Advances in endoscopic resection of sinonasal neoplasms

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Abstract Management of sinonasal diseases has undergone significant change with the advent of endoscopic techniques. A wide variety of pathology can now be surgically managed with the use of endoscopes both within and beyond the sinonasal tract. Endoscopic techniques allow for excellent visualization and complete tumor resection with low morbidity. As experience continues to grow, endonasal endoscopic techniques are becoming the surgical procedures of choice for the management of a wide variety of benign neoplasms.

Keywords Sinonasal neoplasms · Endoscopic surgery · Nasal tumors · Inverted papilloma · Juvenile nasopharyngeal angiofibroma

Introduction

The development of nasal endoscopy and endoscopic techniques has dramatically altered the management of sinonasal pathology. Over the last two decades, endoscopic techniques have become the standard of care for the management of inflammatory sinonasal diseases. Greater experience has led to the application of these techniques to other diseases processes, including the treatment of sinonasal neoplasms. Additionally, endoscopic techniques have been extended to the management of pathology beyond the paranasal sinuses, including the management of pituitary lesions, orbital lesions, pterygopalatine fossa lesions, infratemporal fossa lesions and lesions of the clivus [1–5].

Endoscopic techniques continue to gain acceptance for the management of neoplastic processes. Advantages of endoscopic techniques include the ability to obtain a magnified view with low patient morbidity. A variety of angled scopes allow visualization of areas that may otherwise be difficult to access. Initial work reported on feasibility and safety of endoscopic resection of a variety of lesions. More recent work has focused on oncologic results. Not only have endoscopic techniques been found to be comparable, some authors have reported superior results with endoscopic techniques when compared with open techniques [6]. This paper will review the management of sinonasal papilloma and juvenile nasopharyngeal angiofibroma because these lesions have been the focus of most of the literature regarding endoscopic tumor resection. As experience with endoscopic surgery grows, the techniques may be applied to a broader range of pathology [7]. The techniques are still evolving, and ongoing development of endoscopic techniques may allow management of neoplasms of the paranasal sinuses and skull base with less morbidity than ever before.

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Sinonasal papilloma

Sinonasal papillomas have been categorized into three distinct subtypes based on histologic appearance: inverted papilloma, cylindrical cell papilloma and fungiform papilloma [8]. A pathologic review of 800 cases of sinonasal papilloma found that inverted papilloma is the most common of these subtypes, accounting for 70% of cases [9]. Cylindrical cell papillomas accounted for 19% of cases and fungiform papillomas made up 11% of cases. Although all three subtypes are histologically benign, inverted and cylindrical cell papillomas have been reported to be associated with malignancy. Malignancy association rates have ranged from 4% to 17% for inverted papilloma and from 9% to 13% for cylindrical cell papilloma [8–11].

These lesions have an aggressive growth pattern, with the ability to lead to erosive bony changes and extend beyond the sinonasal tract. In addition, there have been many reports of high recurrence rates after surgical resection. This combination of factors has made complete and aggressive surgical resection the treatment of choice for sinonasal papillomas. Because inverted and cylindrical cell papillomas follow similar clinical courses, the two subtypes will be considered together for the purpose of discussing evaluation and treatment.

Preoperative evaluation

Sinonasal papillomas tend to have a characteristic appearance on endoscopy, consisting of papillary soft tissue masses with an irregular surface. Both inverted and cylindrical cell papillomas also tend to have characteristic locations along the lateral nasal wall [8]. In reviewing the literature, Krouse was able to find 1,106 cases in which sites of tumor involvement were reported. Eighty-two percent of lesions involved the lateral nasal wall. The maxillary sinus was involved in 53.9%, the ethmoid sinus was involved in 31.6%, the frontal sinus was involved in 6.5%, and the sphenoid sinus was involved in 3.9%. It is important to keep in mind that sites of involvement do not necessarily indicate sites of tumor attachment. It is very possible for tumor to enter any of the paranasal sinuses in a dumbbell fashion without actual tumor involvement in that region.

Radiographic imaging studies are helpful in order to assess disease extent, but accurate preoperative determination of tumor extent remains difficult. Computerized tomography (CT) is usually the initial imaging study obtained, and provides excellent definition of the bony anatomy of the paranasal sinuses and surrounding structures. However, CT is unable to provide differentiation between soft tissue and surrounding secretions, and this can often lead to overestimation of disease extent. For this reason, some authors have recommended greater reliance on magnetic resonance imaging (MRI) or intraoperative endoscopy.

MRI can be helpful in differentiating secretions and inflammatory disease from tumor. Oikawa et al. assessed the accuracy of preoperative MRI in the determining the extent of disease in a series of 21 patients with inverted papilloma [12]. The preoperative MRI stage was compared to the intraoperative visualization and the final histopathologic findings. This study found that MRI accurately predicted the Krouse stage of the tumor 86% of the time when compared to the intraoperative and postoperative findings. When evaluating each individual sinus separately, MRI was less accurate and overestimated disease extent in an individual sinus in 7 patients. This work shows that MRI can be more helpful than CT in differentiating between inflammatory disease and tumor, but does have its own limitations.

Due to the limitations of radiologic imaging, intraoperative endoscopy may be the most accurate means of determining disease extent. Sukenik and Casiano compared preoperative CT scan and intraoperative endoscopic findings to the final pathologic findings in 19 patients with inverted papilloma [13]. They found that intraoperative endoscopy was superior in terms of sensitivity and specificity compared to CT.

In our practice, CT is the initial imaging study obtained in all patients with sinonasal papilloma. It provides excellent definition of paranasal sinus anatomy, and can provide evidence of extension of disease beyond the paranasal sinuses. If there is concern for disease extension into regions that cannot be adequately managed endoscopically, we obtain an MRI with contrast. These regions include the frontal sinus, the orbit or the intracranial space. Disease extent into these areas may necessitate an adjunctive open procedure to achieve complete tumor resection, and we find the information provided by MRI helpful in preoperative planning and patient counseling in these cases. We rely most heavily on intraoperative endoscopic visualization to make the final determination of disease extent. In almost all cases, intraoperative endoscopy allows clear differentiation between the tumor and surrounding inflammatory disease.

Radiographic changes that can be seen frequently in patients with inverted papilloma include bony erosive changes and osteitic changes. These bone changes can have implications for both diagnosis and treatment and it is important for surgeons considering endoscopic approaches to be familiar with the significance of these changes.

Erosive bone changes are seen frequently in inverted papilloma [14]. In most cases, these areas represent sites of bony remodeling due to pressure from tumor expansion, rather than sites of direct tumor infiltration [15]. Therefore, in many instances, the presence of bony erosion is not a contraindication to endoscopic approaches. Without tumor infiltration, the mucosa at these sites will remain intact, and tumor will easily dissect away from the underlying mucosa. Therefore, erosive changes may not be as significant a finding in many patients as would initially be thought. If erosive changes are extensive enough to raise suspicion of

dural or periorbital invasion, it may be useful to obtain an MRI to better delineate disease extent.

Radiographic finding of osteitis may have much greater implications because such findings may be helpful in determining sites of tumor attachment (Fig. 1) [16, 17]. As is discussed in greater detail later in this article, endoscopic techniques focus on meticulous resection of all tumor attachment sites, and preoperative determination of the attachment site can be quite helpful in delineating extent of resection. Yousuf and Wright found that the presence of osteitis was able to correctly predict tumor attachment sites in 22 of 28 patients evaluated [17]. If osteitis is seen in regions of the sinonasal tract that are not able to be approached endoscopically, the surgeon can plan for an adjunctive external approach.

Surgical treatment strategies

Over the years, a variety of surgical approaches have been applied to the resection of sinonasal inverted papillomas. These approaches can be categorized as follows: open approaches, transnasal non-endoscopic approaches and transnasal endoscopic techniques. Historically, high recurrence rates had been reported with transnasal approaches. Philips et al. compared outcomes using a variety of non-endoscopic surgical techniques in a series of 112 patients [14]. With a mean follow up of 6 years, the authors found that more limited procedures were associated with higher recurrence rates. Patients undergoing transnasal excision alone had a 58% recurrence rate. Those who underwent transnasal resection and a Caldwell-Luc antrostomy had a recurrence rate of 35%, and patients undergoing the most extensive resections by way of an open medial maxillectomy had the lowest recurrence rate of 13%. These results were mirrored by other series describing unacceptably high recurrence rates with limited procedures [14, 18, 19]. On the other hand, series in which more extensive procedures were performed reported excellent control rates. For example, a series by Myers et al. reported a 4% recurrence rate at a mean follow up of 9 years in 22 patients undergoing medial maxillectomy for inverted papilloma [18]. These data led to medial maxillectomy becoming the gold standard for the treatment of sinonasal inverted papilloma [18].

The high recurrence rates seen with limited resections were most probably related to incomplete resection. That is, patients undergoing limited resections had residual disease rather than recurrent disease because the techniques used did not allow for adequate visualization [6]. Open approaches, on the other hand, relied on the understanding that these tumors originate from the lateral nasal wall or within the paranasal sinuses [8]. Aggressive, enbloc resection of these regions by way of a medial maxillectomy frequently allowed for complete tumor removal, even if visualization of tumor extent was difficult to obtain.

Greater experience with endoscopic techniques for the treatment of inflammatory sinonasal disease led to the application of these techniques to the treatment of sinonasal papillomas. The use of endoscopic techniques does require surgeons to reconsider a major principle of surgical oncology – that of enbloc resection of neoplasms.

Most endoscopic techniques rely on the use of piecemeal resection, but such an approach does not seem to adversely affect the control rates [6]. It is important to remember that enbloc resection in the sinonasal tract is difficult to achieve even with open procedures due to the proximity of the sinonasal tract to the skull base and orbit [20]. For tumors

Fig. 1a Coronal CT image demonstrating an area of osteitis (arrow) along the roof of the right maxillary sinus indicating the site of tumor attachment

Fig. 1b Corresponding intraoperative endoscopic image showing area of osteitis (arrow) along roof of the right maxillary sinus. The osteitic area represented the site of tumor attachment and was drilled down to ensure complete tumor removal

like sinonasal papillomas, endoscopic techniques rely on rapid debulking of the unattached portions of the tumor. This is followed by more aggressive and complete resection of the tumor attachment sites. In the sinonasal tract, tumors can extend to multiple distinct anatomic sites without actually infiltrating the mucosal lining at these sites. For example, tumors that originate along the lateral nasal wall can grow and extend superiorly into the frontal recess and frontal sinus in a dumbbell fashion. If there are no attachment sites in the frontal recess or the frontal sinus, the tumor can be resected without the need for extensive removal of mucosa from the sinus itself.

Some authors have described approaches that incorporate endoscopic techniques while adhering to the principles of enbloc resection [13, 21, 22]. In clinical practice, adhering to the principle of enbloc resection does not appear to be mandatory because excellent control rates have been reported using piecemeal endoscopic resection.

Results of endoscopic surgery for inverted papilloma

Endoscopic techniques for the resection of sinonasal inverted papilloma were reported separately by Wigand and Stammberger in the 1980s [23]. Over the years, these approaches have replaced the use of open medial maxillectomy as the procedure of choice for inverted papilloma in many institutions. The first series to report the results of endoscopic surgery for inverted papilloma in the English literature was published in 1992 by Waitz and Wigand [23]. The authors reported their surgical technique, and compared the results of their endoscopic resections to the results of external resections. When performing endoscopic resections, the authors reported complete macroscopic tumor removal, followed by meticulous resection of the tumor attachment site with appropriate margins. The underlying bone was drilled using a diamond burr in order to remove any foci of tumor that may have infiltrated the bone. Thirty-five of their patients underwent endoscopic resection, and 16 underwent external approaches. The authors found a 17% recurrence rate for the endoscopic resection group and a 19% recurrence for the external resection group [23]. These recurrence rates were comparable to data regarding the results of open resection techniques, and the authors refuted previously published statements that advocated avoidance of transnasal resections.

Other authors began to report favorable results using endoscopic techniques for the management for inverted papilloma [24]. However, at that time, most authors recommended using endoscopic techniques only for limited tumors. They recommended using traditional medial maxillectomy for more extensive tumors [24]. With time, even the largest tumors have been able to be resected endoscopically.

Busquets and Hwang published a comprehensive meta-analysis comparing open and endoscopic techniques for the resection of inverted papilloma [6]. Such an analysis is helpful because analyzing a large number of series can mitigate the bias associated with individual studies. The authors reviewed 30 articles that reported on results of inverted papilloma resection between 1992 and 2004. The authors also added their own institutional data to this compilation. There were a total of 714 patients treated endoscopically and 346 patients treated non-endoscopically. The recurrence rate was found to be 12% for the endoscopic treatment group and 20% for the non-endoscopic treatment group. The difference was found to be statistically significant, and illustrated that endoscopic approaches may actually lead to improved control rates over open techniques.

Such findings are not surprising because the traditional medial maxillectomy may not have been adequate to address disease in a variety of areas, including the sphenoid sinus, lateral aspect of the maxillary sinus, or the frontal sinus [25]. Endoscopic techniques allow detailed visualization of disease at these sites. Furthermore, the surgical resection can easily be tailored to address disease in different anatomic sites, allowing for improved outcomes over the use of open techniques.

Anatomic sites

Most inverted papillomas are amenable to endoscopic resection, but involvement of certain anatomic sites may represent the limits of endoscopic techniques. Lesions that involve the lateral nasal wall, ethmoid sinus and sphenoid sinus are able to be approached endoscopically using the techniques that were originally described by Waitz and Wigand [23]. It is important to have a variety of zero degree and angled endoscopes available to optimize visualization of different anatomic sites. Our preference is to rapidly debulk the tumor using forceps and a microdebrider until the attachment sites are identified. At the attachment sites, great care is taken to remove all mucosa in its entirety. Curettes or diamond burrs are used to ensure complete removal of mucosa from the underlying bone.

Anatomic sites that remain difficult to address endoscopically include the anterior and lateral wall of the maxillary sinus, and the superior and lateral aspects of the frontal sinus [26]. Most areas of the maxillary sinus are able to be visualized and accessed endoscopically after a wide middle meatal antrostomy has been performed. In some instances, we find it helpful to resect the posterior aspect of the inferior turbinate in order to continue the antrostomy down to the level of the nasal floor. Adequate visualization and instrumentation can be achieved using 45 and 70 degrees endoscopes, curved curettes, giraffe forceps and angled microdebrider blades. In our practice, we have

found that it is possible to reach even the most lateral extent of the maxillary sinus using such endoscopic approaches.

The area that remains difficult to visualize and instrument is the anteromedial most aspect of the maxillary sinus. The medial wall of the maxillary sinus from the nasolacrimal duct to the anterior wall of the sinus may be inaccessible endoscopically. In these cases, an adjunctive external approach may be necessary. A traditional Caldwell-Luc approach can be used. A less invasive approach involves the use of a small canine fossa puncture so that instruments and endoscopes can be inserted to address involved areas [21].

Endoscopic resection of frontal sinus disease can also be difficult. In many cases, the tumor may extend into the frontal recess and frontal sinus, but there may be no attachments along the mucosa in these regions. In these instances, the tumor can be delivered from these regions relatively easily using suction tips and blunt instruments. Endoscopic management may also be feasible for certain tumors with attachment sites in the sinus. The posterior and medial most aspects of the frontal sinus are able to be visualized and instrumented using angled scopes, forceps and microdebrider blades. Wider access can be obtained by performing an endoscopic modified Lothrop procedure (also known as a Draf type III frontal sinusotomy). This technique involves the creation of a common outflow tract to the frontal sinus after removal of a portion of the nasal septum, the intersinus septum, and the frontal sinus floor on each side. It maximizes the endoscopic exposure of the frontal sinuses, and allows instrumentation through both nasal cavities. Tumor attachment in the inferior and medial aspects of the frontal sinus may be amenable to such an approach.

Open frontal sinus surgical approaches may be necessary for regions of the sinus that cannot be adequately accessed using endoscopic techniques. The osteoplastic flap has been the time-tested approach to manage extensive frontal sinus pathology, and may be indicated in cases with extensive frontal sinus involvement [27]. This approach provides wide access to all portions of the frontal sinus. A less invasive external technique is the use of a frontal sinus trephination. A trephination can be combined with a transnasal endoscopic technique to address a broad range of frontal sinus pathology without the morbidity associated with more extensive frontal sinus approaches [28]. This combined approach has been termed the “above and below” approach, and can obviate the need for more extensive open frontal sinus surgical techniques [28]. Traditionally, trephination sites have been located in the inferomedial aspect of the sinus. For pathology located in more difficult-to-reach areas of the frontal sinus, the trephination can be positioned over the site of pathology using image guidance [29]. When an osteoplastic flap is necessary, it can be useful to perform the osteoplastic flap

without obliteration [15]. This can facilitate postoperative endoscopic and radiologic surveillance.

Juvenile nasopharyngeal angiofibromas

Juvenile nasopharyngeal angiofibromas (JNA) are vascular tumors that may originate within the sphenopalatine foramen, the pterygopalatine fossa, or the vidian canal [30]. Occurring almost exclusively in adolescent males, these tumors can involve a variety of anatomic locations, including the nasal cavity, paranasal sinuses, the pterygopalatine fossa, the infratemporal fossa, the orbit, or the middle cranial fossa. Traditionally, a variety of open surgical procedures by way of transfacial, transpalatal or infratemporal fossa approaches have been used for the management of JNA [31]. Such approaches can be associated with significant morbidity, and endoscopic techniques have recently been used with greater frequency for the management of JNA. Endoscopic techniques may allow management of appropriately-selected patients with less morbidity than ever before.

The vascular nature of JNA can make endoscopic approaches to resection of these lesions challenging. Active bleeding can make it difficult to maintain endoscopic visualization, and it can be challenging to obtain hemostasis using endoscopic techniques. In order to decrease intraoperative blood loss, most authors advocate the use of preoperative embolization [31, 32]. In addition, recent advances in endoscopic instrumentation have improved the ability to achieve intraoperative hemostasis. These advances include the availability of endoscopic suction bipolar forceps and endoscopic clip applicators. These instruments can help to control bleeding from both arterial and venous sources.

The diagnosis of JNA is typically made based on characteristic radiographic findings without the need for biopsy. Accurate preoperative evaluation is important in determining feasibility of endoscopic approaches for the management of JNA. For smaller tumors, CT scan alone may be adequate in determining disease extent. Preoperative MRI is helpful in determining extension of tumor into regions such as the pterygopalatine fossa, infratemporal fossa, orbit, cavernous sinus or middle cranial fossa. Characteristic findings on imaging studies include the presence of a nasal mass, widening of the sphenopalatine foramen, and a soft tissue lesion involving the pterygopalatine fossa and infratemporal fossa. Extensive lesions can extend into the orbit or intracranial space. The imaging characteristics, combined with the clinical presentation, typically provide enough information for an accurate diagnosis and make biopsy unnecessary. If the diagnosis is uncertain on the basis of imaging studies, biopsy should be performed in the operating room. This allows for a secure airway and allows the surgeon to obtain control of any heavy bleeding that can result after biopsy of these vascular lesions.

Surgical technique

In most instances, adequate access requires a large maxillary antrostomy, ethmoidectomy and sphenoidotomy. It can be helpful to debulk the nasal cavity and nasopharyngeal portion of the lesion so that there is more space for manipulation of the endoscope and instruments. Access to the pterygopalatine and infratemporal fossae is achieved by removing the posterior wall of the maxillary sinus using Kerrison punches, curved curettes or angled drills. When the lateral most extent of the tumor is exposed, the internal maxillary artery can be identified and ligated using an endoscopic clip applicator or using endoscopic bipolar forceps.

Once the sites of tumor involvement are exposed, the tumor can be separated from surrounding soft tissue using blunt dissection because a plane generally exists between the tumor and surrounding tissues [31]. An assistant can help by placing traction on the tumor while the surgeon performs the resection. Robinson et al. have described a technique that incorporates a septal incision to allow an assistant to place instruments through the contralateral nostril in order to provide traction and facilitate dissection [4]. The assistant can also provide constant suction, allowing visualization to be maintained as the resection proceeds. It can be helpful to use dissecting instruments that incorporate suction in order to allow continuous clearing of blood. Such instruments include suction elevators and suction curettes.

Endoscopic techniques certainly allow excellent access to portions of the tumor that involve the nasal cavity and paranasal sinuses. Excellent visualization and access can also be obtained of the pterygopalatine and infratemporal fossae using endoscopic techniques. Tumor infiltration into the regions of the orbit and parasellar region have been considered by some to be relative contraindication to the endoscopic approach [33]. It is important to remember involvement of these areas poses significant challenges even with open techniques [31]. In fact, endoscopy may provide better visualization to these regions than traditional open approaches, and disease at these sites may be more amenable to endoscopic resection than other methods of resection [32].

Results of endoscopic surgery for JNA

Nicolai et al. reviewed their experience with endoscopic resection in 15 patients with JNA [30]. The authors had only one recurrence in this series after a mean follow up period of 51.2 months. Although all patients underwent preoperative embolization, 7 patients had contribution by branches from the internal carotid artery. These branches were not embolized, and the presence of such feeders did not preclude endoscopic resection. Several patients in this

series did have limited involvement of the infratemporal fossa. The authors considered intracranial extension to be a contraindication for endoscopic resection. However, many tumors that extend to the middle cranial fossa remain extradural. In the absence of dural infiltration, intracranial extension may not be an absolute contraindication to an endoscopic approach in experienced hands.

Roger et al. reported on endoscopic resections in 20 patients with a mean follow up of 22 months [32]. Two patients were found to have residual/recurrent tumor. One of these patients had residual disease at the orbital apex, and the other had disease in the interpterygoid region. These patients were followed with serial imaging studies, and no progression of tumor was noted during the course of follow up.

Retrospective reviews by Mann et al. [33] and Pryor et al. [34] have compared the outcomes obtained using endonasal techniques to the outcomes obtained using open techniques. Mann et al. described their experience in 30 patients with JNA over a period of 20 years [33]. In this series, the authors used a variety of approaches, including transpalatal, midface degloving, lateral rhinotomy and endonasal approaches. Fifteen patients were treated using open resection techniques, and 15 patients were treated with the endonasal approach. Although the authors did not describe their surgical technique in detail, it appears that some of the endonasal resection was accomplished using microscopic techniques rather than endoscopic ones. There were 5 patients with recurrences after open surgical approaches, compared to only one recurrence in the endonasal group. These authors use the endonasal approach in all patients with early stage disease, but noted that they did expand the use of this technique for more advanced tumors as their experience increased.

Pryor et al. performed a retrospective review of their experience with surgical resection of JNA between 1975 and 2004 [34]. From 1975 to 2001, patients were treated using various open techniques. After 2001, all patients were treated using endoscopic techniques. Overall, 59 patients were treated using open techniques and 6 were treated using endoscopic techniques. Patients in the endoscopic group were found to have a lower recurrence rate, lower estimated blood loss, fewer complications, and a shorter hospital stay. These retrospective reviews certainly have their limitations, but point towards excellent outcomes with decreased morbidity with the use of endoscopic techniques. Because controlled trials comparing the different approaches are unlikely, future analysis of pooled data may allow more meaningful conclusions to be made.

Conclusions

The use of endoscopic techniques to manage neoplastic processes within and beyond the paranasal sinuses continues

to gain acceptance. In certain instances, like sinonasal papillomas, endoscopic techniques have been shown to have better oncologic outcomes when compared with open techniques. Such results may also be seen with other types of tumors as experience continues to grow. The ability to perform resections with lower morbidity and better outcomes may make endoscopic approaches the standard of care for the management of a wide range of neoplasms. However, certain anatomic regions and certain types of lesions will continue to be difficult to approach endoscopically. Ongoing work will allow surgeons to better delineate the possibilities and limitations of endoscopic tumor resection.

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