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Review Article

Management of pediatric orbital cellulitis: A systematic review

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ABSTRACT

Objectives: Orbital complications account for 74–85% of all complications from acute sinusitis, more often affect the pediatric population, and can result in devastating consequences. Therefore these patients require prompt diagnosis and proper management. We review and summarize the current literature to determine the appropriate management of each stage of pediatric orbital cellulitis and offer a new comprehensive literature-based algorithm.

Methods: Data sources were PubMed/MEDLINE, and Google Scholar. Studies relevant to the management of each subcategory of the Chandler criteria in the pediatric population, limited to the period 1997 through Jan 2018, were compiled and interpreted. Seventy-one studies were reviewed in total.

Results: Pre-septal and post-septal cellulitis can generally be managed non-surgically, while orbital abscess and cavernous sinus thrombosis are managed surgically. For subperiosteal abscess, non-surgical medical management has been successful in certain patients. Results of the literature review were summarized, and subsequently developed into a comprehensive algorithm for management, including criteria for age, location, and volume of abscess on imaging.

Conclusions: Orbital cellulitis, particularly subperiosteal abscesses, in children is not an absolute indication for immediate surgical intervention. Conservative measures can be safe and effective if appropriately used, depending on patient characteristics, clinical course, and imaging.

1. Introduction

Orbital complications account for 74–85% of all complications from acute sinusitis [1]. It can affect all age groups, but is more frequent in pediatric populations [2]. Devastating consequences of acute sinusitis can result, including blindness in patients with orbital complications, as well as venous and intracranial extension [1]. Therefore these patients require prompt diagnosis and proper management.

There are many classification schemes for orbital cellulitis including the Chandler classification and the Maloney classification (Table 1). The Chandler classification is based on specific clinical findings, which today are used in conjunction with CT to determine stage [3]. Moloney et al. attempted to simplify this classification by dividing into 'preseptal' and 'postseptal' depending on penetration of the orbital septum [4]. Because no lymphatic or venous connection exists between these two compartments, the orbital septum prevents infections of the face from spreading into the deep orbit. While preseptal infections most commonly arise from bug bites and trauma to the eyelid, postseptal infections are almost always a sequelae of sinusitis, most commonly the ipsilateral ethmoid sinuses [5].

While multiple risk factors, criteria, and characteristics have been discussed in the literature, there are no established guidelines specific to the management of orbital cellulitis in the pediatric population. Some care pathway algorithms have been proposed for the initial assessment and triage of the patient, often encouraging multidisciplinary involvement and low thresholds to consult relevant services [5,6]. However, no comprehensive algorithm exists addressing all stages of orbital cellulitis and their subsequent surgical vs. medical management. In particular, the role of surgery for subperiosteal abscesses in children has varied in the literature. This study attempts to answer the question of when medical vs. surgical management is most appropriate in each stage of orbital cellulitis within the pediatric population. We review and summarize current literature and offer a new literature-based algorithm for management.

2. Material and methods

The PubMed/MEDLINE and Google Scholar databases were searched for relevant studies using search terms "orbital cellulitis", "subperiosteal", "intraconal abscess", "cavernous sinus thrombosis" or

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Table 1
Chandler and maloney classifications.

Moloney [4]	Chandler Group [73]	Chandler Title	Chandler Description
Preseptal	1	Inflammatory edema	Inflammation/edema limited to the eyelid
Postseptal	2	Orbital Cellulitis	Inflammation including contents posterior to septum
Postseptal	3	Subperiosteal Abscess (SPA)	Purulent collection between bony orbit and periorbita
Postseptal	4	Orbital Abscess	Purulent collection within the orbit itself
Postseptal	5	Cavernous Sinus Thrombosis	Retrograde phlebitis

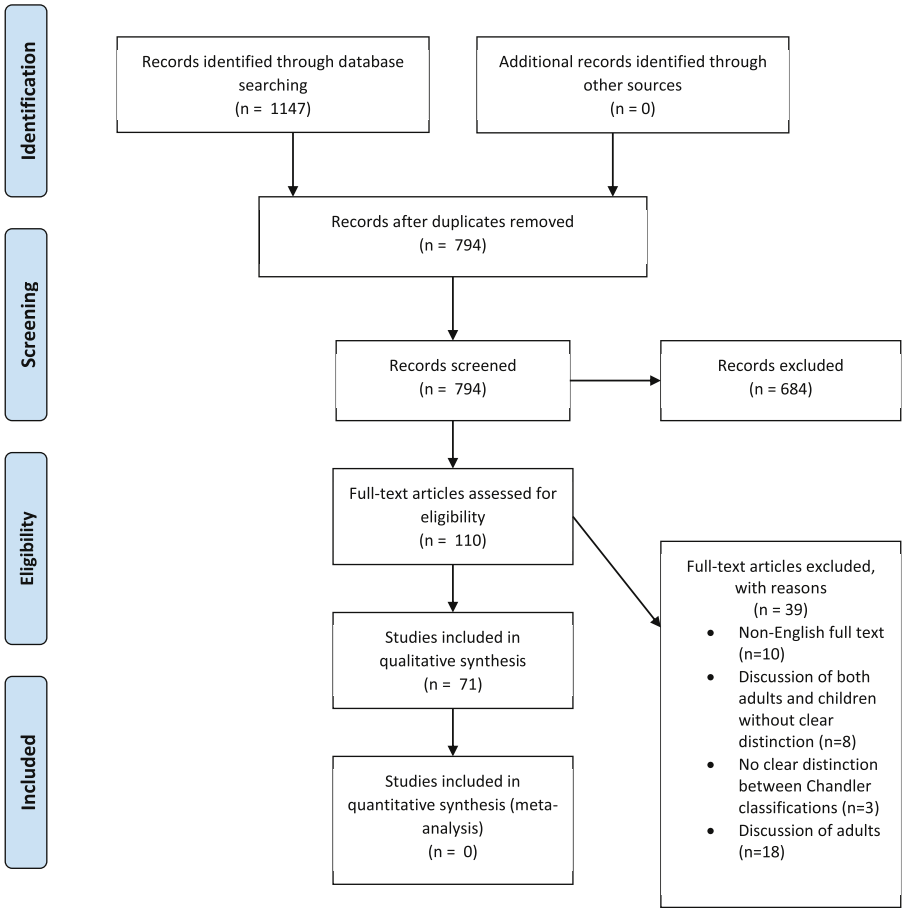

Fig. 1. PRISMA flow chart.

"orbital abscess", and "management", limited to the period 1997 through Jan 2018 according to PRISMA guidelines. Within the Google Scholar database, search terms were used to browse through article titles only. The final results were limited to English language literature, human subjects, and children 0–18 years old (or, in studies that included both children and adults, clear descriptions of each subgroup). Titles and abstracts were reviewed for relevance. The Population, Intervention, Comparison, Outcome (PICO) research framework was used to construct the research question, and carry out the search for whether surgical intervention was indicated to treat each stage of orbital cellulitis. Any study that reported on the medical and/or surgical treatment of pediatric patients with orbital cellulitis and its complications, and also included outcomes, morbidity and/or mortality was eligible for inclusion. Animal studies, editorials, letters, and other reviews were excluded. Studies which did not differentiate results by stages of Chandler criteria (for instance, the outcomes of patients with pre-septal orbital cellulitis and post-septal orbital cellulitis were combined) were also excluded. Ultimately 71 articles were identified for this review (Fig. 1).

3. Results

All the studies reviewed were either retrospective reviews, case reports, or case series. There were no prospective clinical trials.

3.1. Diagnostic imaging

Although orbital cellulitis may have similar characteristics to preseptal cellulitis, such as induration or erythema, clinical signs specifically suggesting post-septal involvement include proptosis, chemosis, ophthalmoplegia, or decreased visual acuity [7–9]. However, periorbital edema can often limit physical exam and hinder ability to differentiate between the two. Therefore, if orbital cellulitis is suspected or if bedside examination cannot rule it out, a sinus CT with contrast is warranted within 24 h of presentation [7,10].

In our literature review, 8 relevant studies were identified pertaining to the diagnostic use of imaging for orbital cellulitis; all were retrospective chart reviews. CT has been found to be accurate for diagnosing orbital cellulitis and subperiosteal abscess (SPA), with reported accuracies ranging from 91 to 100% [11–13]. In one

retrospective review, positive findings on CT correlated to intraoperative findings in all 25 of patients with SPA and/or orbital cellulitis [14]. In a study by Younis et al. concerning orbital complications, the predictive accuracy of a clinical diagnosis was 82% and the accuracy of CT was 91% [11]. Factors that could help target patients with orbital cellulitis for CT scanning include inability to perform complete eye evaluation, proptosis, ophthalmoplegia, pain with external ocular movement, deteriorating visual acuity, or central symptoms (i.e. seizures, focal neurologic deficits, or altered mental status) [10,11,15]. MRI should be considered for cases in which there is either clinical or CT-based suspicion for intracranial complications or cavernous sinus thrombosis such as changes in mentation, persistent fever despite appropriate therapy, or CT findings suggestive of intracranial extension [10,16,17].

CT scan has the added benefit of guiding management once orbital cellulitis is diagnosed. In particular, CT identification of an abscess can help determine need for surgical drainage vs. medical management, as well as assist with intra-operative planning [7,11]. This is discussed below.

3.2. Pre-septal cellulitis

Fifteen retrospective chart reviews were identified in our literature review pertaining to the management of pediatric pre-septal orbital cellulitis, evaluating a total of 1083 pediatric patients. Most cases of isolated pre-septal cellulitis (also reported in the literature as periorbital cellulitis) can be treated with antibiotics, and surgical drainage is rarely necessary. Surgery in these settings often consisted of functional endoscopic sinus surgery, external orbitotomies or, when applicable, drainage of pre-septal fluid collections that had developed from pre-septal cellulitis [18–32]. The vast majority of studies report surgery and/or procedure rates ranging from 0 to 11% [18–20,22–30,32]. Though, one retrospective analysis reported that ten of their 34 (29%) pediatric patients with pre-septal orbital cellulitis required operative intervention (antral washout with or without external frontal-ethmoidectomy) and another reported 23 of 58 (40%) patients required incision and drainage of a preseptal abscess [21,31].

3.3. Post-septal orbital cellulitis

Sixteen retrospective chart reviews of 12,824 patients were identified in our literature review pertaining to the management of pediatric post-septal orbital cellulitis. Multiple studies have demonstrated that orbital cellulitis in children can often be managed non-surgically. Nonsurgical management success rates reported in the literature for pediatric patients range from 77 to 100% [11,18–20,23,24,27–30,33–36] except one retrospective review which reported that only ten of their 27 patients were able to be managed without surgery [31]. Marchiano et al. performed the largest retrospective review, drawing patient data from the Nationwide Inpatient Sample (NIS) database, and found that 6166/6951 (88.7%) pediatric patients with the ICD-9 code for orbital cellulitis were treated non-surgically, though it is not clear how many of these cases also had subperiosteal abscess at time of surgery [36]. Regardless, overall several of these studies endorsed a trial of antibiotics before surgical intervention [18,20,23,24,28,29,36]. For instance, Botting et al. found that 77% of the 35 post-septal orbital cellulitis cases they reviewed were treated successfully with intravenous antibiotics without recurrences, with the eight remaining cases only undergoing surgery following a 48 h trial of IV antibiotics [18].

Clinical deterioration should prompt suspicion for development of subperiosteal abscess, which is discussed below.

3.4. Subperiosteal abscess

After excluding studies which did not distinguish outcomes between pediatric and adult patients, 30 studies were identified. Surgical management in this setting included drainage (endoscopic or external) and/or endoscopic sinus surgery. Three articles endorsed surgical drainage of all cases of subperiosteal abscess: Wan et al., Kinis et al., and Welkoborsky et al. performed retrospective chart reviews on patients who presented with subperiosteal abscess, in total describing 28 of 28 patients who underwent surgical intervention [24,26,29]. Sciarretta et al. also endorses surgical drainage in pediatric patients with SPA and described nine pediatric patients who all underwent surgical drainage. However, it should be noted that these patients underwent surgery only after at least 48 h of antibiotics without improvement [30]. There was also one case report of a single patient who only underwent surgical drainage after four days of IV antibiotics without improvement [37]. However, several other studies show that surgery is not always necessary, though rates vary widely between 14% and 93% [1,14,17,33,38–47,47–50]. This exemplifies the fine balance between the ability in some cases to successfully treat SPA without surgical intervention and the necessity of surgery in other cases to prevent potentially devastating complications. Conservative nonsurgical measures have been attempted with some success in the pediatric population, and are indicated if certain criteria are met [18–20,39,41,50–52].

Most commonly, younger age was found to be associated with greater success with conservative management, and/or less complications from surgery [17,20,33,36,39,44,48,53–55]. While the exact age cutoff ranges from 2 to 9 years old, 9 years as a cut off was the most commonly studied in the literature and most clinically significant (Table 2) [36,53,54].

Other studies describe additional distinguishing characteristics associated with successful nonsurgical management: normal vision, absence of ophthalmoplegia, minimal or no proptosis, and medial location

Table 2
Summary of age-related criteria for subperiosteal abscess.

Study	Summary of age-related findings
Greenberg & Pollard (1998)	In a review of 25 pediatric patients with subperiosteal abscess, the 13 patients who were treated medically were all ≤ 6 years old and had medial abscesses [39].
Garcia & Harris (2000)	29 of 37 (78%) patients < 9 years old were screened using surgical criteria and managed non-surgically, of which 93.1% were successfully treated. Surgical criteria includes age greater than 9 years old, frontal sinusitis, size, recurrence, suspicion of anaerobic organisms, and optic nerve compromise [53].
Herrmann & Forsen (2004)	Of 74 pediatric patients, children ≥ 7 years old were at higher risk for orbital and intracranial complications compared to < 7 years old (9.3% vs. 0%) [17].
Nageswaran et al. (2006)	Of 41 pediatric patients diagnosed with orbital cellulitis, including subperiosteal abscess, there was no difference in surgical rates found between age groups ≤7 years old vs > 7 years old (p = 0.97) [44].
Eviatar et al. (2008)	Of 4 children under 2 years old with subperiosteal abscess, only one required surgery [20].
Smith et al. (2014)	Of 136 cases of orbital cellulitis, including subperiosteal abscess, patients requiring surgery were more likely to be over 9 years old (58.9% vs. 20.0%, P < 0.01) [54].
Marchiano et al. (2015)	In a large retrospective review of 14,149 cases of orbital cellulitis, including subperiosteal abscess, 22.1% of patients 10–19 years old underwent surgery, compared to 12.1% of 5–9 year olds and 5.1% of < 5 year olds (p < 0.001) [36].

Table 3
Summary of characteristics guiding management of subperiosteal abscess.

Study	Summary of findings
Garcia and Harris (2000)	Favor medical therapy if patients had no visual compromise, had a medial abscess of modest size, and had no intracranial or frontal sinus involvement [53].
Rahbar et al. (2001)	Recommended immediate surgical drainage when there is impairment of vision, worsening orbital examination (periorbital erythema or edema, proptosis, and restriction of gaze), signs of systemic manifestation or complication, inability to perform a reliable and serial ophthalmologic examination, an immunocompromised patient, or a lack of response to an initial trial of appropriate IV antibiotics [46].
Starkey and Steele (2001)	Favor medical therapy unless patient has progressive involvement of the optic nerve occurring after 24–36h of IV antibiotic therapy [52].
Younis et al. (2002)	Surgical drainage is indicated in patients who have CT evidence of abscess formation, 20/60 (or worse) visual acuity on initial evaluation, severe orbital complications on initial evaluation, progression of orbital signs and symptoms despite therapy, or lack of improvement within 48 h despite medical therapy [11].
Brown et al. (2004)	Medical management trial for 48h is warranted in pediatric patients with medial SPAs, minimal orbital signs, not immunocompromised, and lack of history/prior treatment of SPA [56].
Oxford and Maclay (2006)	Favor medical therapy in patients with normal vision, absence of opthalmoplegia, normal intraocular pressure (< 20 mmHg), proptosis less than < 5 mm, and abscess width less than 4 mm on CT [45].
Yang et al. (2009)	Favor surgery in patients with pansinusitis, large abscess, concurrent intracranial involvement and poor response to initial IV antibiotics [57].
Ryan (2009)	Patients with larger abscess size (> 10 mm) were more likely to undergo surgery. Neither abscess location nor number of extrocular muscles involved on CT scan was associated with increased likelihood of surgery [48].
Smith et al. (2014)	Children younger than 9 without proptosis, EOM restriction, or elevated IOP have a 7% probability of requiring surgery, whereas a child older than 9 with all of the above risk factors has a 96% probability of requiring surgery [54].
Taubenslag et al. (2016)	Limiting review to children less than 9 years old and frontal sinusitis, favor medical management if abscess was medial [55].
Wan et al. (2016)	Recommended ESS to be performed in all patients with SPA. Though, decreased motility or decreased vision prompted surgery within 24 h [29].
Quintanilla-Dieck et al. (2017)	Limiting review to children with superior or medial SPAs, abscess size was the main predictor for surgery in a multivariate logistic model analysis. Though, patients with superior SPAs were more likely to go to surgery than patients with medial SPAs [47].
Nation et al. (2017)	In a review of patients with SPAs treated medically vs surgically, there was significant differences in abscess width, abscess volume, and presence of gaze restriction. In a subgroup analysis of patients with abscesses ≥ 500 mm^3, 42% were managed non-surgically, which was associated with longer inpatient admissions, antibiotic therapy durations, and PICC placement [50].

of the abscess, were the most commonly cited. Quintaneilla-Dieck et al. found that compared to 12 of 13 patients with superior abscesses requiring surgery, only 13 of 27 patients with medial abscesses required surgery [47]. Furthermore, severe proptosis, worsening visual acuity or motility, worsening orbital clinical findings, elevated intraocular pressure, signs of systemic manifestation or concurrent intracranial involvement, inability to perform a reliable and serial ophthalmologic examination, and poor response to an initial 24–48 h trial of appropriate IV antibiotics were all common indications for surgery (summary found in Table 3) [11,29,39,45–47,50,52–57].

Other reports suggest the decision for intervention be based on the sinus(es) involved. Taubenslag et al. found that 14 of 15 children < 9 years old with frontal sinusitis and medial SPAs were successfully managed medically [55]. However, Marchiano et al., and Garcia & Harris found that frontal sinus involvement correlated with prompt surgical treatment [36,53]. Todman & Enzer found that frontal sinusitis correlated with surgical intervention in cases of abscesses ≥ 1250 mm^3 [58]. Thus, in any patient with frontal sinusitis, strong consideration should be made for surgery. While older patients tend to have smaller sinus ostia and more developed frontal sinuses, older age and frontal sinus involvement are independent risk factors for needing surgery and thus both included in the algorithm [59].

3.4.1. Further management by imaging

In addition to clinical findings, subperiosteal abscess dimensions and volume on CT imaging have emerged as one of the key prognostic features in predicting whether patients will require surgical intervention.

Cut-off SPA volume sizes of 500-1250 mm^3, a length greater than 10–17 mm, and a width greater than 4.5 mm have been previously cited [45–48,58,60,61]. In a recent analysis, Nation et al. found that 43% (11 of 26) pediatric patients with abscesses ≥ 500 mm^3 were still able to be managed medically, with the remainder going to surgery only in the event of clinical deterioration, no clinical improvement after 48 h of antibiotics, or radiographic findings indicative of worsening abscess [50]. Le et al. found that patients with larger SPAs could be successfully treated with systemic antibiotics alone, choosing the abscess cut-off size of 3.8 mL. Specifically, if the SPA volume is < 3.8 mL, then the probability of surgery is 12%; if the SPA volume is > 3.8 mL, then the probability of surgery is 71% [34]. We include this larger, less conservative, cut off within our algorithm, and use additional patient characteristics such as age, clinical findings, and location to help tailor management further.

3.5. Intraconal or orbital abscess

Cases of intraconal or orbital abscess are relatively rare, with only a few case reports and series in the literature, and even fewer studies that describe pediatric patients specifically. Eight retrospective studies and case reports describe 19 pediatric patients with orbital abscesses, and all reported surgical drainage [1,43,51,62,63,63–66]. There are no reports in the pediatric literature of medical management.

3.6. Cavernous sinus thrombosis

An aggressive approach is typically warranted with involvement of the cavernous sinus. The risks of catastrophic complications are much higher, as cavernous sinus thrombosis can cause cranial nerve dysfunction to those that traverse the sinus (III, IV, V_1, V_2, VI), and when severe, internal carotid artery thrombosis with cerebral infarct [18].

Surgical intervention for cavernous sinus thrombosis is generally thought to be mandatory, and is almost always treated via endoscopic drainage of the involved sinuses and collections [67]. However, there are only ten pediatric cases of sinusitis associated cavernous sinus thrombosis described in the literature. Frank et al. identified nine pediatric cases of cavernous sinus thrombosis, of which four also had associated orbital cellulitis. All cases were confirmed by magnetic resonance imaging, all had sinusitis, and all nine patients underwent sinus surgery [68]. Berdai et al. describes a case report of a pediatric patient with cavernous sinus thrombosis who ultimately died from septic shock despite surgical intervention, antibiotics, and anticoagulation [69]. The roles of steroids and anticoagulation remain controversial and debated in the literature, particularly in the setting of infectious etiologies [67,69,70].

4. Algorithm

We present a comprehensive algorithm taking into account

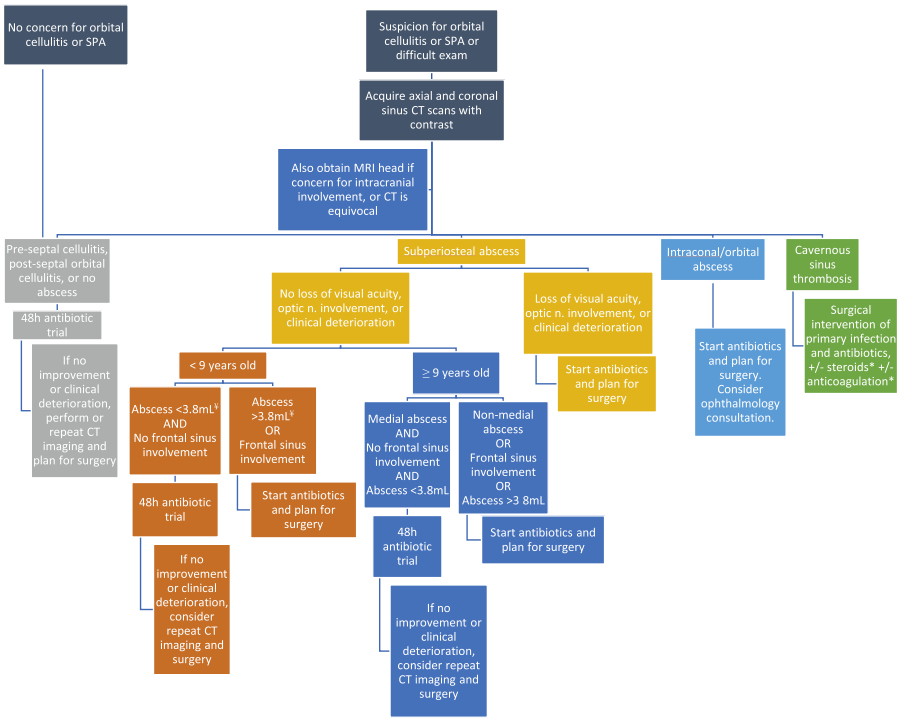

Fig. 2. Management algorithm for each stage of orbital cellulitis.
*use is controversial.
¥ We include this cut off within our algorithm, and use additional patient characteristics such as age, clinical findings, and location to help tailor management further. Cut-off SPA volume size of 1250 mm^3, a length greater than 10–17 mm, and a width greater than 4.5 mm have been previously cited in the literature.

proposed criteria for surgical intervention in the recent literature for the management of pediatric orbital cellulitis based on our literature review (Fig. 2). Several articles also suggest criteria for type of surgery, though this often depended on surgeon experience and/or location of the abscess and is beyond the scope of this review [46,61,71]. Furthermore, bacteriology and specific antibiotic choice is also beyond the scope of this review and can be influenced by local susceptibility patterns, hospital practice, and physician preferences.

5. Discussion

This work includes the most comprehensive and updated review of the literature to date. Due to the retrospective and varied nature of the available studies, there are some inherent weaknesses of this work and the results must be interpreted with caution. If a study's methodology for identifying patients relied on diagnosis code alone, it is possible that patients identified as having post-septal cellulitis did not have a pure cellulitis, but also had an associated subperiosteal abscess (See Section 3.3). This would likely overestimate the reported surgical rates for patients with pure post-septal cellulitis without abscess. Overall however, there seems to be general consensus that pre-septal and post-septal orbital cellulitis in children may be first managed conservatively with antibiotics. We recommend a trial of empiric antibiotic therapy in cases of post-septal orbital cellulitis. However, there should be close monitoring for progression with a low threshold for surgical intervention as the few who do not response to empiric therapy can progress rapidly over 36–48 h, including development of subperiosteal abscess [72,73]. Typically, if there is no improvement by 48 h, or there is a clinical decline before then, surgical intervention is recommended. Repeat imaging prior to surgical intervention should be considered for diagnostic and surgical planning purposes.

With regards to subperiosteal abscesses in children, the literature suggests that this is not an absolute indication for immediate surgical intervention. Based on our review of studies specifically identifying pediatric patients in their outcomes, conservative measures can be safe and effective if appropriately used, depending on patient characteristics, exam findings, clinical course, and imaging. However, several studies did not comment on the nature of the surgical intervention when it was performed (for example, whether a simple infundibulotomy was performed or full endoscopic sinus surgery). This has obvious ramifications for discussion of risks of the surgery. Nevertheless, our proposed algorithm offers characteristics that could predict the viability of a conservative or non-surgical approach as well as signs that could indicate clinical deterioration.

This review also highlights the dearth of studies evaluating the ideal management of intraconal/orbital abscesses or infectious cavernous sinus thrombosis in the pediatric population. However, based on the few available case reports and series in the literature, surgical management seems to be the most appropriate at this time.

Based on these findings, we propose a new comprehensive algorithm for guiding decision making in treating these patients.

6. Conclusions

The contribution of this work is to facilitate patient-centered clinical judgment about the appropriateness of medical vs surgical management of pediatric orbital cellulitis, as well as to provide a reference and stimulus for future studies. In the future, the publication of prospective studies quantifying infectious etiologies, specific antibiotic usage, and surgical techniques would provide a better understanding of these subtleties, which were not included in this review.

Orbital cellulitis, particularly subperiosteal abscesses, in children is not an absolute indication for immediate surgical intervention as classically thought. Conservative nonsurgical measures including close monitoring with antibiotics can be safe and effective if appropriately used, depending on patient characteristics, exam findings, clinical course, and imaging.

Declarations of interest

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References

[1] D.N.P. Suhaili, B.S. Goh, B.S. Gendeh, A ten year retrospective review of orbital complications secondary to acute sinusitis in children, Med. J. Malaysia 65 (1) (2010) 49–52.

[2] S. Lee, M.T. Yen, Management of preseptal and orbital cellulitis, Saudi J. Ophthalmol. 25 (1) (2011) 21–29, http://dx.doi.org/10.1016/j.sjopt.2010.10.004.

[3] J.R. Chandler, D.J. Langenbrunner, E.R. Stevens, The pathogenesis of orbital complications in acute sinusitis, Laryngoscope 80 (9) (1970) 1414–1428, http://dx.doi.org/10.1288/00005537-197009000-00007.

[4] J.R. Moloney, N.J. Badham, A. McRae, The acute orbit. Preseptal (periorbital) cellulitis, subperiosteal abscess and orbital cellulitis due to sinusitis, J. Laryngol. Otol. Suppl. 12 (1987) 1–18.

[5] M.S. Atfeh, H.S. Khalil, Orbital infections: five-year case series, literature review and guideline development, J. Laryngol. Otol. 129 (07) (2015) 670–676, http://dx.doi.org/10.1017/S0022215115001371.

[6] R.A. Crosbie, J. Nairn, H. Kubba, Management of paediatric periorbital cellulitis: our experience of 243 children managed according to a standardised protocol 2012–2015, Int. J. Pediatr. Otorhinolaryngol. 87 (2016) 134–138, http://dx.doi.org/10.1016/j.ijporl.2016.06.025.

[7] L.B. Givner, Periorbital versus orbital cellulitis, Pediatr. Infect. Dis. J. 21 (12) (2002) 1157–1158, http://dx.doi.org/10.1097/01.inf.0000041790.79459.80.

[8] Schwartz G. Etiology, Diagnosis, and treatment of orbital infections, Curr. Infect. Dis. Rep. 4 (3) (2002) 201–205.

[9] H.S. Eustis, M.F. Mafee, C. Walton, J. Mondonca, MR imaging and CT of orbital infections and complications in acute rhinosinusitis, Radiol. Clin. North Am. 36 (6) (1998) 1165–1183, http://dx.doi.org/10.1016/S0033-8389(05)70238-4.

[10] A.V. Mathew, E. Craig, R. Al-Mahmoud, et al., Paediatric post-septal and pre-septal cellulitis: 10 years' experience at a tertiary-level children's hospital, Br. J. Radiol. 87 (1033) (2014) 20130503, http://dx.doi.org/10.1259/bjr.20130503.

[11] R.T. Younis, R.H. Lazar, A. Bustillo, V.K. Anand, Orbital infection as a complication of sinusitis: are diagnostic and treatment trends changing? ENT Ear Nose Throat J. 81 (11) (2002) 771.

[12] F. Teinzer, H. Stammberger, P.V. Tomazic, Transnasal endoscopic treatment of orbital complications of acute sinusitis the graz concept, Ann. Otol. Rhinol. Laryngol. 124 (5) (2015) 368–373, http://dx.doi.org/10.1177/0003489414558110.

[13] K.D. Pereira, R.B. Mitchell, R.T. Younis, R.H. Lazar, Management of medial subperiosteal abscess of the orbit in children—a 5 year experience, Int. J. Pediatr. Otorhinolaryngol. 38 (3) (1997) 247–254, http://dx.doi.org/10.1016/S0165-5876(96)01445-0.

[14] V. Siedek, A. Kremer, C.S. Betz, U. Tschiesner, A. Berghaus, A. Leunig, Management of orbital complications due to rhinosinusitis, Eur. Arch Oto-Rhino-Laryngol Off. J. Eur Fed Oto-Rhino-Laryngol Soc. EUFOS Affil Ger Soc Oto-Rhino-Laryngol - Head Neck Surg. 267 (12) (2010) 1881–1886, http://dx.doi.org/10.1007/s00405-010-1266-3.

[15] T.F. Rudloe, M.B. Harper, S.P. Prabhu, R. Rahbar, D. Vanderveen, A.A. Kimia, Acute periorbital infections: who needs emergent imaging? Pediatrics 125 (4) (2010) e719–726, http://dx.doi.org/10.1542/peds.2009-1709.

[16] R. Kapur, A.R. Sepahdari, M.F. Mafee, et al., MR imaging of orbital inflammatory syndrome, orbital cellulitis, and orbital lymphoid lesions: the role of diffusion-weighted imaging, AJNR Am. J. Neuroradiol. 30 (1) (2009) 64–70, http://dx.doi.org/10.3174/ajnr.A1315.

[17] B.W. Herrmann, J.W. Forsen, Simultaneous intracranial and orbital complications of acute rhinosinusitis in children, Int. J. Pediatr. Otorhinolaryngol. 68 (5) (2004) 619–625, http://dx.doi.org/10.1016/j.ijporl.2003.12.010.

[18] A.M. Botting, D. McIntosh, M. Mahadevan, Paediatric pre- and post-septal periorbital infections are different diseases, Int. J. Pediatr. Otorhinolaryngol. 72 (3) (2008) 377–383, http://dx.doi.org/10.1016/j.ijporl.2007.11.013.

[19] M.V. Al-Madani, A.E. Khatatbeh, R.Z. Rawashdeh, N.F. Al-Khtoum, N.R. Shawagfeh, The prevalence of orbital complications among children and adults with acute rhinosinusitis, Braz. J. Otorhinolaryngol. 79 (6) (2013) 716–719, http://dx.doi.org/10.5935/1808-8694.20130131.

[20] E. Eviatar, H. Gavriel, K. Pitaro, M. Vaiman, M. Goldman, A. Kessler, Conservative treatment in rhinosinusitis orbital complications in children aged 2 years and younger, Rhinology 46 (4) (2008) 334–337.

[21] T. Beech, A. Robinson, A.-L. McDermott, A. Sinha, Paediatric periorbital cellulitis and its management, Rhinology 45 (1) (2007) 47–49.

[22] S.P. Moubayed, T.-T.V. Vu, C. Quach, S.J. Daniel, Periorbital cellulitis in the pediatric population: clinical features and management of 117 cases, J. Otolaryngol - Head Neck Surg. J. Oto-Rhino-Laryngol Chir Cervico-Faciale 40 (3) (2011) 266–270.

[23] S.E. Sobol, J. Marchand, T.L. Tewfik, J.J. Manoukian, M.D. Schloss, Orbital complications of sinusitis in children, J. Otolaryngol. 31 (3) (2002) 131–136.

[24] V. Kinis, M. Ozbay, S. Bakir, et al., Management of orbital complications of sinusitis in pediatric patients, J. Craniofac. Surg. 24 (5) (2013) 1706–1710, http://dx.doi.org/10.1097/SCS.0b013e3182a210c6.

[25] R.E. Brugha, E. Abrahamson, Ambulatory intravenous antibiotic therapy for children with preseptal cellulitis, Pediatr. Emerg. Care 28 (3) (2012) 226–228, http://dx.doi.org/10.1097/PEC.0b013e318248b19b.

[26] H.-J. Welkoborsky, S. Graß, C. Deichmüller, O. Bertram, M.L. Hinni, Orbital complications in children: differential diagnosis of a challenging disease, Eur. Arch. Oto-Rhino-Laryngol. 272 (5) (2015) 1157–1163, http://dx.doi.org/10.1007/s00405-014-3195-z.

[27] O. Sijuwola, A. Adeyemo, A. Adeosun, Orbital complications of rhinosinusitis, Ann. Ib. Postgrad. Med. 5 (1) (2007) 6–8.

[28] R. Gonçalves, C. Menezes, R. Machado, I. Ribeiro, J.A. Lemos, Periorbital cellulitis in children: analysis of outcome of intravenous antibiotic therapy, Orbit Amst. Neth. 35 (4) (2016) 175–180, http://dx.doi.org/10.1080/01676830.2016.1176205.

[29] Y. Wan, G. Shi, H. Wang, Treatment of orbital complications following acute rhinosinusitis in children, Balk Med. J. 33 (4) (2016) 401–406, http://dx.doi.org/10.5152/balkanmedj.2016.141065.

[30] V. Sciarretta, M. Demattè, P. Farneti, et al., Management of orbital cellulitis and subperiosteal orbital abscess in pediatric patients: a ten-year review, Int. J. Pediatr. Otorhinolaryngol. 96 (2017) 72–76, http://dx.doi.org/10.1016/j.ijporl.2017.02.031.

[31] C.E. Foster, E. Yarotsky, E.O. Mason, S.L. Kaplan, K.G. Hulten, Molecular characterization of Staphylococcus aureus isolates from children with periorbital or orbital cellulitis, J. Pediatr. Infect Dis. Soc. (June 2017), http://dx.doi.org/10.1093/jpids/pix036.

[32] N. Friedel, D. Scolnik, A. Rimon, R. Orbach, S. Laat, M.M. Glatstein, Are we overtreating insect bite related periorbital cellulitis in Children? The experience of a large, tertiary care pediatric hospital, Am. J. Ther. (2017), http://dx.doi.org/10.1097/MJT.0000000000000596 Publish Ahead of Print.

[33] S. Fanella, A. Singer, J. Embree, Presentation and management of pediatric orbital cellulitis, Can J. Infect Dis Med Microbiol J. Can Mal Infect Microbiol Médicale AMMI Can 22 (3) (2011) 97–100.

[34] T.D. Le, E.S. Liu, F.A. Adatia, J.R. Buncic, S. Blaser, The effect of adding orbital computed tomography findings to the Chandler criteria for classifying pediatric orbital cellulitis in predicting which patients will require surgical intervention, J. AAPOS Off. Publ. Am. Assoc. Pediatr Ophthalmol Strabismus Am. Assoc. Pediatr. Ophthalmol. Strabismus 18 (3) (2014) 271–277, http://dx.doi.org/10.1016/j.jaapos.2014.01.015.

[35] A. Mahalingam-Dhingra, L. Lander, D.A. Preciado, J. Taylormoore, R.K. Shah, Orbital and periorbital infections: a national perspective, Arch Otolaryngol. Neck Surg. 137 (8) (2011) 769–773, http://dx.doi.org/10.1001/archoto.2011.118.

[36] E. Marchiano, M.D. Raikundalia, E.T. Carniol, et al., Characteristics of patients treated for orbital cellulitis: an analysis of inpatient data, Laryngoscope (August 2015), http://dx.doi.org/10.1002/lary.25529.

[37] K. Suga, Y. Fujii, T. Iwata, S. Hashimoto, H. Yokoi, A case of rhinogenic orbital subperiosteal abscess in a child, Pract. Oto-Rhino-Laryngol. Suppl. 148 (2017) 42–43, http://dx.doi.org/10.5631/jibirinsuppl.148.42.

[38] J.R. Bedwell, S.S. Choi, Medical versus surgical management of pediatric orbital subperiosteal abscesses, Laryngoscope 123 (10) (2013) 2337–2338, http://dx.doi.org/10.1002/lary.24014.

[39] M.F. Greenberg, Z.F. Pollard, Medical treatment of pediatric subperiosteal orbital abscess secondary to sinusitis, J. AAPOS Off. Publ. Am. Assoc. Pediatr. Ophthalmol. Strabismus Am. Assoc Pediatr Ophthalmol Strabismus 2 (6) (1998) 351–355.

[40] S. Gupta, R. Goyal, R.K. Gupta, Clinical presentation and outcome of the orbital complications due to acute infective rhino sinusitis, Indian J. Otolaryngol Head Neck Surg. Off. Publ Assoc. Otolaryngol India 65 (Suppl 2) (2013) 431–434, http://dx.doi.org/10.1007/s12070-013-0646-6.

[41] A. Kessler, L.P. Berenholz, S. Segal, Transnasal endoscopic drainage of a medial subperiosteal orbital abscess, Eur Arch Oto-Rhino-Laryngol Off. J. Eur Fed Oto-Rhino-Laryngol Soc EUFOS Affil Ger Soc Oto-Rhino-Laryngol - Head Neck Surg. 255 (6) (1998) 293–295.

[42] M. Ferguson, A. McNab, Current treatment and outcome in orbital cellulitis, Aust. N. Z. J. Ophthalmol. 27 (6) (1999) 375–379, http://dx.doi.org/10.1046/j.1440-1606.1999.00242.x.

[43] C. Murphy, I. Livingstone, B. Foot, H. Murgatroyd, C.J. MacEwen, Orbital cellulitis in Scotland: current incidence, aetiology, management and outcomes, Br. J. Ophthalmol. 98 (11) (2014) 1575–1578, http://dx.doi.org/10.1136/bjophthalmol-2014-305222.

[44] S. Nageswaran, C.R. Woods, D.K. Benjamin, L.B. Givner, A.K. Shetty, Orbital cellulitis in children, Pediatr. Infect. Dis. J. 25 (8) (2006) 695–699, http://dx.doi.org/10.1097/01.inf.0000227820.36036.f1.

[45] L.E. Oxford, J. McClay, Medical and surgical management of subperiosteal orbital abscess secondary to acute sinusitis in children, Int. J. Pediatr. Otorhinolaryngol. 70 (11) (2006) 1853–1861, http://dx.doi.org/10.1016/j.ijporl.2006.05.012.

[46] R. Rahbar, C.D. Robson, R.A. Petersen, et al., Management of orbital subperiosteal abscess in children, Arch Otolaryngol Neck Surg. 127 (3) (2001) 281–286, http://dx.doi.org/10.1001/archotol.127.3.281.

[47] L. Quintanilla-Dieck, S. Chinnadurai, S.L. Goudy, F.W. Virgin, Characteristics of superior orbital subperiosteal abscesses in children, Laryngoscope 127 (3) (2017) 735–740, http://dx.doi.org/10.1002/lary.26082.

[48] J.T. Ryan, D.A. Preciado, N. Bauman, et al., Management of pediatric orbital cellulitis in patients with radiographic findings of subperiosteal abscess, Otolaryngol–Head Neck Surg. Off. J. Am. Acad Otolaryngol-Head Neck Surg. 140 (6) (2009) 907–911, http://dx.doi.org/10.1016/j.otohns.2009.02.014.

[49] C. Doyon, É. Goodyear, Case report of the family transmission of Streptococcus pyogenes orbital cellulitis, Am. J. Ophthalmol. Case Rep. 6 (2017) 52–54, http://dx.doi.org/10.1016/j.ajoc.2017.02.002.

[50] J. Nation, A. Lopez, N. Grover, D. Carvalho, D. Vinocur, W. Jiang, Management of large-volume subperiosteal abscesses of the orbit: medical vs surgical outcomes, Otolaryngol–Head Neck Surg Off. J. Am. Acad Otolaryngol-Head Neck Surg. 157 (5) (2017) 891–897, http://dx.doi.org/10.1177/0194599817728490.

[51] C.-F. Ho, Y.-C. Huang, C.-J. Wang, C.-H. Chiu, T.-Y. Lin, Clinical analysis of computed tomography-staged orbital cellulitis in children, J. Microbiol. Immunol. Infect Wei Mian Yu Gan Ran Za Zhi 40 (6) (2007) 518–524.

[52] C.R. Starkey, R.W. Steele, Medical management of orbital cellulitis, Pediatr. Infect.

Dis. J. 20 (10) (2001) 1002–1005.
[53] G.H. Garcia, G.J. Harris, Criteria for nonsurgical management of subperiosteal abscess of the orbit22: analysis of outcomes 1988–1998, Ophthalmology 107 (8) (2000) 1454–1456, http://dx.doi.org/10.1016/S0161-6420(00)00242-6.
[54] J.M. Smith, E.M. Bratton, P. DeWitt, B.W. Davies, E.M. Hink, V.D. Durairaj, Predicting the need for surgical intervention in pediatric orbital cellulitis, Am. J. Ophthalmol. (May 2014), http://dx.doi.org/10.1016/j.ajo.2014.04.022.
[55] K.J. Taubenslag, J.G. Chelnis, L.A. Mawn, Management of frontal sinusitis-associated subperiosteal abscess in children less than 9 years of age, J. AAPOS Off. Publ. Am. Assoc. Pediatr. Ophthalmol. Strabismus 20 (6) (2016) 527–531, http://dx.doi.org/10.1016/j.jaapos.2016.08.007 e1.
[56] C.L. Brown, S.M. Graham, M.C. Griffin, et al., Pediatric medial subperiosteal orbital abscess: medical management where possible, Am. J. Rhinol. 18 (5) (2004) 321–327.
[57] M. Yang, B.L. Quah, L.L. Seah, A. Looi, Orbital cellulitis in children-medical treatment versus surgical management, Orbit Amst. Neth. 28 (2–3) (2009) 124–136.
[58] M.S. Todman, Y.R. Enzer, Medical management versus surgical intervention of pediatric orbital cellulitis: the importance of subperiosteal abscess volume as a new criterion, Ophthal Plast Reconstr. Surg. 27 (4) (2011) 255–259, http://dx.doi.org/10.1097/IOP.0b013e3182082b17.
[59] G.J. Harris, Subperiosteal abscess of the orbit. Age as a factor in the bacteriology and response to treatment, Ophthalmology 101 (3) (1994) 585–595.
[60] H. Gavriel, E. Yeheskeli, E. Aviram, L. Yehoshua, E. Eviatar, Dimension of subperiosteal orbital abscess as an indication for surgical management in children, Otolaryngol–Head Neck Surg Off. J. Am. Acad. Otolaryngol-Head Neck Surg. 145 (5) (2011) 823–827, http://dx.doi.org/10.1177/0194599811416559.
[61] F. Tabarino, M. Elmaleh-Bergès, S. Quesnel, M. Lorrot, T. Van Den Abbeele, N. Teissier, Subperiosteal orbital abscess: volumetric criteria for surgical drainage, Int. J. Pediatr. Otorhinolaryngol. 79 (2) (2015) 131–135, http://dx.doi.org/10.1016/j.ijporl.2014.11.021.
[62] W.M.D. Melo, C.K. Sonoda, E. Hochuli-Vieira, M.A.C. Gabrielli, M.F.R. Gabrielli, Paranasal sinus infection causing orbital subperiosteal abscess: surgical management of this devastating entity, Oral Maxillofac. Surg. 17 (2) (2013) 131–135, http://dx.doi.org/10.1007/s10006-012-0343-8.
[63] B. Yazici, N. Orucov, G. Ibrahimzade, Neonatal orbital abscess secondary to Pseudomonas Aeruginosa conjunctivitis, Ophthal Plast Reconstr Surg. (July 2016), http://dx.doi.org/10.1097/IOP.0000000000000754.
[64] T. Chai-Lee, S. Nadarajah, B. Abdullah, et al., Image-guided system endoscopic drainage of orbital abscess caused by methicillin-resistant Staphylococcus aureus in an infant, Int. J. Surg. Case Rep. 33 (2017) 119–123, http://dx.doi.org/10.1016/j.ijscr.2017.02.051.
[65] A. Couturier, C. Chidiac, E. Truy, T. Ferry, Ethmoiditis with subperiosteal and retro-ocular abscesses due to Aeromonas sobria in a 16-year-old boy exposed to the Ardèche river, BMJ Case Rep. 2017 (2017), http://dx.doi.org/10.1136/bcr-2017-219505 bcr2017219505.
[66] R. Verma, B.W. Lee, R.M. Alameddine, et al., Orbital perivenous abscess complicating the diagnosis and management of orbital cellulitis, Ophthal Plast Reconstr Surg. (May 2017), http://dx.doi.org/10.1097/IOP.0000000000000920.
[67] J.R. Ebright, M.T. Pace, A.F. Niazi, Septic thrombosis of the cavernous sinuses, Arch. Intern. Med. 161 (22) (2001) 2671–2676, http://dx.doi.org/10.1001/archinte.161.22.2671.
[68] G.S. Frank, J.M. Smith, B.W. Davies, D.M. Mirsky, E.M. Hink, V.D. Durairaj, Ophthalmic manifestations and outcomes after cavernous sinus thrombosis in children, J. AAPOS Off. Publ. Am. Assoc. Pediatr. Ophthalmol. Strabismus Am. Assoc. Pediatr. Ophthalmol. Strabismus 19 (4) (2015) 358–362, http://dx.doi.org/10.1016/j.jaapos.2015.06.001.
[69] A.M. Berdai, A. Shimi, M. Khatouf, Cavernous sinus thrombophlebitis complicating sinusitis, Am. J. Case Rep. 14 (2013) 99–102, http://dx.doi.org/10.12659/AJCR.883875.
[70] C.A. Press, A. Lindsay, N.V. Stence, L.Z. Fenton, T.J. Bernard, D.M. Mirsky, Cavernous sinus thrombosis in children imaging characteristics and clinical outcomes, Stroke 46 (9) (2015) 2657–2660, http://dx.doi.org/10.1161/STROKEAHA.115.009437.
[71] F. Rubin, S. Pierrot, M. Lebreton, P. Contencin, V. Couloigner, Drainage of subperiosteal orbital abscesses complicating pediatric ethmoiditis: comparison between external and transnasal approaches, Int. J. Pediatr. Otorhinolaryngol. 77 (5) (2013) 796–802, http://dx.doi.org/10.1016/j.ijporl.2013.02.014.
[72] C. Raj, T. Lim-Joon, A complicated case of orbital cellulitis: when the fog doesn't clear, J. Paediatr. Child Health 51 (5) (2015) 552–554, http://dx.doi.org/10.1111/jpc.12792.
[73] C.F. Sinclair, R.G. Berkowitz, Prior antibiotic therapy for acute sinusitis in children and the development of subperiosteal orbital abscess, Int. J. Pediatr. Otorhinolaryngol. 71 (7) (2007) 1003–1006, http://dx.doi.org/10.1016/j.ijporl.2007.02.013.