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Concurrent management of suppurative intracranial complications of sinusitis and acute otitis media in children

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ABSTRACT

Objective: Intracranial complications of sinusitis and acute otitis media (AOM) are rare but life-threatening events. In children with suppurative intracranial complications, concurrent neurosurgical and otolaryngological (ORL) intervention has been recommended to optimize outcomes. The aim of this study was to investigate outcomes following concurrent neurosurgical and ORL intervention.

Methods: A retrospective cohort study of children undergoing neurosurgical intervention for intracranial complications of sinusitis or AOM in two neurosurgical centres in Ireland was conducted.

Results: 65 children were identified. Mean age was 11.9 years. The most prevalent symptoms were headache, pyrexia, altered level of consciousness, facial swelling, and vomiting. Subdural empyema (n = 24, 36.9%) and extradural abscess (n = 17, 26.2%) were the most common complications. 54 underwent same admission ORL intervention; 47 (87%) were performed concurrently or earlier. For rhinogenic infections, 35 (64.8%) underwent endoscopic sinus surgery (ESS), 13 (24.1%) underwent frontal sinus trephine, and 5 (9.3%) underwent maxillary sinus washout alone. For otogenic infections, 10 (90.9%) underwent mastoidectomy and 7 (63.6%) underwent tympanostomy tube placement. 19 (29.2%) had post-operative neurological deficits, of which 2 (3.1%) were permanent. Streptococcus intermedius was the most common pathogen (n = 30, 46.2%). Concurrent intervention reduced the prevalence of residual collection (p = 0.018) and the need for revision neurosurgical intervention (p = 0.039) for sinogenic complications. The same trends did not achieve statistical significance for the otogenic group. Mortality was 0%.

Conclusion: Intracranial complications of sinusitis and AOM are best managed in a specialist centre with multidisciplinary input. Concurrent ORL and neurosurgical intervention reduces abscess recurrence and requirement for revision neurosurgery in sinogenic complications and should represent the standard of care. ESS is the ORL modality of choice in experienced hands.

1. Introduction

Complications of acute bacterial rhinosinusitis (ABRS) have an incidence of approximately 3 per million population per year [1]. The most prevalent of these are orbital, intracranial, and osseous complications. Acute otitis media (AOM), which also represents a source for intracranial suppuration, is most commonly complicated by mastoiditis, the prevalence of which has declined markedly in the antibiotic era from an estimated historical high of 20% prior to the 1950's to approximately 0.24% in contemporary practice [2]. The common links between ABRS and AOM are the aetiopathogenesis of suppurative complications, specifically due to impaired drainage either of the paranasal sinuses or the mastoid air cells, and their potential to result in intracranial sequalae such as subdural empyema, extradural abscess, or cerebral abscess. The prevalence of suppurative intracranial complications, particularly otogenic, has declined markedly with widespread use of antibiotics in the late 20th century [3], but they remain potentially devastating events with significant associated neurological morbidity and mortality [4–6].

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In children with intracranial complications of ABRS or AOM, the principles of management first rely on neurosurgical drainage of localised collections and parenteral antibiotics which should ideally be carried out in a specialist tertiary institution with the required multidisciplinary expertise [7]. Primary source control by the otolaryngologist, either in the form of endoscopic sinus surgery or cortical mastoidectomy, is often utilised as adjuvant management to reduce the risk of abscess recurrence and the need for revision surgery [4,8,9], and was adopted as the optimal course in first-line management for sinogenic brain abscesses in Ireland as far back as 1999 [10].

There have been multiple cohort studies on the topic of combined (performed during the same admission) and concurrent (performed under the same general anaesthetic) neurosurgical and otolaryngological (ORL) intervention in such cases. The largest by Levy et al. identified 572 paediatric patients with intracranial complications of sinusitis, 208 of whom underwent combined surgical management. They concluded that combined intervention did not shorten length of hospital admission relative to neurosurgical management alone [11]. While this finding has been echoed by other recent studies [12–14], there have been several comparable publications which have made the opposing conclusion [15–19]. On both sides of this debate there is inconsistency in the reporting of distinction between concurrent and combined management.

As such, further clarification of any benefit from concurrent intervention for rhinogenic and otogenic intracranial complications is needed.

2. Aim

This study aimed to evaluate if concurrent neurosurgical and ORL intervention improved outcomes for children with suppurative intracranial complications of either ABRS or AOM, as well as to further describe the population of such children who required neurosurgical intervention. Specific objectives included examination of outcome data including recurrence rates, the requirement for revision surgery, prevalence of permanent neurological deficit, length of stay in the intensive care unit (ICU LOS) and length of hospital stay (LOS).

3. Methods

3.1. Study design

A retrospective cohort study was conducted using STROBE standardized reporting guidelines. The study cohort was derived from an existing database of children with suppurative intracranial complications secondary to either rhinosinusitis or otitis media, all of whom required neurosurgical intervention, in two tertiary centres providing acute neurosurgical services in the Republic of Ireland. Data for the study were derived from patients' medical notes and imaging studies. The period of data collection was January 2008 to December 2020, with follow-up complete and correct as of October 2021.

3.2. Inclusion/exclusion criteria

The inclusion criteria were:

1. Age <18 years at time of index presentation.
2. Computed tomography (CT) or magnetic resonance imaging (MRI) proven suppurative intracranial complications including subdural empyema, extradural abscess, or cerebral abscess.
3. Required upfront neurosurgical management in the form of burrhole drainage, craniotomy, or craniectomy <24 h following diagnosis of criterion 2.
4. Either radiological or clinical evidence of rhinosinusitis or AOM as a source for criterion 2.
5. No other likely source of infection to explain criterion 2.
6. Medical records and imaging were available for review.

Exclusion criteria were:

1. Age >18 years at time of index presentation.
2. Intracranial complications of idiopathic aetiology or any cause not rhinogenic or otogenic in nature.
3. Fungal intracranial complications.
4. No requirement for neurosurgical intervention/had trial of conservative management despite confirmed intracranial findings.
5. Prior history of chronic ear disease (i.e., cholesteatoma) in the AOM group.
6. Prior history of chronic rhinosinusitis requiring surgical intervention/review in a rhinology clinic.

3.3. Variables

The outcome variables were mortality, presence of residual/recurrent collection on follow-up imaging studies, requirement for unplanned, collection-directed revision neurosurgical procedures, presence of permanent neurological deficits, ICU LOS, and LOS. The primary exposure variable was concurrent ORL intervention under the same general anaesthetic as the neurosurgical intervention.

The presence of residual/recurrent collection on follow-up imaging variable was captured based on the first follow-up imaging study that was performed.

Children who had undergone ORL intervention directed at the primary source of infection during the same acute episode prior to their neurosurgical intervention (n = 11) were included in the concurrent intervention group. In all cases the delay was due to the intracranial component going initially undetected; it was concluded that as effective source control had already been undertaken in all such cases, they were most appropriately analysed in the test group.

Descriptive variables included gender, age at index presentation, nationality, past medical history, duration and nature of symptoms, Lund-Mackay score [20], type of intracranial complication, source of complication (rhinogenic or otogenic), types of neurosurgical/ORL intervention, presence of additional intracranial/extracranial complications, duration and modality of antimicrobial therapy, microbiological culture results, discharge destination, length of follow-up, and Glasgow come scale (GCS), white cell count (WCC), and C-reactive protein (CRP) on admission. Lund-Mackay scores were only calculated for sinogenic disease.

3.4. Statistical methods

Descriptive statistics for participants' baseline characteristics were generated. The effect of concurrent intervention on outcome variables was analysed with Fischer's exact test and one-way analysis of variance (ANOVA) as appropriate. Fischer's exact test and ANOVA were also applied as appropriate to test for significance of differences in descriptive variables. Statistical analyses were conducted using Stata version 16.1. Statistical significance was assumed at $p < 0.05$.

For statistical purposes, the primary comparison was drawn between those undergoing concurrent versus combined intervention. This was undertaken as this is the most crucial question that this study seeks to address but also removes some of the bias introduced by children whose sinogenic or otogenic disease was mild enough such that ORL intervention was not considered likely to offer any benefit. For comparison a separate analysis of ORL intervention vs no ORL intervention is also shown.

Sinogenic complications have not been subcategorised according to the affected sinus due to the high degree of overlap between these groups – for example, the two most commonly involved sinuses (ethmoid sinuses and frontal sinus) were almost invariably involved together in this cohort, with divergence from this norm noted in only 6

cases.

3.5. Ethical considerations

Clinical audit approval for this study was sought from and approved by the clinical audit departments in Beaumont Hospital and Children's Health Ireland at Temple Street Children's University Hospital (registration number 19.075). The lawful grounds for processing this data falls under the heading of necessity for the performance of a task carried out in the public interest – namely, the clarification of benefits to concurrent intervention as described above. Data may be made available subject to ethical approval and data transfer agreements subject to Irish legislation of European general data protection regulation (GDPR). The authors have no conflicts of interest to declare.

4. Results

65 children were identified. The baseline characteristics of these patients overall and by source of infection are presented in Table 1.

Table 1
Baseline characteristics of children with rhinogenic and otogenic intracranial complications requiring neurosurgical intervention in Ireland, 2008–2020.

Variable		Rhinogenic	Otogenic	Total	p-value
Gender	Male	35 (64.8%)	5 (45.5%)	40 (61.5%)	
	Female	19 (35.2%)	6 (54.5%)	25 (38.5%)	0.311
Age (years)	Mean	11.8	10	11.5	
	Median	12.1	10.2	11.7	
	Range	1.4–16.6	4.1–15.2	1.4–16.6	0.113
Duration symptoms	Median (days)	10	14	10	0.651
Symptoms	Headache	47 (85.5%)	9 (81.8%)	56 (86.2%)	
	Pyrexia	32 (59.3%)	9 (81.8%)	41 (63.1%)	
	Altered LOC	26 (48.2%)	4 (36.4%)	30 (46.2%)	
	Vomiting	21 (38.9%)	8 (72.7%)	29 (44.6%)	
	Facial swelling	22 (40.7%)	2 (18.2%)	24 (36.9%)	
	Seizure	13 (24.1%)	1 (9.1%)	14 (21.5%)	
	Limb weakness	8 (14.8%)	1 (9.1%)	9 (13.9%)	
	Nasal congestion	8 (14.8%)	0 (0%)	8 (12.3%)	
	Photophobia	7 (13%)	3 (27.3%)	10 (15.4%)	
	Facial rash	7 (13%)	0 (0%)	7 (10.8%)	
	Speech disturbance	2 (3.7%)	1 (9.1%)	3 (4.6%)	
	Facial nerve palsy	2 (3.7%)	0 (0%)	2 (3.1%)	
	Neck pain	0 (0%)	7 (63.6%)	7 (10.8%)	
	Ear discharge	0 (0%)	7 (63.6%)	7 (10.8%)	
	Ear pain	0 (0%)	7 (63.6%)	7 (10.8%)	
Past medical history	Atopy	11 (20.4%)	1 (9.1%)	12 (18.5%)	
	Family history atopy	2 (3.7%)	0 (0%)	2 (3.1%)	
	Other	7 (13%)	1 (9.1%)	8 (12.3%)	
Total		54	11	65	

LOC, level of consciousness.

40 (61.5%) were male. More male children had rhinogenic infections (n = 35, 64.8%). There was an even gender distribution in the otogenic infection group – 5 (45.5%) male and 6 (54.5%) female children. The mean age was 11.5 years (median 11.7, range 1 year 4 months–16 years), and was similar in both groups (p = 0.113).

Rhinogenic infections presented with a mean of 14.5 days of symptoms (median 10 days), with the most common scenario being a progressively worsening headache (n = 47, 85.5%), pyrexia (n = 32, 59.3%), altered level of consciousness (n = 26, 48.2%), facial swelling (n = 22, 40.7%) and vomiting (n = 21, 38.9%). A minority presented with persistent pyrexia and various neurological findings as their only findings of note. Otogenic infections had broadly similar presenting symptoms, but also included neck pain, ear pain, and otorrhoea (n = 7, 63.6% for all).

58.5% (n = 38) had no relevant past medical history though in the rhinogenic group a minority had either personal (n = 11, 20.4%) or family (n = 2, 3.7%) history of atopy, most commonly either asthma or chronic rhinosinusitis. An extreme minority had various chronic systemic diseases or syndromes, including type 1 diabetes mellitus, chronic recurring multifocal osteomyelitis, metopic synostosis, type 1 neurofibromatosis, and cri du chat syndrome.

4.1. Radiological and laboratory findings

The results of clinical, radiological, and biochemical assessments of the study cohort are presented in Table 2.

Subdural empyema was the most common complication overall (n = 24, 36.9%), with the rhinogenic group forming 96% of these (n = 23). In this group, extradural abscess and frontal lobe abscess formed 48.2% of the remainder with a small minority consisting of combinations of these 3 pathologies and 2 (3.7%) children with frontal abscesses extending into the parietal lobe. By contrast, subdural empyema (n = 1, 9.1%) and extradural abscess (n = 2, 18.2%) were less prevalent in the otogenic group; cerebellar (n = 5, 45.5%) and temporal lobe abscesses (n = 2, 18.2%) made up the majority of the rest of the cohort. Children with rhinogenic infections were more likely to develop subdural empyema or extradural abscess than children with otogenic infections (p = 0.009), while overall the source of infection was a strong predictor of complication type (p < 0.0001).

66.2% (n = 43) children presented with normal GCS (mean 13.7, median 15), though a minority either were transferred intubated and ventilated due to profound sepsis, presented in status epilepticus, or had mild confusion and lethargy on admission. WCC (mean 15.3, range 5.3–30) & CRP (mean 120.8, range 2–423) varied widely, but were generally markedly raised. 16 (24.6%) presented with normal WCC (<11 × 10^9/L) and 2 (3.1%) presented with normal CRP (<5 mg/L).

The diagnostic imaging modality of choice was CT, providing the diagnosis in 81.5% of cases (n = 53). Of the children who were diagnosed on MRI (n = 12, 18.5%), many had had a non-diagnostic CT while the remainder were due to concerns over radiation exposure. The mean Lund-Mackay score for the rhinogenic group was 9.1 with a range of 0–24. The most commonly affected sinus was the ethmoid sinus (91%) followed by the frontal (83%) and maxillary sinuses (83%). All patients in the rhinogenic group with a Lund-Mackay score of 0 (n = 4) gave a recent history of severe rhinosinusitis for which antibiotics had been prescribed. High Lund-Mackay score was predictive of same admission ORL intervention (p = 0.0005), but no difference was noted as to whether or not this was performed concurrently (p = 0.994). There was no identifiable relationship between Lund-Mackay score and either abscess recurrence (p = 0.156) or revision neurosurgery (p = 0.664). Osteomeatal complex obstruction was present in 29 (53.7%) and was predictive of abscess recurrence (p = 0.037), though not of requirement for revision neurosurgery (p = 0.166). No other subcategory of sinus disease was predictive of outcomes. 10 (90.9%) of children with otogenic infections had identifiable mastoiditis on their index imaging. All

Table 2
Results of clinical, radiological, and biochemical assessment of children with rhinogenic and otogenic intracranial complications requiring neurosurgical intervention in Ireland, 2008–2020.

Variable		Rhinogenic	Otogenic	Total	p-value
Complication type	Subdural empyema	23 (42.6%)	1 (9.1%)	24 (36.9%)	
	Extradural abscess	15 (27.8%)	2 (18.2%)	17 (26.2%)	
	Frontal lobe abscess	11 (20.4%)	0 (0%)	11 (16.9%)	
	Frontoparietal lobe abscess	2 (3.7%)	0 (0%)	2 (3.1%)	
	Subdural & extradural collections	2 (3.7%)	0 (0%)	2 (3.1%)	
	Frontal lobe & subdural collections	1 (1.9%)	0 (0%)	1 (1.5%)	
	Cerebellar abscess	0 (0%)	5 (45.5%)	5 (7.7%)	
	Temporal abscess	0 (0%)	2 (18.2%)	2 (3.1%)	
	Sigmoid sinus abscess	0 (0%)	1 (9.1%)	1 (1.5%)	<0.0001
GCS	Mean	13.6	14	13.7	
	Range	3–15	9–15	3–15	0.707
WCC	Mean	15.5	14.2	15.3	
	Range	5.3–30	9–22.3	5.3–30	0.541
CRP	Mean	120.9	120.7	120.8	
	Range	2–423	3–286	2–423	0.996
Diagnostic imaging modality	CT	43 (79.6%)	10 (90.9%)	53 (81.5%)	
	MRI	11 (20.4%)	1 (9.1%)	12 (18.5%)	0.673
Lund-Mackay Score	Mean	9.1	–	9.1	
	Median	8	–	8	
	Range	0–24	–	0–24	

GCS, Glasgow coma scale; WCC, white cell count; CRP, C-reactive protein; CT, computed tomography.

patients had at least one follow-up imaging study which occurred less than 1 week post operatively in 86.2% of cases and after a median of 2 days.

Typical microorganisms cultured from samples taken intra-operatively varied between both groups. For rhinogenic infections, streptococcus intermedius was the causative organism in 50% (n = 27); other identified organisms included streptococcus constellatus (n = 3, 5.6%), streptococcus anginosus (n = 2, 3.7%), and streptococcus pyogenes (n = 2, 3.7%). For otogenic infections streptococcus pneumoniae and intermedius were equally prevalent (n = 3, 27.3%).

4.2. Outcomes

4.2.1. Rhinogenic complications

The management and outcomes of children with rhinogenic infections are presented in Table 3.

54 children with rhinogenic infections were identified. All required neurosurgical intervention in the form of burrhole evacuation (n = 14, 25.9%), craniotomy (n = 32, 59.3%), or craniectomy (n = 8, 14.8%). Where the frontal sinus was the primary focus of disease, cranialisation of the frontal sinus was undertaken as a matter of routine. The timing of ORL surgery had no impact on the choice of neurosurgical approach (p = 0.556). Endoscopic sinus surgery (ESS) was the most commonly used

Table 3
Management and outcomes of children with rhinogenic intracranial complications requiring neurosurgical intervention in Ireland, 2008–2020.

Variable		ORL same admission	ORL concurrent	Total	p-value combined vs no ORL	p-value concurrent vs combined
NSx intervention	Burrhole	10 (22.7%)	8 (21%)	14 (25.9%)		
	Craniotomy	28 (63.6%)	25 (65.8%)	32 (59.3%)		
	Craniectomy	6 (13.6%)	5 (13.2%)	8 (14.8%)	0.339	0.556
ORL intervention	ESS	35 (79.5%)	29 (76.3%)			
	Frontal sinus trephine	13 (29.5%)	10 (26.3%)			
	Washout only	5 (11.4%)	5 (13.2%)			
Mortality		0 (0%)	0 (0%)	0 (0%)	1	1
Abscess recurrence	None/Trace	34 (77.3%)	32 (84.2%)	44 (81.5%)		
	Recurrence	10 (22.7%)	6 (15.8%)	10 (18.5%)	0.339	**0.018**
Revision NSx	Yes	12 (27.3%)	8 (21%)	13 (24.1%)		
	No	32 (72.7%)	30 (79%)	41 (75.9%)	0.237	**0.039**
Neurological deficit	None	27 (61.4%)	25 (65.8%)	35 (64.8%)		
	Temporary	15 (34.1%)	12 (31.6%)	17 (31.5%)		
	Permanent	2 (4.5%)	1 (2.6%)	2 (3.7%)	0.647	0.149
ICU LOS (days)	Mean	1.55	1.44	1.39		
	Median	1	0.5	0		
	Range	0–12	0–12	0–12	0.599	0.196
LOS (days)	Mean	23.7	23	22.2		
	Median	21	20.5	20		
	Range	7 to 65	7 to 65	7 to 65	0.729	0.974
Follow-up (months)	Mean	14.2	14	13.6		
Total		44 (81.5%)	38 (70.4%)	54		

NSx, neurosurgery; ORL, otolaryngological; ICU LOS, intensive care unit length of stay; LOS, length of hospital admission; ESS, endoscopic sinus surgery.

modality of ORL intervention (n = 35, 79.5%) followed by frontal sinus trephination (n = 13, 29.5%), with both modalities being undertaken in some instances. 5 (11.4%) underwent maxillary sinus washout only.

The incidence of recurrence was 18.5% (n = 10). Abscess recurrence on initial follow-up imaging did not require revision surgery in all instances. The performance of same-admission ORL surgery had no significant impact on abscess recurrence (p = 0.339). Those who had concurrent ORL intervention were less likely to develop abscess recurrence (p = 0.018). Revision neurosurgery was carried out for a variety of indications in 24.1% (n = 13) of cases. The revision rate in the combined management group 27.3% (n = 12), and was lowest in the concurrent intervention group at 21% (n = 8). The use of concurrent intervention produced a lower rate of revision neurosurgery compared with combined intervention (p = 0.039).

17 (31.5%) children developed a temporary neurological deficit which resolved within their follow-up period. These included seizures, dysphasia, coma, hemiparesis, and transient memory disturbance. 2 patients (3.7%) developed permanent neurological deficits, specifically epilepsy and persistent hemiparesis. No difference in neurological outcome was noted among the treatment groups.

Mean ICU LOS was 1.39 days (median 0, range 0–12). 64.3% (n = 18) of children requiring ICU admission only required 1–2 days admission. ICU LOS did not vary significantly between the treatment groups (p = 0.196). Mean LOS was 22.2 days (median 20, range 7–65). Most children with prolonged LOS remained inpatients due to ongoing requirement for IV antibiotics and unsuitability for or delay in accessing outpatient antimicrobial therapy (OPAT) services. 19 (29.7%) were discharged to other hospitals and 10 (15.6%) were discharged to OPAT – the remainder (n = 35, 54.7%) were discharged home. Mortality for the study cohort was 0%. Mean outpatient follow-up was 13.6 months (range 1–68.3 months), at which time all observed patients had no further recurrence.

4.2.2. Otogenic complications

The management and outcomes of children with otogenic infections are presented in Table 4.

11 children with otogenic infections were identified. All required neurosurgical intervention in the form of burrhole evacuation (n = 6, 54.5%), craniotomy (n = 2, 18.2%), or craniectomy (n = 3, 27.3%). Cortical mastoidectomy was performed in all children who underwent ORL intervention (n = 10, 100%), with another 7 (70%) undergoing concomitant tympanostomy tube placement.

Abscess recurrence on follow-up imaging occurred in 2 patients (18.2%), both of which required revision neurosurgery. The failure group in the otogenic population was too small for meaningful analysis of the effect of concurrent ORL intervention. There were no postoperative neurological deficits noted.

Mean ICU LOS was 0.36 days (median 0, range 0–3). Mean LOS was 22.2 days (median 20, range 7–65). The profile of ICU admission and hospital stay in the otogenic group strongly resembled that of the rhinogenic group, but was too small for meaningful statistical analysis. Mortality for the study cohort was 0%. Mean outpatient follow-up was 13.6 months (range 1–51.6 months), at which time all observed patients had no further recurrence.

4.3. Other management

All patients received an initial course of 2 weeks IV antibiotics followed by variable oral or intravenous regimens for a total duration of 6 weeks. Initial empiric antibiotic therapy was in consultation with microbiology colleagues empiric regimes and included a third generation cephalosporin (cefotoxamine, ceftriaxone, or ceftazidime), metronidazole, and flucloxacillin. Following culture of responsible organisms, most patients were rationalised to intravenous antibiotics based on sensitivities (most commonly intravenous benzylpenicillin). No resistant organisms were cultured.

5. Discussion

The results presented above represent the current standard of care in Ireland for intracranial complications of sinusitis and mastoiditis in children, and are a direct and favourable reflection upon the position paper published by Fenton et al., in 1999 [10]. The local preferred approach in children for whom neurosurgical intervention is deemed appropriate has for many years been:

Table 4
Management and outcomes of children with otogenic intracranial complications requiring neurosurgical intervention in Ireland, 2008–2020.

Variable		ORL same admission	ORL concurrent	Total	p-value combined vs no ORL	p-value concurrent vs combined
NSx intervention	Burrhole	6 (60%)	6 (66.7%)	6 (54.5%)		
	Craniotomy	1 (10%)	1 (11.1%)	2 (18.2%)		
	Craniectomy	3 (30%)	2 (22.2%)	3 (27.3%)	0.182	0.4
ORL intervention	Cortical mastoidectomy	10 (100%)	9 (100%)			
	Tympanostomy tube	7 (70%)	7 (63.6%)			
Mortality		0 (0%)	0 (0%)	0 (0%)	–	–
Abscess recurrence	None/Trace	9 (90%)	9 (100%)	9 (81.8%)		
	Recurrence	1 (10%)	0 (0%)	2 (18.2%)	0.182	0.1
Revision NSx	Yes	1 (10%)	0 (0%)	2 (18.2%)		
	No	9 (90%)	9 (100%)	9 (81.8%)	0.182	0.1
Neurological deficit	None	10 (100%)	9 (100%)	11 (100%)		
	Temporary	0 (0%)	0 (0%)	0 (0%)		
	Permanent	0 (0%)	0 (0%)	0 (0%)	–	–
ICU LOS (days)	Mean	0.4	0.11	0.36		
	Median	0	0	0		
	Range	0–3	0–1	0–3	0.914	–
LOS (days)	Mean	15	14.1	15.5		
	Median	15.5	15	16		
	Range	6 to 23	6 to 21	6 to 23	0.959	–
Follow-up (months)	Mean	14.6	13.8	13.6		
Total		10 (90.9%)	9 (81.8%)	11		

NSx, neurosurgery; ORL, otolaryngological; ICU LOS, intensive care unit length of stay; LOS, length of hospital admission.

1. The most minimally invasive neurosurgical approach which will afford appropriate access to the anatomical region of interest,
2. Concurrent ORL intervention, and
3. Concurrent placement of a peripherally inserted central catheter (PICC) to facilitate prolonged IV antibiotic therapy.

As shown, success with the former two is evident, with 87% of those who ultimately required ORL intervention having this performed concurrently with neurosurgical intervention. PICC line placement in this group of septic patients has given some cause for concern locally due to the risk of bacterial seeding, but while data for other specific organisms does not yet exist, there is retrospective data to support the viability of early long line placement in, for example, active staphylococcus aureus bacteraemia [21]. Despite this, PICC placement in the context of confirmed bacteraemia remained an uncertain area on a recently published guide for appropriateness of PICC use [22]. Ambiguities regarding pathogen, intensity of bacteraemia, and clearance of infection have all been highlighted as sticking points, and early input from infectious disease specialists was considered to be appropriate to evaluate the safety of PICC placement; unfortunately this is likely not feasible in cases such as those described above as many present in extremis requiring urgent intervention without a sufficient interval for bacterial cultures to be completed. Most of the children in this study instead had PICC lines placed in the days following their index neurosurgery once cultures were available.

This dataset is, to the best of the authors' knowledge, the largest single study evaluating concurrent intervention ORL intervention for intracranial complications of sinusitis in paediatric patients requiring neurosurgical intervention, and also one of the larger studies of such children requiring neurosurgical intervention. Levy et al. [11] represents by far the largest examination of this population, but the strength of numbers of this multi-centre study is counterbalanced by the lack of clarification regarding timing of ORL procedures and the measurement of LOS and cost of admission as the only primary outcome markers. Koizumi et al. [12] presented 255 patients but notably included adults in their cohort, only 52 of whom were children. They also included all patients who received ESS during the same admission and did not adjust for timing of these procedures, ultimately concluding "ESS may not have significant benefits with respect to reducing mortality, blood transfusion, readmission, revision neurosurgery, or length of stay". While their numbers are equivalent to the rhinogenic cohort of this study with disparate findings, the distinction of timing of procedures is the feature that distinguishes this study from other publications. Notably, among the studies which demonstrated benefits associated with combined management, Din-Lovinescu et al. [17] had a relatively large cohort of children who underwent concurrent management (n = 30) and demonstrated shorter LOS in this cohort. Finally, a review by Scullen et al. [18] identified those who underwent simultaneous intervention had less than half the morbidity encountered in those who underwent neurosurgical intervention alone.

Despite the encouraging findings of this study that concurrent intervention reduces the prevalence of abscess recurrence and revision neurosurgery, there was no statistically significant effect on LOS. Analysis of time to discharge in this study was complicated by several variables which could not be adjusted for in a systematic manner, perhaps most importantly the variation in discharge destination, which did not seem to be directly correlated with any other findings. Another key feature was significant lack of availability of OPAT early in the study cohort, which resulted in many patients remaining admitted for uniform lengths of time despite clinical recovery and regardless of initial interventions. Despite the aforementioned variables, there was a tendency towards shorter LOS in those who underwent concurrent intervention.

It is recognised by the authors that the accepted use of the Lund-Mackay scoring system is for staging of chronic rhinosinusitis [20]; indeed, there is no widely accepted radiological grading system for ABRS. The Lund-Mackay scores were used in this study to provide an objective metric of severity of disease encountered in the study cohort, and a wide range of disease severity is thereby displayed. Lund-McKay scores also universally improved on follow-up sinus imaging where this was available, another useful feature of the system. No patient with rhinogenic disease and a Lund-Mackay score of less than 3 underwent ORL intervention, and this is considered by the authors to be the appropriate management in the event of minimal or no identifiable sinus disease at the time of neurosurgical intervention. This is reflected in the statistical analyses shown – where any ORL intervention versus no ORL intervention was examined, the impact of ORL interventions is attenuated. By comparison, the comparison of concurrent versus combined intervention excludes those who had no intervention, and directly addresses the primary hypothesis of this study. The 4 patients with scores of 0 were included under the heading of sinogenic complications as they gave a definite history of a recent episode of ARS managed either in the community or in another institution with topical nasal preparations and antibiotics. All patients who fell into this category of low burden sinus disease were investigated for alternative sources – ultimately no such source was found in all the included patients. Osteomeatal complex obstruction was the only single aspect of Lund-Mackay score that predicted any outcome measure – as a marker of relatively severe sinus disease in its own right this is unsurprising.

Paranasal sinus and middle ear disease were presented separately in this study to display the comparability of outcomes and overall approach to intracranial sequalae. Both processes share the pathophysiology of ineffective sinus drainage, be it at the osteomeatal complex or the aditus ad antrum, and both have a propensity to result in intracranial suppuration – these features combined were the basis for comparing the two groups at all. In addition, analysis of outcome data was purposefully focused on neurological and overall inpatient course outcomes rather than ORL outcomes to ensure that ORL intervention was examined primarily as an adjuvant management modality. In keeping with internationally observed trends, otogenic intracranial complications are now quite rare [3], and represented the minority in this cohort. It is likely that this, combined with a very small control group for whom concurrent intervention was not employed, resulted in the lack of any statistically significant difference between those managed with concurrent or combined intervention. Also in keeping with the current body of published works are the findings that rhinogenic complications were primarily observed in males in early adolescence with members of the streptococcus milleri group as the causative organism [4,5,9,17,19,23].

ESS was the preferred modality in this study and is, in the authors' view, the gold standard ORL intervention for complicated ABRS. Despite this, it must be recognised that many factors limit the use of this technique, especially in children with an already narrow nasal space exacerbated by inflamed mucosa and the presence of large volumes of mucopus. External approaches were not uncommonly used and obtained source control as evidenced by comparable outcomes with the ESS group and remain an important alternative where adequate expertise in ESS is not available or when the endoscopic approach fails.

The strengths of this study lie primarily in the identification of a single factor that differentiates meaningful and reproducible ORL contribution to the management of severely ill children, as well as the robust and statistically significant nature of the findings. It is, however, limited by its retrospective nature and the lack of randomisation inherent with observational data. Nonetheless, it is the view of the authors that prospective research on this vulnerable patient group would be neither feasible nor appropriate.

6. Conclusion

Intracranial complications of sinusitis and acute otitis media are rare but life-threatening events best managed in a specialist centre with multidisciplinary input. Where neurosurgical intervention is required, concurrent ORL intervention under the same general anaesthetic is associated with reduced abscess recurrence and reduced requirement for

revision neurosurgery in sinogenic complications. ESS is the ORL modality of choice in experienced hands.

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Conflicts of interest/Competing interests

We here declare that we have no conflicting/competing interests.

Availability of data and material

Available subject to ethical approval and data transfer agreement.

Code availability

Stata 16.1.

Authors' contributions

Concept and design: Nae, O'Riordan, Amin, Crimmins.
Acquisition, analysis, or interpretation of data: Sexton, Cleere.
Drafting of the manuscript: Sexton.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Sexton.

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