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A comprehensive review on pituitary hydroscopy and the role of endoscopic diving techniques

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ABSTRACT

Pituitary hydroscopy is a new technique in skull base surgery that involves transnasal neuroendoscopy and gentle fluid distention of the sella turcica. Hydroscopy allows for a more thorough inspection of the sellar region and may make it easier to remove additional tumour cell foci. Endoscopic Diving Technique, on the other hand, uses a continuous water flow that is driven in front of the endoscope to aid explore the surgical cavity and improve image clarity. After tumour removal, a double-path aspirator is implanted inside the sella turcica and tumour cavity, providing a pressured flow with continuous irrigation in the Modified Endoscopic Diving Technique. Several groups' recent uses of diving techniques attest to the increased interest in these approaches. The development of dedicated surgical devices will improve the efficacy of diving procedures in the future. More research is needed right now to improve the effectiveness of diving techniques.

INTRODUCTION

To understand the current renaissance of endonasal pituitary surgery, it's necessary to look back at the historical and anatomic progression of thought that has led to contemporary technical advancements and better patient care. Shorter operative times, decreased blood loss, improved differentiation between normal tissue and tumour, better visualisation of intrasellar and parasellar structures, shorter hospital stays, improved patient satisfaction, and decreased need for nasal packing have all been seen since the endoscope was married to the trans-sphenoidal approach. Furthermore, this union has brought the otolaryngologist and the neurosurgeon together as a true surgical team, allowing novel concepts like extracapsular tumour dissection, new approaches to investigate the tumour bed, improved tumour removal with angled views and hydroscopy.⁶

Keywords

pituitary surgery,
skull base surgery,
hydroscopy,
endoscopy,
diving techniques



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Pituitary hydroscopy is a new technique in skull base surgery that involves transnasal neuroendoscopy and gentle fluid distention of the sella turcica. Hydroscopy provides for a more thorough inspection of the sellar region during minimally invasive pituitary surgery, as well as the excision of extra tumour cell foci. When compared to typical neuroendoscopic procedures, preliminary data suggests that hydroscopy may result in a lower rate of cerebrospinal fluid (CSF) leak and revision surgery. Hydroscopy is a safe and effective addition to traditional pituitary techniques, and endoscopic skull base surgeons should include it in their toolkit. Endoscopic resection of pituitary neoplasms appears to have the major benefit of a broader, potentially angled field of view, which may be especially advantageous for big tumours with extrasellar extension, according to the data. Endoscopic pituitary surgery has been linked to better rates of gross total resection, endocrinological cure, visual prognosis, shorter hospital stays, less postoperative discomfort, septal perforation, CSF leak, and a lower rate of diabetes insipidus as a result of its benefits.¹⁶

A constant water flow is propelled in front of the endoscope in Davide Locatelli's⁹ Endoscopic Diving Technique (EDT). EDT is a flexible tool for exploring the surgical cavity and enhancing visibility. After tumour removal, a double-path aspirator is implanted inside the sella turcica and the tumour cavity in Marco Ceraudo's³ Modified Endoscopic Diving Technique. This creates a pressured flow with continual irrigation, which aids in the removal of more minor tumour foci.

HISTORY

The creation of the cystoscope by Nitze in the 1800s provided the technological foundation for hydroscopy.¹¹ Herman Schloffer used a lateral rhinotomy to perform the first transsphenoidal approach to the pituitary in 1907. After an open approach via the nasal dorsum, Kocher described the first submucosal resection of the bony nasal septum and vomer to get access to the rostrum of the sphenoid in 1909.⁸ Hirsh, a rhinologist, invented and championed the substantial breakthrough of the transnasal, transseptal technique in 1910. Hirsch tweaked the techniques he'd learned to access the sphenoid for infection therapy. The submucosal excision of the septum, developed by Kilian in 1904, was later added to his basic procedure. In 1914,

Cushing described his sublabial, transseptal, transsphenoidal method using these techniques as well as those of Kanavel and Halstead. Following that, in the 1960s, the adoption of an operational microscope considerably increased visualisation of the sella.¹³

For vision of urological structures, early cystoscopes depended on air insufflation; later developments of this technology incorporated fluid distention, which enhanced patient comfort and surgeon visibility. The first attempts to apply endoscopic techniques to neurological pathology focused on the ventricles and other fluid-filled regions, with Victor L'Espinasse, a French urologist, examining the choroid plexus of two children with hydrocephalus using a cystoscope in 1910.¹⁷ Jankowski performed the first purely endoscopic, endonasal pituitary excision in 1992, thanks to technological breakthroughs in endoscopes and cameras in the 1970s, and Jho and Carrau published the first extensive series of endoscopic pituitary surgery in 1997.⁵ Endoscopic transsphenoidal methods to the pituitary have grown quite prominent in the last 25 years.

ANATOMICAL CONSIDERATIONS

The pituitary gland is a reddish-grey organ that rests in the sella turcica, a deep depression on the superior portion of the sphenoid bone's body, and measures around 1 cm in diameter. It's hidden behind the tuberculum sellae, which is itself hidden behind the optic chiasm. The dorsum sellae and the posterior clinoid processes define the sella's posterior boundary. The clivus is a bony extension of the dorsum sellae that slopes inferiorly and connects to the occipital bone. The anterior clinoid processes are formed by the tuberculum sellae's lateral expansions. The diaphragm, a dural fold spanned by the pituitary stalk, forms the roof of the fossa. The diaphragm and the pituitary capsule are separated by an arachnoid invagination. The roof of the cavernous sinus is formed by the diaphragm's lateral expansion. The optic chiasm and nerves, the carotid arteries, the third, fourth, fifth, and sixth cranial nerves in the cavernous sinus, as well as the basilar artery and brainstem posteriorly, are all within close proximity to the pituitary gland. As a result, proper anatomy knowledge is required during these approaches.¹⁵

The sphenoid sinus is pneumatized into the

sphenoid bone in a variety of ways, and three types of sphenoid pneumatization patterns are classified based on their relationship to the sella. A conchal type is one that has just slightly pneumatized and yet has thick bone across the sella's face. Sellar type denotes a sinus that has pneumatized to the sella's face, whereas post-sellar type describes a sinus that has pneumatized beyond the sella's face. The sellar and post-sellar types of sinuses make up the majority of adult sinuses.¹⁵ The two sphenoid sinuses are separated by a septum that is off the midline in 60 to 70% of cases, resulting in asymmetry between the two cavities. Additionally, numerous septations may be present. The walls of the sphenoid sinuses have many structures running along them. The Vidian nerve's canal goes laterally along the floor. At approximately 5 and 7 o'clock, the carotid arteries flow along the lateral walls. At approximately 2 and 11 o'clock, the optic nerves run more superiorly along the lateral walls. Between the bulges of these two structures is the optico-carotid recess, which can extend into the anterior clinoid process. The sphenoid ostium runs along the anterior wall's superior aspect.¹⁴

PRINCIPLES OF ENDOSCOPIC DIVING TECHNIQUE

The diving technique makes use of hydraulic concepts (flow and pressure) as well as visual approaches (lens effect given by liquid film). The procedure entails not only flushing the surgical cavity, but also the production of a saline solution lens: the first step is to determine the proper distance from the wall to be visualised in order to eliminate any turbulence induced by the liquid flow. The focus, which differs from that utilised in open-air surgery, is changed at this point. The surgeon must generate a field with a stationary flow, which means that the lines of flow must correspond with the lines of current, and the particles must follow trajectories that are not rectilinear but remain constant throughout time. The saline solution within the surgical cavity forms a fluid layer with a stationary flow that works as a concave-convex lens.⁹

ADVANTAGES OF THE TECHNIQUE

1. Removal of micro residues with final hydrodissection of the lesion.
2. As a result of the flushing pressure, structures, fistulas, and perforations of the cavernous sinus walls can be seen in the presence of bleeding.

3. Exploration of places buried by the cistern's fall as the saline solution flow re-expands the pseudocapsule through pressure and direction adjustments.
4. Hematic residues are removed, and bleeding is modest, preventing clear visibility.
5. Smaller visual field but greater visualisation due to the lens effect with amplification of vision.⁹

LIMITATIONS OF THE TECHNIQUE

1. A panoramic vision is not possible due to the short focal distance.
2. In a small field, there is no stereoscopic view.
3. Bleeding can make you feel disoriented.⁹

PREOPERATIVE CONSIDERATIONS

Hydroscopy is recommended for patients undergoing transnasal, endoscopic pituitary and selected parasellar surgery. Certain diseases of the sella turcica less often require intraoperative hydroscopy: Rathke's cleft cysts can be easily marsupialized without it, while adamantinomatous craniopharyngiomas often have a fibrotic capsule that makes hydroscopy difficult. To continue with surgery, individuals with pituitary pathology must have a thorough preoperative evaluation and be recommended for transnasal, endoscopic surgical therapy. Multidisciplinary teamwork across neurosurgery, endocrinology, ophthalmology, and otolaryngology is the best way to make management suggestions. Surgical intervention is usually reserved for compressive symptoms, rapid development, or acute apoplexy in hormonally inert tumours. Size, type of hormone, and response to medical care are factors that affect surgery for a hormone-secreting tumor. Prolactinomas are treated with dopamine agonists at first, with surgical removal reserved for tumours that continue to grow. On the other hand, tumours that produce growth hormone or adrenocorticotrophic hormone are frequently treated with surgery up front. Unless contraindicated, all patients have thin-cut computed tomography (CT) of the paranasal sinuses and magnetic resonance imaging (MRI).²

SURGICAL TECHNIQUES:

On the operating table, the patient is positioned supine with a horseshoe headrest. The head is retained in a neutral position or slightly tilted to the right and elevated 10 to 30 degrees. The image

guidance and endoscopic monitors, as well as the nurse's table, are all placed at the patient's head, directly in front of the surgeons. The rigid endoscopes 0, 30, 45, and 70 degrees with diameters of 4 and 2.7 mm, 18 cm in length, and an external cover attached to the irrigation system are employed.⁹ The procedure is performed with a standard 4-mm endoscope with various angulations; for the most part, the straight endoscope gives the best illumination and vision. After the sella is accessed and the tumour is removed, angled scopes are frequently utilised later in the surgery. The use of stereoscopic endoscopes to provide a three-dimensional vision has been described.¹⁴

The endotracheal tube is attached to the left lower lip to obtain general anaesthesia. The bed is turned 90 degrees counterclockwise, and preoperative CT and MRI images are combined before registration with a stereotactic image guidance system using facial surface matching. In the case that a fat graft is necessary for reconstruction, the abdomen is sterilely prepped. The availability of equipment and the strategy for surgical pathology specimens are evaluated, as well as key characteristics of the patient's anatomy.¹⁶ Pledgets soaked in a solution of 0.05 percent oxymetazoline hydrochloride decongest the nasal canals. Greater palatine artery blocks, which are performed by injecting 1.5 mL of a 1 percent lidocaine solution with 1/100,000 epinephrine trans-orally into the greater palatine canal bilaterally, provide further hemostasis. Finally, a sphenopalatine artery block is achieved by injecting additional lidocaine with epinephrine endoscopically in the vicinity of the sphenopalatine foramen.¹ For better visualisation and subsequent hydroscopy, the endoscopic operation begins with the use of a 0-degree Hopkins rod equipped with a suction/irrigation system.¹⁶

The sphenoid ostia are recognised and the bilateral middle turbinates are lateralized. A nasoseptal flap may be lifted prior to performing a broad bilateral sphenoidotomy with removal of the rostrum and posterior septectomy, depending on the risk of CSF leak. Alternatively, the nasoseptal flap pedicle can be shifted inferiorly from the sphenoid face and posterior nasal septum without lifting the flap entirely, protecting the flap pedicle while permitting tissue regeneration if the flap is not required for reconstruction. After visual and imaging guidance, establish the position of the internal

carotid arteries and optic nerves, the bony sellar face is removed with a 4-mm diamond drill bit and Kerrison rongeur. An inferiorly pedicled, U-shaped incision in the dura is produced, which is then reflected inferiorly and resected, with an otolaryngologist and neurosurgeon working in a two-surgeon, four-handed method. Standard microneurosurgical procedures are used to visualise and resect the tumour, taking care not to disturb the normal gland, cavernous sinus, or diaphragm. The 0-degree endoscope and irrigating sheath are inserted into the sella after gross total resection, and the sella is irrigated continuously with sterile saline. Suction or extra dissection may be used to identify and remove small particles of remaining tumour.¹⁶ Hydroscopy uses regular saline irrigation with a water pressure of several cm linked to either straight or angled endoscopes. The saline flooding the field expands the sella's soft tissue borders, including the diaphragm, while also increasing visibility by washing away minute amounts of blood and clot. With increased visualisation, this approach allows for a thorough examination of the cavity and the removal of as much tumour tissue as feasible.¹⁴

After the surgeon has removed the majority of the lesion and visualised a new cavity, the surgeon can enter the space with the endoscope thanks to continual irrigation from the pump. Filling the dead space with saline solution allows the endoscope to be inserted into the tumour, allowing for a great "underwater" view of the remaining tumour, capsule, normal pituitary tissue, and cavernous sinus walls. The tumour is removed using this diving technique, which involves injecting saline solution into the hollow created following tumour resection and testing for residual tumour.⁹ Hemostasis is achieved at the end of the procedure utilising a hemostatic substance such as microfibrillar collagen in thrombin. This is let to sit in the sella for a few minutes before being irrigated out. In the vast majority of cases, sella reconstruction is not required. In present practise, the only rationale for reconstruction is intraoperative suspicion of a CSF leak. If a leak is discovered, it is repaired with a little fat plug, sometimes augmented by a small resorbable microplate.¹⁴

The Endoscopic Diving Technique was introduced by Davide Locatelli. The irrigation pump is triggered and the endoscope is put into the surgical cavity according to the surgeon's desire (after full tumour

resection or anytime the amount of resection has to be evaluated). Continuous water flow is propelled in front of the endoscope, rapidly filling the cavity and allowing diving to begin. EDT is a versatile technique for exploring the surgical cavity and improving image clarity; it varies from Senior's "sellar hydroscopy"¹⁴ in that it goes beyond simple observation of the surgical field, acting as an operative instrument all around. The irrigation stream's directed force may aid tumour hydro-dissection by washing out residuals. The intra-cavity pressure can contrast bleeding as blood is diluted and washed away inside the cavernous sinus.⁹

Marco Ceraudo introduced the Modified Endoscopic Diving Technique. The double-path aspirator is put inside the sella turcica and the tumour cavity after tumour removal in this procedure. The surgeon's assistant switches on the tap to flood the tumour cavity with a pressurised flow; if necessary, a nurse can maintain pumping the infusion pressure bag to provide continuous irrigation. The double-path technology lets you halt the suction while also increasing the hydrostatic pressure created by the saline infusion. The endoscope is inserted into the tumour cavity, which is filled with saline solution, allowing a clear view of the diaphragma sellae, cavernous sinus walls, and pituitary gland, as well as the detection of any tumour remnants inside the parapituitary recess that can be washed away from the sella. The optic system and the irrigation supply are divided into two distinct tools in the modified endoscopic diving technique, allowing surgeons to point the flow on a specific structure while the endoscope can be oriented in the same direction or not. Furthermore, the irrigation source and the optic system can be located at varying distances.³

There were some changes between Locatelli *et al.*'s endoscopic diving technique and Ceraudo *et al.*'s modified endoscopic diving approach. The irrigation system injects saline solution directly onto the endoscope's outer lens in the endoscopic diving technique. Second, the distance between the optic and the irrigation system is fixed in the endoscopic diving technique for the same reason. Third, a rotary pump produces constant irrigation in the surgical field in the endoscopic diving technique. Fourth, despite the fact that the irrigation system utilised during the treatment is included in a comprehensive endoscopic equipment package, it can become an

expense in a department's budget. Furthermore, many irrigation systems (i.e., irrigation system and optic lens) supplied by different medical corporations are incompatible, which could drive up expenses even more.³ Because dedicated instruments are not required, Ceraudo's process offers easy reproducibility and lower costs.¹⁰

POSTOPERATIVE CONSIDERATIONS

The patient is admitted to the ward for 48 hours after surgery to allow for routine neurologic monitoring. On the first postoperative day, an MRI is conducted to assess the extent of the resection. Antibiotics and hormonal replacement, if necessary, are usually given to patients before they are sent home. To avoid mucus being displaced into the open sellar cavity, patients are told not to blow their noses or sneeze through their noses. Sinonasal endoscopy is performed at the first postoperative visit, about 3 weeks later, to ensure proper healing; normally, the posterior sphenoidotomy is covered by a healthy mucosal layer.¹⁴

COMPLICATIONS

Meningitis, cerebral haemorrhage, ophthalmoplegia, carotid damage, and perioperative death are all rare consequences.⁹ During the initial postoperative period, diabetes insipidus can be found in up to 60% of patients, but it is usually temporary, with only around 3% of patients requiring long-term care. CSF leak is the most prevalent significant consequence.¹

RESULTS OF DIFFERENT STUDIES

Senior *et al.*¹³ presented a series of more than 50 cases of pituitary hydroscopy employing the ClearESS irrigation system in 2005, noting that in about 25% of cases, the use of this approach resulted in an additional tumour diagnosis and removal.

Senior *et al.*¹⁴ described a case series of 176 individuals who underwent a total of 193 minimally invasive pituitary surgery procedures in 2008. The authors found that patients having hydroscopy had a decreased risk of CSF leak (24 vs 45 percent, $p=0.005$). These preliminary findings show that hydroscopy after pituitary surgery may enhance outcomes, but more prospective, controlled trials are needed.

Davide Locatelli⁹ performed 410 surgical procedures in 2009 to remove lesions in the sellar, cavernous sinus, and clival regions using diving

surgery. They removed 379 pituitary adenomas (92%), 21 craniopharyngiomas, 5 meningiomas, 4 chordomas, and 1 epidermoid during the procedure. They were able to speed up and improve the surgical excision of numerous lesions in the sellar and parasellar regions using this surgical method.

In 2017, China's Hai-Bin Gao⁷ performed Endoscopic Diving Technique on a total of 37 pituitary adenoma patients. The endoscopic diving approach, he claims, also allows the surgeon to view the undersea environment within the sella turcica.

Deyan Popov¹² performed intrasellar hydroscopy on 51 of his endoscopic group's cases in 2018. Overall, the endoscopic group had an 81.82 percent remission rate.

In 2019, Marco Ceraudo³ performed 76 endoscopic surgical procedures using the modified endoscopic diving technique. Marco Ceraudo discovered that by combining the OLYMPUS InstaClear with a specific irrigation sheath (which is generally used to clean the endoscope lens during surgery), he was able to get a continuous water flow comparable to that generated by Locatelli et al⁹. Cleaner and sharper images can be obtained by combining EDT with Ultra High Definition or 4K systems to better understand minute anatomical details (especially in the presence of underwater vision during EDT), find tumour residuals or a clear cleavage plane, and differentiate pathological tissues from adhesions or scar tissues.³

CONCLUSIONS

Pituitary hydroscopy is a safe, new addition to minimally invasive pituitary surgery that allows for a more complete inspection of the sella turcica using moderate saline irrigation. Hydroscopy after gross complete tumour excision frequently results in the elimination of extra, undetected tumour, potentially lowering the risk of recurrence and reducing the need for future surgery. Several groups' recent uses of diving techniques attest to the increased interest in these approaches. The development of dedicated surgical devices will improve the efficacy of diving procedures in the future. More research is needed right now to improve the effectiveness of diving techniques.

List of Abbreviations:

CSF: Cerebrospinal Fluid

EDT: Endoscopic Diving Technique

CT: Computed Tomography

MRI: Magnetic Resonance Imaging

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Conflict of interest:

The authors have no conflicts of interest.

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