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PROS AND CONS IN ENDOCRINE PRACTICE

Pro: endoscopic endonasal transsphenoidal pituitary surgery is superior to microscope-based transsphenoidal surgery

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Abstract The introduction of the endoscope to transsphenoidal pituitary surgery is relatively new, but represents a major advancement in the field. The use of the endoscope to visualize the sella via a direct endonasal approach offers the surgeon dramatically better visualization as well as improved range of motion compared to the operating microscope. Growing evidence confirms that these improvements directly translate into better surgical resections and outcomes. Further, patient comfort and satisfaction are higher with the endonasal method compared with other transsphenoidal approaches, and it is a cost effective technology. This position paper will outline the reasons that endoscopic endonasal transsphenoidal surgery is the preferred method for pituitary surgery, and why it will likely be adopted as the standard technique for transsphenoidal surgery worldwide.

Keywords Pituitary · Transsphenoidal · Surgery · Endoscopy · Microscope

Endoscope-based transsphenoidal pituitary surgery represents a major technical advancement for both patient and surgeon, and should replace microscope-based surgery whenever feasible. All surgical technologies must be evaluated with respect to their ability to achieve four goals: (1) achieve the primary objective of the surgery; (2) maximize patient safety; (3) maximize patient comfort and; (4) minimize costs so long as this does not adversely impact on patient safety or other clinical goals. In the case of transsphenoidal pituitary tumor surgery, endoscopy offers significant advantages over microscope-based surgery in all four arenas.

The *primary objective* of most transsphenoidal pituitary surgeries is complete removal of a tumor or cyst, while simultaneously preserving the normal pituitary gland and surrounding neurovascular structures. To achieve this goal, a surgeon naturally prefers maximal visualization of the entire sella and parasellar region, and the greatest degree of freedom for manual dissection and removal of the tumor. Endoscopy improves upon both extent of visualization and extent of mobility, and therefore, constitutes a logical step forward in the evolution of these procedures. Note that the basic methodology for performing transsphenoidal surgery was developed in the early twentieth century [1, 2], but was abandoned by neurosurgeons by 1930 due to a lack of ability to adequately visualize the tumor using this approach [3]. In the mid-1960s, the surgical microscope was introduced [2]. The microscope provided markedly better illumination and magnification of the sella than any previous technology. Within 5–7 years transsphenoidal surgery replaced craniotomy as the preferred method for pituitary surgery, a trend that has continued to the present [2, 4, 5]. In other words, it was not the surgical approach that was a limiting factor, but the absence of a technology to permit the surgeon adequate visualization and mobility via this route when removing tumors.

Endoscopy represents the next level of technical evolution. The operating microscope is positioned outside the body a large focal distance (250–350 mm) from the sella. Visualization of the sella is accomplished by looking into the sphenoid sinus through a speculum, providing tunnel vision, with little ability to see objects beyond the extent of the speculum. In contrast, the endoscope is positioned directly within the sphenoid sinus only 1–2 cm from the

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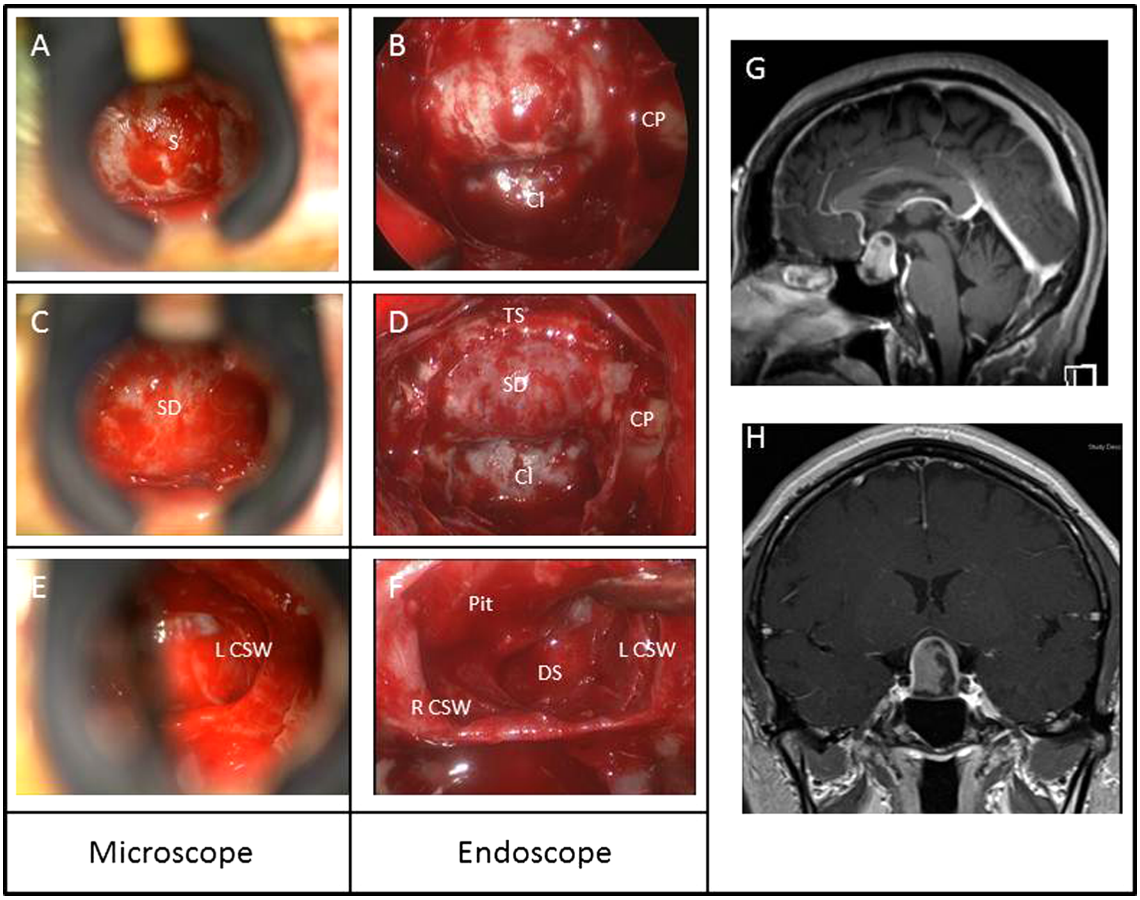

Fig. 1 Comparison of typical exposures obtain during endonasal transsphenoidal surgery with the microscope (panels **a**, **c**, **e**) and endoscope (panels **b**, **d**, **f**). Each photograph was taken from the video capture system of the microscope (Pentero^{TM}, Carl Zeiss, Oberkochen GE) or the endoscope (4 mm diameter 0° rigid scope, Karl Storz Endoscopy, Tuttlingen GE) with a high definition (HD) camera (Image 1$^{®}$, Karl Storz Endoscopy). **a**, **b** Exposure of sella turcica, bone intact; **c**, **d** removal of sellar bone and exposure of sellar dura; **e**, **f** after tumor removal, empty sella. *S* sella; *SD* sellar dura; *CP* carotid protuberance; *Cl* clivus; *R-CSW* right cavernous sinus wall; *L-CSW* left cavernous sinus wall, *DS* dorsum sella, *TS* tuberculum sella, *Pit* pituitary gland. Note the dramatically improved field of view and image clarity obtained with the endoscope, compared to the "tunnel vision" view of the microscope. MRI of the initial tumor is shown in panels G and H. The results shown here are typical. The images are stored via digital capture, but not in HD resolution, and are, therefore, slightly less clear than the surgeon's resolution

surgical bed. Rather than tunnel vision, the endoscope creates a panoramic and dramatically larger view. In fact cadaveric studies suggest that the endoscopic field of view is 3–4 times larger than the microscopic view via an endonasal approach, and almost twice as large as through a sublabial approach [6]. Because the endoscope can be so easily manipulated and repositioned within the sella, the actual field of view available to the surgeon is even greater and allows the surgeon to visualize beyond the lateral edges of the cavernous sinus, and both above and below the sella. Angled endoscopes further expand the visual capabilities, allowing the surgeon to see around corners and edges that are simply not feasible with a microscope [7]. A larger field of view translates directly into two results: (1) greater ability to see residual tumor; and (2) greater ability to see critical neurovascular structures such as the carotid artery, cavernous sinus, or suprasellar cisterns. Greater visualization of surgical anatomy is advantageous in removing tumor and preserving normal structures. In turn, endoscopy facilitates larger resections and higher rates of hormonal remission for functional tumors [8–13]. Because a "picture is worth a thousand words," one needs only to compare the field of view, which obtained by utilizing a microscope and endoscope in the same surgery, at identical times in the operative procedure, to become convinced of the veracity of this statement (Fig. 1).

However, improved visualization does not always result in more extensive or safer tumor removal. In this regard, surgeon range of motion is at least as critical as good visualization. It is this important observation that further underscores the power of endoscopic surgery. With a microscope-based endonasal approach to the sella, a speculum is used to push the nasal structures aside and create a tunnel down which the microscope visual pathway is created. This is true for many microscope-based neurosurgical approaches, but is particularly limiting for the endonasal method because opening of the speculum collapses the contralateral nostril, forcing the surgeon to utilize a single nostril to pass instruments. Lateral excursions of instruments are relatively limited because of the rigid walls of the speculum. The net effects are restricted mobility and frequent obstruction of the visual pathway with instruments. Using the endoscope, the surgeon achieves the exact opposite result. Because the endoscope obviates the need for a speculum, surgery is typically performed using a binasal technique in which instruments are manipulated through both nares. This provides the surgeon with dramatically improved range of motion for instruments as well as the camera. In turn, the surgeon is not only able to better visualize the surgical field but also can actually take advantage of this visualization with improved dexterity. These statements are not a reflection of personal preference, but are reflected in the ever growing literature on endoscopic pituitary surgery that routinely reports more extensive resection and high rates of hormonal remission for endocrine active tumors such as growth hormone or ACTH secreting adenomas than reported using the microscope [8, 10–12, 14–21].

Patient safety is also maximized using the endoscope. The most frequent complications associated with pituitary surgery include loss of pituitary hormone function, diabetes insipidus, CSF leak, and carotid artery injury, with carotid injury being the most serious [22]. Several studies report complications of endoscopic versus microscopic surgery. These data indicate that the risks of these complications are at least similar in both groups [23–29], and perhaps slightly reduced in the endoscopic group [30]. The rate of carotid injury reported in both approaches is between 0.3–0.9 % [23–25, 28]. Of note, a meta-analysis by Ammirati et al. [31] did report a higher rate of "vascular complications" in endoscopic surgery relative to microscope, but the authors considered cavernous sinus bleeding that limited resection as a vascular complication, and did not provide any specific data on rates of carotid injury. A review of the individual papers utilized to generate that meta-analysis demonstrated no significant differences in reported carotid injuries between the two groups. Rates of rhinological complications are generally reduced in the endoscopic group [19, 29, 32–34] with only one series noting increased complications in acromegalic patients [19]. There is a learning curve to complication avoidance from endoscopic surgery that is not as steep in microscopic surgery due to the large field of view and range of motion available with this method [36, 37]. However, once a surgeon gains familiarity with this wide view of the skull base, he/she quickly learns to take advantage of the improved visualization to more completely and safely remove tumor, while visualizing the structures to be preserved. While endoscopy has a learning curve, it is not less safe, and most data would suggest at least equivalent safety.

Patient comfort is also an important determinant of the value of a given surgical procedure. The rapid adoption of endoscopy in general, thoracic, urological, and gynecological surgery was largely due to the ability of these procedures to produce equivalent surgical results, while simultaneously improving patient post-operative comfort and wound healing. Endoscopic endonasal pituitary surgery enjoys similar success. Because this procedure does not employ a sub-mucosal resection of nasal structures, patients generally report less pain, bruising, and post-operative rhinological dysfunction compared to microscope-based sub-mucosal procedures such as the standard sublabial or columellar approaches [9, 16, 27, 32, 38–42], although higher self-reported rates of sinusitis were noted in one series of patients with acromegaly [19].Sub-mucosal procedures also require the use of post-operative nasal packs, which are very uncomfortable [39]. The frequency of rhinological complaints was one reason that neurosurgeons were quick to adopt the endonasal approach. An endonasal approach using the microscope enjoys similar benefits to patient comfort and the endoscopic approach, but in turn, compromises the capacity for surgical resection, as the endonasal microscopic view is by far the most constricted view with the least and range of motion [6]. Surgical outcomes data for endonasal microscopic pituitary surgery are similar to those reported for sublabial microscopic approaches [22, 26, 43], while purely endoscopic outcomes appear to be superior to those of both groups [21]. In other words, it appears that it is the tool used to visualize the tumor (microscope vs. endoscope) rather than the surgical approach (endonasal vs. sublabial, etc.) that likely impact on extent of resection. Endoscopy uses an endonasal extra-mucosal pathway for better patient comfort, while simultaneously providing superior extent of resection and equivalent safety than microscope-based surgery.

A final issue is the *cost of technology*. Technologies that may improve surgical outcomes, but are extremely expensive or difficult to maintain, are less likely to be integrated into daily surgical practice on a wide scale basis. Modern day endoscopy equipment, including high-definition cameras and monitors, is widely utilized by almost every hospital for a host of procedures, and thus most hospitals will have the necessary video stack and light source equipment needed to perform these procedures. Therefore, converting to endoscopic pituitary surgery does not typically represent a major financial investment for most hospitals, and is not a significant barrier to implementation.

Endoscopic pituitary surgery is certainly not without its difficulties and limits. Because the scope sits within the nostril or sphenoid sinus, blood and other bodily fluids can easily cloud the lens. This can be particularly problematic in the face of heavy bleeding, which can completely obscure the field of view. To compensate for this, the surgeon must be facile with rapidly cleaning the lens and at times working with a less than perfect image. Additionally, the magnification factor and optical quality of the microscope are slightly superior to that of endoscopes, even though the difference is nominal in the majority of procedures and more than compensated for the improved degree of visualization and dexterity the endoscope provided the surgeon. Further, neurosurgeons are used to having stereoscopic vision with the microscope, while endoscopy is two-dimensional [44]. Interestingly, the lack of stereoscopic vision is rapidly adapted to by surgeons, and in general not felt to be a limiting factor to pituitary surgery after a brief learning curve. The relative lack of importance of stereoscopic vision is also evidenced by the dramatic success of endoscopic methods in other surgical specialties [45–47]. Stereoscopic endoscopes are available [48], although their real advantage over standard scopes has not yet been established, Over time they may indeed prove to represent an incremental improvement. Finally, for a surgeon to perform bimanual tumor removal there must be a way to hold the endoscope with a "third hand". This is most frequently accomplished by a second surgeon manipulating the endoscope [7, 12], although an endoscope holder can also be used [12]. Regardless, it can be more difficult to manipulate the endoscope than the microscope, and is a significant component of the learning curve associated with endoscopy. While each of these limitations has some validity they are more than compensated for by the multitude of advantages endoscopy provides for transsphenoidal surgery.

If endoscopic pituitary surgery is safer, has better outcomes, improves patient comfort, and is not prohibitively expensive to implement, why has it not been universally adopted? First, it must be acknowledged that to date there is not a large body of evidence that endoscopy is clearly superior, with several studies suggesting equivalency between the two methods [18, 19, 31]. Importantly, no papers suggest endoscopy to be clearly inferior. Unfortunately validation of the superiority of one surgical method over another tends to evolve over years to decades. Having stated that, I believe the lack of conclusive evidence is not the primary reason why endoscopy has not yet been universally adopted. Rather, the reason primarily rests with neurosurgeons' lack of familiarity with endonasal endoscopic methods, coupled with their extreme comfort using the operating microscope. Until recently endoscopic skills were not a component of neurosurgical training. But this appears to be changing. Many practicing surgeons now rely upon a partnership with otolaryngologists to facilitate the learning process [49]. Others are taking advantage of the large number of fellowships and post-graduate courses designed to teach endoscopic techniques. Many neurosurgery residents are gaining exposure as a routine component of their training, and will likely integrate it into their own surgical practices [49]. As the barrier for performing endoscopic pituitary surgery is reduced or eliminated, undoubtedly it will become the accepted standard for pituitary adenoma resections. In my opinion the "train has already left the station" and endoscopy is well on its way to replacing microscope-based methods as the preferred standard for transsphenoidal surgery.

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