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Case Report

Modified orbitofrontal approach for optic nerve sheath hemangioma: Illustrative case and literature review

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ABSTRACT

Background: Optic nerve sheath hemangiomas (ONSHs) are rare vascular tumors from the blood vessels surrounding the optic nerve, accounting for <1% of optic tumors and 0.5% of vascular malformations. Although benign, their location near the optic nerve poses a risk of significant nerve damage and vision loss. Symptoms often include visual disturbances, eye pain, and strabismus, making it difficult to make a diagnosis. Advances in imaging, especially magnetic resonance imaging (MRI), have improved early detection and diagnosis. In addition, insights into the molecular mechanisms, including endothelial signaling and angiogenesis, have facilitated the development of more effective treatments, such as targeted therapies and minimally invasive surgical options.

Case Description: We present the case of a 57-year-old woman who experienced progressive left-eye swelling, increased tearing, and declining visual acuity. Imaging studies, including MRI and computed tomography scans, revealed a left intraconal mass suggestive of ONSH. A transcranial-modified orbitofrontal approach was employed for tumor resection due to its proximity to vital structures. Postoperative histopathology confirmed hemangioma. At 1-year follow-up, the patient exhibited significant improvement in visual function and resolution of orbital swelling.

Conclusion: This case highlights the critical role of surgical intervention in managing ONSHs that threaten visual function and cause mass effects. The transcranial-modified orbitofrontal approach proved effective in providing optimal access for safe tumor resection and improving visual outcomes. Integrating advanced imaging techniques and intraoperative monitoring contributes significantly to enhancing prognosis in ONSH cases.

Keywords: Fronto-orbital approach, Optic nerve sheath hemangioma, Orbital approach, Surgical decompression, Visual impairment

INTRODUCTION

Epidemiology and etiology

Optic nerve sheath hemangiomas (ONSHs) are rare benign vascular tumors that develop within the sheath of the optic nerve. These tumors are typically slow-growing, with symptoms often not manifesting until the tumor reaches considerable size. The pathophysiology of

ONSHs involves endothelial cell proliferation, frequently influenced by factors like vascular endothelial growth factor (VEGF), although the precise molecular mechanisms remain an area of active research.[6,8] VEGF plays a significant role in angiogenesis in a variety of tumors, not just ocular ones, suggesting a common molecular pathway for neovascularization across different organ systems.[9,10] Epidemiologically, ONSHs are uncommon, representing only a small fraction of orbital tumors; however, they can have serious implications for vision and ocular function. Most cases occur in adults, typically between the ages of 30 and 50, with a few cases reported in children.[12,17] Similar to other vascular tumors, the onset of symptoms is gradual, and delayed diagnosis is common, particularly in cases with slow tumor progression.[12,13]

Clinical manifestations

Clinically, ONSHs present with symptoms such as progressive vision loss, optic disc swelling, and proptosis, although some cases may remain asymptomatic for an extended period. Early diagnosis through imaging, particularly magnetic resonance imaging (MRI) with gadolinium enhancement, is essential to evaluate the size, location, and characteristics of the tumor.[15] This diagnostic method is in line with findings from previous studies that highlight MRI as the gold standard for diagnosing ONSHs, with characteristic imaging features such as a well-defined intraconal mass enhancing homogeneously.[13,15] Similar cases reported in the literature suggest that tumors may remain undiagnosed for months or even years, emphasizing the importance of awareness of ONSH in clinical practice, particularly in patients with unexplained visual symptoms.[13,17]

Diagnostic methods

MRI is considered the gold standard for diagnosing ONSHs, providing detailed anatomical views, and detecting tumor extension.[2,5,9] Gadolinium-enhanced MRI (Gd-MRI) is the imaging modality of choice due to its superior soft-tissue contrast and ability to delineate tumor extent and its relationship with adjacent structures.[2] The enhanced contrast allows for optimal visualization of the tumor's vascular characteristics, which is critical in identifying hemangiomas, especially given the complex anatomy of the optic nerve and surrounding tissues.[12,15] Studies have shown that gadolinium-based MRI enhances the detection of well-defined intraconal masses, a hallmark of ONSHs, by providing detailed imaging that distinguishes these tumors from other orbital and intracranial lesions.[2,5,12,13] The ability to precisely assess the location and size of the hemangioma plays a key role in determining the most appropriate treatment approach, whether surgical or otherwise, improving patient outcomes.[11,13]

Given the rarity of ONSHs and their potential for significant visual impairment, surgical intervention is often necessary. Treatment options vary depending on tumor location and size, ranging from observation to more invasive approaches such as endonasal resection, radiation therapy, or craniotomy.[11] The choice of surgical approach is critical for minimizing complications and ensuring complete tumor resection, especially in cases with extensive involvement of the optic nerve and surrounding structures. Recent studies corroborate that the approach to surgery should be individualized based on tumor characteristics and patient factors to optimize outcomes and minimize risks.[7,12]

In this report, we describe the case of a 57-year-old female with ONSH who underwent successful tumor resection using a transcranial modified orbitofrontal approach. This technique involves a single-piece craniotomy with lateral and superior orbital osteotomy, providing optimal exposure to the tumor while minimizing risks associated with brain retraction and damage to surrounding tissues, which is consistent with findings from other studies on similar orbital tumors.[12,15] The transcranial modified orbitofrontal approach has been shown to provide significant advantages over other techniques due to its minimally invasive nature, faster recovery times, and reduced postoperative morbidity. By minimizing brain manipulation and preserving critical neurovascular structures, this approach reduces the risk of complications while allowing for precise resection of tumors in difficult locations.[7,12,13] These advantages have been corroborated by multiple studies, highlighting its increasing popularity as an optimal choice for treating ONSHs and other orbital tumors.[11,12]

Histopathological features

Cavernous intraocular hemangiomas are characterized by large vascular spaces lined with mature endothelium and a dense stromal component. Acute thrombosis is a common feature, with fibrin clots encased in CD31-positive endothelium. Perivascular areas show increased cellularity with CD31+ and VEGFr2+ staining, while regions of Ki67 positivity indicate active proliferation. The presence of CD68+ cells signals inflammatory activity. In addition, the stroma contains CD31+ microcapillaries and smooth muscle cells marked by smooth muscle actin (SMA) staining, which integrate into the vascular architecture.[16] These findings are consistent with the histopathological descriptions of similar vascular tumors, where endothelial cell proliferation and immune response play crucial roles in tumor growth and progression.[9,16]

Molecular pathogenesis

VEGF plays a crucial role in the progression of hemangiomas. In these tumors, VEGF expression is elevated and contributes

to neovascularization and tumor growth. VEGF exists in several isoforms through alternative splicing, with VEGF-165 being the predominant form in hemangiomas, VEGF-121 and VEGF-165 being secreted, while VEGF-189 and VEGF-206 are matrix-bound.[9]

Hypoxia, a common feature in tumors, triggers the stabilization of hypoxia-inducible factor 1α (HIF-1α), which activates VEGF expression.[9] In hemangiomas, mutations in the *VHL* gene or alterations in the hypoxic response can lead to continuous HIF-1α activation, promoting persistent VEGF expression, even in normoxic conditions. In addition, mutations in the tumor suppressor gene p53 prevent cells from undergoing apoptosis in response to hypoxia. This failure to trigger apoptosis allows the selection of hypoxia-resistant cells, which proliferate and contribute to tumor growth, further enhancing growth factor expression and tumor progression.[1]

VEGF functions as a mitogen for endothelial cells and drives neovascularization, but the resulting blood vessels in hemangiomas are often structurally abnormal and highly permeable, fostering tumor growth and enhancing tumor expansion. Secondarily, altered tumor vasculature promotes immune evasion by altering tumor vasculature and impairing immune cell infiltration, creating an immunosuppressive microenvironment that allows the tumor to escape immune surveillance.[10]

Treatment options

Surgical Management: Surgery remains the primary treatment modality for ONSHs, particularly in symptomatic cases or those with progressive visual loss. The choice of surgical approach depends on tumor size, location within the optic nerve sheath, and the degree of intraorbital extension. Key surgical techniques include:

Transcranial approaches

Fronto-orbito-zygomatic (FOZ) approach

This approach provides excellent exposure to the optic nerve sheath and orbital apex, involving a combined frontal, orbital, and zygomatic osteotomy. It allows for decompression of the optic canal and excision or debulking of the tumor while minimizing brain manipulation.[6,12] Similar studies have shown that this approach offers excellent visualization of the optic nerve and surrounding structures, making it effective in resecting large tumors.[7,12]

Modified orbito-frontal approach

This variation involves similar principles but preserves the zygomatic arch, offering a less invasive option while providing adequate access for tumor resection or biopsy.[6,12] Compared to other transcranial approaches, the modified orbitofrontal approach provides significant advantages. Its minimally invasive nature results in faster recovery times and reduced postoperative morbidity by minimizing brain manipulation and preserving critical neurovascular structures. In addition, this approach provides superior access to the optic nerve and orbital apex, enabling precise tumor resection and improved visual function preservation. The reduced need for extensive osteotomies or brain retraction simplifies the surgical procedure, lowering the risk of complications and enhancing overall patient outcomes.[11-13] These findings align with similar studies reporting improved outcomes and lower complication rates with this approach.[12,15]

Endoscopic approaches

Transethmoidal-transsphenoidal approach

Although less commonly used, this approach may be suitable for select cases of anterior skull base extension. It allows access to the optic canal and intracranial portion of the optic nerve sheath with minimal morbidity.[8,15] Similar studies have explored the feasibility of endoscopic approaches for managing tumors with specific anatomical locations, providing a minimally invasive alternative with promising results.[8,15]

Intraoperative neurophysiological monitoring

To minimize postoperative neurological deficits, intraoperative neurophysiological monitoring is essential during surgery near the optic nerve and chiasm, ensuring real-time assessment of visual evoked potentials and cranial nerve function.[6,7,11] These monitoring techniques have been shown to reduce the risk of neurological injury and improve surgical outcomes, aligning with best practices described in the literature on neurosurgical management of orbital and optic nerve tumors.[6,7,11]

CASE PRESENTATION

Patient history and clinical findings

A 57-year-old female presented with a 2-year history of progressive left eye swelling, epiphora, conjunctival injection, and gradual visual acuity decline to perception of light. The ophthalmological examination revealed optic disc edema and decreased visual acuity in the left eye. Pre-surgical visual acuity was measured using the Snellen test, with a result of 20/25 in the right eye and 20/30 in the left eye, both outside the normal range. Imaging studies, including MRI and computed tomography, confirmed a left intraconal mass exerting mass effect on the optic nerve and globe, consistent with optic nerve sheath meningioma [Figure 1]. In

addition, extrinsic ocular motility of the left eye was noted with proptosis and exodeviation, and there was a limitation of elevation and depression movements. Intraocular pressure was 10 mmHg in the right eye and 16 mmHg in the left eye. Fundus examination showed a pale optic nerve, congested vessels, a macula with loss of architecture, and an applied retina.

Imaging studies

Gd-MRI demonstrated a well-circumscribed intraconal lesion along the left optic nerve sheath.

Surgical approach

Given the tumor's location and extent within the left orbit, a transcranial-modified orbitofrontal approach was chosen. This technique involved a single-piece craniotomy with lateral and superior orbital osteotomy, providing adequate exposure to the optic canal and intraconal space while minimizing brain retraction. Intraoperatively, careful dissection was performed to separate the tumor from the adjacent optic nerve and extraocular muscles, allowing for maximal safe resection [Figures 2 and 3].

Histopathological examination

The postoperative histopathological examination confirmed the diagnosis of a cavernous nodular fibrohemangioma located in the left intraorbital region, consistent with ONSH. Macroscopically, the specimen presented as a dense, ovoid tissue structure measuring 2 × 1.8 cm with a grayish, uniformly firm, rubbery surface. Serial sections revealed a congestive, fibrous tissue thickness with areas suggestive of necrosis. Microscopically, findings included subacute intraluminal inflammatory changes along with scattered dystrophic and degenerative calcifications.

Postoperative course and follow-up

The patient's postoperative course was uneventful, with a resolution of orbital swelling and improvement in visual acuity. While the updated or new ophthalmological scales for assessing postoperative visual outcomes were not included in the ophthalmology report, the patient's progress was closely monitored. Regular ophthalmological assessments and

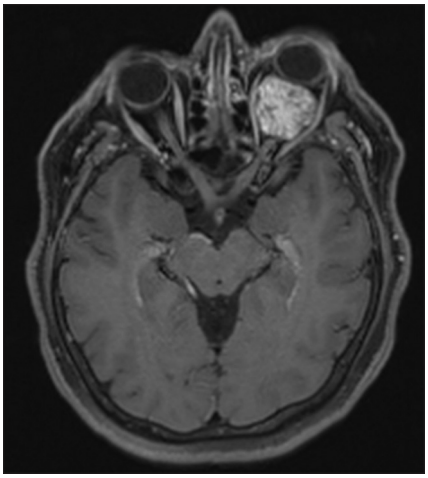

Figure 1: Axial T1-weighted magnetic resonance imaging with gadolinium contrast showing a homogeneous enhanced, circumferential, and regular lesion in the left orbit; the lesion is located behind the eye, superior to the optic nerve, and produces a mass effect with proptosis.

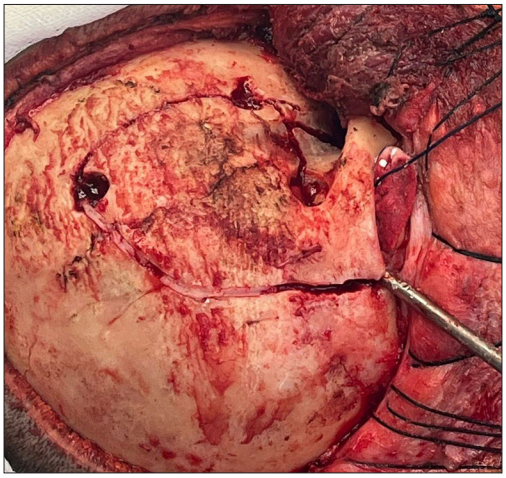

Figure 2: Osteotomy of the roof and lateral wall of left orbit with the superior branch of the zygoma.

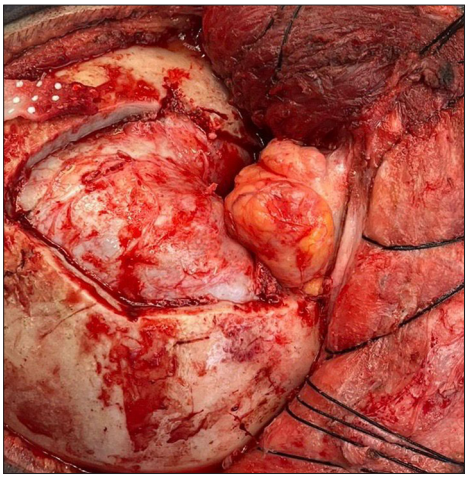

Figure 3: Surgical exposure of the superior and lateral part of the left orbit after removing the fronto-orbital bone flap.

imaging studies were conducted to track tumor recurrence or residual disease [Figures 4 and 5]. The patient demonstrated favorable neurological outcomes, as evidenced by the resolution of the decreased visual acuity. At the 1-year follow-up, there was no evidence of tumor recurrence, and the patient remained stable, showing continued improvement in visual function.

DISCUSSION

ONSHs are rare, and their molecular pathogenesis remains an area of active research. It is believed that mutations in genes regulating endothelial cell proliferation, such as VEGF, contribute to the formation of these vascular tumors.[8,9] VEGF plays a critical role in angiogenesis, not only in ocular tumors but also in various other tumors of the brain, head, and neck, suggesting its importance in tumor formation and progression.[10,14] In line with these findings, studies on the pathophysiology of ONSHs have shown that aberrant VEGF signaling may drive the abnormal growth of blood vessels within the optic nerve sheath.[8,9,16] Clinical manifestations include progressive visual loss, optic disc edema, and proptosis. Similar findings have been reported in other case studies, where patients exhibited gradual visual acuity decline over months or even years, emphasizing the slow and insidious onset of these tumors.[13,17] Diagnostic imaging, particularly MRI with gadolinium contrast, was essential in confirming the diagnosis, with imaging findings similar to those described in previous reports of ONSHs.[12,15]

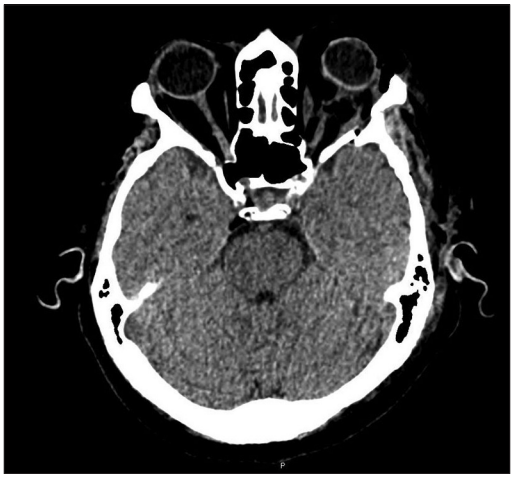

Figure 4: Post-surgical axial computed tomography that shows total resection of the left orbital neoplastic lesion.

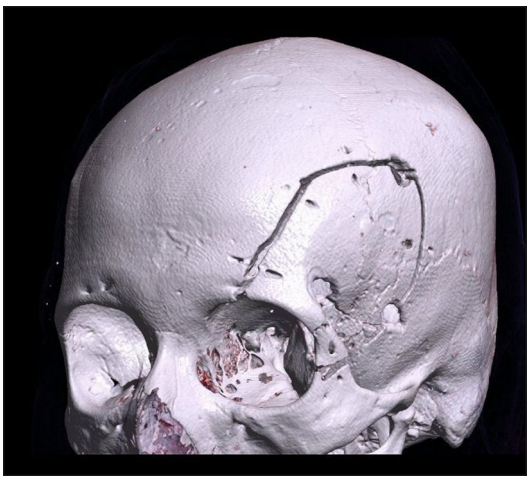

Figure 5: Post-surgical 3D reconstruction computed tomography that shows frontal-orbital osteotomy and bone flap apposition.

The modified orbitofrontal approach has emerged as a promising technique for managing ONSHs, especially in cases where there is progressive visual deterioration and mass effect in the intraorbital region. This approach's ability to decompress the orbital roof and lateral wall while providing clear access to intraorbital lesions is in line with findings from other studies that highlight its effectiveness in treating orbital tumors, including hemangiomas.[7,12,15] Notably, studies have shown that this approach significantly improves surgical outcomes while minimizing complications associated with more invasive techniques.[8,10] As described in several case series, the modified orbitofrontal approach has been associated with faster recovery times, lower complication rates, and better preservation of visual function, further supporting its use in ONSH cases.[11,13] Continued advancements in surgical technology and technique refinement will likely further enhance the efficacy and safety of this approach, improving the quality of life for patients with orbital pathologies.[8,10]

Optimal treatment strategies

The management of ONSHs requires individualized treatment strategies that take into account tumor size, location, and patient-specific factors such as age and comorbidities. As demonstrated in other reports, surgical resection remains the cornerstone of treatment, with the goal of complete tumor removal while preserving visual function.[7,12] Similar to other studies on orbital tumors, advances in surgical techniques, such as minimally invasive approaches and intraoperative imaging, have improved surgical outcomes and reduced morbidity in ONSH surgeries.[6,8,15] For instance, the use of intraoperative navigation and neurophysiological monitoring during resection has been shown to improve precision and minimize risk to surrounding structures, which is consistent with our experience.[6,7] Surgical management of ONSHs is often required when the tumor causes visual impairment or other complications, and the tumor's location typically guides the choice of surgical approach, as it did in our patient. While endonasal approaches have been described, studies

suggest that the transcranial modified orbitofrontal approach provides superior access to the optic canal and intraconal space, thereby facilitating safer and more effective resections in challenging cases.[12,15]

Alternative treatment strategies

Observation can be used in patients with stable or negligible visual decline and minimal tumor progression. This approach avoids surgical risks, but the ONSH growth may affect visual improvement after treatment and the potential for progressive vision loss. Moreover, this treatment needs control imaging evaluation (MRI) and visual function assessment for years to intervene if progression occurs.[4,8,12] While observational management has been effective in some cases, the risk of progressive visual deterioration remains a concern, especially if the tumor grows or leads to additional complications.[12,15]

Radiotherapy, especially stereotactic radiosurgery (SRS), is an effective option when patients have unresectable tumors, residual disease, or recurrence. This approach provides excellent local tumor control and minimal collateral damage.[3,12] However, radiotherapy is associated with potential complications, such as optic neuropathy, which emphasizes careful patient selection and treatment planning.[6,15] Research has shown that the use of SRS in cases of residual tumors can offer good outcomes, though its long-term effects need further study to fully understand potential risks, especially with respect to optic nerve damage.[6,15]

Endoscopic approaches, like the transethmoidal transsphenoidal route, offer a minimally invasive option for cases with anterior skull base extension. These techniques minimize morbidity and avoid extensive craniotomy, but they are limited to specific tumor locations, restricting their widespread use.[10,14] Endoscopic procedures are gaining popularity due to their reduced invasiveness, but their efficacy is limited to tumors accessible through the nasal passage, and they may not offer the same level of decompression as traditional surgical approaches.[14]

This study highlights the advantages of the Modified Orbito-Frontal Approach, which offers enhanced access to the optic nerve sheath and orbital apex while minimizing brain manipulation. Compared to the FOZ Approach, this technique reduces surgical time and postoperative complications, with improved preservation of visual function. Endoscopic techniques and radiotherapy are less invasive alternatives; however, they lack the decompressive benefits of surgical resection, restricting their utility to select clinical contexts.[6,10] The Modified Orbito-Frontal Approach is especially beneficial in tumors that are difficult to reach with endoscopic techniques, offering an optimal balance of accessibility, safety, and outcomes.[12]

ROLE OF ADJUVANT THERAPY

In cases where complete resection is not feasible or in the presence of residual or recurrent tumors, adjuvant therapies may be considered, including SRS and conventional radiotherapy. Studies have shown that SRS can be particularly effective in treating small residual lesions or recurrent tumors, providing a targeted approach while minimizing damage to surrounding healthy tissue.[3,12] The combination of surgical resection and SRS has improved long-term outcomes in several series.[5,6,15] In addition, the use of SRS as an adjuvant therapy has been associated with improved visual function preservation and local tumor control in cases of incomplete resection.[6,15]

Challenges in management and limitations

Despite significant advances in diagnostic imaging and surgical techniques, managing ONSHs remains challenging, particularly when tumors are located near critical neurovascular structures. As highlighted by recent studies, the proximity of ONSHs to the optic nerve, carotid artery, and other essential structures requires meticulous planning to minimize surgical complications.[6,7] Techniques such as preoperative neuroimaging with tractography and intraoperative neurophysiological monitoring are critical for minimizing risk during surgery, as has been shown in multiple clinical reports.[12,15] Nevertheless, the potential for visual morbidity and damage to adjacent structures remains a significant concern, particularly in large or inaccessible tumors. Postoperative complications, such as infections, bleeding, and worsening vision, continue to be reported in the literature, reinforcing the need for frequent postoperative monitoring.[11,14]

Future directions and research

Future research on ONSHs should focus on elucidating the molecular markers and genetic pathways associated with their pathogenesis. This would provide critical insights into the development of targeted therapies and personalized treatment approaches, as suggested by recent studies on other vascular anomalies.[17,18] Multicenter collaborations and large-scale prospective studies are necessary to establish evidence-based treatment protocols and optimize long-term outcomes for patients with ONSHs, as demonstrated in studies examining other orbital and intracranial vascular lesions.[6,9,10] Moreover, ongoing advancements in intraoperative imaging and molecular diagnostics may offer novel ways to guide surgical decision-making and improve prognosis for patients undergoing resection of these rare and complex tumors.[8,12,14]

CONCLUSION

ONSHs are rare, challenging tumors that require prompt diagnosis and tailored treatment. The modified orbitofrontal

approach is particularly beneficial for patients experiencing painless visual deterioration and intraorbital mass effect for several reasons. First, it is less invasive compared to other surgical techniques while still offering excellent visibility of the orbital contents. This enables targeted removal of bone and tumor tissue, which helps preserve the patient's visual function and reduces postoperative morbidity. In addition, by removing bone fragments from the orbital roof and lateral wall, this approach effectively decompresses the optic nerve and surrounding vital structures, which is crucial for alleviating the mass effect caused by the tumor, potentially improving or stabilizing visual acuity. Finally, the direct access provided by the orbitofrontal approach allows for a more precise and complete resection of the tumor, which is particularly important in cases where the lesion is situated in challenging locations within the orbit. This clear operative field is essential for avoiding damage to critical structures, making the modified orbitofrontal approach a preferred option in these clinical scenarios.

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