III nerve below inside the interpeduncular cistern, can be identified in both images (adult, cerebellopontine angle tumor), (adult, aqueduct stenosis) (Author's personal archive).

b) Very transparent floor - This type of floor is characterized by a thin and very transparent membrane. On this floor, it is possible to visualize all anatomical structures located inside the interpeduncular cistern, mainly the arterial structures (basilar and posterior cerebral arteries) (figs.5a,b,c). In the study, we found **4/24** cases, where in 3 cases, we observed the characteristics of ascending ballooning or herniate ballooning (upward ballooning phenomenon) [16,28], which occurs due to the pressure difference between the third ventricle and cistern after the perforation of membrane during the surgery (figs.5d,e).

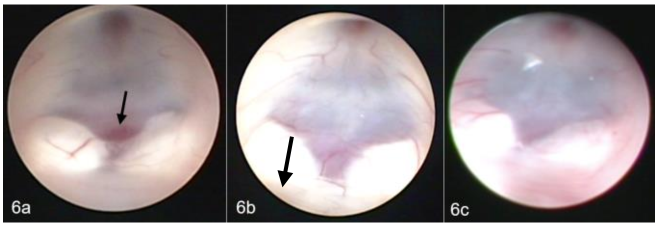


Figures.5a,b,c – Very transparent floor. Through this membrane, it is possible to fully see the basilar arteries, posterior cerebral arteries (PCa), cranial nerve III. In 10a (adult/aqueductal stenosis), in 10b (adult/chronic hydrocephalus) and in 10c (child/aqueductal stenosis) (Author's personal archive).



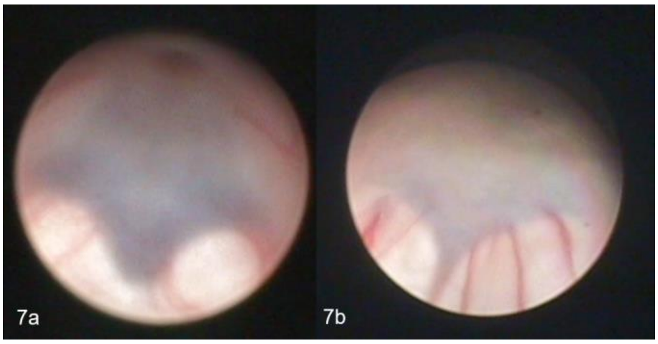
Figures.5d,e – Image of a very transparent floor being perforated in 10d, followed by an image after perforation, showing the "upward ballooning phenomenon" (black arrow) in 10e. (adult / chronic hydrocephalus) (Author's personal archive).

2) Mixed floor - This type of floor is characterized by an thin and mixed membrane, where only part of the content inside the interpeduncular cistern is visible, but not in detail (figs.6a,b,c). In the study, we found 19/99 cases. In the literature, this type of floor is called as "partially effaced" or "erased floor" [16,17,20].



Figs.6a,b,c– Mixed floor. The black arrow points to the premamillary recess where the top of the basilar artery is located, in 3a (child, Dandy-Walker malformation) and in 3b (child, choroid plexus hyperplasia) and in 3c (child, aqueduct stenosis) (Author's personal archive).

3) Opaque floor - This type of floor is characterized by an tick and opaque membrane, and the content located inside the interpeduncular cistern is not visible (figs.7a,b). In the study, we found 50/99 cases. In the literature, this type of floor is the most common membrane found and called "thickened floor" or "opaque floor" (16,17,18,19,21,22).



DOI: 10.46900/apn.v7i1.260

Figures.7a,b– Opaque floor in 4a (child, arachnoid cyst of the interhemispheric fissure) and in 4b (adult, cerebellopontine angle tumor) (Author's personal archive).

3a) Ballooned opaque floor – This type of floor presents a ballooned opaque membrane (without membrane perforation) (fig.8). This type of floor is described in the literature with the same name [17,22].

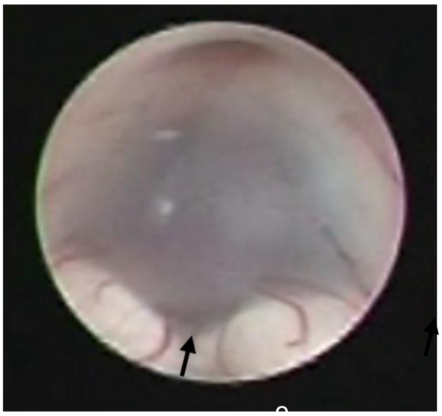
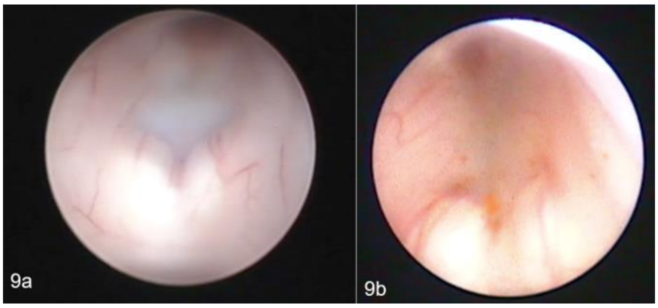


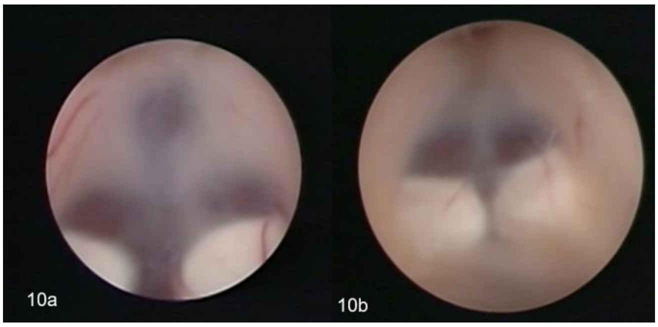
Fig.8 – Ballooned opaque floor (child, aqueduct stenosis). Note a membrane ascending (black arrow) (Author's personal archive).

3b) Narrow opaque floor. This type of floor presents an opaque membrane and narrow side by side (figs.9a,b). In the literature, this type of floor is described as “narrow third ventricle” [16,17,21,22,23].



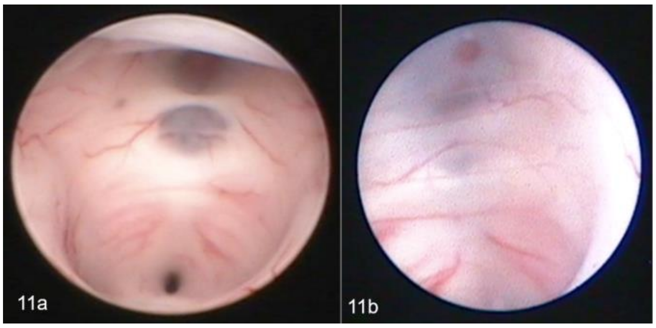
Figures.9a,b- Narrow opaque floor. In 12a (adult, neurocysticercosis), and in 12b (child, prematurity) (Author's personal archive).

3c) Funnel-shaped opaque floor - This type of floor, the distance between the side walls is reduced, often due to the smaller distance between the mamillary bodies. For the latter type of floor, it may be associated with a malformative etiology (myelomeningocele) or congenital hydrocephalus (HPN) and hydrocephalus of prematurity (figs.10a,b).

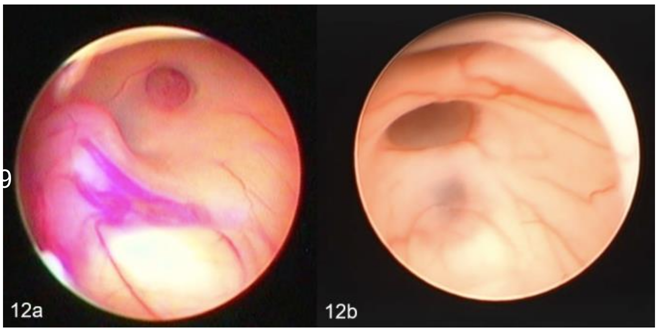


Figures.10a,b – Funnel-shaped opaque floor in 13a (child, myelomeningocele), in 13b (adult, PNH) (Author's personal archive).

4) Deformed floor - This floor has a thin and ill-defined membrane, making it difficult to define the content located below the TC (inside the interpeduncular cistern). In our study, we found 6/99 cases. This type of floor is particularly found in patients with hydrocephalus of malformative etiology (myelomeningocele) and chronic hydrocephalus (fig.11a,b,12a,b,13a,b). In the literature, this type of floor has called “deformed floor” [23,24,25,26].

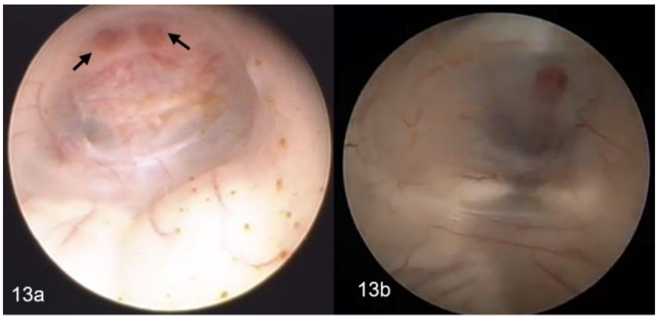


Figures.11a,b – Deformed floor (children’s with myelomeningocele) (Author's personal archive).



Figures.12a,b– Deformed floor in 6a (child, chronic hydrocephalus), in 6b (child, myelomeningocele) (Author's personal archive).

DOI: 10.46900/apn.v7i1.260



Figures.13a,b– Deformed floor, two infundibular recesses (black arrows) in 7a (adult, chronic hydrocephalus), in 7b (child, chronic hydrocephalus) (Author's personal archive).

Other types of floors (membranes) are described in the literature [16,17,20] as anomalies or variants: "elevated floor of the basilar complex, floor with displaced mammillary bodies, floor with thickened tissue band, elevated floor, floor with prominent basilar artery, floor with separated mammillary bodies, floor with elongated third ventricle, floor with interthalamic bands", but not found in our study.

DISCUSSION

In patients with hydrocephalus, dilation of the ventricular system causes variations in the floor membrane of the third ventricle. Under normal conditions, the third ventricle is a small, narrow, slit-shaped cavity filled with fluid. In patients with hydrocephalus [dilated ventricular system], the third ventricle distends and lengthens, acquiring a thin and transparent membrane. Depending on the chronicity of the hydrocephalus, the membrane changes transparent appearance to a thick membrane. This concept is based on the theory that "the thickness of the membrane of the floor of the third ventricle has an inverse relationship with the chronicity of hydrocephalus," that is, the more chronic the hydrocephalus, the thicker the membrane. Thus, in acute hydrocephalus the floor membrane of the third ventricle is thin and transparent, at a certain stage it may present a mixed appearance and in a chronic state it evolves into a thick and opaque membrane, a type found in the majority of cases in our study and as described in the scarce literature on the subject [16,17,18,19,20,21,22,23,25,26].

Four common types of membranes on the floor of the third ventricle were identified in our study and in literature reports, which we classify as "main types of membrane": membrane with a "transparent" appearance, membrane with a "mixed" appearance, membrane with a "thick or opaque" appearance, and membrane with a "deformed" appearance. We add a "subdivision of the main membranes" that present characteristics of membranes with a transparent and opaque appearance, but with some details or anomalies, being very "vascularized transparent floor," "transparent floor with small prepontine space," "very transparent floor with phenomenon ascending ballooning," and "ballooned opaque floor," "narrow opaque floor," and "funnel-shaped opaque floor."

Floors with a transparent membrane (figs.2a,b) make it possible to identify by endoscopic lens the vascular contents within the interpeduncular cistern. In the literature, this type of membrane is called transparent membrane, translucent membrane, delicate membrane, or thin membrane [16,17,18,19,20]. In our experience, using the correct surgical technique during ETV, perforation and widening of the membrane is considered easy and safe [vascular contents are visible], but can affect the surgical outcome when in inexperienced hands. Furthermore, the Liliequist membrane is easily observed and differentiated from the main membrane after perforation. In our study, we found three subdivisions of common transparent membranes, some of which are discussed in the literature.

A very vascularized transparent membrane (figs.3a,b) was found in our study, but only commented on in the literature. This type of membrane presents a small space with a transparent membrane for viewing the contents within the interpeduncular cistern, covered by a large vascular area, making perforation and enlargement of the main membrane and the Liliequist membrane a high risk of injury, which can affect the surgical outcome. However, the procedure, when performed by experienced surgeons, can provide a better result. Transparent membranes with a small prepontine space (figs.4a,b) present a high risk of vascular and nerve injury during the ETV, which may affect the surgical result and needs to be worked on by experienced hands.

Floors with very transparent membranes have been described in the literature but not documented images [16,28]. In our studies, we found and documented four patients with this type of membrane, where the contents located within the interpeduncular cistern, mainly the vertebral and posterior communicating arteries, were fully observed (figs.5a,b,c). In our experience, this type of floor has a very thin and very smooth membrane, which requires great care during ETV, as it becomes slippery during drilling, which can affect the surgical result [vascular injury]. Many times, after perforation it is difficult to visualize the Liliequist membrane, as it may be absent or very adhered to the main membrane. The phenomenon of upward ballooning (figs.5d,e) is a common occurrence [100% of our cases after membrane perforation] and results from a difference in pressure between the ventricular system and the cistern, which may affect the surgical result.

In 3/4 of our cases, the ETV was performed but failed, requiring a change of procedure [shunt valve] due to stoma closure. In 1 case, the patient was less than 1 year old, we treated with a shunt valve and during a complication of the shunt system, 1 year and 6 months later, we opted for ETV

DOI: 10.46900/apn.v7i1.260

due to the change in the appearance of the floor of the third ventricle, with a favorable result because of the change of membrane – very transparent membrane to mixed membrane). Floors with opaque membranes (figs.4a,b) were the most common found in our study, as well as in the scarce literature.

In this type of floor, the vascular and neural content located within the interpeduncular cistern is not visible, which requires the correct technique during the surgical procedure [ETV], due to the risk of vascular and nervous injury, as it can affect the surgical result. This type of floor is described in the literature as thick or opaque [16,17,22]. Its perforation is quick and easy and the Liliequist membrane is always visible. As a detail, there is always a small amount of bleeding on the surface of the membrane during perforation, but it is generally easy to control. It is a typical symptom of chronic hydrocephalus, in adults and children.

In our study we found 3 "subdivisions" with ballooned opaque floors (fig.11) without being perforated, also described in the literature with the same name [16,17,18,19,21,22]. This floor is difficult to drill, which increases the risk of injury, which can affect the surgical result. An opaque and narrow third ventricle floor (figs.12a,b) is discussed in the scarce literature, being named as a narrow third ventricle. It has the same characteristics as the opaque floor, but it becomes more dangerous during a surgical procedure [ETV], due to it being very narrow from one side to the other, which can affect the surgical result.

We also find the funnel-type opaque floor (figs.13a,b), which have the same characteristics as opaque floors, where they have a reduced distance between the lateral walls and may be associated with a malformative etiology (myelomeningocele) or congenital hydrocephalus (PNH) and hydrocephalus of prematurity, which can affect the surgical outcome.

Deformed floor (fig.5a,b,6a,b,7a,b) has a thin and poorly defined membrane, which makes it difficult to define the content located below the membrane [23,24,25,26]. In our experience, the anatomy of this type of floor is difficult to recognize, difficult to drill, and can affect the surgical result.

CONCLUSION

Due to the few studies described in the literature on the subject and knowing that each type of anatomical variation can affect surgical result, even in experienced hands, we believe that a broader study, with a greater number of cases among children and adults, could confirm the frequency of the floor types described and/or add others, thus helping to prevent injuries.

DISCLOSURES

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the local Ethics Committee, Comitê de Ética da Santa Casa de São José dos Campos. São Paulo.

Consent to participate

The patient gave consent to use his information and images for publication.

Conflict of interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

CONTRIBUTIONS

-**Humberto Belem de Aquino**: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing
-**Carlos Umberto Pereira**: Data curation, Formal Analysis, Investigation, Writing – original draft, Writing – review & editing
-**Enrico Ghizone**: Investigation, Writing – original draft
-**Cesar Massami Yukita:** Investigation, Writing – original draft
-**Heber Martim Vieira**: Investigation, Writing – original draft

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DOI: 10.46900/apn.v7i1.260