The Superior Medullary Velum and its Contribution to Obstructive Hydrocephalus: Anatomical Characterization and Surgical Targeting Considerations in an Image-Based Case Review

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■ BACKGROUND: **Obstructive hydrocephalus caused by a membranous or synechial occlusion at the level of the superior medullary velum (SMV) is likely under-recognized and may be mislabeled as aqueductal stenosis. We aimed to describe the anatomical pattern of these "velar obstructions" and discuss their surgical targeting implications.**

■ METHODS: **We retrospectively rereviewed 94 patients previously classified as primary aqueductal stenosis (1995–2015) and identified 5 cases (5%) with an obstruction caudal to the aqueductal tectum, at the SMV. A targeted literature search retrieved 18 additional reports with midline sagittal magnetic resonance imaging compatible with a velar-level occlusion. In the primary series, morphometrics were obtained from calibrated imaging. Literature cases were used for qualitative/topographic assessment. The SMV was segmented into A (externally free) and B (covered by the lingula), and the occlusion site was classified as A, AB junction, or B.**

■ RESULTS: **In the combined cohort (n = 23), the AB junction was the most frequent site (12/23). In the primary series (n = 5; mean age: 34 years; range: 14–47), the sagittal depth of the dilated cavity averaged 24 mm (range: 17–33) and consistently exceeded the length of the aqueductal tectum. Morphometric patterns were heterogeneous. Across cases with reported treatment (20/23), endoscopic third ventriculostomy was the most common strategy, alone or combined with transaqueductal fenestration.**

■ CONCLUSIONS: **Velar occlusion is a distinct imaging-anatomical pattern that may influence endoscopic planning. Any endoscopic fenestration at the SMV level ("velarplasty") should be framed as investigational and must explicitly account for the nearby trochlear nerve decussation and vermian/lingular relationships.**

INTRODUCTION

In published studies, images improperly identified as aqueductal obstructions are occasionally encountered, although the blockage is located caudally to the aqueduct, namely in the superior medullary velum (SMV), the upper portion of the fourth ventricle.[1-21]

Although the hydrodynamic consequences do not differ from the more commonly recognized aqueductal pathology, these rare cases could be more aptly termed "velar obstructions". This

Key words
- Aqueductoplasty
- Cerebral aqueduct
- ETV
- Hydrocephalus
- Stenosis
- Superior medullary velum
- Trochlear nerve
- Velar obstruction
- Velarplasty

Abbreviations and Acronyms
CN IV: Trochlear nerve
CSF: Cerebrospinal fluid
ETV: Endoscopic third ventriculostomy
FV: Frenulum veli
SMV: Superior medullary velum

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uncommon anatomical feature has not been comprehensively discussed despite some notable hints that can be found in the literature. Barkovich first defined these cases as "far caudal aqueductal obstructions", demonstrating that he had noticed the peculiar position of such obstruction. A few years later, Dinçer termed analogous cases as aqueductal obstruction due to "septum of velar synechiae near the fourth ventricle".[15] Similarly, Cinalli et al. mentioned a potential occlusion at the level of "the junction between the tectal plate and the SMV", making it interpretable as the extreme boundary of the aqueduct rather than the SMV per se.[20] More recently, Özcan et al., in their classification of focal stenosis and membrane formation of the cerebral aqueduct, provided a precise, well-defined classification of stenosis: pars anterior, ampulla, pars posterior, and finally the SMV.[22]

Beyond the subtle nuances of anatomical classifications, this uncommon subgroup of velar obstructions is worthy of interest and could even suggest more specific indications of endoscopic treatment, which should be specifically named "velarplasty". In this study, some paradigmatic images of velar obstructions are presented and compared with similar cases found in the literature, delineating the morphological characteristics of this peculiar, poorly investigated type of occlusive hydrocephalus.

Anatomy of the Structures Caudal to the Aqueductal Tectum

The SMV is a membrane characterizing the superior segment of the roof of the fourth ventricle, bordered by the superior cerebellar peduncles (Supplemental Figure 1). It begins with the frenulum veli (FV), which is anchored at the caudal extremity of the cruciate sulcus, located at the end of the inferior colliculi. The FV, true to its name, functions as a midline suspensory ligament, helping the SMV to be kept suspended. Its geometry resembles a narrow triangle, with the apical angle positioned at the extremity of the inferior colliculi.[23] Topographically, this small yet significant structure connotes the transition from the aqueductal cavity to the fourth ventricle.

Possibly due to its limited relevance in standard surgical corridors, the SMV has been marginally studied.[24] It appears as a thin V-shaped membrane, narrow rostrally and broader caudally, usually convex toward the floor of the fourth ventricle (Supplemental Figure 1).[25] It lies between the superior cerebellar peduncles and continues caudally toward the fastigium. Histologically, the SMV contains white matter fibers (including cerebello-tectal and tecto-cerebellar connections).[26] Importantly, the rostral SMV/FV region is closely related to the decussation of the trochlear nerve (CN IV) fibers; therefore, the SMV cannot be considered devoid of functional neural structures.[27] Any endoscopic fenestration in this area requires a safety strategy aimed at avoiding the rostral decussation zone and minimizing thermal injury.

The ventral surface of the SMV, in contact with the fourth ventricle, is coated with ependyma. The dorsal surface is partly free, covered by the cerebrospinal fluid (CSF) of the subarachnoid space (labeled as A in all the figures) and partly covered by the Lingula of the cerebellum (labeled as B) (Figure 1). The length of the free portion should not exceed 25%–30% of the covered portion, although some authors consider them equal.[24] As discussed later, the border between these 2 parts A and B has a particular interest as a privileged site of velar adhesions and occlusions.

MATERIALS AND METHODS

Among hydrocephalic patients treated at our department between 1995 and 2015, 94 cases had been classified as primary aqueductal stenosis and were managed with endoscopic procedures (11 pediatric, 83 adults; mean age: 47 years; range: 1–82). During a dedicated imaging rereview, 5 cases were reclassified as having an obstruction caudal to the aqueductal tectum, at the level of the SMV ("velar obstruction").

Literature cases were identified through a targeted search of PubMed and Google Scholar and by screening references of relevant reviews and case series. We included reports providing a midline sagittal magnetic resonance imaging (or equivalent) that allowed assessment of the caudal aqueduct/SMV region and showed a membranous or synechial obstruction located caudal to the tectum. Reports without sufficient imaging to localize the obstruction were excluded.

Morphometric measurements (SMV segment lengths; sagittal depth of the dilated cavity; and diameters at the adytum, ampulla, and caudal tectum) were performed only for the 5 primary cases using calibrated imaging (Figures 1 and 2). For literature cases, sketches overlaid on published images were created solely to illustrate topography (Supplemental Figure 2) and were not pooled with primary measurements for quantitative statistics. The SMV was segmented into A (externally free) and B (covered by the lingula), and the presumed adhesion/occlusion site was categorized as A, AB junction, or B. Given the retrospective design and the use of anonymized data, this study was conducted in accordance with local regulations and the Declaration of Helsinki.

RESULTS

The 23 cases (5 primary and 18 literature-derived) encompassed membranous occlusions (Figure 2) and more complex synechial configurations (Figure 3) at the SMV level. Topographically, the AB junction appeared to be a frequent site of adhesion/occlusion (12/23), followed by distal B-segment involvement. In the primary series, the dilated cavity depth averaged 24 mm (17–33 mm), consistently extending beyond the aqueductal tectum, and the SMV-A/SMV-B relationship varied widely, suggesting a spectrum from marked ballooning of the free velum to more distal/rigid patterns (Table 1). Treatment information was available for 20 cases: endoscopic third ventriculostomy (ETV) alone was reported in 47%, transaqueductal fenestration/aqueductoplasty in 31%, and combined strategies in 15% (Table 2). In our experience, ETV was judged unsafe in 2 patients because of unfavorable third-ventricular floor/prepontine anatomy; in these cases, a transaqueductal approach to the obstructing membrane was used, while ETV was added when deemed safe (Table 1).

DISCUSSION

The cerebral aqueduct is commonly defined from the adytum to the caudal limit of the tectum at the level of the inferior colliculi. Accordingly, some authors may interpret distal membranous obstructions as "caudal aqueductal" lesions. However, in the

Table 1. Primary Institutional Cases (Calibrated Measurements)

Cases	Age (years), Sex	Surgical Procedure	SMV-A (mm)	SMV-B (mm)	Site of Occlusion	Sagittal Extent (mm)	Aq1 Dilatation (mm)	Aq2 Dilatation (mm)	Ampullar Dilatation (mm)
1	38, M	AQP	32	16	AB	24	8	20	24
2	47, M	AQP + ETV	22	8	A	33	6	11	9
3	31, F	AQP	14	22	AB	24	8	12	14
4	41, F	ETV	5	24	B	22	8	3	10
5	14, M	ETV	5	24	B	17	5	2	7

SMV, superior medullary velum; Aq1, aqueduct diameter at the adytum; Aq2, aqueduct diameter at the most caudal part of the tectum; M, male; AQP, aqueductoplasty; ETV, endoscopic third ventriculostomy; F, female.

cases highlighted here, the obstructing membrane/synechiae is located caudal to the tectum and involves the SMV, that is, the superior roof of the fourth ventricle. Recognizing this topography is not merely semantic: it affects endoscopic targeting, risk assessment, and the choice between ETV and local fenestration.

The involvement of the SMV in an obstructive pathological condition recalls the historical term for this anatomical structure, known as the Vieussens' valve or the "valvula cerebri major."[28] This nomenclature arises from its convex shape directed toward the floor of the fourth ventricle. In earlier times, the shape of the SMV was mistakenly interpreted as an evolutionary adaptation by the brain to prevent the escape of CSF from the internal ventricles. Our previous studies using endoscopic techniques have characterized the roof of the fourth ventricle, showing the convex bulging shape of the SMV.[29-31] This configuration indeed resembles a valve, aligning with the observations made by the

Table 2. Literature-Derived Cases Used for Qualitative/Topographic Assessment (Morphometrics not Pooled with Primary Measurements)

Cases	Age (years), Sex	Surgical Procedure	Site of Occlusion
A	17	ETV	B
B	N/A	VPS	AB
C	20	ETV	AB
D	23	ETV	A
E	25	ETV	A
F	17	ETV	B
G	N/A	AQP	A
H	N/A	AQP	AB
I	42	ETV	AB
J	10	–	AB
K	N/A	N/A	AB
L	N/A	AQP	B
M	N/A	ETV + AQP	A
N	N/A	ETV	A
O	N/A	AQP	AB
P	N/A	N/A	AB
Q	N/A	AQP	AB
R	N/A	ETV + AQP	A

ETV, endoscopic third ventriculostomy; N/A, not available; VPS, ventriculoperitoneal shunt; AQP, aqueductoplasty.

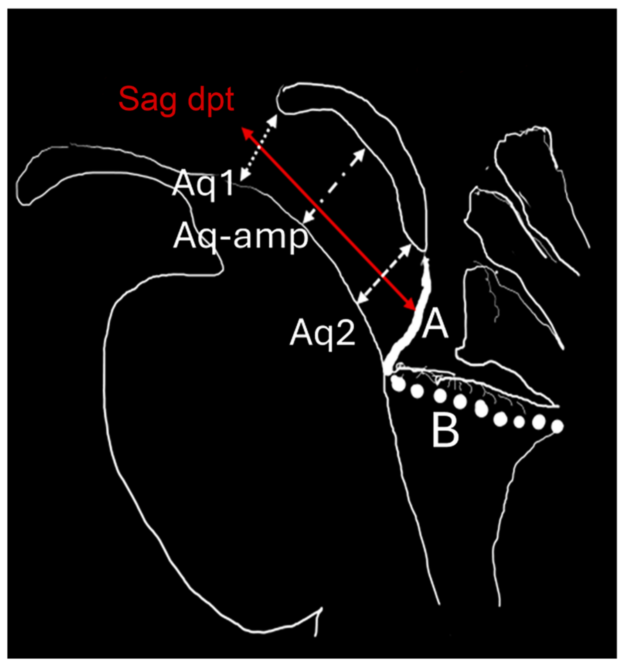

Figure 1. Sketch-guide illustrating the measurements of the cavity caused by velar obstruction: the sagittal depth of the ballooning (Sag dpt), the cranial dilatation of the aqueduct at the adytum (Aq1), at the ampullary level (Aq-amp), and at the most caudal part of the tectum (Aq2). The continuous *white line* (**A**) designates the part of SMV that is externally free and solely bordered by the subarachnoid space. *White dotted lines* indicate the portion of SMV externally capped by the vermian lingula. SMV, superior medullary velum.

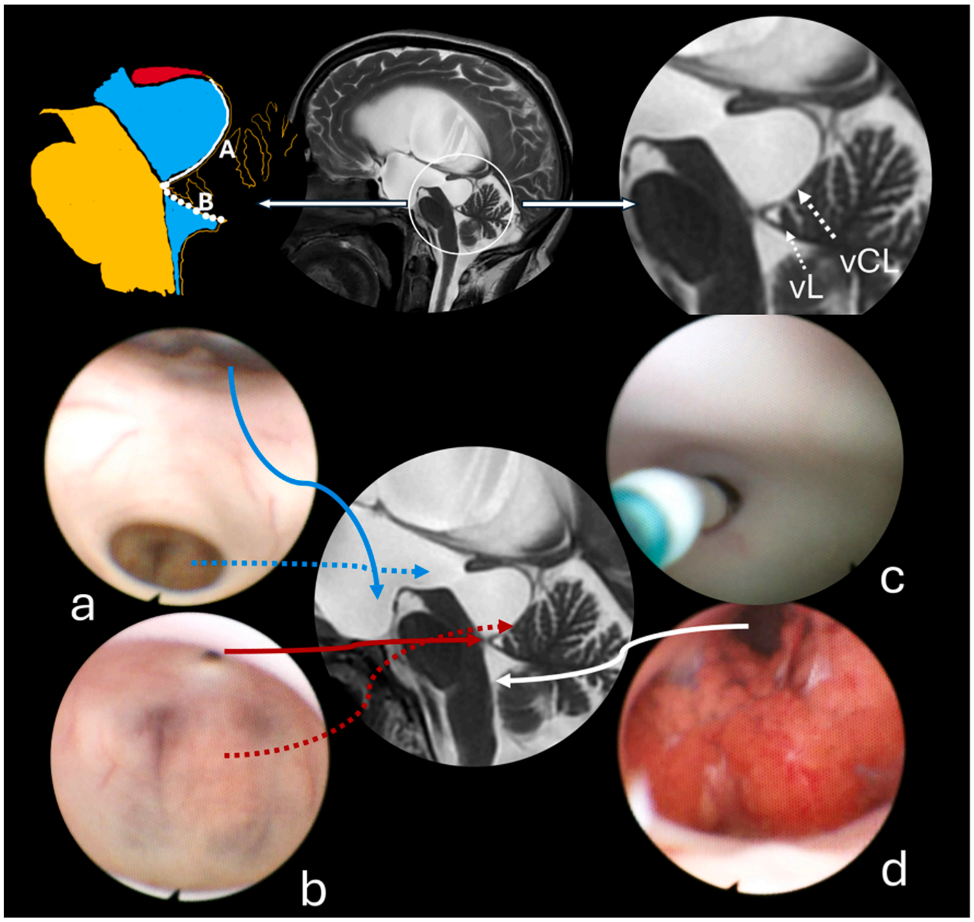

Figure 2. The figure illustrates the case n.1 (Table 1). In the upper part, the sketches reflect the relevant areas; the aqueductal tectum (*red*), and the 2 components of the SMV: **A**, the free part indicated with a solid white line mainly covered by vermian Central Lobule (vCL) and **B**, drawn with dotted white line, the caudal component covered by the vermian Lingula (vL). In the inferior part, sequences of the "aqueductoplasty". (**A**) The third ventricle floor superiorly, a *solid blue arrow* shows the dilation into the interpeduncular cistern with the profile of the basilar artery; posteriorly, the aqueductal adytum (*dotted blue arrow*). (**B**) View inside the ballooning: a small hole opens into the fourth ventricle (*solid red arrow*); the *dotted red arrow* indicates the dorsal vermis (Central Lobule-Lingula), covered by the thinned translucent membrane of the SMV, demonstrating that the obstruction is not in the aqueduct. (**C**) Fogarty balloon opening the obstruction. (**D**) View of the fourth ventricle with the Magendie foramen (*white arrow*). SMV, superior medullary velum.

notable French anatomist (Supplemental Figure 1). The most cranial part of the SMV is called FV, which is implanted caudally between the 2 posterior colliculi.

A possible pathogenic hypothesis suggested in the past for aqueductal stenosis could be even more pertinent for velar obstructions. According to this hypothesis, the increased pressure in the subarachnoid space, potentially caused by communicating hydrocephalus, might push down the SMV, thereby promoting the formation of adhesions. This could convert communicating hydrocephalus into obstructive hydrocephalus.[32,33] Moreover, it is crucial to recognize that the cranial segment of the SMV is thin and more susceptible to being compressed. In contrast, the caudal portion is better protected by the vermian lingula.

The mechanical effects of these velar occlusions are predictable. The adhesion occurs more frequently at the junction between segments A and B of the SMV. Consequently, segment A becomes significantly dilated, leading to marked ballooning, often equating in length to the aqueductal tectum. Conversely, in case of proper aqueductal obstructions, the shape of the dilation of the aqueduct of Sylvius varies depending on the location of the obstruction.[20] When it occurs at the level of the adytum, the aqueductal lumen does not enlarge; instead, only a subtle CSF stream can be seen. If the obstruction occurs more caudally, particularly at the end of the tectum, a dilation in the sagittal plane, resembling an open mouth, is frequently observed. As Cinalli aptly illustrated, "...the whole tectal plate can pivot backward, opening largely the whole length of the

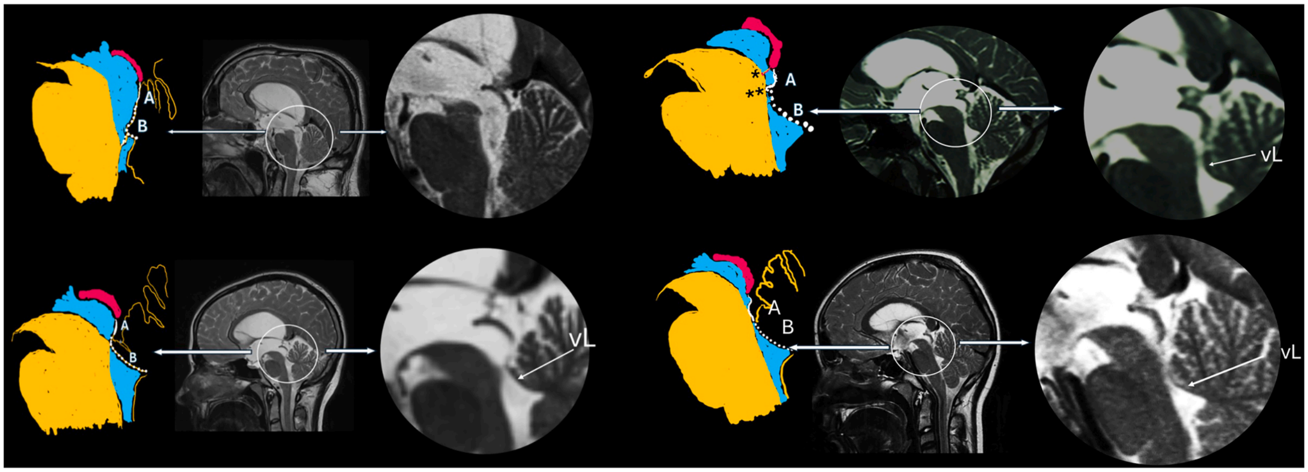

Figure 3. The figure summarizes cases 2, 3, 4, and 5 of our series detailed in Table 1. The sketches show the aqueductal tectum (*red*), the 2 components of the SMV: the free part (**A**), evidenced by a *solid white line*, and the caudal component (**B**) covered by the vermian Lingula (vL), drawn with *dotted white line*. Top right image: there are 2 obstructive membranes (*), the caudal one being the most significant for the blockage. SMV, superior medullary velum.

aqueduct."[20] Conversely, the notable ballooning of the aqueduct and caudal structures is shown only when membranous occlusions occur beyond the tectum, specifically at the level of the SMV in the fourth ventricle. In our cases, we observed the dilatation ratio of the aqueductal tectum (adytum, mean 6 mm, compared to the caudal posterior colliculi 6 mm) averaged around 1 (Supplemental Figure 2, Tables 1 and 2). That indicates that the tectum is uniformly expanded and distended much above the base of the aqueductal channel, providing evidence that the occlusion does not involve anatomically the aqueduct. With such ballooning, it is challenging to define the tensile strength of structures past the tectum; the small FV remains vaguely perceptible in terms of its shape and consistency. The cranial portion of the frenulum, being traversed by the trochlear decussating fibers, could mechanically have a certain solidity; the caudal portion of the FV instead shares the same characteristics of the SMV, and with it could widely become stretched and expanded.

The reported incidence of SMV-level (velar) obstructions varies widely across studies (from approximately 2%–3% to > 30%),[22,34] likely reflecting heterogeneous diagnostic criteria, referral patterns, and, importantly, differences in magnetic resonance imaging protocols (availability of heavily T2-weighted steady-state sequences such as 3D-Constructive Interference in Steady State/Fast Imaging Employing Steady-State Acquisition) that improve visualization of thin membranes and reduce flow-void misinterpretation. This variability supports the need for a clearer, imaging-based definition and standardized reporting.

From a treatment standpoint, most reported patients were managed with ETV, alone or in combination with transaqueductal fenestration/aqueductoplasty. Because many literature reports lack standardized follow-up and outcome reporting, comparative effectiveness and long-term patency (including readhesion/restenosis) remain uncertain, representing a key limitation and a priority for future multicenter data collection.

In cases where the obstructing membrane is clearly located at the SMV, a local fenestration may be conceptually described as "velarplasty". However, this should not be proposed as a new standard treatment on the basis of the present data. Instead, it should be framed as an investigational, anatomy-driven option in selected patients (e.g., when ETV is not feasible or as an adjunct), with explicit attention to safety. First, the rostral SMV/FV region is related to the CN IV decussation; therefore, fenestration should avoid the rostral decussation zone and the use of thermal energy. Second, manipulation of segment B implies proximity to the lingula/vermis and potential cerebellar morbidity. When performed, cold instruments and/or gentle balloon dilation may reduce collateral injury. Recent technical reports on endoscopic fenestration of the SMV in related contexts (e.g., trapped fourth ventricle) further support the anatomical feasibility while underscoring the need for outcome data.[35]

CONCLUSIONS

Velar membranous/synechial occlusion at the level of the SMV is an under-recognized cause of obstructive hydrocephalus that can be mistaken for aqueductal stenosis on routine imaging. An explicit imaging-anatomical characterization may improve diagnostic accuracy and endoscopic planning. While ETV remains an established and effective treatment for many patients, local SMV-level fenestration ("velarplasty") should be considered investigational and must incorporate a safety strategy that respects the CN IV decussation and vermian relationships. Prospective studies with standardized imaging and clinical outcome reporting are needed to define indications, risks, and durability.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Pierluigi Longatti: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francesca Siddi:** Writing – review & editing, Validation, Methodology, Formal analysis. **Alessandro Fiorindi:** Validation, Formal analysis, Data curation. **Giorgio Gioffrè:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Alessandro Boaro:** Writing – review & editing, Validation, Formal analysis, Data curation. **Francesco Di Paola:** Writing – review & editing, Validation, Data curation. **Adi Ahmetspahic:** Validation, Formal analysis, Data curation. **Alberto Feletti:** Writing – review & editing, Writing – original draft, Validation, Supervision, Investigation, Formal analysis, Data curation, Conceptualization.

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