Surgical Cavity in Extended Endoscopic Endonasal Approach to the Skull Base and their Relationship with Cerebrospinal Fluidleak

By Marlon Ortiz Machín MD PhD, Omar López Arbolay MD PhD, Carlos Vargas Gálvez MD & Ambiorix Ottenwalder Díaz MD

Abstract- Cerebrospinal fluid leak represents a fearsome complication after Extended Endoscopic Endonasal Approach to the skull base. A descriptive observational study was performed in 550 patients operated for skull base tumors through Extended Endoscopic Endonasal Approaches, between 2010 and 2021 at the Ameijeiras Hospital. Surgical cavity was classified according to relation with intracranial hydrodynamic system into: type 0 (no contact with the hydrodynamic system), type 1 (subarachnoid cavity), type 2 (cisternal cavity), and type 3 (ventricular cavity). A significant increase CSF leak incidence was determined in type 2 (10,8 %) and type 3 (18 %) cavity and it was associated to increment of hydrodynamic energy secondary to Bernoulli laws.

Keywords: extended endonasal endoscopic approach (EEEA), cerebrospinal fluid (CSF) leak, surgical cavity, bernoulli laws.

GJMR-A Classification: LCC Code: RC400

SURGICALCAVITYINEXTENDEDENDOSCOPICENDONASALAPPROACHTOTHESKULLBASEANDTHERRELATIONSHIPWITHCEREBROSPINALFLUIDLEAK

Strictly as per the compliance and regulations of:

Surgical Cavity in Extended Endoscopic Endonasal Approach to the Skull Base and their Relationship with Cerebrospinal Fluidleak

Marlon Ortiz Machín MD PhD [α], Omar López Arbolay MD PhD [σ], Carlos Vargas Gálvez MD [ρ]
& Ambiorix Ottenwalder Díaz MD [ω]

Abstract- Cerebrospinal fluid leak represents a fearsome complication after Extended Endoscopic Endonasal Approach to the skull base. A descriptive observational study was performed in 550 patients operated for skull base tumors through Extended Endoscopic Endonasal Approaches, between 2010 and 2021 at the Ameijeiras Hospital. Surgical cavity was classified according to relation with intracranial hydrodynamic system into: type 0 (no contact with the hydrodynamic system), type 1 (subarachnoid cavity), type 2 (cisternal cavity), and type 3 (ventricular cavity). A significant increase CSF leak incidence was determined in type 2 (10,8 %) and type 3 (18 %) cavity and it was associated to increment of hydrodynamic energy secondary to Bernoulli laws.

Keywords: extended endonasal endoscopic approach (EEEA), cerebrospinal fluid (CSF) leak, surgical cavity, bernoulli laws.

I. Introduction

Surgery of cranial base tumors has historically been one of the most complex and challenging disciplines in Neurosurgery. The difficult access and its intimate relationship with critical neurovascular structures make any surgical procedure a high-risk one.[1] Endoscopic approaches through natural corridors, Endoscopic Endonasal Approaches, allow minimizing the degree of cerebral invasiveness and improving tumor resection, with excellent results, visualization and dynamism.[2] With endoscopic approaches, there is evidence of a lower frequency of complications compared to traditional transcranial approaches, however, the CSF leak increases and can trigger other cascading complications such as meningitis and hydrocephalus.[3] In the following article, surgical cavity are classified depending on the contact with the intracranial hydrodynamic system and are related to the appearance of CSF fistula.

II. Method

A descriptive observational study was performed in 550 patients operated for skull base tumors through Extended Endoscopic Endonasal Approaches, between 2010 and 2021 at the Ameijeiras Hospital. Surgical cavities were classified in relation to the intracranial hydrodynamic system into: type 0 (no contact with the hydrodynamic system), type 1 (subarachnoid cavity), type 2 (cisternal cavity), and type 3 (ventricular cavity) (Table 1) (Figure1). The statistical analysis was performed using the IBM® SPSS® version 23.0 program. To determine the relationship between postoperative CSF leak and the type of surgical cavity, it was performed the Pearson's chi-square test, with statistical significance $p < 0.05$. In all cases, the same multilayer repair method was used at the cranial base, which included: fat, fascia lata, and Hadad-Basagasteguy nasoseptal flap.

Table 1: Type of surgical cavity according to relation to the intracranial hydrodynamic system

Surgical cavity	Description	Examples of tumors
Type 0	No contact with the hydrodynamic system	Adenomas with intracapsular dissection, chordomas of the clivus and malignant sinonasal tumors without intracranial invasion
Type 1	Subarachnoid (contact and subarachnoid dissection)	Adenomas with rupture of the arachnoid, meningiomas of the olfactory groove, small meningiomas of the sellar tubercle
Type 2	Cisternal (contact and cisternal dissection)	Adenomas with extracapsular dissection, large meningiomas of the sellar tubercle, cisternal craniopharyngiomas, clivus and petroclival meningiomas or cholesteatomas, chordomas with intracranial invasion
Type 3	Ventricular (contact and intraventricular dissection)	Craniopharyngiomas with ventricular invasion, giant adenomas with ventricular invasion, gliomas, and hypothalamic hamartomas

Author α: Ameijeiras Hospital. Havana. Cuba. 2022. e-mail: marlonneuro@gmail.com
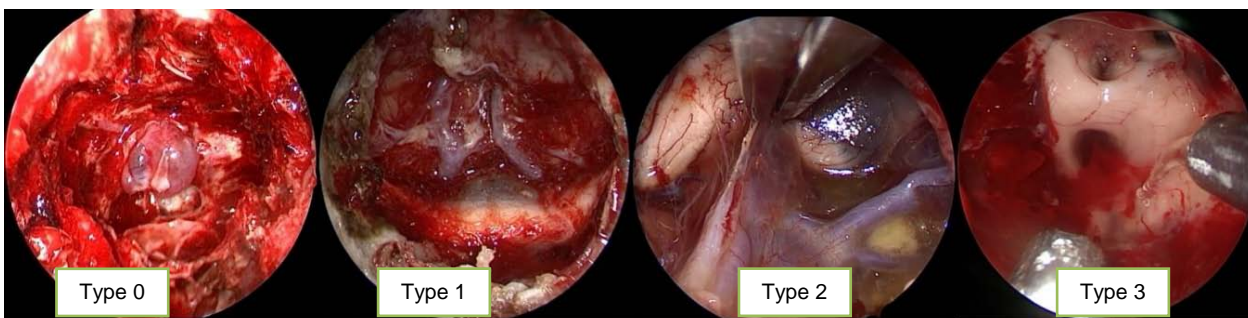
Fig. 1: Type of surgical cavity in relation to the intracranial hydrodynamic system. Type 0: no contact with the hydrodynamic system, Type 1: subarachnoid contact and dissection, Type 2: cisternal dissection, in this case in the interpeduncular cistern, Type 3: dissection inside the third ventricle.

III. RESULTS

Table 2 shows the distribution of patients with CSF leak according to the type of surgical cavity. It can be seen that in type 0 the incidence of fistula was 0.7%, in type 1 it was 5%, while in type 2 it was 10.8% and in type 3 it was 18%. Figure 2 shows the increase in the CSF fistula as the type of surgical cavity increases.

Table 2: Distribution of patients with CSF leak according to the type of surgical cavity

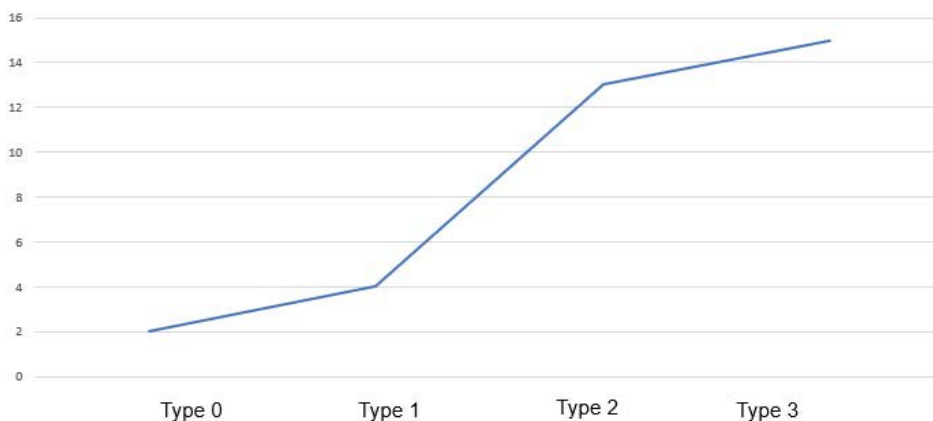| CSF leak	Type of surgical cavity								Total		P
	Type0	%	Type1	%	Type2	%	Type3	%	N	%	
No	265	99,3 %	76	95 %	107	89,2%	68	82 %	516	93,8 %	
Yes	2	0,7 %	4	5 %	13	10,8 %	15	18 %	34	6,2 %	0,000
Total	267	100 %	80	100 %	120	100 %	83	100 %	550	100 %	

Source: Medical records

Fig. 2: Incidence of CSF fistula according to the type of surgical cavity

IV. DISCUSSION

The intracranial CSF circulation system is considered a hydrodynamic system. In physics and physiology, liquids do not flow through a pressure or velocity gradient, but through an energy gradient, which explains why sometimes the liquid flows against pressure and velocity gradients, which constitutes the Bernoulli Effect, where the pressure and velocity are part of that energy.[4,5]

The CSF circulates from central hydrodynamic points of high energy, for example the cerebral ventricles, to points of lower energy such as the cisternal and subarachnoid spaces, until it is finally absorbed into the venous system through the arachnoid villi (point of very low energy).[6]

Intracranial tumors and especially cranial base tumors are approached by advanced surgical techniques such as Extended Endoscopic Endonasal

Approaches, achieving radical surgical exeresis in most cases. However, the resulting surgical cavity may contact or be part of some point of the intracranial hydrodynamic system therefore receives the influences of the hydrodynamic laws.[1,2,6]

Table 2 and Figure 2 show a significant increase in the CSF leak index as the type of surgical cavity increases, showing a higher incidence in types 2 and 3.

Before analyzing this behavior, it is important to consider some concepts:

Surgical cavity: after a systematic review we did not find a precise concept, therefore, we define it as the anatomical space resulting from the surgical approach once the tumor exeresis has been performed.

Hydrodynamic pressure: It is the force exerted by the fluid in motion on the walls of the cavity. This movement is defined by a vector field of velocities corresponding to the particles of the fluid and a scalar field of pressures, corresponding to the different points of the fluid in the cavity.[6,7]

Flow rate or output: It is the amount of liquid that flows in a given time by a part of the hydrodynamic system, for example, the amount of liquid that flows through the surgical cavity in 1 second.[6]

How do the laws of hydrodynamics influence surgical cavity?

First, if the surgical site is high-energy (the ventricular system), the hydrodynamic effect can overcome the resistance of the repair barrier, impede healing, and cause a CSF leak.

Second, the pressure of the CSF in motion increases in the surgical cavity above the pressure of the corresponding hydrodynamic point, that is, the pressure in the type 3 or ventricular surgical bed is going to be higher than the pressure in the Monro hole, this effect occurs because this surgical space will constitute a widening of the hydrodynamic system.[6-8]

If we take an Extended Endoscopic Endonasal Approach to the Tubercle and Sphenoid Plane in the excision of a suprasellar tumor that reaches the third ventricle (Example: Craniopharyngioma) as an example, the surgical cavity that is created is type 3 (ventricular). That is, a cavity is created wide in ventricular contact that will suffer an increase in pressure higher than other normal ventricular points, for example, the hole of Monro. [6,7,9,10]

For this demonstration, the law of fluid continuity must be applied; the amount of liquid that flows through Monro's foramen in a given time is the same as that which will flow through the surgical cavity, that is:

Monro flow = Surgical cavity flow

As the areas of the Monro foramen and the surgical cavity are different; to establish that equality then the liquid experiences an increase or decrease in flow velocity. For example, it increases its speed at the level of Monro's foramen and decreases at the level of the surgical cavity.

If we apply Bernoulli's theorem, which deals with the law of conservation of energy, then the sum of the kinetic, potential and pressure energies of a moving liquid at a given point is equal to that of any other point and mathematically is expressed:

P1+ KE1+ GPE1 = P2 + KE2 + GPE 2

If we take into account that the Potential Energy is similar in a patient lying down at rest with a slight flexion of the head of 15 degrees, at point 1 (Monro's hole) and Point 2 (surgical cavity), then:

P1+ KE1+ GPE1 = P2 + KE2 + GPE 2

P1+ KE1 = P2 + KE2, so using the formula for kinetic energy:

P1+ ½ Density x V1^2 = P2 + ½ Density x V2^2, since it is the same fluid, the density is the same.

P1+ ½ Density x V12 = P2 + ½ Density x V22, then this equality depends on the variables pressure and speed of the liquid.

We had previously defined that the velocity of the liquid in the surgical cavity was lower than in the Monro Foramen, then: according to the laws of hydrodynamics to maintain equality in this Bernoulli equation, the pressure of the liquid in the surgical cavity is greater than the fluid pressure in the Monro foramen. These equations can be applied to both ventricular, cisternal and subarachnoid points.[6,7,11]

This hydrodynamic increase in CSF pressure in the surgical cavity explains the higher frequency of CSF fistula appearance as the type of surgical cavity increases.

V. Conclusions

According to the obtained results, it is essential to define the type of surgical cavity resulting from tumor exeresis and predict consequent hydrodynamic effects. The skull base repair strategy should have a broader concept that includes a multilayer repair barrier as a point of high resistance, as well as a decrease in hydrodynamic pressure in the surgical cavity through different methods: transient continuous spinal drainage (in Type 2) as well as permanent or temporary ventricular drainage (in Type 3). This would favor total healing and a decrease in the incidence of CSF leak.

Bibliography

1. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. Neurosurg Focus. 2005; 19 (1): E3. Cited in: PubMed; PMID 16078817.

2. Gardner PA, Kassam AB, Snyderman CH, Carrau RL, Mintz AH, Grahovac S, et al: Outcomes following endoscopic, expanded endonasal resection of suprasellar craniopharyngiomas: a case series. J Neurosur..2008; 109(1): 6–16. DOI: 10.3171/JNS/2008/109/7/0006. Cited in: PubMed; PMID 18590427.

3. Landriellbañez FA, Hem S, Ajler P, Vecchi E, Ciraolo C, Baccanelli M, et al. A new classification of complications in Neurosurgery. World Neurosurg. 2011; 75(5-6): 709-15. DOI: 10.1016/j.wneu. 2010.11.010. Cited in: PubMed; PMID 21704941.

4. Pollay M. The function and structure of the cerebrospinal fluid outflow system. Cerebrospinal Fluid Res. 2010 Jun 21; 7: 9. doi: 10.1186/1743-8454-7-9. PMID: 20565964; PMCID: PMC2904716.

5. Shepard RB, Simpson DC, Sharp JF. Energy equivalent pressure. Arch Surg. 1966 Nov; 93(5): 730-40. doi: 10.1001/archsurg.1966.0133005 0034005. PMID: 5921294.

6. Machín MO, Arbolay OL. Concerns of cerebrospinal fluid leak in aggressive expanded endonasal endoscopic approach for craniopharyngiomas. J Neurol Stroke. 2020; 10 (4): 154-156. DOI: 10.15406/jnsk.2020.10.00430

7. Schmidt E, Ros M, Moyse E, Lorthois S, Swider P. Bernoulli´s Principle Applied to Brain Fluids: Intracranial Pressure Does Not Drive Cerebral Perfusion or CSF Flow. Acta Neurochir Suppl. 2016; 122: 107-11. Doi: 10. 1007/978-3-319-22533-3-21. PMID: 271165887

8. Rekate HL. A consensus on the classification of hydrocephalus: its utility in the assessment of abnormalities of cerebrospinal fluid dynamics. Childs Nerv Syst. 2011 Oct; 27(10): 1535-41. doi: 10.1007/s00381-011-1558-y. Epub 2011 Sep 17. PMID: 21928019; PMCID: PMC3175041.

9. BERING EA Jr, SATO O. HYDROCEPHALUS: CHANGES IN FORMATION AND ABSORPTION OF CEREBROSPINAL FLUID WITHIN THE CEREBRAL VENTRICLES. J Neurosurg. 1963 Dec; 20: 1050-63. doi: 10.3171/jns.1963.20.12.1050. PMID: 14186107.

10. Wagshul ME, Eide PK, Madsen JR. The pulsating brain: A review of experimental and clinical studies of intracranial pulsatility. Fluids Barriers CNS. 2011 Jan 18; 8(1): 5. doi: 10.1186/2045-8118-8-5. PMID: 21349153; PMCID: PMC3042979.

11. Czosnyka M, Pickard JD. Monitoring and interpretation of intracranial pressure. J Neurol Neurosurg Psychiatry. 2004 Jun; 75(6): 813-21. doi: 10.1136/jnnp.2003.033126. PMID: 15145991; PMCID: PMC1739058.