Postoperative Imaging Findings Associated with Transpalpebral Craniotomy Approach to Anterior Cranial Fossa

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Abstract

Background and Purpose The transpalpebral “eyelid” approach is a novel alternative to the traditional ciliary or supraciliary incision for supraorbital frontal craniotomy and access to the anterior cranial fossa. Though a prior publication from our institution has described the surgical approach in detail along with cosmetic and clinical outcomes, postoperative imaging findings have not yet been described. As this surgical technique becomes more widely practiced, it is essential for neuroradiologists, oculoplastic surgeons, and skull base neurosurgeons to be familiar with the expected postoperative imaging findings, especially those that prompt subsequent intervention.

Materials and Methods A retrospective, institutional review board approved review was performed of 102 patients who underwent transpalpebral surgical approach at Allegheny General Hospital from June 2007 through May 2015. Operative reports, pathology reports, preoperative imaging, postoperative imaging, and postoperative clinical documentation were reviewed.

Results Forty-nine percent of patients had solely benign expected postoperative imaging findings, 37% had various atypical findings not requiring further intervention (most commonly asymmetric globe protrusion and bone cement in a paranasal sinus), 6% had findings prompting minimally invasive bedside procedures (most commonly pseudomeningocele), and 8% had findings requiring surgical intervention.

Conclusion The majority of imaging following the transpalpebral approach showed typical, benign findings, such as minimal pneumocephalus and asymmetric globe protrusion. Nonetheless, members of the clinical team should be aware of the small number of findings requiring intervention, especially pseudomeningocele.

Keywords

- radiology
- anterior cranial fossa
- minimally invasive
- minicraniotomy

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Introduction

The goals of minimizing iatrogenic trauma, improving outcomes, and maximizing efficiency have guided the development of minimally invasive approaches in skull base surgery over the past century.^{1,2} However, the advancement of minimally invasive approaches is accompanied by increasing technical challenges, potential for novel complications, and unique postoperative imaging features.

The supraorbital frontal minicraniotomy is a commonly applied minimally invasive technique for accessing the anterior cranial fossa.^{1,3–14} This approach permits access to anterior cranial fossa and suprasellar structures with limited soft tissue dissection, craniotomy, and brain retraction. Traditionally, this technique involves a ciliary or supraciliary eyebrow incision.^{3,7,15,16} Although cosmesis with both incisions may be acceptable, the ciliary incision can damage hair follicles causing local alopecia, whereas the supraciliary incision can result in scarring above the eyebrow. In addition, both incisions involve a frontalis muscle cut with an associated risk of brow asymmetry.^{10,17} The transpalpebral approach, also referred to as upper blepharoplasty, upper eyelid, or supratarsal fold approach, follows the natural skin crease of the upper eyelid. This technique allows a craniotomy and exposure similar to that attained with the traditional ciliary or supraciliary incision.^{17–19} Moreover, utilizing this approach, the surgeon can achieve a superior cosmetic outcome, as the resultant scar becomes concealed within the upper eyelid crease, and there is a reduced risk of eyebrow asymmetry and alopecia.¹⁸

The transpalpebral approach has been adapted at our institution to provide access to the anterior skullbase²⁰ (see “Methods” for further technical description). As with most neurosurgical procedures, imaging is routinely obtained in the immediate postoperative period to assess the surgical changes. It is therefore imperative that the clinical team interpreting the postoperative imaging studies be familiar with expected and atypical benign findings, as well as findings that require prompt neurosurgical intervention. A series of cases performed at our institution were reviewed to better characterize these postoperative findings.

While a smaller case series describing the surgical approach and the clinical and cosmetic outcomes of the initial cases at our institution has been published, the associated imaging findings have not yet been described. We reviewed the transpalpebral cases performed at our institution to date to characterize the postoperative imaging findings that were benign and expected, as well as the atypical findings and those that prompted intervention.

Methods

A skull base neurosurgeon (K.A.), in collaboration with an oculoplastic neuroophthalmologist (E. H.), has adapted the transpalpebral “eyelid” approach to the anterior cranial base. This technique has been described in detail elsewhere along with the clinical and cosmetic outcomes.¹⁷ Initially, a lumbar drain is placed, and 20 to 40 mL of cerebrospinal fluid (CSF) is

drained intraoperatively for brain relaxation. An incision is made through the skin of the upper eyelid crease within 2.5 cm lateral to the lateral canthus to avoid injury to the temporal branch of the facial nerve²⁰ (→Fig. 1A). Next, the orbicularis oculi muscle is elevated from the orbital septum. The orbital rim is identified, and the periosteum is divided at the midpoint of the orbital rim. The periorbital is then dissected from the orbital roof, and the temporalis muscle is dissected until bone is exposed (→Fig. 1B and 1C). A one-piece fronto-orbital bone flap is created that extends from a sphenoid keyhole (burr hole) medially to the lateral edge of the supratrochlear notch. To form the bone flap, cuts are made through the supraorbital ridge, zygomatic bone, and orbital roof (→Fig. 1D–F).

If a frontal sinus wall is violated during the craniotomy, it is sealed with bone cement to maintain mucociliary drainage of the frontal sinus. At the conclusion of surgery, the lumbar drain is removed. The bone flap is replaced and secured with several low-profile titanium plates and screws. The sphenoid ridge area is reconstructed with malleable low-profile mesh with an overlying layer of bone cement covering the sphenoid keyhole to restore the natural contour of the sphenoid wing area. The frontal periosteum is reapproximated to the periorbital, and the eyelid incision is sutured.

Following institutional review board (IRB) approval, a retrospective review was performed of 102 consecutive patients who underwent the transpalpebral surgical approach from June 2007 through May 2015 at a single institution (Allegheny General Hospital; Pittsburgh, Pennsylvania, United States). Clinical and surgical data, including operative reports, pathology reports, and postoperative clinical documentation, were reviewed with documentation of surgical indication, intra- and perioperative findings, and subsequent invasive procedures. Pre- and postoperative imaging for each patient was independently reviewed on the institution's picture archiving and communications system (PACS) by a board-certified, fellowship-trained neuroradiologist (M.G.) in conjunction with a radiology resident (D. M., A. W., or P.T.). All preoperative as well as immediate and remote postoperative imaging studies were assessed independent of the associated imaging reports in the medical record. Baseline intracranial anatomy, pre- and postoperative appearances of the operative lesion, and postoperative findings were documented.

Imaging findings were then classified as benign, expected (type I), atypical findings not requiring further intervention (type II), atypical findings that prompted minimally invasive bedside procedures (type III), and atypical findings requiring repeat surgery (type IV). In patients with findings belonging to multiple classification types, the most severe type of classification was assigned (→Table 1).

Results

A total of 102 patients were included in this retrospective study and ranged in age from 11 to 79 years, with a mean age of 54 years. Seventy-five (74%) patients were females and 27 (26%) were males. Surgical indications included 33 anterior

Fig. 1 Anatomy relevant to the transpalpebral “eyelid” approach to the anterior cranial fossa. (A) Photograph showing the location of the incision made through the skin of the upper eyelid crease (dotted line) staying within 2.5 cm lateral to lateral canthus (free of facial nerve branches). The dashed line represents the path of the frontal branch of the facial nerve. (B) Sagittal cross-sectional schematic diagram of the eyelid showing the soft tissue layers of the upper eyelid. (C) Sagittal cross-sectional schematic diagram of the eyelid showing the elevation of the orbital septum from the orbital septum after incision through the upper eyelid crease. The periosteum is then divided at the superior orbital rim. (D–F) Lateral (D), frontal (E), and oblique frontal (F) views demonstrate the fronto-orbital craniotomy that is made through the transpalpebral incision. The bone flap extends from the sphenoid keyhole (*) medially to the supratrochlear notch and involves portions of the superior and lateral walls of the orbit (Images 1B–F are reproduced with permission from Mayfield Clinic, Cincinnati, Ohio, United States).

cranial fossa tumors, 74 aneurysms, and 2 cases of osseous dysplasia (►Fig. 2).

Preoperative imaging was available for 99 patients (97%) with the remaining 3 patients obtaining imaging at an outside facility that was never imported into our institution's PACS. Given the retrospective nature of this study, postoperative imaging intervals were variable. However, initial postoperative imaging via computed tomography (CT) was obtained within 24 hours for 98 patients (96%), and initial postoperative imaging for the remaining 4 patients was obtained within 1 month. Additional follow-up imaging was performed as clinically indicated.

Type I (benign, expected) findings occurred exclusively in 49% of patients. Such findings included craniotomy hardware and bone cement, small pneumocephalus, minimal extra-axial fluid, and mild periorbital soft tissue swelling (►Fig. 3).

Thirty-eight patients (37%) demonstrated Type II (benign, atypical) findings not requiring further intervention. Among these, 14 patients had asymmetric globe protrusion, 15 patients had bone cement in the frontal and/or ethmoid sinuses, 11 had residual aneurysm, 11 had a small acute

cerebral infarction, 7 had a pseudomeningocele, and 22 had a moderate-to-large hematoma of the eyelid (►Fig. 4). We defined asymmetric globe protrusion as greater than or equal to 2 mm difference between the globes in distance from the cornea to the interzygomatic line. If the asymmetric protrusion developed postoperatively, we attributed it to surgery; if it was present preoperatively, it was not categorized as a postoperative abnormality.

Of note, 11 patients had small eyelid pseudomeningoceles that initially increased on further studies, prior to subsequently decreasing in size and eventually resolving without intervention. On average, these pseudomeningoceles had decreased to baseline by postoperative day 18 (►Fig. 5), though imaging intervals varied between patients, and it was therefore difficult to assess precisely when pseudomeningocele size peaked or resolved.

Type III findings (atypical, requiring minimally invasive bedside intervention) were present in 6% of patients. Such procedures included lumbar drain placement for the treatment of pseudomeningocele, typically in the eyelid (►Fig. 6) and incision and drainage of eyelid hematoma. Following

Table 1 Patient demographics, including age and gender

Demographics	Min	Max	Mean
Age	11	79	54
Gender	Female	Male	
	74% (n = 75)	26% (n = 27)	
Postoperative findings	N	Percentage	
Type I	50	49	
Small eyelid hematoma	74	73	
Type II	38	37	
Asymmetric globe protrusion	14	14	
Sinus cement	15	15	
Acute cerebral infarction	11	11	
Pseudomeningocele	7	7	
Moderate-large eyelid hematoma	22	22	
Enlarging pseudo-meningocele	11	11	
Type III	6	6	
Pseudomeningocele	4	4	
Eyelid hematoma	2	2	
Type IV	8	8	
Pseudomeningocele	4	4	
Large pneumocephalus	1	1	
Orbital rim nonunion	1	1	
Osteomyelitis	1	1	

Abbreviations: N, patient number; Percentage, raw percentage of patients with this imaging finding.
Notes: Summary of classification (Types I–IV) and most commonly occurring imaging findings in each subtype. Note that while patients may demonstrate multiple imaging findings, final characterization into type I–IV is based on the most severe finding. Therefore, individual patient numbers do not summate to 100 percent. For example, though 73% of patients had an expected small eyelid hematoma, only 46% of patients had isolated type I findings.

these procedures, all patients required no further interventions and were discharged from the hospital in an average of 6 days.

Type IV findings (atypical, requiring surgical intervention) were present in 8% of patients. The most common type IV finding was pseudomeningocele refractory to lumbar drain placement requiring shunt placement and/or repeat craniotomy and duraplasty. Three additional patients underwent repeat craniotomy for hardware revision. Early in the case series, a patient developed a large eyelid collection

that was initially suspected to be infectious in etiology but was culture negative. Following bedside incision and drainage with subsequent recurrence, the decision was made to return to the operating room for drainage and hardware revision. The two additional hardware revisions involved one case of nonunion and one case of cellulitis and osteomyelitis. Two patients underwent additional surgery for large pneumocephalus.

The patient with an eyelid infection demonstrated peri-orbital cellulitis refractory to antibiotics and incision and drainage. This prompted a follow-up CT of the orbits approximately 4 months after the initial surgery demonstrating osseous lucency surrounding the cranioplasty hardware and cement (►Fig. 7A). Further workup with magnetic resonance imaging (MRI) demonstrated an enhancement of the surrounding bone compatible with osteomyelitis (►Fig. 7B–D). Adjacent dural enhancement was noted on this follow-up examination, but had decreased compared to postoperative imaging obtained 4 months prior (►Fig. 7E–I). Additionally, the patient reported symptoms of periorbital pain and swelling but was neurologically intact, thus favoring postoperative dural enhancement over infection. The patient returned to the operating room for repeat cranioplasty and placement of antibiotic-impregnated methyl-methacrylate and subsequently improved.

Eleven patients (11%) developed a small acute cerebral infarct postoperatively. All but four of the infarcts involved the basal ganglia; five were within the caudate head, two affected the internal capsule, one involved the temporal lobe, and three involved the frontal lobe. These were likely to be a result of occlusion during aneurysm clipping of small perforator branches arising from the anterior cerebral artery or supraclinoid internal carotid artery. All acute infarcts were asymptomatic with no documented remote clinical sequelae. No brain retraction injuries were observed. However, it should be noted that MRI is more sensitive for the detection of brain retraction injury, and the majority of postoperative imaging was via CT.

Discussion

The transpalpebral approach to the anterior cranial fossa is a novel, minimally invasive surgical technique.^{17–19} In addition to the benefits of decreased postoperative pain and shorter hospital stays provided by all minimally invasive techniques, the transpalpebral incision offers improved cosmesis with reduced risks of local alopecia, brow asymmetry, and facial nerve injury compared with the standard eyebrow incisions.^{17–19}

Given these advantages, the transpalpebral technique is likely to be more widely practiced in the future. Therefore, all members of the clinical team caring for the postoperative patient, including neuroradiologists, neurosurgeons, and oculoplastic ophthalmologists, must be familiar with the spectrum of postoperative findings associated with this approach. In particular, one must distinguish between benign, expected postoperative findings and findings indicating the potential need for additional intervention.

Fig. 2 Surgical indications. Surgical indications, as recorded in the operative note, for 102 patients. Note that several patients had multiple indications for the same surgery (e.g., multiple aneurysms) and numbers do not equal 102. (A) Nonvascular or non-high-flow vascular indications comprised a total of 35 (32%) indications and included meningiomas, neuronal and plasma cell neoplasms, hyperostosis, and cavernomas. (B) Aneurysms comprised a total of 74 (68%) indications, most commonly of the anterior communicating artery. ACA, anterior cerebral artery; AComm, anterior communicating artery; ICA, internal carotid artery; MCA, middle cerebral artery; PComm, posterior communicating artery.

A prior review of anterior cranial fossa surgeries performed at our institution via the transpalpebral approach revealed that this technique is an effective and safe alternative to the traditional brow incisions.¹⁷ In this study, we sought to characterize the spectrum of postoperative imaging findings one could encounter on follow-up imaging. One half of patients had exclusively type I findings, such as minimal pneumocephalus and mild incisional soft tissue swelling. As with any surgical procedure, these findings are expected and resolve spontaneously without closer imaging observation or invasive procedures.

Postoperative imaging for slightly greater than one third of the patients revealed various atypical abnormalities that also resolved spontaneously or did not require further intervention. Asymmetric globe protrusion and periorbital fluid collection were the most common among these. An enlarging eyelid collection was observed to have spontaneously resolved in 11 patients by postoperative day 18, on average, in our series of patients. However, as daily imaging was not obtained, it was not possible to determine exactly when

these collections appeared or resolved. It is therefore important to keep in mind that an unremarkable immediate postoperative examination may display worsening features on subsequent examination. While thresholds for intervention among neurosurgeons will vary, it is also important to note that the collections in these 11 patients resolved spontaneously, and if acted upon immediately after visualization of an enlarging collection, these might have resulted in seemingly unnecessary procedures.

The frontal and/or ethmoid sinuses were violated intraoperatively in 15% of all cases, resulting in the presence of bone cement within a sinus. Despite this finding, no adverse clinical outcome was associated with paranasal sinus violation or repair. Members of the clinical team should be aware that bone cement may be present in the frontal sinus postoperatively but that it is likely to be clinically insignificant.

Six patients (6%) demonstrated postoperative imaging findings that prompted minimally invasive bedside procedures. Pseudomeningocele was the most common among these and usually treated with lumbar drain placement. It most often occurred in the eyelid, appearing as a low-density collection with extremely well-demarcated margins (►Fig. 6). We hypothesize that this collection forms in the potential space between the anterior and posterior lamellae of the eyelid created by the transpalpebral incision and elevation of the orbicularis muscle from the orbital septum.

Finally, 8% of patients demonstrated atypical imaging findings requiring surgical intervention. The most common finding among these patients was pseudomeningocele refractory to lumbar drain. Large pneumocephalus and large eyelid collections requiring surgical decompression occurred rarely. A single case of infection was identified on postoperative imaging, which prompted repeat craniotomy for removal and replacement of surgical hardware. Although unusual, these clinically significant imaging abnormalities are important to recognize.

The main limitation of this study was its retrospective nature. An attempt was made to limit the bias of the authors through reviewing imaging and classifying findings independent of the original radiologist's interpretation.

Another limitation of this study was the subjective nature of measurements and size assessments. The observers within this study were consistent, but our assessments of size classification of eyelid hematomas and pseudomeningoceles as "small," "moderate," and "large" were not quantified and may not be easily externally reproducible. In addition, variability is expected among the thresholds maintained by different surgeons to intervene upon pseudomeningoceles and hematomas. As such, imaging and clinical findings prompting a particular management course may have been treated differently by a different surgeon.

Finally, our study focused primarily on imaging findings and did not review clinical complications that lacked imaging correlates. Conversely, many of the imaging findings would not be classified as a clinical or surgical complication. In this sense, this study did not completely evaluate the safety or efficacy of the transpalpebral approach but rather served as a guide for the clinical team unfamiliar with the unique

Fig. 3 Type I changes. These imaging findings represent benign, expected findings on postoperative imaging following the transpalpebral “eyelid” approach to the anterior cranial fossa. (A) Axial CT at the level of the orbits shows mesh and bone cement cranioplasty for reconstruction of the sphenoid ridge (arrow). An aneurysm clip is present. (B) Coronal CT at the level of the orbits shows mesh and bone cranioplasty along the frontal and zygomatic bones (arrow). (C) Axial CT shows a small amount of pneumocephalus and extra-axial fluid resulting in mild local mass effect (asterisk). (D) Axial CT shows a small periorbital hematoma (arrowhead) and subcutaneous emphysema (arrow) within the left periorbital soft tissues. CT, computed tomography.

postoperative imaging findings associated with this surgical technique.

The transpalpebral technique is a relatively novel surgical technique, and this study is the largest series published on this technique.¹⁷ As the surgical approach is adopted by more surgeons, the frequency of the imaging findings we have reported may change. However, our observations

remain useful in the interim to assist neuroradiologists and surgeons in identifying the most common expected postoperative findings and findings that may prompt intervention.

This review has revealed imaging findings that are to be expected following the transpalpebral surgical approach, as well as findings that may require further intervention.

Fig. 4 Type II changes. These imaging findings represent atypical findings on postoperative imaging that do not require further intervention. (A) Axial CT at the level of the orbits shows a well-circumscribed low-density collection in the left upper eyelid seen on POD 1, most consistent with a pseudomeningocele (arrow). This collection was not present on POD 0 and resolved spontaneously. (B) Axial CT at the level of the frontal sinuses shows bone cement within the right frontal sinus (arrow). CT, computed tomography; POD, postoperative day.

Fig. 5 Delayed eyelid collection. Several patients demonstrated an evolving eyelid collection, which increased over several postoperative studies prior to decreasing and eventually resolving spontaneously. In this patient, a small periorbital collection was present on POD 0 (arrow, A), enlarged on POD 2 (B) and POD 3 (C), and resolved by POD 21 (D). POD, postoperative day.

Familiarity with these findings will allow the clinical team to more quickly, accurately, and confidently recognize the potentially and clinically significant abnormalities, especially in practices where the transpalpebral approach is not yet commonly encountered. As this approach gains broader clinical implementation, a review of a larger number

of cases may be useful to more accurately assess the incidence of the imaging findings we have described. An investigation that incorporates clinical, radiographically occult findings would also be useful for further evaluating the overall safety and efficacy of the transpalpebral approach but is outside the scope of this study.

Fig. 6 Type III changes. These imaging findings prompted further intervention. (A) Axial CT at the level of the orbits on POD 9 shows a large fluid-density collection in the right eyelid with well-circumscribed, nearly imperceptible margins (solid arrow). The collection measured 5 HU. Note the smaller collection lateral to the greater wing of the sphenoid (dashed arrow). This collection resolved upon replacement of a lumbar drain. (B) Axial CT at the level of the orbits shows a large periorbital hematoma (arrow) with gas within the left orbit. The periorbital hematoma did not resolve spontaneously and required incision and drainage approximately 1 month after the initial surgery. HU, Hounsfield Units.

Fig. 7 Orbital cellulitis and osteomyelitis. (A–D) Axial noncontrast CT (A), T1W precontrast (B), T1W postcontrast (C), and T2W (D) images through the level of the zygoma demonstrating a perihardware lucency with corresponding increased T2 signal intensity and postcontrast T1 enhancement compatible with osteomyelitis (arrow). (E–G) Precontrast axial T1W (E), postcontrast axial T1W (F), and postcontrast coronal T1W (G) images through the left frontal lobe and orbit demonstrate dural enhancement with inferior displacement of the orbital roof (dashed arrows). Precontrast T1W (H) and postcontrast T1W (I) imaging 4 months prior to 7A–G had demonstrated an even greater degree of dural enhancement (dashed arrows), which had decreased substantially over a 4-month interval without intervention, favoring that this enhancement represented postoperative changes rather than intra-axial extension of infection. CT, computed tomography; T1W, T1-weighted; T2W, T2-weighted.

Conclusion

Imaging following the transpalpebral “eyelid” approach to the anterior cranial fossa most commonly shows benign findings requiring no intervention, such as minimal pneumocephalus, frontal sinus bone cement, eyelid pseudomeningoceles, and eyelid hematomas. Occasionally, postoperative imaging reveals abnormalities requiring bedside interventions, particularly eyelid pseudomeningocele requiring lumbar drain or further surgical interventions. As more surgeons adopt the transpalpebral technique, members of the multidisciplinary clinical team caring for these patients must be familiar with the expected postoperative imaging findings as well as more atypical findings that may affect patient management.

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