Craniopharyngioma adherence to the hypothalamus

TO THE EDITOR: We have viewed with great interest the special supplement published by *Neurosurgical Focus* in January 2013 (*Neurosurgical Focus*, Video Atlas of Operative Surgery: Intraventricular Lesions: Microscopic and Endoscopic Approaches, Vol 34: January 2013) in which a compilation of videos demonstrating different surgical procedures for third ventricle lesions is presented. Three of these outstanding didactic videos show, in microscopic detail, the surgical view and delicate maneuvers used to remove craniopharyngiomas (CPs) largely or exclusively involving the third ventricle. The featured techniques utilize three utterly different operative pathways: 1) the subfrontal translamina terminalis approach (Liu JK: Modified one-piece extended transbasal approach for translamina terminalis resection of retrochiasmatic third ventricular craniopharyngioma. *Neurosurg Focus (Suppl)* 34(1):Video 1, 2013);²⁰ 2) the frontal transcortical-transforaminal approach (Chamoun R, Couldwell WT: Transcortical-transforaminal microscopic approach for purely intraventricular craniopharyngioma. *Neurosurg Focus (Suppl)* 34(1):Video 4, 2013);³ and 3) the endoscopic extended transsphenoidal approach (de Lara D, Ditzel Filho LFS, Muto J, et al.: Surgical management of craniopharyngioma with third ventricle involvement. *Neurosurg Focus (Suppl)* 34(1):Video 5, 2013).⁸ Taken together, these videos provide comprehensive evidence of one of the paradigmatic controversies in the surgical treatment of CPs: the possibility of a complete and safe removal of lesions closely attached to the hypothalamus. A range of surgical approaches seems to be equally valid to successfully remove such highly challenging lesions as third ventricle CPs whenever the approach is performed by an experienced and skilled neurosurgeon. Nevertheless, the reasons for choosing each of these specific approaches for the particular cases of CPs featured in these videos are not explicitly stated, nor is the rationale for using a considered approach usually discussed in articles or monographs about this kind of tumor, apart from the surgeon's preference based on his or her experience. Assuming that the likelihood of a successful patient outcome is obviously related to a surgeon's experience, the need for a rationale to guide the surgical plan for these rare and rather heterogeneous lesions is unquestionable. Although these three CPs largely involve the third ventricle and cause gross morphological distortion of the hypothalamus, several topographical and

morphological particularities displayed by each lesion on preoperative MRI studies can provide useful clues to anticipate the tumor-hypothalamus relationship and to help the surgeon plan the proper surgical strategy accordingly. Among these relationships, the extent and degree of CP adhesion to the hypothalamus is the fundamental factor to be taken into account. We think that the surgeon's intuition regarding the CP's accurate anatomical location and the type of hypothalamic involvement has largely contributed to the appropriate selection of the route and surgical technique to be performed in each case.

In this letter we wish to highlight some fundamental topographical and pathological differences among the three CPs presented in these videos; these differences can be observed on MRI studies and revealed in the surgical field (Fig. 1 and Table 1). In particular, we would like to address the issue of CP adherence to the hypothalamus as a factor related to the specific type of third ventricle involvement by the lesion. This factor is too often overlooked or simply ignored, but it significantly influences the possibility of a safe total resection of the CP through a specific approach. We are firmly convinced that the successful outcome for each of these three CPs had much to do with the choice of the most suitable surgical approach that optimally dealt with the type and degree of hypothalamic adherence associated with each topographical category of intraventricular CP.

In the video by Chamoun and Couldwell, the microsurgical removal of two purely third ventricle CPs is shown (Fig. 1b1–b5).³ The primary intraventricular location of these solid masses was suspected when the anatomical sparing of the pituitary stalk and the tumor-free suprasellar cistern were observed on the preoperative sagittal and coronal MRI studies of both patients (Fig. 1b1–b2). The frontal transcortical-transforaminal (FTV) approach to these lesions was favored by the presence of enlarged lateral ventricles and a dilated foramen of Monro. Although the anatomical integrity of the third ventricle floor (TVF) can hardly be demonstrated on routine preoperative MRI studies, several clinical and radiological data strongly supported the topographical diagnosis of purely intraventricular tumors in these patients. Both lesions were solid and had round shapes with smooth surfaces. Moreover, both of them enhanced homogeneously after Gd administration. These features, typical of the squamous-papillary CP variant, differ greatly from those of the solid-cystic, multilobulated structure displayed by the adamantinomatous CP, which usually has its origin below the third ventricle. In fact, a careful assessment of the MRI studies presented in this video allows identifica-

Fig. 1. Representative MR images and intraoperative photos selected from the surgical videos by de Lara et al. (a_1 – a_4),⁸ Chamoun et al. (b_1 – b_4),³ and Liu et al. (c_1 – c_4),²⁰ showing the distinctive topographical and pathological features of the three categories of intraventricular CPs discussed in this letter. For each topographical category, an illustration of the tumor–third ventricle anatomical relationship is displayed on the far right (a_5 , b_5 , c_5). Each CP type presented a specific extension and degree of adherence to the surrounding neural structures. Sagittal T1-weighted MR image (a_1) obtained after Gd enhancement, showing a small round solid tumor centered at the level of the TVF, between the optic chiasm and the mammillary body. Notice the anatomical integrity of the pituitary stalk and the pituitary gland. Intraoperative photos (a_2 – a_4) show the surgical steps for tumor removal through an extended endonasal transplanum–transtuberulum sellae approach (EEA) approach. The lower pole of the tumor is embedded within the TVF, at the junction of the optic chiasm (a_2 , black arrow) and the upper pituitary stalk (white arrow) (a_3). The intactness of the pituitary stalk with its portal vessels is preserved (white arrow). The entire circumferential rim of adherence between the CP and the surrounding walls of the infundibulum and posterior aspect of the optic chiasm can be perfectly visualized and suitably dissected with this inferior approach without distorting the delicate adjacent neural structures or perforating vessels to the hypothalamus and chiasm undersurface. After removing the tumor a circumferential defect or breach at the TVF (chiasm–infundibulum junction) is left, allowing endoscopic exploration of the third ventricle (3v) (a_4). The rim of adherence of the tumor, which had developed and replaced the proper neural layer of the TVF, is evident in this photo (black arrows). This lesion is classified as an infundibulo-tuberal, or not strictly intraventricular, CP (a_5). Published with permission from de Lara et al: *Neurosurg Focus (Suppl)* 34(1):Video 5, 2013. Sagittal (b_1) and coronal (b_2) T1-weighted MR images obtained after Gd enhancement, showing a round solid tumor that occupies the anteroinferior recesses of the third ventricle, above an anatomically intact pituitary stalk. Notice the anatomical integrity of the pituitary gland as well as the grainy tumor structure, a reflection of the berry-like epithelial protrusions of the squamous-papillary histological CP variant. Intraoperative photos (b_3 – b_4) show the surgical steps for tumor removal through the frontal transcortical-transforaminal approach. The papillary soft structure of the tumor is confirmed intraoperatively (b_3). Notice how the upper portion of the lesion does not present significant adherences to the fornix or the third ventricle walls. After removing the central bulk of the tumor, its pedicle-like attachment to the ependymal outlining of the TVF is revealed (b_4 , white arrow). This lesion is classified as a purely or strictly intraventricular CP (b_5). Published with permission from Chamoun et al: *Neurosurg Focus (Suppl)* 34(1):Video 4, 2013. Sagittal T1-weighted MR image (c_1) obtained after Gd enhancement, showing a mixed solid-cystic multilobulated mass that predominantly involves the third ventricle. These morphological features are typical of the adamantinomatous histological CP variant. Notice the CP engulfment of the pituitary stalk, which cannot be identified as an independent structure, as well as the occupation of the suprasellar cistern by the tumor. Intraoperative photos (c_2 – c_3) showing the surgical steps for tumor removal through the subfrontal transbasal translamina terminalis (TLT) approach. The lamina terminalis (LT) is opened after exposing the prefixed optic chiasm (OC, c_2). Notice how the tumor is hidden at a retrochiasmatic position, which prevents the surgeon from attempting its removal through the interoptic or optic-carotid spaces. After achieving the removal of the upper and central portions of the lesion through the lamina terminalis (c_3), the chiasm recovers its original position and the interoptic space becomes widened to expose the suprasellar, extraventricular lower tumor portion (ev) while the tight adherences to the breached remnants of the TVF can be dissected under direct view through the lamina terminalis (iv). After removing the tumor (c_4), a wide defect or breach at the TVF can be observed both intraoperatively and on the postoperative MRI study (white arrow). This lesion is classified as a secondary intraventricular CP (c_5). Published with permission from Liu et al: *Neurosurg Focus (Suppl)* 34(1):Video 1, 2013.

TABLE 1: Characteristics among the strictly, not strictly, and secondarily intraventricular CP topographical categories*

CP Characteristic & Category	Strictly IV CPs	Not Strictly IV CPs	Secondary IV CPs
no. of patients	31	51	30
age			
children, age <18 yrs	19%	44%	60%
adults, age >18 yrs	81%	56%	40%
shape			
round	74%	40%	0%
elliptical	26%	57%	33%
multilobulated	0%	3%	67%
consistency			
pure solid	58%	27%	6%
cystic-basal solid	3%	8%	16%
pure cystic	33%	41%	33%
mixed solid-cystic	6%	23%	43%
sella turcica involvement			
invaded by tumor	3%	17%	47%
tumor free	97%	83%	53%
pituitary stalk involvement			
whole stalk infiltrated/invaded	10%	47%	90%
partial/whole stalk free of tumor	90%	53%	10%
suprasellar cistern involvement			
free of tumor	55%	12%	0%
partial occupation	39%	55%	27%
wholly occupied	6%	37%	63%
CP extensions into basal cisterns			
present	0%	18%	47%
absent	100%	82%	53%
pituitary gland			
visible intact	100%	88%	60%
compressed/invaded by tumor	0%	12%	40%
hydrocephalus			
present	80%	65%	60%
absent	20%	35%	40%
histology			
adamantinomatous	25%	78%	100%
squamous-papillary	75%	22%	0%
hypothalamus level relative to CP on coronal MRI			
lower third	73%	28%	5%
mid third	23%	60%	63%
upper third	4%	12%	32%

* IV = intraventricular. Data obtained from Pascual et al., 2013.²⁵

tion of a grainy tumor structure in both lesions, a distinctive sign reflecting the papillary, berry-like epithelial protrusions of this rare CP variant. The anterobasal portion of both tumors pointed into the funnel-shaped infundibular and chiasmatic recesses of the third ventricle, an additional sign supporting development of the tumors within the third ventricle (Fig. 1b2). Even a thin gray rim of neural tissue around the lower pole of the tumors can be

observed after a thorough examination of the MRI, a definite sign to make the diagnosis of a purely intraventricular CP (Fig. 1b1). Squamous-papillary CPs are known to develop predominantly within the third ventricle, and they are more frequently diagnosed in adult or elderly patients who have atypical clinical manifestations, such as abnormal changes in behavior, dementia-like cognitive deficits, Korsakoff-like short-term memory loss, and/or new-onset

gait imbalance.^{6,24,25,29} Some of these symptoms are described for the two elderly patients presented in the video, clinical findings that substantiate the diagnosis of purely third ventricle squamous-papillary CPs.

Intraoperative images of the two CPs shown in the video by Chamoun and Couldwell confirmed the papillary soft structure that could be anticipated with the morphological and topographical characteristics displayed on preoperative MRI (Fig. 1b3). Nevertheless, the fundamental fact to predict for these uncommon lesions is not the intactness of the TVF but rather the degree of tumor adherence to the walls and/or floor of the ventricle, which mark the boundaries of the vital hypothalamus. The type of hypothalamic attachment of any CP involving the third ventricle represents the key aspect in envisioning the feasibility of a safe gross-total removal of the lesion, as well as the surgical risks associated with the choice of a specific surgical approach. In an extensive review of 105 well-described intraventricular CPs described in medical literature between 1953 and 2003, we could classify the degree of CP adherence in 45 cases that provided a detailed description of the tumor–third ventricle relationships.²³ More than 90% of third ventricle CPs presenting with a narrow pedicle-like basal attachment to the TVF corresponded to the squamous-papillary variant. These tumors could be easily removed from the third ventricle after sectioning this attachment, without inflicting noticeable damage to the hypothalamus. Conversely, around 70% of CPs showing tight adhesions to the third ventricle walls and/or floor belonged to the adamantinomatous variant. The FTV approach was used in 40% of the intraventricular CPs analyzed in our study and, together with the transcassal (TC) approach, yielded the highest mortality rate (45%), independent of the degree of removal achieved. Besides the fact that some of these cases were surgically treated before standard microsurgical techniques had been established, the major reason for such high mortality was the inability of surgeons to accurately differentiate the easily dissected CPs of the squamous-papillary type from the adamantinomatous tumors tightly adhered to the hypothalamus. Interestingly, mortality associated with FTV approach was higher after partial removal of the tumor than after a gross-total excision. This finding strongly suggests that the degree of CP adherence to the hypothalamus is a major determinant of a successful operative outcome.

The FTV and TC approaches to intraventricular CPs compel the surgeon to start the debulking and dissection of the tumor from its upper portion, without allowing adequate assessment of its basal pole from the beginning of the surgical procedure. It is precisely in this region where the lesion presents the tightest adherences to the hypothalamus. Undue surgical maneuvers, such as grabbing the tumor capsule and pulling it from its basal attachment without direct vision and proper sharp dissection along the plane of cleavage between the tumor and the hypothalamus, may cause irreversible traumatic or ischemic injury to this vital area, leading to a fatal outcome, as occurred in many of the cases in our historical series.^{22,23} Such a setback is not generally posed by purely third ventricle CPs of the squamous-papillary type, and the FTV

approach represents a safe pathway in this much more easily dissectible subgroup of intraventricular tumors. The results of the straightforward, undemanding dissection of the two CPs treated by Chamoun and Couldwell exemplify the loose attachment of the tumors to the hypothalamus. Therefore, the accurate preoperative topographical and histological diagnosis of intraventricular CPs is of paramount importance before selecting the FTV approach for the removal of such lesions. Heavily T2-weighted and 3D-FIESTA MRI sequences have proved to be helpful methodologies in making an accurate preoperative diagnosis of purely intraventricular CPs of the squamous-papillary type and should be used to plan the appropriate surgical approach accordingly.^{12,32,38}

In contrast to the previously discussed surgical procedures, the video by Liu displays the microsurgical removal of a retrochiasmatic, largely intraventricular CP through the subfrontal transbasal translamina terminalis (TLT) approach (Fig. 1c1–c5).²⁰ The TLT approach through a bilateral subfrontal route allows a wide exposure and complete exploration of the subchiasmatic and parasellar extraventricular extensions of CPs, as well as exploration of the intraventricular extension of the tumor, especially of the basal third ventricle, where the CP's tightest attachment to the hypothalamus is usually found. For these reasons, the TLT approach is quite suitable for dealing with CPs involving both the suprasellar and the third ventricle compartments, the group of CPs classified as extra-intraventricular tumors in Steno's topographical scheme.^{34,35} The most remarkable feature of these CPs is their extremely tight and wide adherence to the hypothalamus. A major drawback of the TLT approach is the limited exposure of the upper intraventricular and posterior interpeduncular (extraventricular) portions of the tumor, but these areas have proved to present the loosest adhesions to neural structures and can be safely mobilized without direct visual control.^{15,36,39} The major advantages of the TLT approach are the optimal surgical view and the control of both third ventricle walls that it provides. Many extra-intraventricular CPs present a circumferential, tight band of attachment to the TVF around their central portion that can be observed and dealt with properly from the beginning of tumor excision with the TLT approach.

Two principal topographical variants of extra-intraventricular CPs can be differentiated on preoperative diagnostic studies: 1) lesions developing initially at the suprasellar area and eventually invading the third ventricle after breaking through its floor; and 2) CPs originating at the TVF itself and growing predominantly into the third ventricle but also protruding into the suprasellar cistern, located either within the neural layer of the infundibulum or retroinfundibularly, within the tuber cinereum.^{1,10,21,22,24–26} In our classification model we have termed the former category as “secondary intraventricular” CPs and the latter as “not strictly intraventricular,” or “infundibulo-tuberal,” CPs.^{23,35} Definite anatomical and pathological features identifiable on preoperative MRI are useful clues to help surgeons differentiate between these two topographies (Table 1).

The lesion displayed in the preoperative MRI in the video by Liu has the typical features of a suprasellar ada-

mantinomatous CP. Occupation of the chiasmatic cistern by the tumor, the envelopment of the pituitary stalk, the mixed solid-cystic consistency of the mass, and above all its multilobulated morphology are all features suggesting primary suprasellar development of the CP below the third ventricle (Fig. 1c1). On coronal MRI this CP shows a “three-leaf-clover” shape, a sign indicating expansion of the two basal-lateral lobules of the lesion into the sub-arachnoid spaces of the suprasellar region, while its upper lobule protrudes into the third ventricle. The pituitary stalk has been severely stretched or enveloped by the mass, and no traces of it can be identified on preoperative MRI. Moreover, no anatomical remnants of the TVF are apparent on these preoperative images. Taken together, all the above-mentioned characteristics point to a secondary intraventricular CP, a tumor growing initially below the third ventricle but whose upper cystic pole has broken through the TVF into the third ventricle cavity.³⁵ This secondary intraventricular topography is particularly damaging to the hypothalamus and represents one of the CP types associated with a higher risk of postoperative morbidity related to hypothalamus insufficiency.

In contrast to secondary intraventricular CPs, not strictly intraventricular, or infundibulo-tuberal, lesions are characterized by their moderate size, smooth round or elliptical shape, and usually homogeneous consistency, either pure solid or unilocular cystic.^{23–25} As these tumors have a subpial development within the TVF, a thin neural layer of tissue surrounds the whole tumor capsule.²² These lesions progressively stretch the TVF remnants while expanding along the compartment offering the least resistance, the third ventricle cavity. The final smooth round or elliptical shape is explained by the modeling effect of the third ventricle margins on the lesion. The small, pure solid CP shown in the video by de Lara et al. corresponds to such a category of infundibulo-tuberal, or not strictly intraventricular, CPs (Fig. 1a1–a5).⁸ This lesion, centered at the level of the infundibulum, partially protrudes behind the optic chiasm into the suprasellar cistern, although its major bulk is lodged in the anteroinferior third ventricle (Fig. 1a1). The infundibulo-tuberal topography, which represents approximately 40% of CPs diagnosed in adults, is associated with the highest surgical risk of hypothalamic injury, as lesions with these features are truly embedded within the functional hypothalamus.^{1,10,21,24}

The intrinsic hypothalamic nature of the CP reported by de Lara et al. is nicely evidenced in the outstanding surgical pictures obtained with the endoscope through the extended endonasal transplanum–transtuberulum sellae approach (EEA; Fig. 1a2–a4). As the learning curve for this approach has gradually improved and the surgical techniques to achieve a CSF leak–proof closure of the bone defect created at the skull base have been steadily implemented, the EEA has been applied increasingly, broadening its indications from the removal of exclusively intrasellar CPs to sellar-suprasellar CPs and, more recently, to intraventricular CPs.^{2,7,14,18} In the case discussed here, Lara et al. show unambiguously how this tumor is embedded or buried in the substance of the TVF itself, just at the optic chiasm–infundibulum junction, above the arachnoid layer that envelops the pars tuberalis and

the undersurface of the optic chiasm (Fig. 1a2–a3). The tumor spared the pituitary stalk and the intracranial spaces within the chiasmatic (suprasellar) cistern. Very recently, Qi et al. microscopically analyzed the meningeal relationships of CPs and grouped this type of lesion developing within the infundibulum under the term “sub-arachnoid” CPs, as these tumors grow above the intact arachnoid layer outlining the infundibulum.³¹ In fact, this category of infundibulo-tuberal CPs is formed by subpial lesions, presumably developed, according to Ciric’s theory, from epithelial cells of the embryo’s primitive mouth or from noninvolved remnants of the craniopharyngeal duct.^{4,11} These epithelial cells would have migrated with Rathke’s pouch to be included within the floor of the diencephalic vesicle before the leptomeningeal layer is formed (at the 8th week of embryo development).²⁴

From a surgical perspective, the CPs developing at the TVF itself pose the challenge of achieving a safe, nontraumatic dissection of the wide circumferential plane of tight adhesion to the adjacent hypothalamus, usually formed by a thick layer of reactive gliosis.^{21,22,31,35,39} In 1926, Critchley and Ironside were the first authors to describe the glial reaction around CPs involving the third ventricle as a distinctive consistent “third element” adjacent to the lesion, besides the epithelial and connective tissues of the mass.⁵ Percival Bailey emphasized that the extreme adhesiveness of the glial layer was a sign indicating that the cleavage plane of the lesion was positioned within the normal hypothalamus.¹ Theoretical discussions about the functionality of the neural layer of tissue covering the tumor capsule of intraventricular CPs were initiated by French authors like Pertuiset et al. and Van den Bergh and Brucher.^{27,37} While some authors shared Pertuiset’s view about the risk of violating the theoretically viable layer of TVF neural tissue surrounding the tumor,^{21,33} other experts, such as Sweet, Hoffman, or Konovalov, defended Van den Bergh’s opinion about the nonfunctional nature of the gliotic layer.^{13,17,36} A few researchers who analyzed the boundaries of infundibulo-tuberal CPs had observed “fingers” or “islands” of tumor epithelial tissue invading the adjacent brain at the level of the hypothalamus.^{13,28,33,36} Some experts regarded these epithelial elements penetrating the neural tissue as a true histological invasion and the major obstacle to total surgical removal.^{17,33,39} Others considered such an apparent CP invasion as the residual manifestation of the original site of CP growth.^{1,11,22,34}

In an attempt to answer the question of CP invasiveness, Kubota et al. and Kobayashi et al. conducted systematic microscopic studies of the tumor-brain interface of CPs involving the third ventricle.^{16,19} In 1980 Kubota et al. documented a thick layer of gliosis (0.5 to 2.5 mm) surrounding the basal, solid portion of infundibulo-tuberal CPs; at some points, however, no layer of gliosis was interposed between the tumor capsule and the viable hypothalamus.¹⁹ For his part, Kobayashi confirmed that the brain-tumor interface of predominantly intraventricular CPs showed finger-shaped protrusions of solid epithelial cords invading the adjacent brain at the level of the TVF.¹⁶ Consequently, two not mutually exclusive possibilities can occur: the presence of a functionless interface of reactive gliosis, and direct contact between the tumor and the hy-

pothalamic nuclei, even in the same lesion. This finding emphasizes the high risk associated with the indiscriminate attempt of total removal of infundibulo-tuberal CPs.

Given that infundibulo-tuberal CPs remain hidden in a retrochiasmatic position, the subfrontal and pterional approaches to the suprasellar area prevent the surgeon from properly assessing the cleavage plane of dissection within the hypothalamus.^{13,27,36,39} In the last decade, the EEA has proved a useful technique to overcome the shortcomings associated with these transcranial approaches.^{2,7,14,18} It enables the surgeon to optimally visualize, from a brain undersurface perspective, those CPs that replace the TVF and to gain the best surgical control of the circumferential rim of tumor adhesion to the hypothalamus, causing minimal distortion to the adjacent neural structures or perforating vessels.²⁶ Sharp dissection of the tumor plane of attachment, parallel to both the posterior chiasm aspect and the anterosuperior infundibular border, leaves an open circular defect at the chiasmatic-infundibular junction through which endoscopic exploration of the third ventricle cavity is possible (Fig. 1a4). Such a breach at the TVF can be observed on postoperative MRI in all infundibulo-tuberal CPs that have been totally removed.^{9,30}

To conclude, regardless of the surgical approach chosen, the histological arrangement of the interface between the capsule of an intraventricular CP and the vital hypothalamus is the fundamental characteristic to bear in mind when deciding about the degree of tumor removal to be performed.^{26,31,34} The extension and strength of the attachment of the tumor will depend on the CP's anatomical point of development along the vertical hypophyseal-hypothalamus axis, as well as its original position in terms of the leptomeningeal layer (pia mater and arachnoidea).^{31,35} In contrast to strictly intraventricular CPs, which usually present a pedicular attachment to the TVF without accompanying reactive gliosis, CPs expanding within the hypothalamus (infundibulo-tuberal, or not strictly intraventricular, CPs) or tumors invading secondarily the TVF show a wide circumferential band of attachment to the neural structures of the third ventricle, including the optic chiasm, the infundibulum, and the hypothalamic walls.^{22,24,35} The FTV and TC approaches would be more favorable to remove purely intraventricular CPs of the squamous-papillary type showing a loose or pedicular attachment to the intact TVF. The TLT and EEA approaches should be considered when dealing with either extra-intraventricular lesions or CPs developing primarily at the level of the TVF.

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Disclosure

The authors report no conflict of interest.

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RESPONSE: I appreciate the comments by Pascual and colleagues highlighting the importance of topographical characteristics of CPs involving the third ventricle as a way to anticipate tumor adherence to the hypothalamus, as this factor may determine one's choice of surgical approach. The authors have suggested that CP adherence to the hypothalamus is a major determinant in predicting the risk associated with radical resection and operative outcomes, and that specific surgical approaches may be more appropriate than others to deal with the type and degree of hypothalamic adherence associated with the topography of third ventricular involvement. In their analysis of three recently published operative videos of CP resection,^{1,2} they concluded that an FTV or TC approach may be more favorable for removing purely intraventricular CPs, while TLT and EEA approaches should be considered for extra-intraventricular variants, which tend to exhibit more adherence to the hypothalamus. These same authors have elegantly reported on a series of papers emphasizing the topographical relationship among CPs, the third ventricle, and hypothalamic adherence as a factor to consider when selecting a surgical approach.^{8–12}

In my view, the key to a successful, safe radical resection of a CP is direct visualization of the tumor-hypothalamus interface in order to perform meticulous microdissection from the critical structures (direct visual control) and thereby avoid blind dissection of this region, which may be associated with higher risks of morbidity and mortality. This principle of direct visual control applies not just to the hypothalamus but to all neighboring critical structures at risk, including the optic chiasm, the perforating vessels supplying the chiasm from the superior hypophyseal arteries, and the internal carotid and basilar circulation arteries. In addition to the topography of third ventricular involvement, the choice of the optimal surgical approach is largely based on a number of other factors, including the anatomical location, relationship with the chiasm (prechiasmatic, retrochiasmatic, infrachiasmatic, suprachiasmatic), relationship with the pituitary stalk (pre-infundibular, transinfundibular, retro-infundibular),³ extension of the lesion (sylvian fissure, interhemispheric fissure, anterior skull base, retroclival region), presence of vascular encasement, history of prior surgery (endonasal versus craniotomy), tumor consistency (solid, cystic, mixed), and surgeon preference and experience.⁶

Craniopharyngiomas are often retrochiasmatic in location and thus have an intimate relationship to the undersurface of the optic chiasm and hypothalamus. Direct visualization of this region is critical to perform safe, meticulous extracapsular microdissection of the tumor from the undersurface of the optic chiasm and hypothalamus. The endoscopic endonasal approach (transplanum trans-tuberculum corridor) offers the most direct route to the retrochiasmatic region while affording excellent visualization of the undersurface of the optic chiasm, hypothalamus, and third ventricle.^{5,7} The small perforating branches arising from the superior hypophyseal arteries that supply the optic chiasm are best visualized and controlled with the view from below (EEA). Preservation of these perforators is critical for successful visual outcomes. Although these tumors often adhere to the hypothalamus, safe and

careful two-handed microsurgical dissection of the tumor from the hypothalamus can be achieved. Midline anterior fossa, retrosellar, and retroclival tumor extension can be accessed by expanding the bony corridors along the cranial base accordingly. A limitation of the endonasal approach is the ability to safely dissect tumor from vascular structures when considerable tumor extends laterally into the sylvian fissure or superiorly into the interhemispheric fissure. In such cases, a transcranial approach from above may be more appropriate to address these issues.

When approaching these tumors from above via a transcranial approach, retrochiasmatic CPs are frequently hidden from the surgeon's operative view, located underneath and behind the chiasm.⁴ Thus, one must open the lamina terminalis in order to access the retrochiasmatic tumor with third ventricular extension. Cranial base approaches to the lamina terminalis can be performed using either an anterolateral approach (orbitozygomatic, pterional, supraorbital) or a midline approach (transbasal subfrontal, transbasal interhemispheric). The major limitation of an anterolateral trajectory is the lack of visualization of the ipsilateral wall of the third ventricle and hypothalamus (blind spot). However, a midline transbasal approach provides direct visualization of both ependymal walls of the third ventricle and the hypothalamus, thereby eliminating the ipsilateral blind spot for safe dissection of the tumor.⁴ Nevertheless, this approach is still limited by an inability to visualize the region directly beneath the optic chiasm and nerves, especially in cases with a small prechiasmatic window, whereby tumor dissection is often blind and preservation of perforators to the visual apparatus is critical.

Craniopharyngioma surgery can be technically challenging when attempting gross-total resection because of the lesion's intimate relationship with and potential adherence to critical structures. These formidable tumors come in all shapes and sizes, and it is important to recognize that not one surgical approach fits all. The armamentarium of the CP surgeon should be equipped with all possible approaches and routes (open transcranial and endonasal endoscopic) to the cranial base and cerebral ventricles, and it is critical to understand the advantages and limitations of each approach. In some instances of extensive CPs occupying multiple regions, staging the surgery with a combination of approaches may be considered.

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RESPONSE: We appreciate the comments by Dr. Pascual and colleagues regarding our video presentation on the two patients with intraventricular CPs removed via an FTV approach. This approach was chosen in these cases because the tumor was anticipated to have arisen within the third ventricle, given the tumor's shape, which conformed to the walls and floor of the ventricle, and the pituitary stalk in its native position, which indicated that the suprasellar cistern was likely free of tumor.

If a tumor has these radiographic features, I choose a transcranial approach to remove it, either through a transcortical (if the ventricles are enlarged, as demonstrated in the cases in the video) or a transcallosal approach or through a translamina terminalis approach (if the ventricles are small). Since I am choosing this approach to preserve the hypothalamus, third ventricular floor, and pituitary stalk, the standard tenets of microsurgical dissection are applied: careful sharp dissection of the tumor-ventricular plane, under direct vision, to minimize any manipulation damage to the walls or the floor of the third ventricle. Damage to these structures would invalidate the reasons for choosing this approach, which is to preserve hypothalamic-pituitary function. If the dissection plane is difficult, I err on the side of leaving a film of tumor attached to the walls and floor to preserve function.

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Letter to the Editor

RESPONSE: We agree with Pascual et al.'s analysis related to the CP type presented and resected in our video. It definitely represents an infundibulo-tuberal CP with major growth anterior to the pituitary stalk and the undersurface of the optic chiasm, which defines this tumor as a CP Type I.¹ The superior portion of the tumor had invaded the third ventricle, respecting the lateral walls. The entire dissection was performed through an endoscopic endonasal extended approach, which allows great visualization of the suprasellar space.

With the use of high-definition endoscopes, visualization of the small perforators and the superior hypophyseal arteries occurs immediately after the dural opening, since the tumor pushes the suprasellar arachnoid anteriorly. Once the dura mater is opened and the arachnoid is dissected, preserving the superior hypophyseal arteries, the superior aspect of the pituitary gland is explored posteriorly in order to reach the pituitary stalk inferoposterior to the tumor. Then, the optic apparatus is encountered, and the undersurface is dissected free of tumor under direct visualization, which is the main advantage of this approach. The tumor, which originated from the infundibulo-tuberal area, is located between the optic chiasm and the pituitary stalk. It expands that region and the entire microsurgical dissection occurs below the chiasm and above the pituitary stalk. The endonasal route offers a midline approach to a midline lesion and a caudal-cranial orientation of sight, which provides the

surgeon with a great angle of view of the undersurface of the optic apparatus and hypothalamus. Thus, with superior visualization, the surgeon has an incomparable opportunity to evaluate the tumor's behavior and determine if total resection is possible. As pointed out by Pascual et al., infundibulo-tuberal CPs often infiltrate the hypothalamus, and only with adequate visualization is the surgeon able to realize the necessity of leaving tumor remnant adherent to the brain, avoiding blind maneuvers that could compromise the patient's hypothalamic function.

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Please include this information when citing this paper: DOI: 10.3171/2014.3.FOCUS1464. ©AANS, 2014