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Orbital outcomes after orbit-sparing surgery and free flap reconstruction

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ABSTRACT

Objective: To identify functional outcome and orbital complication rate of the preserved orbit and to identify predictors of orbital impairment in periorbital free flap reconstruction.

Materials and methods: A retrospective review was conducted on patients undergoing orbit-sparing surgery with periorbital free flap reconstruction at a tertiary institution from 2006 to 2017. Orbital complication rate and orbital functional outcomes were analyzed. A univariable and multivariable logistic regression analysis was used to assess predictors of functional outcome.

Results: Forty-nine patients met inclusion criteria. Ninety-eight percent of patients maintained a functional eye post-operatively. Most periorbital free flaps, 37 (75.5%), were performed following oncologic resection. Overall orbital function was graded as functional without impairment in 29 (59.2%) patients, functional with impairment in 19 (38.8%) patients, and nonfunctional in 1 (2.0%) patient. Postoperative orbital sequelae occurred in 32 (65.3%) patients. Twenty-one (42.9%) patients underwent 35 revision operations for late orbital sequelae. Extent of resection (OR, 5.93; CI 95%, 1.05–33.4; $p = 0.044$) and adjuvant RT (OR, 4.69; CI 95% 1.18–18.6; $p = 0.028$) significantly correlated with impairment in a functional orbit on multivariable analysis.

Conclusion: Orbit-sparing surgery with periorbital free flap reconstruction carries a significant risk of a variety of orbital sequelae, most commonly ectropion, requiring surgical intervention. However, most patients maintain a functional eye. The need for delayed exenteration/enucleation is low and is primarily limited to cancer recurrence. Significant predictors of complications include extent of resection and adjuvant radiation therapy.

Introduction

Orbital preservation in craniofacial lesions with orbital involvement is an area of active debate when involvement of the globe or intraconal orbit is not evident [1–6]. While studies have supported orbital preservation as a means of improving patients' quality of life [4–6], orbital sequelae can lead to increased dysfunction and need for subsequent corrective surgery [2,4,6]. Such sequelae include malposition of the globe, diplopia, lid dysfunction, ectropion, and nasolacrimal system obstruction resulting in epiphora [2,4]. Additionally, adjuvant radiotherapy poses an increased risk of toxicity to the preserved orbit and can also add to these complications [4,6,7]. Free tissue transfer offers a large volume of bony and soft tissue for reconstruction which can be used to support of the eye, but functional reconstruction of the periorbital and orbital structures after extensive resection is challenging [8–10]. To date, no study has explored orbital sequelae after orbit-sparing reconstruction with free tissue transfer. The objective of this study is to identify the orbital complication rate and functional outcome of the preserved orbit and to identify predictors of orbital impairment.

Materials and methods

Patient population

Following Institutional Review Board (IRB) approval, medical records were queried for all patients who underwent periorbital microvascular free flap reconstruction between December 2006 and December 2017. Patients were included if they underwent periorbital resection with orbital preservation and microvascular free flap reconstruction. Periorbital surgery was defined as complete or partial

Abbreviations: BCC, basal cell carcinoma; CI, confidence interval; CVD, cardiovascular disease; IRB, Institution Review Board; OR, odds ratio; RT, radiation therapy; SCC, squamous cell carcinoma

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Table 1
Clinical characteristics.

Characteristics (N = 49)	N (%) or Median (Range)
Age in years	62 (32–86)
Male	26 (53.1)
Comorbidities	
Hypertension	23 (46.9)
Cardiovascular disease	10 (20.4)
Diabetes	7 (14.3)
Hypothyroidism	5 (10.2)
Pulmonary disease	3 (6.1)
Renal disease	3 (6.1)
Smoking status	
Current	11 (22.4)
Past	15 (30.6)
Never	23 (46.9)
Alcohol	
Current	21 (42.9)
Never	28 (57.1)
Prior radiation therapy	11 (22.4)
Prior chemotherapy	8 (16.3)

resection of any of the following structures: orbital rims or walls, eyelids, medial and lateral canthi, or lacrimal sac. The decision for exenteration remains controversial, but generally, at our institution, the decision to perform an orbital exenteration is based on tumor invasion into the orbital apex, bulbar conjunctiva/sclera, extraocular muscles, or beyond the periorbita with significant involvement of the orbital fat or intraconal orbit. Tumors that did not meet these criteria had orbit-sparing surgery and are included in this study. Reconstruction was performed by four attending surgeons (H.K, R.H, A.L, and J.C).

Variables

All patients' charts were reviewed for demographic information, comorbidities, previous radiation therapy (RT), previous chemotherapy, adjuvant RT, adjuvant chemotherapy, and smoking and alcohol consumption. Surgical and pathological variables included for analysis were indication for surgery, extent of resection, tumor pathology, tumor subsite, type of microvascular free flap reconstruction, ischemia time, and additional concurrent orbital procedures performed. Extent of resection was categorized into ocular adnexa (eyelids, canthi), orbital floor or roof, bony multi-segment (floor/roof + one or more walls), and ocular adnexa + bone segment resection.

The main outcome measures included orbital sequelae, need for and type of subsequent orbital surgery, and need for eventual exenteration or enucleation. Late orbital sequelae were divided according to site and included anterior eye (ectropion, ptosis, canthus/eyelid wound dehiscence, corneal abrasion/ulceration, lagophthalmos, brow ptosis, periorbital bulk, eyelid edema, entropion), lacrimal system (epiphora), orbital malposition (hypoglobus, enophthalmos, and hyperglobus), infection (implant exposure/infection, preseptal cellulitis), vision loss, and orbital rim necrosis.

Ocular function was determined from postoperative clinic notes and was graded as functional vision without impairment, functional vision with impairment, or nonfunctional based on a prior study [4]. Functional vision was defined as binocular vision with no change in visual acuity or partial loss in visual field or acuity with residual function for day-to-day activities. Functional vision with impairment included one or more significant orbital sequelae. Nonfunctional vision included patients with blindness, light-perception only, non-serviceable visual acuity, and intractable diplopia.

Table 2
Surgical characteristics.

Characteristics (N = 49)	N (%) or Median (Range)
Indication	
Cancer	37 (75.5)
Infection	8 (16.3)
Deformity	3 (6.1)
Osteonecrosis	1 (2.0)
Pathology (n = 37)	
Sinonasal squamous cell carcinoma	14 (37.8)
Basal cell carcinoma	6 (16.2)
Melanoma	4 (10.8)
Cutaneous squamous cell carcinoma	3 (8.1)
Adenoid cystic carcinoma	3 (8.1)
Adenocarcinoma	2 (5.4)
Ameloblastoma	1 (2.7)
Osteosarcoma	1 (2.7)
Mucoepidermoid carcinoma	1 (2.7)
Angiosarcoma	1 (2.7)
Nasopharyngeal carcinoma	1 (2.7)
Laterality	
Left	26 (53.1)
Right	15 (30.6)
Bilateral	8 (16.3)
Recurrent or primary cancer (n = 37)	
Primary	28 (75.7)
Salvage	9 (24.3)
Extent of resection	
Ocular adnexa	5 (10.2)
Floor/Roof	25 (51.0)
Bony multi-segment	7 (14.3)
Ocular adnexa + bone	12 (24.5)
Type of free flap	
Musculocutaneous/fasciocutaneous	36 (73.5)
Osteocutaneous	13 (26.5)
Orbital procedures (n = 24)	
Implant used	17 (34.7)
Dacryocystorhinostomy	4 (8.2)
Tarsorrhaphy	2 (4.1)
Skin graft	2 (4.1)
Hughes flap	2 (4.1)
Medial canthopexy	1 (2.0)
Canthoplasty	1 (2.0)
Septal composite graft	1 (2.0)
Orbicularis flap	1 (2.0)
Ischemia time (minutes) (n = 47)	106 (60–228)
Length of stay (days)	7 (3–23)
Length of follow up (months)	17.5 (1.2–139.2)
Adjuvant radiation therapy (n = 35)	20 (57.1)
Adjuvant chemotherapy (n = 35)	12 (34.3)

Statistical analysis

Descriptive statistics were used to characterize the study population and summarize surgical characteristics and outcomes. Data is displayed as mean ± standard deviation or median (range). A univariable logistic regression analysis was conducted between the independent variables and orbital impairment. Odds ratios (OR) and 95% confidence intervals (CI) are reported. Variables that were found to be significant at the $\alpha = 0.10$ level in the univariable models were considered for the multivariable analysis to estimate odds ratio. Co-linearity amongst the independent variables was assessed using variance inflation factor before inserting them into the multivariable model. p-values were two-tailed, and significance was set to 0.05 alpha. All statistical analysis was

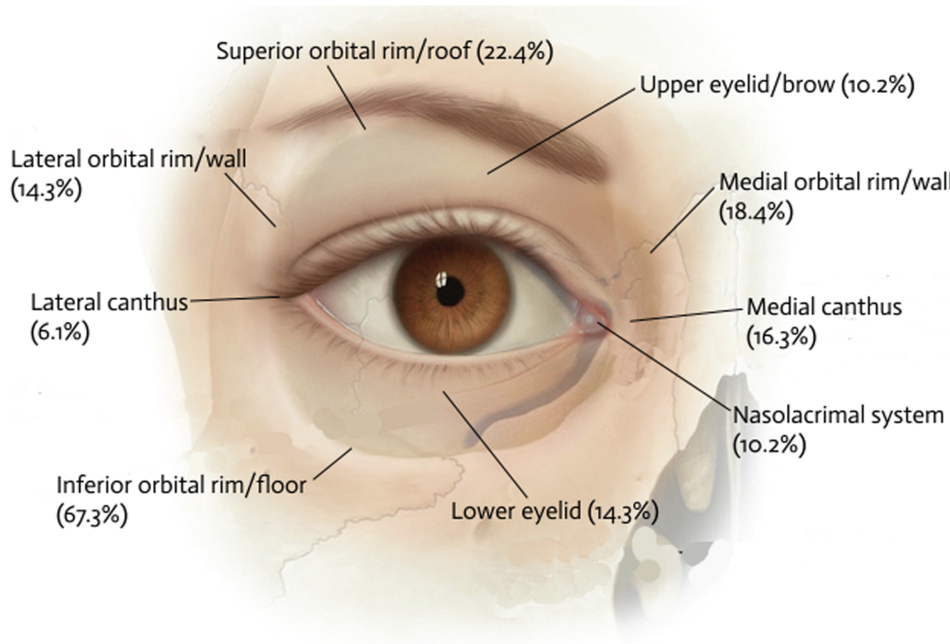

Fig. 1. Defect incidence in different orbital anatomic locations. Most defects included orbital floor (67.3%), followed by orbital roof (22.4%), and medial wall (18.4%). Lowest incidence was seen in lateral canthus (6.1%), followed by nasolacrimal system (10.2%) and upper eyelid (10.2%).

conducted in SPSS version 25 (IBM, Armonk, NY).

Results

Patient characteristics

Forty-nine patients who underwent orbit-sparing midfacial and craniofacial resection with microvascular reconstruction met inclusion criteria (Table 1). The median age of patients was 62.0 (32.0–86.0). Most patients, 26 (53.1%), were male. Hypertension, 23 (46.9%), cardiovascular disease 10 (20.4%), and diabetes mellitus 7 (14.3%) were the most common comorbidities. Eleven patients (22.4%) had prior radiation therapy and 8 (16.3%) patients had prior chemotherapy.

Surgical details are recorded in Table 2. Most periorbital free flaps, 37 (75.5%), were performed following oncologic resection. In 35 of these cases, the reconstruction was primary. Secondary reconstruction after oncologic resection was done for cosmetic deformity in 1 patient and osteoradionecrosis of the skull base after radiation for nasopharyngeal carcinoma in another patient. Other indications for periorbital free flaps included chronic frontal sinusitis in 8 (18.4%) patients, posttraumatic deformity in 2 (4.1%) patients, deformity after herpes zoster virus infection in 1 (2.0%) patient, and medication related osteonecrosis in 1 (2.0%) patient. Defect location is recorded in Fig. 1. Pathology was notable for squamous cell carcinoma (SCC) in 17 patients. Twenty patients (40.8%) received adjuvant RT and 12 patients received adjuvant chemotherapy (24.5%).

Osteocutaneous reconstruction was performed in 13 (26.5%) of patients including 6 (12.2%) osteocutaneous radial forearm free flaps, 5 (10.2%) fibula free flaps, 1 (2.0%) scapula free flaps, and 1 (2.0%) chimeric scapular tip and latissimus dorsi free flaps. The remaining 36 (73.5%) patients underwent fasciocutaneous/myocutaneous free flaps including 28 (57.1%) anterolateral thigh free flaps and 8 (16.3%) radial forearm free flaps. Median ischemia time was 106 min (range 60–228). Twenty-four patients underwent orbital procedures at time of initial surgery. These included periorbital implants in 17 (34.7%) patients, split thickness skin grafts in 2/49 (4.1%) patients, a tarsal-conjunctival flap in 2 (4.1%) patients, a septal mucosa and perichondral composite graft in 1/49 (2.0%) patient, and an orbicularis flap in 1 (2.0%) patient. Other orbital procedures included a prophylactic dacryocystorhinostomy in 4 (8.2%) patients, tarsorrhaphy in 2 (4.1%) patients, medial canthopexy in 1 (2.0%) patient, and canthoplasty in 1 (2.0%) patient. Median postoperative length of stay was 7 (3–23) days. Median follow up was 17.5 months (1.2–139.2).

Orbital outcomes

Overall orbital function was graded as functional without impairment in 29 (59.2%) patients, functional with impairment in 19 (38.8%) patients, and nonfunctional in 1 (2.0%) patient. Postoperative orbital sequelae occurred in 32 (65.3%) patients (Table 3). Twenty-one (42.9%) patients underwent 35 operations for late orbital sequelae (Table 4). Median time from surgery to orbital complication was 3 months (0–93).

Anterior orbital sequelae included ectropion in 14 (26.5%) patients. Facial nerve was paralyzed in 1 patient and weak in another. Five patients underwent ectropion repair. Ptosis occurred in 6 (12.2%) patients, and 1 underwent repair. Canthal or eyelid wound dehiscence occurred in 6 (12.2%) patients for which all 6 underwent local or regional flap repair (4 primary closure/local advancement, 2 paramedian flap) (Fig. 2). Corneal abrasions or ulceration developed during the postoperative period in 5 (10.2%) patients, 2 of whom required a tarsorraphy. Brow ptosis occurred in 4 (8.2%) patients, with 3 requiring repair. Lagophthalmos occurred in 3 (6.1%) patients with 1 patient requiring eyelid surgery. Two patients suffered from periorbital asymmetry due to flap bulk and required operative debulking of original flap.

Lacrimal system dysfunction and epiphora was seen in 7 (14.3%) patients. Orbital malposition included hypoglobus in 6 (12.2%) patients, enophthalmos in 3 (6.1%) patients, and hyperglobus in 1 (2.0%) patient. Two of these patients required orbital floor reconstruction with new osteocutaneous free flaps and two patients required implant replacements. The patient with hyperglobus required lowering of original osseous portion of the free flap. One patient underwent a calvarial bone graft with medpor implant to reconstruct inferior orbital rim. Implant exposure and infection occurred in 4 (8.2%) patients. One patient required implant removal with resolution of infection. Two patients

Table 3
Orbital sequelae.

Orbital outcomes (N = 32)	N (%) or Median (Range)
Anterior eye	
Ectropion	14 (28.6)
Ptosis	6 (12.2)
Canthus/eyelid wound dehiscence	6 (12.2)
Corneal abrasion/ulceration	5 (10.2)
Brow ptosis	4 (8.2)
Lagophthalmos	3 (6.1)
Peri-orbital bulk	2 (4.1)
Orbital-related oncologic outcome	
Recurrence	8 (16.3)
New primary	1 (2.0)
Lacrimal system	
Epiphora	7 (14.3)
Orbit malposition	
Hypoglobus	6 (12.2)
Enophthalmos	3 (6.1)
Hyperglobus	1 (2.0)
Implant exposure/infection	4 (8.2)
Vision Loss	1 (2.0)
Orbit rim necrosis	1 (2.0)
Functional Outcome	
Functional without impairment	29 (59.2)
Functional with impairment	19 (38.8)
Nonfunctional	1 (2.0)
Time from initial surgery to orbital complication (months)	3 (0–93)
Patients requiring orbital surgery	21 (42.9)
Type of surgery[a]	
Local flap reconstruction	11 (22.4)
Ectropion repair	5 (10.2)
Exenteration/enucleation	4 (8.2)
Cancer resection	4 (8.2)
Free flap reconstruction	4 (8.2)
Brow ptosis repair	3 (6.1)
Original flap debulking	2 (4.1)
Primary closure of dehiscence	2 (4.1)
Implant removal	2 (4.1)
Implant replacement	2 (4.1)
Tarsorrhaphy	2 (4.1)
Lagophthalmos surgery	1 (2.0)
Original flap adjustment	1 (2.0)
Implant + bone graft placement	1 (2.0)
Ptosis repair	1 (2.0)
Debridement	1 (2.0)

[a] Twenty-one patients underwent 35 operations for orbital complications.

required multiple procedures including an osteocutaneous radial forearm free flap and anterolateral thigh flap in one patient and temperoparietal and anterolateral thigh free flap in another.

One patient suffered a nonfunctional orbit due to complete vision loss from his initial trauma (gunshot wound). The orbit was preserved initially with hope of vision recovery, however, eventually underwent enucleation.

Eight patients (16%) had local recurrences during the follow-up period. Three patients (5.7%) with recurrence in region of the orbit underwent salvage exenteration for recurrence. One patient originally had cutaneous BCC, 1 patient had cutaneous SCC, and 1 patient had mucoepidermoid carcinoma of the nasal cavity. Three patients (5.7%) required resection. Pathology included adenoid cystic carcinoma of maxilla, cutaneous angiosarcoma, and polymorphous low-grade adenocarcinoma (1 patient each). The remaining two patients with local recurrence were admitted into a clinical trial. Additionally, a new orbital primary occurred in 1 patient. This patient originally had a malignant melanoma of the brow and later developed a cutaneous SCC.

Predicting impairment in functional orbit

A univariable logistic regression analysis identified extent of resection (adnexa + bone resection versus single segment resection (adnexa or single floor/roof resection); OR, 4.67; CI 95%, 1.12–19.5; $p = 0.04$), rigid reconstruction (presence of implant or bone graft vs soft tissue; OR, 3.53; CI 95%, 1.07 = 11.7; $p = 0.04$), and adjuvant RT (OR, 5.84; CI 95%, 1.67–20.4; $p = 006$) as variables to include in multivariable model based on alpha of 0.10 (Table 4). After adjusting for confounders, adnexal and bony resection (OR, 5.93; CI 95%, 1.05–33.4; $p = 0.044$) and adjuvant RT (OR, 4.69; CI 95% 1.18–18.6; $p = 0.028$) were significantly correlated with impairment in a functional orbit.

Discussion

Functional outcomes in orbit-sparing surgery has been an area of debate. An early study by Stern et al assessing ocular functional outcome after orbit-sparing surgery for sinonasal carcinoma concluded that most patients do not have useful eye function after ablation [11]. Since then, multiple authors have reported functional outcome after orbit-sparing surgery [4,12,13]. Rajaprukar et al. studied the functional outcomes of 16 preserved orbits in malignant sinonasal tumors with orbital involvement with all patients having a functional orbit at the time of last follow-up [12]. Sakashita et al. conducted a multi-institutional retrospective study evaluating ocular function among treatment modalities in patients with maxillary sinus cancer with orbital invasion [13]. In the 7 patients who underwent surgery with orbit preservation, all patients had a functional orbit postoperatively. In our study of patients undergoing orbit-sparing surgery with periorbital free flap reconstruction, 98% of patients maintained a functional eye. In contrast, our particular study focuses on patients with orbital preservation and patients undergoing surgery for additional indications such as cosmesis and cutaneous malignancies. Only one patient had a nonfunctional eye requiring delayed enucleation. This patient had vision loss due to traumatic injury at initial presentation. Orbit preservation was deemed to be appropriate in hope that vision might return, but the patient ultimately required enucleation.

Although the preserved orbit was almost always functional in our series, it should be noted that 65.3% of patients had late orbital sequelae. This includes 21 patients that required 35 additional orbit-related procedures. Ectropion was the most common late orbital sequelae in our series occurring in 28.6% of patients. The second most common complication was epiphora seen in 13.2% of patients. Imola et al. assessed orbital outcomes after orbit-sparing surgery in sinonasal malignancy and found similar rates of ectropion (20.4%) and epiphora (13.0%) [8]. Similar results were reported in other studies [12,13]. In this study, 54 patients underwent orbit-sparing surgery for sinonasal malignancy with various methods of reconstruction, 13 of which received a free flap reconstruction. In contrast, our series focuses on patients with orbit-sparing surgery for various malignant and non-malignant indications and reconstruction with free tissue transfer.

Adjuvant RT had a significant correlation with impairment in our series. Adjuvant therapy is known to increase risk of complications in orbit preserving surgery [3,4,6]. Particularly, radiation therapy increases the risk of optic atrophy, ectropion, dryness, and cataract formation [4]. Although our study showed increase in rate of orbital impairment in patients with radiation therapy, there were no cases of a nonfunctional orbit after adjuvant radiation therapy.

Interestingly, we found that rigid reconstruction had significant correlation with orbital impairment on univariable analysis, but statistical significance was eliminated on multivariable analysis. We feel this is due, in part, to extent of resection being a confounding factor when assessing correlation between rigid vs soft tissue reconstruction

Table 4
Univariable and multivariable analysis of orbital functional outcome.[a]

Predictor	Functional without impairment (n = 29)	Functional with impairment/nonfunctional (n = 20)	Univariable analysis Odds Ratio CI (95%)	p-value	Multivariable analysis Odds Ratio CI (95%)	p-value
Age (years)	63.2 ± 13.6	60.1 ± 12.8	0.987 (0.944–1.031)	0.550		
Male sex	16 (55.2)	10 (50.0)	0.813 (0.259–2.545)	0.722		
Comorbidities						
CVD	7 (24.1)	3 (15.0)	0.555 (0.125–2.469)	0.439		
Hypertension	15 (51.7)	8 (40.0)	0.622 (0.196–1.972)	0.420		
Diabetes	5 (17.2)	2 (10.0)	0.533 (0.093–3.069)	0.481		
Hypothyroidism	3 (10.3)	2 (10.0)	0.963 (0.146–6.358)	0.969		
Smoking status						
Never	14 (48.3)	9 (45.0)	Ref			
Current/Past	15 (51.7)	11 (55.0)	1.141 (0.364–3.578)	0.821		
Alcohol consumption						
Never	18 (62.1)	10 (50.0)	Ref			
Current	11 (37.9)	10 (50.0)	1.636 (0.516–5.187)	0.403		
Prior RT	8 (27.6)	3 (15.0)	0.463 (0.106–2.021)	0.306		
Prior chemotherapy	5 (17.2)	3 (15.0)	0.847 (0.178–4.033)	0.835		
Indication						
Other causes	8 (27.6)	4 (20.0)	Ref			
Cancer	21 (72.4)	16 (80.0)	1.52 (0.389–5.968)	0.545		
Tumor Pathology						
Other	11 (52.4)	9 (56.3)	Ref			
SCC	10 (47.6)	7 (43.8)	1.169 (0.316–4.320)	0.815		
Lateralization						
Bilateral	6 (20.7)	2 (10.0)	Ref			
Unilateral	23 (79.3)	18 (90.0)	2.348 (0.423–13.047)	0.329		
Cancer						
Primary	14 (66.7)	14 (87.5)	Ref			
Recurrent	7 (33.3)	2 (12.5)	0.286 (0.05–1.623)	0.158		
Year of surgery	2013 ± 2.50	2013 + 2.96	0.980 (0.790–1.215)	0.852		
Defect laterality[b]						
Medial (n = 13)	6 (60.0)	7 (70.0)	Ref			
Lateral (n = 7)	4 (40.0)	3 (30.0)	0.643 (0.101–4.097)	0.640		
Floor vs Rood defects						
Floor (n = 31)	16 (69.6)	15 (83.3)	Ref			
Roof (n = 10)	7 (30.4)	3 (16.7)	0.457 (0.099–2.101)	0.314		
Extent of resection						
Single segment	**21 (72.4)**	**9 (45)**	Ref			
Bony multi-segment	**4 (13.8)**	**3 (15)**	1.750 (0.323–9.469)	0.516	2.642 (0.384–18.185)	0.324
Adnexa + bone	**4 (13.8)**	**8 (40)**	**4.667 (1.115–19.54)**	**0.035**	**5.925 (1.052–33.359)**	**0.044**
Rigid reconstruction	10 (34.5)	13 (65.0)	3.529 (1.067–11.669)	0.039	3.849 (0.938–15.791)	0.061
Adjuvant RT	**7 (24.1)**	**13 (65.0)**	**5.837 (1.669–20.414)**	**0.006**	**5.035 (1.291–19.645)**	**0.020**
Adjuvant Chemotherapy	5 (17.2)	7 (35)	2.585 (0.683–9.786)	0.162		
Ischemia time	111.1 ± 46.6	121.7 ± 46.6	1.005 (0.993–1.018)	0.425		
Length of stay	8.5 ± 4.50	8.2 ± 4.40	0.983 (0.862–1.122)	0.803		

Abbreviations: CVD, Cardiovascular disease. SCC, squamous cell carcinoma. RT, radiation therapy.

[a] Categorical variables presented as number (%) and continuous variables as mean ± standard deviation unless otherwise indicated. All variables with $p < 0.10$ in the univariable analysis were considered in the multivariable analysis algorithm, but only the final model is presented. Bold values demonstrate statistical significance in the final multivariable model.

[b] Medial defects are defined as medial canthus, medial wall/rim, and nasolacrimal system defects. Lateral defects are defined as lateral canthus and lateral wall/rim defects.

and orbital impairment. Patients with rigid reconstruction are more likely to have extensive resections including bone and soft tissue adnexa and worse orbital outcomes. A study by Sampitharao et al conducted an analysis of 34 consecutive patients who underwent orbital floor resection for malignancy and free tissue transfer [14]. In comparing rigid bone reconstruction and soft tissue reconstruction, they found that there was statistically significant difference in malposition rates between bony and soft tissue reconstruction ($p = 0.040$), but similar to our study, there was no statistical difference in terms of functional outcome including aesthetics, eye movement, and visual acuity. Our

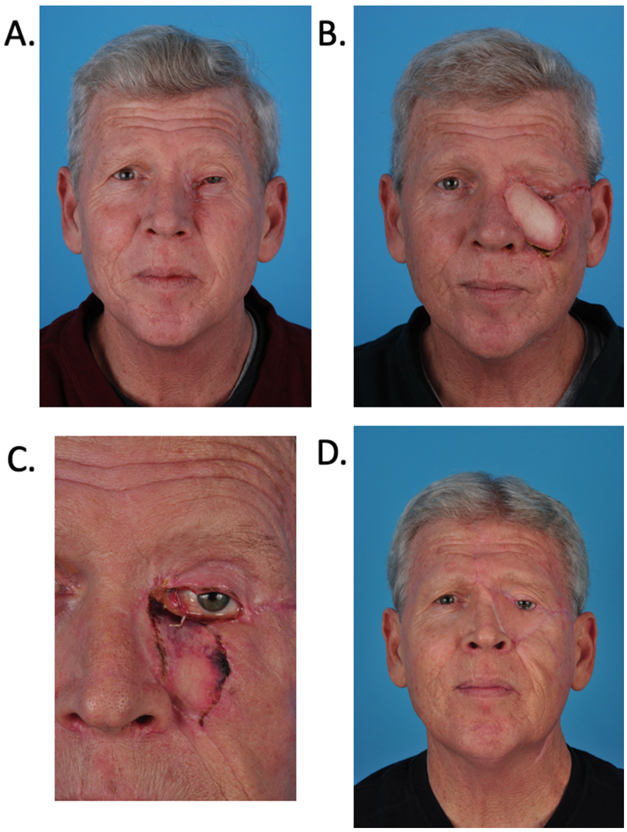

Fig. 2. Case of orbital complication requiring local flap reconstruction after primary orbit-sparing surgery and anterolateral thigh free flap. This patient is a 58-year-old male with basal cell carcinoma of the left medial canthus (A) who underwent resection and reconstruction with an anterolateral thigh free flap, a cervicofacial (mustarde) rotational flap, and nasal septal mucosa and perichondrium composite graft for conjunctival repair (B). He did not undergo adjuvant RT. He subsequently developed ptosis and a medial canthus defect (C) requiring a paramedian forehead flap (D) with improved orbital outcome.

results support the conclusion that although orbital sequelae are common and requires further treatment, the value of preserving visual function is immeasurable.

There are some limitations to this study including its retrospective design. Further, the defects included incorporate diverse anatomic structure which can impact orbital function in a variety of ways. Nevertheless, the data in this report can allow surgeons to anticipate the potential for ocular dysfunction in planning periorbital reconstruction with free tissue transfer. Additionally, providers can identify high-risk patients with history of radiation or those requiring extensive bony and adnexal resection and counsel these patients appropriately.

It is important to note that the outcomes reflected in our study correlate closely with reconstructive volume and surgical experience. Operative volume has been reported as a valuable prognosticator of outcomes after head and neck surgery. Particularly, in oncologic head and neck surgery, treatment center experience predicts complications, readmission, as well as long term survival [15–17]. An important adjunct factor in providing good outcomes in such patients is a multidisciplinary approach to care. At our institution, the integrated surgical team that includes head and neck oncologic surgeon, a reconstructive surgeon, an ophthalmologist, and a neurosurgeon. The treatment team also includes radiation and medical oncologists, specialty trained nursing staff, and a case manager. Our experience includes over 300 upper and midfacial free flaps from a set of over 1000 over the 11 year period from which this consecutive subset of patients was selected, and the outcomes are thereby reflective of a relatively high volume experience of this less common application of free flaps for head and neck reconstruction.

Appropriate patient and flap selection is critical to outcomes. The decision to preserve the orbit is based on the relationship between orbital function and oncologic safety. As described above, appropriate oncologic criteria for orbital preservation is critical. Flap selection varies by surgeon preference, but, in general, soft tissue of the periorbital region can be replaced with skin from a variety of flaps: the advantages of common flaps are described briefly. Skin of the forearm provides a thinner layer with a better color match than skin from the subscapular system or anterolateral thigh flaps. In some cases, an optimal skin match can be achieved by a skin graft over a myofascial flap. Bony reconstruction can aid in support of the preserved eye as well as palatal reconstruction. A limited orbital rim defect is well reconstructed with radius from a forearm flap while a larger defect is best addressed with fibula or in cases of larger soft tissue defects, a scapular system flap. The subscapular system offers abundant bone well suited to maxillary reconstruction which can be utilized in various configurations.

Adjuvant radiation therapy for the periorbital region increases the risk of impaired orbital function. Therefore, in the setting of orbital preservation, the patient must be aware of the likelihood of subsequent radiotherapy and possible sequelae. Our choice of reconstruction has shifted over time and we have begun to favor use of the subscapular system flaps for midfacial reconstruction, though not reflected in this series. The functional impact has yet to be measured, but such practice shifts are a common limitation of retrospective studies.

Conclusion

Orbit-sparing surgery with periorbital free flap reconstruction is feasible in a subset of patients with good functional outcomes. Need for delayed exenteration/enucleation in this population is low and is primarily limited to cancer recurrence. However, orbital complications are common often requiring further corrective surgery. Adjuvant radiation therapy and extensive resection puts patients at higher risk for orbital impairment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Reyes C, Mason E, Solares CA, Bush C, Carrau R. To preserve or not to preserve the orbit in paranasal sinus neoplasms: a meta-analysis. J Neurol Surg B Skull Base 2015;76:122–8.
[2] Weizman N, Horowitz G, Gil Z, Fliss DM. Surgical management of tumors involving the orbit. JAMA Otolaryngol Head Neck Surg 2013;139(8):841–6.
[3] Suárez C, Ferlito A, Lund VJ, et al. Management of the orbit in malignant sinonasal tumors. Head Neck 2008 Feb;30(2):242–50.
[4] Imola MJ, Schramm Jr. VL. Orbital preservation in surgical management of sinonasal malignancy. Laryngoscope 2002;112(8 Pt 1):1357–65.
[5] Carrau RL, Nuss DW, Snyderman CH, et al. Squamous cell carcinoma of the sinonasal tract invading the orbit. Laryngoscope 1999;109:230–5.
[6] Amsbaugh MJ, Yusuf M, Silverman C, Bumpous J, Perez CA, Potts K, et al. Organ preservation with neoadjuvant chemoradiation in patients with orbit invasive sinonasal cancer otherwise requiring exenteration. Radiat Oncol J. 2016 Sep;34(3):209–15.
[7] Mendenhall WM, Amdur RJ, Morris CG, et al. Carcinoma of the nasal cavity and paranasal sinuses. Laryngoscope 2009;119(5):899–906.
[8] Kakibuchi M, Fujikawa M, Hosokawa K, et al. Functional reconstruction of maxilla with free latissimus dorsi-scapular osteomusculocutaneous flap. Plast Reconstr Surg

2002;109(4):1238–45.
[9] Cordeiro PG, Santamaria E, Kraus DH, Strong EW, Shah JP. Reconstruction of total maxillectomy defects with preservation of the orbital contents. Plast Reconstr Surg 1998;102(6):1874–87.
[10] Santamaria E, Cordeiro PG. Reconstruction of maxillectomy and midfacial defects with free tissue transfer. J Surg Oncol 2006;94:522–31.
[11] Stern SJ, Goepfert H, Clayman G, Byers R, Wolf P. Orbital preservation in maxillectomy. Otolaryngol Head Neck Surg 1993;109:111–5.
[12] Rajapurkar M, Thankappan K, Sampathirao LM, Kuriakose MA, Iyer S. Oncologic and functional outcome of the preserved eye in malignant sinonasal tumors. Head Neck 2013;35:1379–84.
[13] Sakashita T, Hayashi R, Homma A, et al. Multi-institutional retrospective study for the evaluation of ocular function- preservation rates in maxillary sinus squamous cell carcinomas with orbital invasion. Head Neck 2015;37:537–42.
[14] Sampathirao LM, Thankappan K, Duraisamy S, et al. Orbital floor reconstruction with free flaps after maxillectomy. Craniomaxillofac Trauma Reconstr 2013;6(2):99–106.
[15] Killeen SD, O'Sullivan MJ, Coffey JC, Kirwan WO, Redmond HP. Provider volume and outcomes for oncological procedures. Br J Surg 2005;92:389–402.
[16] Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. JAMA 1998;280:1747–51.
[17] Philips R, Martin D, Eskander A, et al. Effect of adjuvant radiotherapy treatment center volume on overall survival. Oral Oncol. 2018 Mar;78:46–51. https://doi.org/10.1016/j.oraloncology.2018.01.004. Epub 2018 Jan 20 PubMed PMID: 29496057.