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Diaphragma Sellae in Transsphenoidal Pituitary Adenoma Surgery: Anatomical, Radiological and Operative Considerations

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Abstract: **Diaphragma sellae is the dural fold which covers the sella turcica and extends over the pituitary gland, except in the center which is defective because of the pituitary stalk presence. It can be elevated in cases of pituitary adenoma and this elevation can be in different degrees. Diaphragma sellae elevation may even affect the pattern of adenoma growth. During endoscopic transsphenoidal pituitary surgery, the descent of diaphragma sellae is one of the master scenes. Surgeons try as much as they can to guard against the early descent of diaphragma sellae due to its effect in surgical field block and possibility of residual tumor presence or cerebro-spinal fluid leak. Not many articles were done about diaphragma sellae in the literature covering all the applied points related to it. In this article, we try to discuss important points regarding the diaphragma sellae, including its anatomy, radiological picture and the operative considerations related to it.**

Keywords: **Diaphragma sellae, pituitary macroadenoma, transsphenoidal surgery, cerebrospinal fluid leak.**

I. INTRODUCTION

Diaphragma sellae (DS) is an extension of the dura mater which extends over the diaphragma sellae. This part is always neglected in the research work and not always dealt with in detail, although it has an important significance in guiding pituitary adenoma growth[1]. DS was first described in MRI by Daniels et al.[2] as a single low intensity shadow above the pituitary gland. During transsphenoidal endoscopic endonasal approach for pituitary adenoma, there is a complex structure which may appear in the surgical field. This structure is referred to as the diaphragma sellae although it is not only formed of the diaphragma sellae, but also form other structures. This structure also can be formed of arachnoid mater, adenoma pseudocapsule, flattened pituitary gland or the diaphragma sellae itself[3]. This review aims to give the reader concentrated data about DS anatomy, radiological findings and surgical significance.

II. DIAPHRAGMA SELLAE ANATOMY

The pituitary gland arises from the inferior aspect of the hypothalamus, and is comprised of two lobes; anterior and posterior. The pituitary stalk makes the connection between the pituitary gland and the hypothalamus a functional connection. The pituitary gland lies inside a bony cavity called the "sella turcica"[4]. This cavity is saddle shaped and lies superior to the sphenoid air sinus, separated from it by a thin bony plate; the sellar floor. Lateral to the sella turcica lie the two cavernous sinuses on both sides. Each cavernous sinus contains the internal carotid artery and the following nerves; the occulomotor nerve (III), the trochlear nerve (IV), the ophthalmic and the maxillary braches of the trigeminal nerve (V) and the abducent nerve (VI). The top of the sella turcica is covered by DS. DS is a fold which is derived from the dura mater of the skull base interna. It has a central hole which transmits the pituitary stalk[1]. Superior to DS lies the suprasellar cistern which contains the optic chiasma[4,5]. Detailed anatomical illustration can be seen in (Fig. 1).

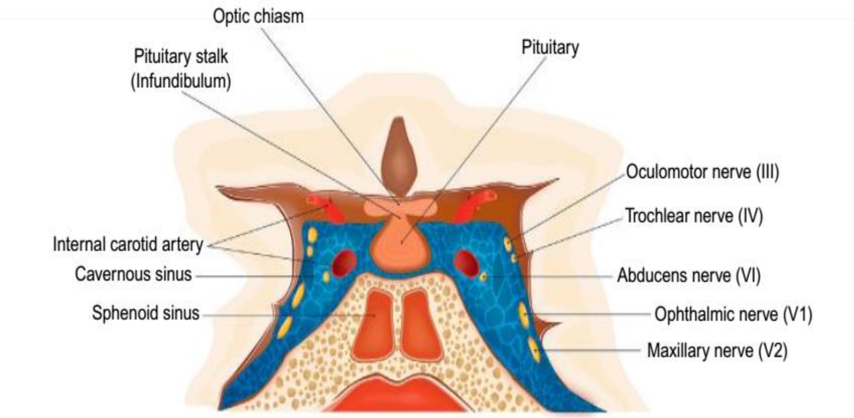

Figure 1: Normal sellar anatomy. Pituitary gland lies in the sellar cavity. Cavernous sinuses lie on both sides of the sella turcica. Figure is from "MRI Atlas of pituitary pathology"[5].

Diaphragma sellae is continuous anteriorly with the dura mater of the anterior cranial fossa and posteriorly with the dura mater of the posterior cranial fossa, while laterally it is reflected over the top of the cavernous sinus. It tends to be thin at the center and thick at the periphery. It tends to be rectangular rather than being circular, and concave or covex rather than being flat. It is consisted of two layers; meningeal and periosteal[4]. The hole of the diaphragma sellae is called the diaphragmal opening. This opening can be variable in size and may be stretched in cases of pituitary macroadenoma[6]. It tends to be rectangular rather than being circular, and concave or covex rather than being flat[4]. The diaphragmal opening normally transmits the pituitary stalk, but can transmit in addition to it an arachnoid fold in cases of increased intracranial pressure, a condition called "empty sella syndrome"[7]. There are bony projections to which DS is attached. These projections are the anterior and the posterior clinoid processes, the tuberculum and the dorsum sellae. A detailed view of the diaphragma sella anatomy and the related structures can be seen in (Fig. 2).

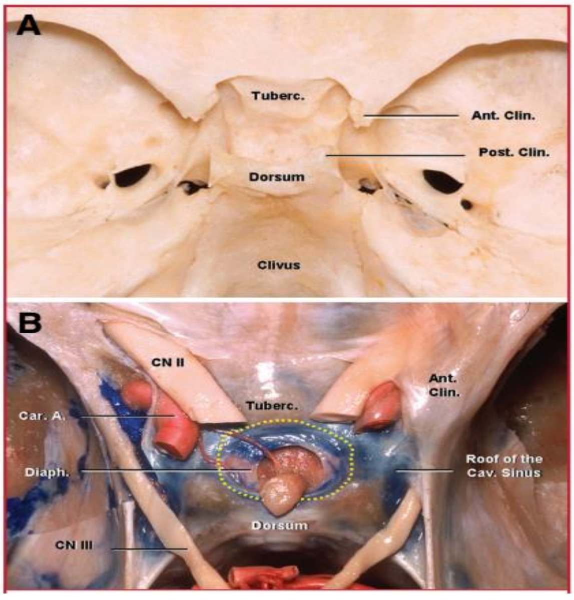

Figure 2: Skull base interna, superior view. A, osseous relationships of the skull base. B, dural relationships of the skull base are shown. The diaphragma sellae is located in the skull base center and continues anteriorly with the dura mater that covers the planum of the sphenoid bone and the anterior cranial fossa, posteriorly with the dura mater covering the dorsum sellae and clivus, and laterally with the superficial layer of the roof and lateral wall of the cavernous sinus. A., artery; Ant., anterior; Car., carotid; Cav., cavernous; Clin., clinoid; CN, cranial nerve; Diaph., diaphragm; Post., posterior; Tuberc., tuberculum; yellow dotted line, limits of the diaphragma sellae. Figure is from Campero A, Martins C, Yasuda A, Rhoton AJ. Microsurgical anatomy of the diaphragma sellae and its role in directing the pattern of growth of pituitary adenomas. Neurosurgery [Internet]. 2008;62(3):717–23. Available from: https://www.ncbi.nlm.nih.gov/pubmed/18425018.[1]

III. RADIOLOGICAL FEATURES OF DIAPHRAGMA SELLAE

The sellar protocol MRI is the most illustrating imaging method for the sellar region. The pituitary gland and stalk usually enhance with contrast injection[5]. As mentioned before, DS was first described in MRI by Daniels et al.[2] as a single low intensity shadow above the pituitary gland. On advances of imaging technology, visualization was improved of all the sellar structures including the diaphragma sellae. The diaphragma opening width can be measured and it is directly proportionate to the size of pituitary adenoma[6] i.e. the larger the adenoma, the wider the diaphragmal opening. Elevation of the diaphragma sella also increases with the increase of adenoma size[6]. The pituitary stalk has an intimate relationship with diaphragmal opening deviations in cases of pituitary adenoma[6]. In the sellar protocol MRI, the pituitary stalk's width is normally less than 4 mm, usually narrower than the optic chiasma and its maximum diameter is usually at the point of insertion into the pituitary gland[8]. It is mostly central in position, but it is not necessary to find a pituitary pathology if there is a slight deviation in the pituitary stalk towards a side[9]. Detailed radiological picture of DS on MRI is shown in (Fig. 3).

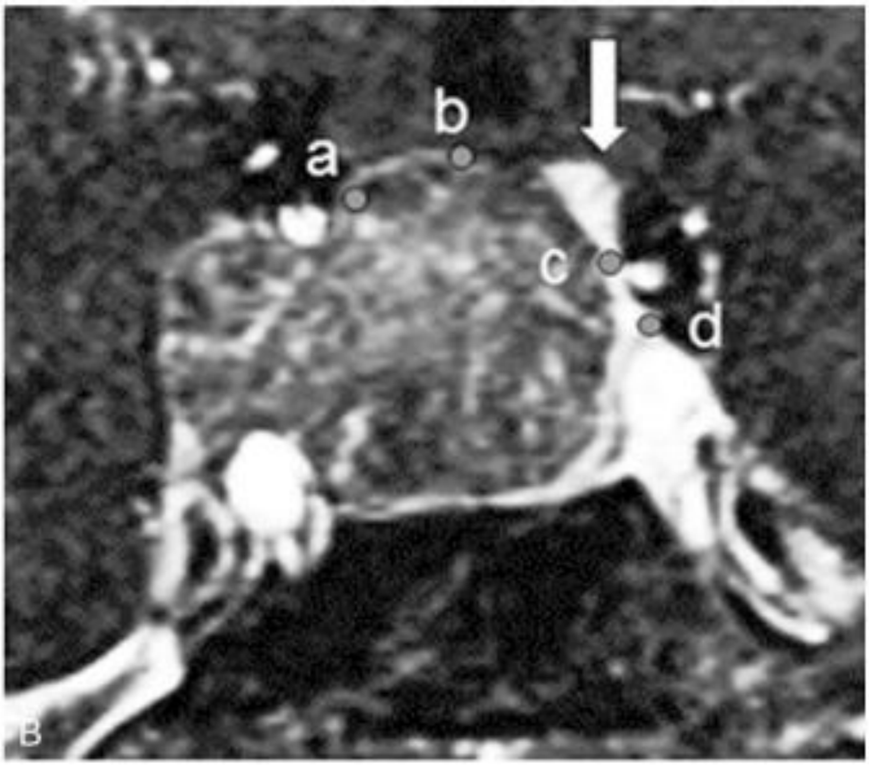

Figure 3: Showing the diaphragma features on MRI. A.The right bordering of diaphragma sellae dura connecting to the lateral wall of cavernous sinus. B. Diaphragma sellae dura end on the right of diaphragmal opening. C. Diaphragma sellae dura end on the left of diaphragmal opening. D. The left starting point of diaphragma sellae dura. The distance between "b" and "c" was diaphragmal opening width. The sum of the distance of "a"-"b" and "c"-"d" was the width of diaphragma sellae dura on both sides of diaphragmal opening. This figure is from "Wei L, Xi Z, Lin S, Zhao Q, Jing J, Wang S. MRI research of diaphragma sellae in patients with pituitary adenoma. Int J Clin Exp Med [Internet]. 2015;8(8):12842–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/26550199"[6].

IV. OPERATIVE CONSIDERATIONS DURING TRANSSPHENOIDAL SURGERY FOR PITUITARY ADENOMA

For many years, transcranial approach was the main standard for pituitary adenoma surgery. Transsphenoidal approach emerged as an effective technique because of many advantages[10]. Approaching the adenomas through the nasal cavity without opening the skull is much less traumatic to the cranial cavity and causes minimal operative approach. In addition, the transcranial approach necessitates brain retraction and arachnoid dissection, the thing which is not needed it the transsphenoidal approach. Moreover, it can provide an excellent chance for very clear visualization of the pituitary adenoma and the nearby structures in the majority of cases, at least more than the transcranial approach which can lead to traction over the optic chiasma or give a chance to injury of important structures. Finally, transsphenoidal approach can cause a minimal surgical scar, the thing which is important for almost all of the patients.

At first, this approach was applied through the operative microscope, but with technological advances and with the emergence of the neurosurgical endoscope, many centers worldwide use it nowadays[4]. This can be explained by the cumulative experience of the neurosurgeons worldwide in using the neurosurgical endoscope. The operative microscope provides a three dimensional view, which is important for many surgeons. On the other hand, the endoscope provides an excellent visualization of the surgical view as an expanded view, although it is only two dimensional. Both of the tools can be used simultaneously to aid each other[4,6,11].

During the transsphenoidal approach, Dura mater is usually incised in a cruciate fashion. With large macroadenomas, the adenoma is classically seen immediately on incising the dura. A round blunt dissector is used to separate the tumor capsule from the dura circumferentially. To reduce the possibility of early or severe descent of DS during the operation, the adenoma is removed in a piecemeal fashion in a sequential manner. First, the surgeon should start with the lowermost portion of the tumor, then the lateral portions and finally the uppermost (or the anterior) parts. This step is very important trying to delay the descent of diaphragma sellae and to reduce the effect of this descent on the surgical field block[12]. In addition, the central part of the tumor should be delayed to avoid applying traction over the diaphragma sellae at the center, leading to its descent. The tumor is mainly fragmented using the ring curette and then suctioned (Fig. 4).

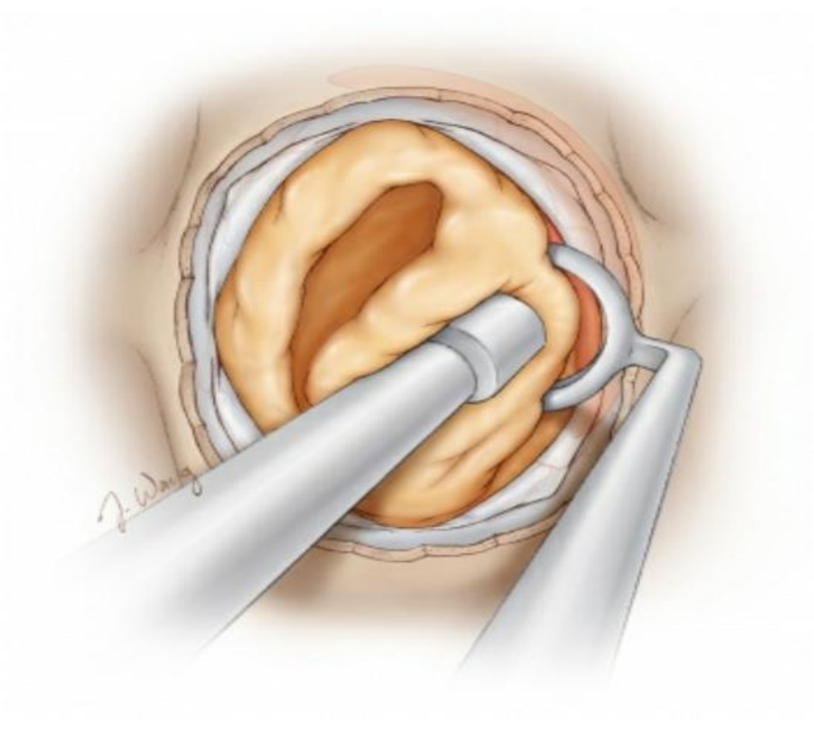

Figure 4: Piecemeal removal of pituitary adenoma. Ring curette is used to dislodge and fragment the tumor, then the suction is used to remove it. This Figure is from "Hendricks B, Cohen-Gadol A. Pituitary Macroadenoma. In: Neurosurgical Atlas [Internet]. Neurosurgical Atlas, Inc.; 2016. Available from: www.neurosurgicalatlas.com/volumes/ brain-tumors/pituitary-and-parasellar-tumors/endoscopic-and-microscope-guided-adenoma-resection/pituitary-macroadenoma"[12].

A very careful inspection of the cavernous sinus medial wall should be done to avoid leaving residual tumor. This step is fundamental. Meticulous handling is strongly required in cases of cavernous sinus invasion to avoid injury of the internal carotid artery. Angled endoscope can help in this situation. Tumor removal from the corners continues with diaphragma sellae descent occurrence using the ring curette, but very carefully (Fig. 5).

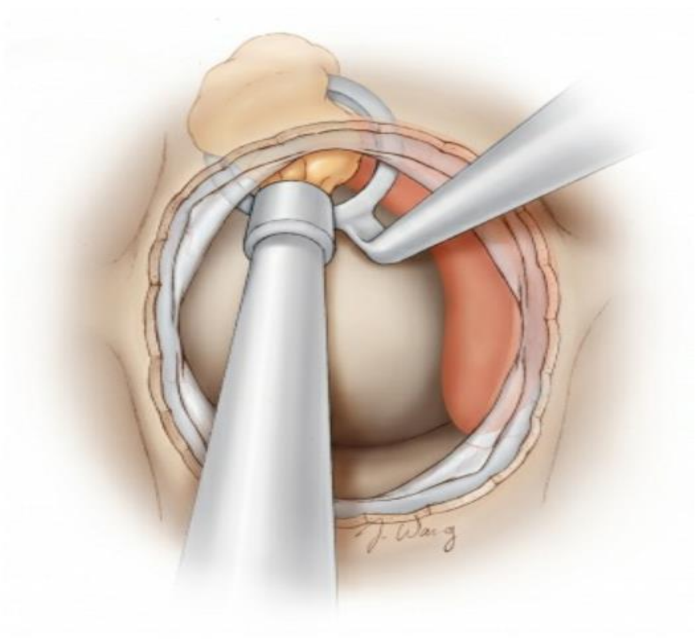

Figure 5: Adenoma removal from the corners using the ring curette. Diaphragma sellae descent is noticed. This Figure is from "Hendricks B, Cohen-Gadol A. Pituitary Macroadenoma. In: Neurosurgical Atlas [Internet]. Neurosurgical Atlas, Inc.; 2016. Available from: www.neurosurgicalatlas.com/volumes/brain-tumors/pituitary-and-parasellar-tumors/ endoscopic-and-microscope- guided-adenoma-resection/pituitary-macroadenoma"[12].

During the transsphenoidal endoscopic pituitary adenoma surgery, the diaphragma sellae descent occurs early in many cases showing different patterns and degrees of descent during the surgery. If the descent is blocking the surgical view, the surgon should push againt it gently using cottonoids between the diaphragma sellae and the ring curette[12].

Till present, no solid classification of the different patterns of diaphragma sellae descent is present. There are even no solid guidelines for the prediction of neither the occurrence nor the pattern of descent during the surgery are present. This is beside having only a very limited number of studies focused on diaphragma sellae descent as an objective criterion for successful resection of pituitary adenoma. One of the valuable trials till present to study the diaphragma sellae as a surgical reference to pituitary transsphenoidal adenoma surgery was that done by Guinto B G et al. in 2011[3], by studying 100 cases of non-functioning pituitary macroadenoma. They suggested a classification of the diaphragma sellae descent during the surgery into four types: type A: symmetrical descent with a central fold corresponding to the pituitary stalk; type B: asymmetrical with a lateralized fold; type C: symmetrical and uniform descent without any fold; and type D: minimal or no descent in absence of visible residual tumor. Their results suggested that the tumor volume can be more important to determine the type of descent rather than the tumor morphology. This can be evaluated from our point of view as the best trial published till now trying to classify the phenomenon of diaphragma sellae descent, but it still needs more improvement to make it more precise in predicting the degree of surgical field block during the operation and the relationship between the surgical complications and the degrees of DS descent.

V. CONCLUSION

Diaphragma sellae anatomy, its relationship to anatomical structures and its effect on directing pituitary adenoma growth must be deeply understood by neurosurgeons, especially those doing transsphenoidal pituitary adenoma operations. The effect of diaphragma sellae on directing pituitary adenoma growth is a rich topic for research. Neurosurgeons performing operations for pituitary adenoma through the transsphenoidal approach should give great care to diaphragma sellae descent as an important event. Extra effort by researchers should be given trying to predict the factors controlling diaphragma sellae degrees of descent during the transsphenoidal approach and its effect on outcome regarding presence of residual tumor, pituitary stalk affection or CSF leak occurrence.

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