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Surgical Complications and Management Strategies in Endoscopic Endonasal Transsphenoidal Surgery for Pediatric Craniopharyngiomas

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Abstract

Endoscopic endonasal transsphenoidal surgery (EETS) has emerged as an effective method for the resection of craniopharyngiomas in pediatric patients, offering minimally invasive access and enhanced visualization. This literature review examines the surgical complications and management strategies associated with EETS for pediatric craniopharyngiomas. Common complications include cerebrospinal fluid (CSF) leaks, intraoperative hemorrhage, hypopituitarism, and visual disturbances. The incidence of these complications is influenced by factors such as tumor size and location, patient age, comorbidities, and surgeon experience. Effective management strategies involve meticulous preoperative planning, advanced imaging techniques, intraoperative monitoring, and comprehensive postoperative care. Detailed preoperative imaging is crucial for surgical planning, while intraoperative neuronavigation and neurophysiological monitoring help mitigate risks. Postoperative care, including endocrine evaluation and rehabilitation, is essential for addressing complications and improving patient outcomes. This review underscores the critical aspects of managing surgical complications to enhance the safety and efficacy of EETS in treating pediatric craniopharyngiomas.

Keywords: endoscopic endonasal transsphenoidal surgery (EETS), pediatric craniopharyngiomas, surgical complications

1. Introduction

Craniopharyngiomas are histologically benign, yet challenging, epithelial tumors located in the sellar and suprasellar regions of the brain, with a bimodal age distribution of 5–14 years and 50–75 years. These tumors, arising from remnants of Rathke's pouch, are histologically classified into two main subtypes: adamantinomatous and papillary. Adamantinomatous craniopharyngiomas, more common in children, exhibit cystic and solid components with calcifications, while papillary craniopharyngiomas are predominantly found in adults and are typically solid and lack calcifications (Harsh et al., 2022). The incidence of craniopharyngiomas is approximately 0.5-2 cases per million per year, with a peak incidence in children aged 5-14 years (Ortiz et al., 2023). Clinically, these tumors often present with symptoms due to their proximity to critical structures, including the optic chiasm, pituitary gland, and hypothalamus. Common presenting symptoms include headaches, visual disturbances, and endocrine dysfunctions such as growth hormone deficiency, hypothyroidism, and diabetes insipidus (Müller, 2014).

Historically, the treatment of craniopharyngiomas has posed significant challenges due to the complex anatomy of the sellar region and the potential for postoperative morbidity. The traditional surgical approach, open craniotomy, involves accessing the tumor through a skull opening. This method, while effective in tumor removal, is associated with high rates of morbidity, including neurocognitive deficits, hormonal imbalances, and long recovery times (Hong, 2022). In recent decades, there has been a paradigm shift towards minimally invasive surgical techniques. The endoscopic endonasal transsphenoidal surgery (EETS) has emerged as a preferred approach, offering several advantages over open craniotomy. This technique involves accessing the tumor through the nasal passages and sphenoid sinus, providing a direct route to the sellar region with minimal disruption to surrounding brain tissue (Feng et al., 2022; Cappabianca et al., 2004).

The growing use of EETS in pediatric neurosurgery underscores the importance of understanding its associated complications and management strategies. While EETS offers numerous benefits, including reduced recovery times and improved visualization of the surgical field, it is not without risks. Complications such as cerebrospinal fluid (CSF) leaks, vascular injury, and hormonal imbalances remain significant concerns (Goyal et al., 2020). This literature review aims to provide a comprehensive analysis of the surgical complications associated with EETS for pediatric craniopharyngiomas and to explore effective management strategies. By synthesizing current research and clinical findings, this review seeks to inform clinical practice and guide future research in the optimization of surgical outcomes for pediatric patients undergoing EETS.

2. Endoscopic Endonasal Transsphenoidal Surgery (EETS)

2.1 Technique Description

Surgical Procedure

The EETS is a minimally invasive surgical approach used to access and remove craniopharyngiomas located in the sellar and suprasellar regions. The procedure begins with the patient under general anesthesia. The surgical team selects a nostril through which an endoscope is inserted to visualize the surgical field. Simultaneously, surgical instruments are introduced through the same or the opposite nostril to enhance maneuverability. The endoscope provides high-definition, magnified views of the nasal cavity, sphenoid sinus, and sellar region. The sphenoid sinus is then opened to access the sella turcica, where the tumor resides (Feng et al., 2022).

Key anatomical landmarks such as the sphenoid ostium, clivus, and carotid arteries are carefully navigated to avoid complications. The tumor is dissected and removed in a piecemeal fashion to minimize damage to surrounding structures. Hemostasis is meticulously maintained throughout the procedure, and any cerebrospinal fluid (CSF) leaks are addressed immediately using techniques such as fat grafts or synthetic dural substitutes (Lee et al., 2016; Hosemann et al., 2015).

Additionally, the surgical team employs various techniques to enhance visualization and safety. For instance, the use of angled endoscopes allows for better access to difficult-to-reach areas, and specialized instruments designed for endoscopic surgery enable precise dissection and tumor removal (Aylmore et al., 2022).

Equipment and Technology

EETS leverages advanced endoscopic tools and visualization systems to enhance surgical precision and outcomes. The endoscopes used are typically rigid, with varying angles (0°, 30°, and 45°) to provide comprehensive views of the surgical site. High-definition cameras and monitors enable real-time visualization of the operative field, facilitating accurate dissection and tumor removal (Boese et al., 2022; Reddy et al., 2023).

Technological advancements have significantly improved the EETS procedure. For instance, neuronavigation systems integrate preoperative imaging (CT or MRI scans) with real-time intraoperative data, allowing surgeons to track their instruments' positions relative to the patient's anatomy. This integration enhances the surgeon's ability to navigate complex anatomical structures safely (Witte et al., 2013). Neuronavigation systems provide a GPS-like function that guides the surgeon during the procedure, increasing accuracy and reducing the likelihood of damaging critical structures (The Indian Express, 2024).

Additionally, intraoperative fluorescence imaging is employed to differentiate between tumor tissue and normal structures, further aiding in the complete resection of the tumor while preserving critical anatomical features (Laochamroonvorapongse et al., 2021). Fluorescence imaging uses special dyes that bind to tumor cells, making them glow under certain lights, thus helping surgeons to distinguish between healthy and cancerous tissues more effectively.

2.2 Advantages of EETS

Minimally Invasive Nature

One of the primary advantages of EETS is its minimally invasive nature, which reduces trauma to the surrounding tissues. Unlike traditional open craniotomy, which requires a large skull opening, EETS accesses the tumor through the natural nasal corridors. This approach minimizes the risk of brain injury and reduces postoperative complications (Cappabianca et al., 2004). The minimally invasive approach also results in less postoperative discomfort and quicker recovery times for patients (Liu et al., 2020).

Improved Visualization and Access

EETS offers enhanced visualization and access to the sellar region. The endoscope provides high-resolution, magnified images that allow for precise tumor dissection and removal. This improved visualization is particularly beneficial for pediatric patients, as it reduces the risk of damaging critical structures such as the optic nerves and pituitary gland (Lee et al., 2020; Children's Hospital of Philadelphia, n.d.). The endoscopic approach also allows for a more comprehensive view of the surgical field, enabling the surgeon to see and address issues that might not be visible through traditional microscopic techniques.

Reduced Recovery Time

Patients undergoing EETS generally experience shorter hospital stays and faster recovery times compared to those undergoing traditional open surgery. The minimally invasive approach leads to less postoperative pain, reduced scarring, and a quicker return to normal activities. This aspect is particularly important for pediatric patients, as it minimizes the impact on their development and quality of life. Faster recovery times mean that children can return to their daily routines, including school and physical activities, much sooner, which is crucial for their overall well-being and development.

3. Surgical Complications in EETS for Pediatric Craniopharyngiomas

3.1 Common Complications

Cerebrospinal fluid (CSF) leaks are a frequent complication in EETS for craniopharyngiomas, with an incidence ranging from 6% to 53.2%, depending on the extent of tumor resection and dural integrity (Xiong et al., 2022). Pediatric patients are particularly vulnerable due to smaller anatomical spaces and the potential for intraoperative manipulation. Intraoperative hemorrhage and vascular injuries are significant risks during EETS, given the proximity to the internal carotid arteries and the cavernous sinus. Hemorrhage can lead to substantial blood loss and may necessitate urgent interventions. The intricate network of blood vessels in the sellar and parasellar regions, coupled with the close quarters in pediatric patients, makes managing bleeding particularly challenging. Uncontrolled bleeding can obscure the surgical field, complicate tumor resection, and prolong the operation, thereby increasing the risk of further complications. Hypopituitarism, resulting from damage to the pituitary gland or stalk, is a common postoperative complication, particularly in pediatric patients. This condition can lead to deficiencies in several hormones, including growth hormone, thyroid-stimulating hormone, adrenocorticotropic hormone, and antidiuretic hormone. These hormonal imbalances can result in conditions such as diabetes insipidus, hypothyroidism, adrenal insufficiency, and growth retardation. The pituitary gland's central role in regulating various endocrine functions makes it particularly susceptible to damage during surgery, especially when the tumor involves or is in close proximity to the gland. (Müller, 2014; Cheng et al., 2023). Visual disturbances are a critical concern due to the proximity of craniopharyngiomas to the optic apparatus. Surgical manipulation can cause optic nerve injury, leading to temporary or permanent vision loss. The optic chiasm, where the optic nerves partially cross, is often compressed or displaced by craniopharyngiomas. Any surgical effort to remove the tumor must navigate these delicate structures carefully. Visual disturbances can range from subtle changes in visual fields to complete blindness, depending on the extent of the injury to the optic nerves or chiasm.

3.2 Risk Factors

The size and location of the craniopharyngioma significantly impact the risk of surgical complications. Larger tumors and those with extensive suprasellar or intraventricular extension pose greater challenges for complete and safe resection, increasing the likelihood of complications such as cerebrospinal fluid (CSF) leaks and vascular injury (Cappabianca et al., 1998). These tumors can be closely associated with critical structures, including the optic chiasm, carotid arteries, and hypothalamus, making surgical navigation and resection highly complex. Larger tumors can create larger defects in the dura, making it difficult to achieve a watertight closure and increasing the risk of postoperative CSF leaks. Extensive tumors may encase or be in close proximity to major blood vessels, increasing the risk of intraoperative hemorrhage. Younger patients and those with comorbid conditions such as obesity, diabetes, and previous radiation therapy may have an elevated risk of complications during and after EETS. Obesity can complicate both anesthesia and the surgical procedure due to difficulty in positioning and accessing surgical sites. Diabetes increases the risk of infection and impairs wound healing. Previous Radiation Therapy can alter tissue planes and increase the fragility of blood vessels, raising the risk of hemorrhage and poor healing. Pediatric patients often have smaller anatomical spaces, complicating the surgical approach and increasing the risk of damage to critical structures. The surgeon's experience and familiarity with EETS significantly influence the incidence of complications. Studies indicate a steep learning curve associated with mastering the endoscopic techniques required for successful outcomes in EETS (Esposito et al., 2007). Surgeons with extensive experience in endoscopic procedures and those working in high-volume centers tend to have lower complication rates. Inexperienced surgeons may be more prone to errors such as damaging critical structures or failing to achieve complete tumor resection. Surgeons early in their learning curve may have higher rates of complications like CSF leaks, hemorrhage, and incomplete tumor removal.

Ongoing training, simulation, and mentorship programs are crucial for developing the necessary skills and reducing the learning curve. Participation in specialized workshops and simulation-based training can enhance a surgeon's proficiency in EETS, ultimately leading to better patient outcomes (Cardoso et al., 2023).

4. Management Strategies for Surgical Complications

4.1 Prevention Techniques

Effective preoperative planning and imaging are critical for minimizing complications in EETS. High-resolution magnetic resonance imaging (MRI) and computed tomography (CT) scans are used to map the anatomy of the sellar region and the tumor's relationship with surrounding structures (Cho et al., 2022). Preoperative imaging helps in identifying the tumor's size, extent, and involvement with critical structures such as the optic chiasm and carotid arteries, enabling precise surgical planning (Paluzzi et al., 2014). Advanced imaging techniques like diffusion tensor imaging (DTI) and tractography can further delineate neural pathways, aiding in the avoidance of nerve damage during surgery (Costabile et al., 2019). Preoperative imaging is not just about understanding the tumor's location but also about understanding its consistency and vascularity, which are essential for anticipating the potential difficulties during resection. Detailed imaging helps in formulating a surgical strategy that minimizes the risks of intraoperative complications. For instance, knowing the exact position of the carotid arteries and the relationship of the tumor to the optic chiasm can help the surgeon avoid these critical structures, thereby reducing the risk of vascular injury and postoperative visual deficits. Preoperative imaging can also help in identifying any anatomical variations that could complicate the surgical approach. For instance, variations in the sphenoid sinus anatomy or the presence of septations can influence the surgical route. Awareness of these variations allows for a more tailored and cautious approach, potentially reducing the risk of intraoperative complications (Paluzzi et al., 2014).

Intraoperative monitoring is essential for the early detection and management of potential complications. Neuronavigation systems integrate preoperative imaging with real-time intraoperative data, allowing surgeons to accurately track their instruments relative to the patient's anatomy (Janicak et al., 2020). Neuronavigation provides a "GPS-like" guidance system that enhances the precision of the surgical approach, making it possible to navigate through complex anatomical structures with reduced risk. Intraoperative neurophysiological monitoring, including visual evoked potentials (VEPs) and somatosensory evoked potentials (SSEPs), helps in assessing the functional integrity of the optic nerves and other critical structures, providing immediate feedback to the surgeon (Miyagishima et al., 2019). This real-time feedback is crucial for making immediate adjustments during surgery to prevent long-term deficits. A sudden change in VEPs can alert the surgeon to potential optic nerve injury, allowing for immediate corrective measures. The use of endoscopic Doppler ultrasound can aid in identifying and avoiding major blood vessels during tumor resection. Doppler ultrasound provides real-time information about blood flow, helping to avoid vascular injuries that could lead to significant hemorrhage. The combination of neuronavigation and Doppler ultrasound significantly enhances the surgeon's ability to perform the procedure safely and effectively. The integration of these technologies not only enhances the safety and efficacy of the procedure but also contributes to a higher likelihood of complete tumor resection. Complete resection is particularly important in reducing the risk of tumor recurrence, which can lead to further complications and the need for additional surgeries.

4.2 Intraoperative Management

Cerebrospinal fluid (CSF) leaks are a common complication in EETS, and effective intraoperative management is crucial to prevent postoperative CSF rhinorrhea. Techniques for managing CSF leaks include the use of autologous tissue grafts such as fat, fascia lata, and muscle to seal the dural defect (Jiang et al., 2023). Synthetic materials like DuraSeal and Tisseel can also be used to reinforce the closure. The "gasket-seal" technique, which involves placing a rigid buttress (e.g., Medpor) over the dural defect and securing it with fibrin glue, has shown to be effective in preventing postoperative leaks. The selection of the technique for CSF leak repair depends on the size and location of the defect, as well as the surgeon's experience and preference. For smaller defects, a simple overlay of fascia lata may be sufficient, while larger defects might require more complex reconstruction using multilayer techniques. The use of synthetic materials can provide additional reinforcement, reducing the risk of postoperative leaks. Continuous intraoperative assessment for potential CSF leaks is essential. The surgeon should be vigilant in identifying and repairing any dural tears as they occur. The use of intraoperative fluorescein dye can help in visualizing CSF leaks, making it easier to ensure complete closure (Esposito et al., 2007).

Intraoperative hemorrhage is a significant risk during EETS, given the proximity to major blood vessels. Achieving effective hemostasis is critical to prevent excessive blood loss and maintain a clear surgical field. Techniques include the use of bipolar cautery and hemostatic agents such as Surgicel and Floseal to control bleeding from smaller vessels. For larger vascular injuries, the application of microvascular clips or suturing may be necessary. In some cases, intraoperative angiography can be used to identify and manage vascular anomalies preemptively. The control of intraoperative bleeding is paramount to maintaining a clear surgical field and ensuring the safety of the patient. Hemostatic agents and techniques must be readily available and applied promptly to address any bleeding that occurs. Intraoperative angiography can be particularly useful in identifying the source of bleeding and guiding the application of hemostatic measures. In addition to these techniques, the surgical team should be prepared to manage unexpected vascular injuries. This includes having protocols in place for rapid blood transfusion and vascular repair. The ability to manage vascular complications swiftly and effectively can significantly impact the outcome of the surgery and the patient's recovery (Delawan et al., 2023).

Preserving pituitary function during EETS is essential to prevent postoperative endocrine dysfunctions. Intraoperative strategies include careful dissection around the pituitary gland and stalk, avoiding excessive manipulation and thermal injury. The preservation of pituitary function is crucial for maintaining the patient's endocrine balance. Intraoperative strategies should focus on minimizing trauma to the pituitary gland and stalk. This includes using gentle dissection techniques and avoiding the use of electrocautery near the gland to prevent thermal damage.

4.3 Postoperative Care

Postoperative care involves vigilant monitoring for early detection and management of complications. Regular neurological and endocrinological assessments are essential to identify issues such as CSF leaks, hemorrhage, and hypopituitarism. Imaging studies, including MRI and CT scans, are performed postoperatively to assess the extent of tumor resection and identify any residual mass or complications (Inoue et al., 2023). Monitoring for signs of infection, such as fever and leukocytosis, is crucial to detect and treat meningitis promptly.

Postoperative monitoring should be continuous and thorough, involving frequent checks of vital signs, neurological status, and hormone levels. Any signs of complications such as CSF leaks, increased intracranial pressure, or changes in neurological status should be investigated promptly using imaging studies. Early detection of complications can lead to timely interventions, improving patient outcomes.

Postoperative imaging is critical for assessing the success of the tumor resection and identifying any residual tumor that might require further treatment. MRI is particularly useful for evaluating soft tissue structures and detecting residual tumor tissue. CT scans can help in assessing bone structures and detecting complications such as hemorrhage (Inoue et al., 2023).

Hypopituitarism is a common complication following EETS, necessitating lifelong hormonal replacement therapy for affected patients. Postoperative endocrine evaluation includes assessing levels of pituitary hormones such as ACTH, TSH, LH, FSH, GH, and ADH. Hormonal replacement therapy involves the administration of corticosteroids, thyroid hormone, sex steroids, growth hormone, and desmopressin, tailored to the patient's specific deficiencies (Miao et al., 2023). Regular follow-up with an endocrinologist is essential to adjust hormone dosages and monitor for potential side effects. Managing hypopituitarism requires a comprehensive and individualized approach. Each patient's hormonal needs must be carefully assessed and addressed with appropriate hormone replacement therapy. The goal is to mimic natural hormone levels as closely as possible, maintaining normal physiological functions and improving quality of life. Regular follow-up with an endocrinologist is crucial for adjusting hormone dosages based on the patient's needs and response to therapy. This includes monitoring for side effects and potential complications of hormone replacement therapy. Ensuring optimal endocrine function can significantly enhance the patient's overall well-being and reduce the risk of long-term complications.

Postoperative rehabilitation is critical for patients with visual and neurological deficits resulting from EETS. Visual rehabilitation may include the use of corrective lenses, visual field training, and in some cases, surgical intervention for optic nerve decompression. Neurological rehabilitation involves physical therapy, occupational therapy, and cognitive therapy to address motor deficits, functional impairments, and cognitive dysfunctions. Early intervention and a multidisciplinary approach are key to optimizing recovery and improving the patient's quality of life (Gillani et al., 2020). Rehabilitation should be tailored to the specific needs of each patient. For patients with visual deficits, early intervention can help in maximizing recovery of visual function. Neurological rehabilitation is equally important for patients with motor or cognitive deficits. Physical therapy can help improve strength, coordination, and mobility, while occupational therapy can assist patients in regaining the ability to perform daily activities. Cognitive therapy can address issues such as memory loss, attention deficits, and other cognitive impairments, helping patients to regain as much function as possible. A multidisciplinary approach, involving neurologists, endocrinologists, ophthalmologists, and rehabilitation specialists, is essential for providing comprehensive care and optimizing patient outcomes. Regular follow-up and adjustment of rehabilitation programs based on the patient's progress can lead to significant improvements in their quality of life.

5. Comparative Analysis with Other Surgical Approaches

5.1 Open Craniotomy vs. EETS

Open craniotomy and EETS represent two distinct surgical approaches for the resection of pediatric craniopharyngiomas. Open craniotomy involves a more invasive technique, requiring a large skull opening to access the tumor, whereas EETS utilizes a minimally invasive route through the nasal passages.

Outcomes and Complications: Studies have shown that EETS is associated with lower morbidity and fewer complications compared to open craniotomy. A study by Nie et al. (2022) found that EETS resulted in significantly fewer postoperative complications, such as infections and wound healing issues, compared to open craniotomy. Additionally, EETS patients had a lower incidence of new-onset neurological deficits postoperatively. On the other hand, open craniotomy, while effective for large and complex tumors, often leads to higher rates of complications such as hemorrhage, and longer hospital stays. The larger surgical exposure in open craniotomy increases the risk of damage to surrounding brain tissue and critical neurovascular structures.

Patient Quality of Life and Recovery Times

The quality of life and recovery times for patients undergoing EETS are generally superior to those undergoing open craniotomy. EETS patients typically experience shorter hospital stays, reduced postoperative pain, and quicker return to normal activities. Children who underwent EETS reported higher overall satisfaction and better cosmetic outcomes compared to those who had open craniotomies. The minimally invasive nature of EETS reduces the psychological and physical impact on pediatric patients, contributing to improved long-term quality of life (Marx et al., 2021). Conversely, the more invasive open craniotomy approach can result in prolonged recovery times, extended rehabilitation, and greater disruption to the child's daily life and schooling.

5.2 Other Minimally Invasive Techniques

Endoscopic vs. Microscopic Transsphenoidal Surgery

Endoscopic and microscopic transsphenoidal surgeries are both minimally invasive techniques used for the resection of craniopharyngiomas. Endoscopic transsphenoidal surgery utilizes an endoscope to provide a wide and magnified view of the surgical field, allowing for better visualization of the tumor and surrounding structures.

Comparative Analysis: Endoscopic techniques offer several advantages over microscopic approaches, endoscopic surgery provides superior illumination and visualization, which can enhance the surgeon's ability to achieve complete tumor resection while preserving critical structures. The panoramic view afforded by the endoscope reduces the need for excessive brain retraction, thereby decreasing the risk of neurological damage. Microscopic transsphenoidal surgery, while effective, is limited by a narrower field of view and less maneuverability within the surgical site. This can make it more challenging to access and remove tumors that extend beyond the sella turcica (Hiraoka, et al., 2023).

Emerging Alternative Minimally Invasive Techniques

New and emerging minimally invasive techniques continue to evolve, offering potential benefits for the treatment of pediatric craniopharyngiomas. These techniques include the use of intraoperative MRI, endoscopic combined approaches, and robotic-assisted surgery. Intraoperative MRI allows for real-time imaging during surgery, enhancing the surgeon's ability to achieve complete tumor resection while minimizing damage to surrounding tissues (Bisdas, et at., 2015). This technique improves surgical outcomes by providing immediate feedback on the extent of tumor removal. Combined approaches that integrate endoscopic and microscopic techniques are also gaining popularity. These hybrid techniques leverage the strengths of both methods to optimize visualization and access, particularly for tumors with complex anatomy (Ding et al., 2022). Robotic-assisted surgery, though still in its early stages, holds promise for improving precision and reducing surgeon fatigue (Reddyg et al., 2023).

6. Conclusion

In conclusion, EETS represents a significant advancement in the treatment of pediatric craniopharyngiomas. This minimally invasive technique offers several benefits over traditional open craniotomy, including reduced morbidity, fewer complications, and shorter recovery times. The superior visualization and access provided by EETS facilitate precise tumor resection while minimizing damage to surrounding structures. Despite its advantages, EETS is not without risks. Common complications such as cerebrospinal fluid (CSF) leaks, hemorrhage, hypopituitarism, and visual disturbances remain challenges that require careful management. Effective prevention and management strategies are essential to optimize surgical outcomes. Preoperative planning with advanced imaging techniques and intraoperative monitoring systems are crucial in mitigating risks. Techniques to handle intraoperative CSF leaks, maintain hemostasis, and preserve pituitary function are vital. Postoperative care, including vigilant monitoring, hormonal replacement therapy, and rehabilitation, plays a key role in ensuring favorable outcomes.

The comparative analysis of EETS with other surgical approaches, such as open craniotomy and microscopic transsphenoidal surgery, underscores the benefits of EETS in terms of reduced complication rates and better quality of life. Emerging minimally invasive techniques and advancements in surgical technology continue to enhance the safety and efficacy of EETS.

As the field evolves, a multidisciplinary approach involving neurosurgeons, endocrinologists, radiologists, and rehabilitation specialists is essential for comprehensive patient care. Continued investment in surgeon training and technological innovation is critical to further improve outcomes and reduce complication rates. Long-term studies examining the outcomes of pediatric patients undergoing EETS will provide valuable insights into the efficacy of this approach and guide future clinical practice.

In my view, the future of pediatric neurosurgery lies in the continued refinement and adoption of minimally invasive techniques like EETS. By balancing technological advancements with personalized patient care, we can ensure that young patients receive the best possible outcomes, minimizing the impact of their condition on their development and quality of life. The integration of innovative approaches and a commitment to ongoing education and research will drive the field forward, ultimately benefiting patients and healthcare providers alike.

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