Received: 21 August 2021 | Accepted: 26 September 2021
DOI: 10.1111/coa.13869

ORIGINAL ARTICLE

WILEY

Acute paediatric mastoiditis in the UK before and during the COVID-19 pandemic: A national observational study

Matthew E. Smith[1] | G. Huw Jones[2] | John C. Hardman[3] | Jaya Nichani[4] | Sadie Khwaja[5] | The INTEGRATE (The UK ENT Trainee Research Network) UK Acute Paediatric Mastoiditis Audit Collaborators | Iain A. Bruce[6] | Peter Rea[7]

[1]Department of Otolaryngology, Salford Royal Hospital, Manchester, UK
[2]Department of Otolaryngology, Gloucestershire Hospitals NHS Foundation Trust, Gloucester, UK
[3]The Head and Neck Unit, The Royal Marsden Hospital, London, UK
[4]Paediatric Otolaryngology Department, Royal Manchester Children's Hospital, University of Manchester, UK
[5]Department of Otolaryngology, Manchester University Foundation Trust, Manchester, UK
[6]Paediatric ENT Department, Royal Manchester Children's Hospital, MAHSC, University of Manchester, UK
[7]Department of Otolaryngology, Leicester Royal Infirmary, Leicester, UK

Correspondence
Matthew E. Smith, Salford Royal Hospital, Stott Lane, Salford, Manchester, M6 8HD, UK.
Email: m.e.smith@doctors.org.uk

Funding information
The British Association for Paediatric Otolaryngology, Grant/Award Number: NA; ENTUK (The professional membership body for Ear Nose and Throat surgery in the UK), Grant/Award Number: NA; The British Society of Otology, Grant/Award Number: NA; The North West ENT Research Fund, Grant/Award Number: NA

Abstract

Objectives: To explore the impact of COVID-19 on the management and outcomes of acute paediatric mastoiditis across the UK.

Design: National retrospective and prospective audit.

Setting: 48 UK secondary care ENT departments.

Participants: Consecutive children aged 18 years or under, referred to ENT with a clinical diagnosis of mastoiditis.

Main outcome measures: Cases were divided into Period 1 (01/11/19-15/03/20), before the UK population were instructed to reduce social contact, and Period 2 (16/03/20-30/04/21), following this. Periods 1 and 2 were compared for population variables, management and outcomes. Secondary analyses compared outcomes by primary treatment (medical/needle aspiration/surgical).

Results: 286 cases met criteria (median 4 per site, range 0–24). 9.4 cases were recorded per week in period 1 versus 2.0 in period 2, with no winter increase in cases in December 2020-Febraury 2021. Patient age differed between periods 1 and 2 (3.2 vs 4.7 years respectively, $p < 0.001$). 85% of children in period 2 were tested for COVID-19 with a single positive test. In period, 2 cases associated with *P. aeruginosa* significantly increased. 48.6% of children were scanned in period 1 vs 41.1% in period 2. Surgical management was used more frequently in period 1 (43.0% vs 24.3%, $p = 0.001$). Treatment success was high, with failure of initial management in 6.3%, and 30-day re-admission for recurrence in 2.1%. The adverse event rate (15.7% overall) did not vary by treatment modality or between periods 1& 2.

Conclusion: The COVID-19 pandemic led to a significant change in the presentation and case mix of acute paediatric mastoiditis in the UK.

KEYWORDS
acute mastoiditis, antibiotic, COVID, paediatric, surgery

Iain A. Bruce and Peter Rea Joint senior authors.

The INTEGRATE (The UK ENT Trainee Research Network) UK Acute Paediatric Mastoiditis Audit Collaborators are listed in.

1 | INTRODUCTION

Mastoiditis is the most common complication of acute otitis media (AOM),[1] predominantly affecting young children and with a high rate of intracranial complications.[2] The SARS-CoV-2 (COVID-19) pandemic and the resulting societal changes have altered the presentation and frequency of many conditions seen by otolaryngologists. At the outset of the pandemic, there was concern that COVID-19 may promote acute mastoiditis, following the identification of the virus in the mastoid and middle ear,[3] with one group reporting a significant increase in complicated mastoiditis in early 2020.[4] However, it also became clear that globally there was a significant decrease in children presenting to healthcare teams with AOM,[5-7] suggesting mastoiditis should in fact be dropping in incidence.

In early March 2020, established management practices in otolaryngology were disrupted in ways not seen before, in an effort to protect staff and patients from COVID-19, and to maintain capacity within the health system. Acute paediatric mastoiditis was no exception, with professional bodies in the UK recommending initial medical treatment, with curettage as primary surgical treatment[8] to avoid the potential for viral transmission (via aerosol generation) with high-speed drilling.

In response to the anticipated changes in both the pathophysiology of AOM and resultant care of these patients, the objective of the present study was to explore the impact of COVID-19 on the management and outcomes of acute paediatric mastoiditis across the UK.

Key Points

- The incidence of acute paediatric mastoiditis significantly dropped during the COVID-19 pandemic
- There was no winter peak in mastoiditis cases in 2020–2021
- Compared with preceding months, mastoiditis during the pandemic was associated with lower inflammatory markers and fewer complications.
- Clinicians adopted a more conservative approach to management during the pandemic, with reduced imaging and surgical intervention.
- Patient outcomes were similar before and during the COVID-19 pandemic, with low rates of disease recurrence.

2 | METHODS AND MATERIALS

This manuscript has been prepared with reference to the STROBE checklist for cohort studies.[9] The protocol was published in advance at https://entintegrate.co.uk.

2.1 | Ethical considerations

The Health Research Authority decision tool determined the study design to fall under the remit of audit, and so no ethical approval was required (http://www.hra-decisiontools.org.uk/research/).

2.2 | Study design and setting

A national observational study of the management of acute paediatric mastoiditis by the UK secondary care ENT departments was completed. Data collection was retrospective over the 12-month period, 1 November 2019 – 31 October 2020, and prospective over the 6-month period, 1 November 2020 – 30 April 2021. The time period was designed to capture the management of cases before and during the COVID-19 pandemic.

Site recruitment was coordinated by INTEGRATE (The UK ENT Trainee Research Network). All UK ENT departments were invited to participate via national advertisement. Sites could open at any point during the retrospective data collection period.

2.3 | Participants

Consecutive children aged 18 years or under at the date of admission, and who were referred to ENT with a clinical diagnosis of acute mastoiditis (according to local team), were eligible for inclusion. The primary method for retrospective case identification was a search of ICD-10 coding using H70-derived codes (mastoiditis and related conditions).

2.4 | Data collection

Data collection was via online electronic case report forms (eCRF, see Supplementary Material) utilising REDCap (Research Electronic Data Capture) a secure, web-based application. Quality was controlled by limited data entry, predefined data formats and range checks. eCRF variables and data fields were decided by steering committee consensus following literature review.

Local site information was collected at the point of registration. Collected case data included demographics, symptoms/signs, laboratory results including COVID-19 status, computed tomography (CT) and magnetic resonance (MR) scan reports, medical and surgical management details, 30-day (from discharge) re-admission details and adverse events. Data were stored on the AIMES Health Cloud (ISO 27001 certified).

2.5 | Data analysis

Individuals treated at more than one hospital had records combined. Cases were divided into two periods representing the time before the UK population were instructed to reduce non-essential social contact (01/11/19-15/03/20, Period 1) and the time following this (16/03/20-30/04/21, Period 2). Descriptive statistics were calculated, and statistical differences between Periods 1 and 2 were assessed for population variables, management and outcomes: T test for continuous variables and chi-square test for dichotomous variables. Post hoc Bonferroni adjustment of p-values accounted for multiple analyses within variable groups.[10]

Secondary analyses compared outcomes by primary treatment, grouped as medical (no invasive intervention), needle aspiration (of a subperiosteal abscess) and surgical (any other invasive procedure). Secondary treatments were defined locally as an intervention required after intended medical treatment alone, or occurring after a primary operation for surgical/needle aspiration. Population differences between conservatively managed patients (ie medical management or needle aspiration) and surgically managed patients were assessed to explore clinical decision-making.

Analyses were performed in Excel v16.49 (Microsoft Corp. Redmond, Washington) and SPSS v27.0 (IBM Corp. Armonk, New York).

3 | RESULTS

Forty-eight UK sites participated, including 16 tertiary paediatric ENT centres (see Acknowledgements). All sites submitted data covering the complete retrospective and prospective periods, with 286 cases meeting eligibility criteria (two excluded for exceeding age criteria). The median number of cases per site was 4 (range 0–24, interquartile range 2–11).

3.1 | Incidence

A peak in mastoiditis cases was seen in the winter months (December-March) 2019–2020 with 149 children admitted. A peak was not observed in the equivalent period in 2020–2021 (33 admitted) (Figure 1). In period 1, 9.4 cases were recorded per week, compared to 2.0 in period 2.

3.2 | Population

The demographics and background variables for children presenting with mastoiditis are shown in Table 1. The overall median age was 4.0 years (range 1 month-18 years), with a significant difference in age in periods 1 and 2 (3.2 vs 4.7 years respectively, $p < 0.001$) (Figure 2).

Within period 2, 85.0% of children (91/107) underwent polymerase chain reaction tests for COVID-19 with a single positive case reported. Aspects of the cohort significantly differed between periods (Table 1): A greater proportion of patients had cholesteatoma or a recorded comorbidity in period 2, while fewer patients presented with coryzal symptoms. Blood test results in period 2 were suggestive of less severe disease, with significantly lower values for all inflammatory markers tested (white cell counts and C-reactive protein [CRP]).

3.3 | Microbiology

One or more organisms were cultured in 56.6% of cases where a sample was taken, with some more likely to be associated with intracranial complications (Table 2). There was a significant decrease in *S. pneumoniae*, group A Strep and *H. influenzae*-associated mastoiditis in period 2, with *P. aeruginosa* significantly increasing in incidence to become the dominant organism in this period.

3.4 | Management

Approximately one quarter of children in the cohort had recorded initial management in primary care, unchanged between periods 1 and 2 (Table 1). Conversely, management in secondary care demonstrated a significant switch towards more conservative management in period 2 (Table 3). During the pandemic, a greater proportion of children underwent medical management alone or needle aspiration. Needle aspiration was the only defined

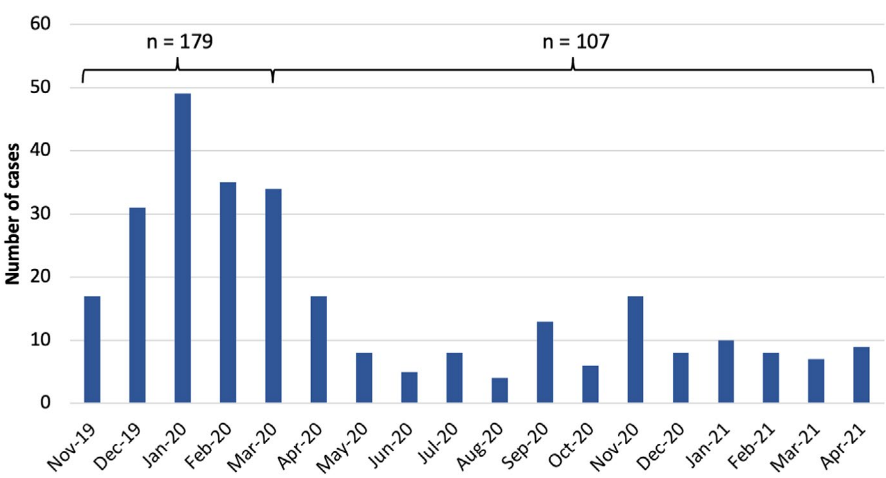

FIGURE 1 Incidence and total case number of acute paediatric mastoiditis before and after the UK introduction of COVID-19 measures (periods: 01/11/19-15/03/20 and 16/03/20-30/04/21)

TABLE 1 Case numbers, demographics and presenting features of children with acute mastoiditis, grouped by time of presentation before and after the UK introduction COVID-19 measures (Periods: 01/11/19-15/03/20 and 16/03/20-30/04/21)

Background variables					
Variable	**Status**	**Total**	**Before 15–04–20**	**After 15–04–20**	**Sig pre vs post**
Total cases n	–	286	179	107	–
Period studied in weeks	–	78	19	54	–
Cases per week	–	3.7	9.4	2.0	–
Sex n (%)	Male	161 (56.3)	95 (53.1)	66 (61.7)	0.155
	Female	125 (43.7)	84 (46.9)	41 (38.3)	
Age in years median (range)	–	4.0 (1month–18)	3.2	4.7	<0.001*
Ethnicity n (%)	White	224 (78.3)	143 (79.9)	81 (75.7)	1.000
	Asian or Asian British	23 (8.0)	12 (6.7)	11 (10.3)	1.000
	Black, African, Black British or Caribbean	10 (3.5)	7 (2.9)	3 (3.8)	1.000
	Mixed or multiple ethnic groups	17 (5.9)	10 (5.6)	7 (6.5)	1.000
	Another ethnic group	12 (4.2)	7 (3.9)	5 (4.7)	1.000
Comorbidities n (%)	Cholesteatoma	16 (5.6)	4 (2.2)	12 (11.2)	0.008*
	BMI>25	3 (1.0)	1 (0.6)	2 (1.9)	1.000
	Asthma	6 (2.1)	2 (1.1)	4 (3.7)	1.000
	Immunodeficiency	1 (0.3)	0 (0.0)	1 (0.9)	1.000
	Genetic syndrome	8 (2.8)	2 (1.1)	6 (5.6)	0.208
	Cochlear implant	4 (1.4)	3 (1.7)	1 (0.9)	1.000
	Other	49 (17.1)	19 (10.6)	30 (28.0)	<0.001*
	None	232 (81.1)	159 (88.8)	73 (68.2)	<0.001*
COVID test	Positive	1	0	1	–
	Negative	112	22	90	–
	Not done	173	157	16	-
Primary care management n (%)	No GP review / no treatment	140 (49.0)	86 (48.0)	54 (50.5)	1.000
	Oral antibiotics alone	72 (25.2)	47 (26.3)	25 (23.4)	1.000
	Topical antibiotics alone	9 (3.1)	4 (2.2)	5 (4.7)	1.000
	Oral and topical antibiotics	10 (3.5)	2 (1.1)	8 (7.5)	0.025*
	Not known	56 (19.6)	38 (21.2)	18 (16.8)	1.000
Presenting symptoms n (% of those with recorded history)	Otalgia	218 (87.9)	132 (87.4)	86 (88.7)	1.000
	Pyrexia	165 (65.2)	103 (66.9)	62 (62.6)	1.000
	Coryzal Sx	83 (35.5)	65 (44.8)	18 (20.2)	<0.001*
	Headache	29 (14.5)	65 (11.4)	16 (18.6)	1.000
	Otorrhea	95 (36.5)	50 (31.4)	45 (44.6)	0.032*
	Irritability	75 (35.0)	46 (34.3)	29 (36.2)	1.000
	Facial palsy	4 (1.6)	4 (2.4)	0 (0.0)	1.000

(Continues)

TABLE 1 (Continued)

Background variables					
Variable	Status	Total	Before 15–04–20	After 15–04–20	Sig pre vs post
Blood tests Mean value	White cells (10^9/l)	13.7	14.6	12.3	0.042*
	Neutrophils (10^9/l)	8.9	10.0	7.1	0.006*
	Lymphocytes (10^9/l)	3.8	4.1	3.2	0.012*
	Haemoglobin (g/l)	109.8	106.3	115.8	0.018*
	Platelets (10^9/l)	417.1	454.6	354.6	<0.001*
	C-reactive protein (mg/l)	74.5	86.3	54.4	<0.001*
Organism n positive (%)	1+ organism identified via culture	82 (28.7)	50 (28.0)	32 (30.0)	1.000
	No organism cultured	63 (22.0)	41 (22.9)	22 (20.6)	1.000
	No sample taken	141 (49.3)	88 (49.2)	53 (49.5)	1.000
	Multiple organisms n (% of those with positive culture)	20 (24.4)	12 (24.0)	8 (25.0)	1.000

Note: Includes Bonferroni adjustment where appropriate.* *$p < 0.05$*.

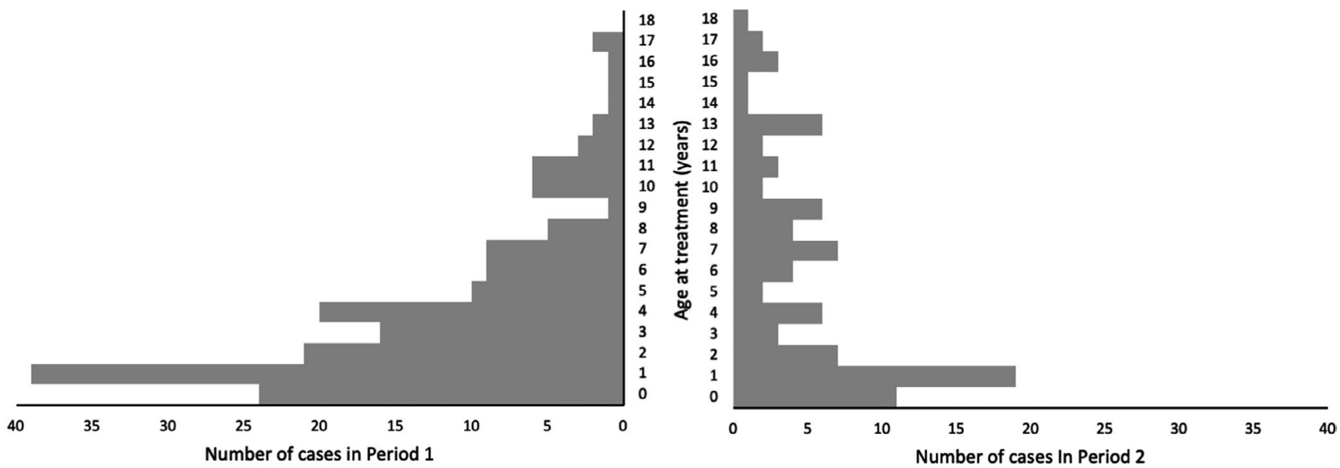

FIGURE 2 Age distribution of children presenting with acute mastoiditis in Period 1 (01/11/19-15/03/20) and Period 2(16/03/20-30/04/21)

invasive procedure to increase in period 2, but overall powered drill mastoid surgery, with or without adjuvant ventilation tube insertion, remained the most frequent procedure (Figure 3). Median time to surgery from admission was 1 day. Around 1 in 5 children were transferred between hospitals, with no difference between periods.

3.5 | Management group characteristics

The surgically and conservatively (medical treatment or needle aspiration) managed groups differed significantly for two variables: age (4.7 years surgical vs 5.4 conservative ($p = 0.029$)) and admission CRP value (86.6 mg/L surgical vs. 67.9 conservative ($p = 0.002$)). Other symptoms, test values and complication data were comparable between groups (full results in Table S1).

3.6 | Outcomes

Outcomes are presented in Table 3. Length of inpatient stay was comparable between periods 1 and 2, and longer for patients treated surgically than medically (median 6.0 versus 2.0 days respectively). Regardless of management, treatment success was high, with failure of initial management (medical or surgical) requiring delayed surgery in 6.3% of children overall, and a 30-day

TABLE 2 Organisms cultured in cases of acute mastoiditis and their association with intracranial complications (ICC)

Organism	Number of cases by organism		Rate of cases per week by organism		Incidence rate difference in total cohort	Associated ICC	Percentage of organism cases with ICC
	Before 15-04-20	After 15-04-20	Before 15-04-20	After 15-04-20	P =	All (Abscess)	All (Abscess)
Strep pneumoniae	9	3	0.47	0.06	0.006*	1(1)	8.3 (8.3)
Staph aureus	8	7	0.42	0.13	0.188	4(1)	26.7 (6.7)
Group A strep	18	1	0.95	0.02	<0.001*	5(1)	26.3 (5.3)
Pseudomonas	2	17	0.11	0.31	0.017*	0(0)	0.0 (0.0)
Anaerobes	9	5	0.47	0.09	0.034*	3(2)	21.4 (14.3)
Candida	0	4	0.00	0.07	0.126	0(0)	0.0 (0.0)
Haemophilus Influenzae	8	0	0.42	0.00	<0.001*	1(1)	12.5 (12.5)
Fusobacterium necrophorum	4	3	0.21	0.02	0.268	4(3)	57.1 (42.9)
Other	5	3	0.26	0.06	0.134	2(1)	25.0 (12.5)

Note: * $p < 0.05$.

re-admission rate of 4.2% for any cause and 2.1% for recurrence of sepsis or collection. The overall adverse event rate was 15.7% and did not vary by treatment modality or between periods 1 and 2 (Table 3).

4 | DISCUSSION

4.1 | The number of acute paediatric mastoiditis cases has reduced during the COVID-19 pandemic

Historically, the incidence of acute paediatric mastoiditis has been relatively stable over time[11,12]; however, this study demonstrates a significant reduction following the introduction of COVID-19-related measures. Acute mastoiditis is usually a complication of AOM, with known seasonal variation associated with viral upper respiratory tract infections (URTI).[13,14] The incidence of AOM has significantly reduced since early 2020,[5-7] probably due to greatly reduced social, childcare and education-related contact between young children during the pandemic. This reduction in AOM has likely led to the observed reduction in mastoiditis cases, with the 2020/21 winter peak absent in comparison to 2019/20. No evidence was identified for COVID-19 as a cause of mastoiditis, with only one positive case, reflecting background population prevalence.

4.2 | The COVID-19 pandemic reduced seasonal variation in mastoiditis cases

Several differences between periods 1 and 2 can be seen in the population of affected children, and in the characteristics of the infections. It is hypothesised that these differences are due to the loss of the URTI-driven winter peak in infection. In line with this, the number of children with mastoiditis presenting with coryzal symptoms more than halved in period 2.

This loss of the winter effect is most clearly seen in the age of patients, and in the organisms identified. In period 1, the spectrum and proportion of organisms are comparable to other series where most cases occurred in winter.[2,15] In contrast in period 2, cases with organisms typically associated with AOM, such as *S. pneumoniae* and *H. influenzae*, were greatly reduced, with an accompanying increase in cases associated with *P. aeruginosa* and Candida. Camanni et al. reported cases of paediatric mastoiditis limited to summer months (June-September), finding *P. aeruginosa* to be the most commonly isolated organism, accounting for 51.6% of positive samples.[16] Our study did not collect data from the preceding summer to compare with period 2 unfortunately, and it is noted that *P. aeruginosa* can be prominent in some multi-year series.[17,18]

A median age of 3.2 years in period 1 was significantly younger than the 4.7 years in period 2. The pre-COVID-19 figure is comparable to a recent UK series,[17] though older than most large International cohorts (1.3–2.1 years).[11,12,19] In line with our

TABLE 3 Secondary care management and outcomes of children with acute mastoiditis, grouped by time of presentation before and after the UK introduction COVID-19 measures (Periods: 01/11/19-15/03/20 and 16/03/20-30/04/21)

Secondary Care Management					
Variable	**Status**	**Total**	**Before 15–04–20**	**After 15–04–20**	**Sig pre vs post**
Imaging n (%)	CT only	90 (31.5)	53 (29.6)	37 (34.6)	1.000
	MRI only	16 (5.6)	11 (6.2)	5 (4.7)	0.028*
	CT and MRI	25 (8.7)	23 (12.9)	2 (1.9)	0.004*
	None	155 (54.2)	92 (51.4)	63 (58.9)	0.844
Antibiotics n (%)	Co-amoxiclav	136 (47.6)	76 (42.5)	60 (56.1)	0.026*
	Tazocin	7 (2.4)	2 (1.1)	5 (4.7)	0.060
	Metronidazole	96 (33.6)	67 (37.4)	29 (27.1)	0.074
	Ceftriaxone	96 (33.6)	63 (35.2)	33 (30.8)	0.450
	Cefuroxime	10 (3.5)	10 (5.6)	0 (0.0)	0.013*
	Cefotaxime	23 (8.0)	16 (8.9)	7 (6.5)	0.453
	Ceftazidime	7 (2.4)	6 (3.4)	0 (0.0)	0.200
	Ciprofloxacin	5 (1.7)	1 (0.6)	4 (3.7)	0.047*
	Clindamycin	9 (3.1)	6 (3.4)	3 (2.8)	0.797
	Other	21 (7.3)	14 (7.8)	7 (6.5)	0.404
Initial management n (%)	Medical management only	176 (61.5)	100 (55.9)	76 (71.0)	0.011*
	Needle aspiration	7 (2.5)	2 (1.0)	5 (4.7)	0.020*
	Surgical intervention	103 (36.0)	77 (43.0)	26 (24.3)	0.001*
Hospital transfer	–	54 (18.9)	37 (20.7)	17 (15.9)	0.510
Outcomes					
Length of stay (days)	Overall median	3.0	3.0	3.0	0.265
	Medical treatment	3.0	3.0	2.0	0.471
	Needle treatment	5.0	2.5	5.5	0.733
	Surgical treatment	5.0	5.0	6.0	0.412
Delayed surgery required during admission	Any treatment	18 (6.3)	10 (5.6)	8 (7.5)	0.942
	Initial medical treatment	5 (2.8)	3 (3.0)	2 (2.6)	0.884
	Initial needle treatment	2 (28.6)	0 (0.0)	2 (40.0)	0.290
	Initial surgical treatment	11 (10.7)	7 (9.1)	4 (15.4)	0.369
Adverse events (any) n (%)	Overall	45 (15.7)	33 (18.4)	12 (11.2)	0.105
	Medical treatment only	10 (5.7)	7 (7.0)	2 (2.6)	0.191
	Needle treatment	1 (14.3)	0 (0.0)	1 (20%)	0.495
	Surgical treatment	35 (34.0)	26 (33.8)	9 (34.6)	0.937
Intracranial complication n (%)	1+ complication	40 (14.0)	29 (16.2)	11 (10.3)	0.162
Adverse events by type n (%)	Sigmoid sinus ±IJV thrombosis	26 (9.1)	20 (11.2)	6 (5.6)	0.678
	Intracranial abscess	16 (5.6)	10 (5.6)	6 (5.6)	0.972
	Meningitis	5 (1.7)	4 (2.2)	1 (0.9)	1.000
	Facial weakness	3 (1.0)	3 (1.7)	0 (0.0)	1.000
	Extra-cranial/temporal abscess (beyond subperiosteal)	6 (2.1)	4 (2.2)	2 (1.9)	1.000
	Sensorineural hearing loss	0 (0.0)	0 (0.0)	0(0.0)	–
	Iatrogenic	0 (0.0)	0 (0.0)	0 (0.0)	–
	Other	8 (2.8)	5 (2.8)	3 (2.8)	1.000

TABLE 3 (Continued)

Secondary Care Management					
Variable	Status	Total	Before 15–04–20	After 15–04–20	Sig pre vs post
30-day re-admission n (%)	Overall	12 (4.2)	5 (2.8)	7 (6.5)	<0.001*
	Medical treatment only	6 (3.7)	2 (2.1)	4 (6.1)	0.016*
	Needle treatment	0 (0.0)	0 (0.0)	0 (0.0)	–
	Surgical treatment	6 (6.2)	3 (3.9)	3 (14.3)	0.001*
30-day recurrence requiring re-admission n (%)	Overall	6 (2.1)	3 (1.7)	3 (2.8)	0.520
	Medical treatment only	3 (1.8)	1 (1.0)	2 (3.0)	0.408
	Needle treatment	0 (0.0)	0 (0.0)	0 (0.0)	–
	Surgical treatment	3 (3.1)	2 (2.6)	1 (4.8)	0.743

Note: Includes Bonferroni adjustment where appropriate.* $p < 0.05$.

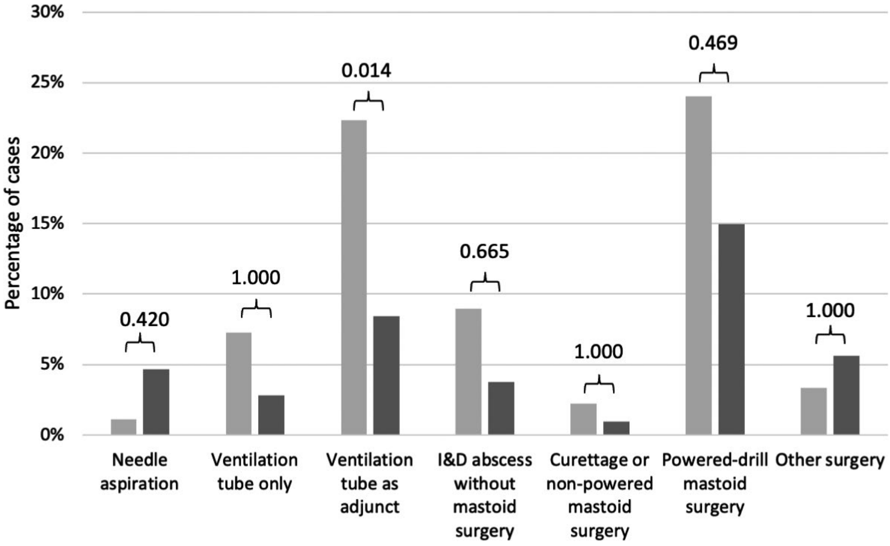

FIGURE 3 Type of non-medical management, as a percentage of all subjects, before (light grey bars) and after (dark grey bars) the introduction of COVID-19 measures in the UK. Bonferroni-corrected P-value for comparison of paired bars

hypothesis, Camanni et al. found children aged 5–9 years were most commonly affected by mastoiditis in the summer, and an association between older age and *P. aeruginosa* as a causative organism for mastoiditis is described[16,18]

The weekly rate of cases associated with *P. aeruginosa* significantly increased in period 2, which may not be expected from simply suppressing URTI-related infection. Children with Pseudomonas-associated mastoiditis are more likely to have had previous otologic problems,[18] but there was no significant change in the presentation rate of cholesteatoma-associated mastoiditis (unchanged at 0.21 cases per week before COVID-19 measures and 0.22 after) or in the rate of preceding primary care management.

4.3 | Acute mastoiditis is frequently associated with complications, but severity appeared milder during the pandemic

The reported complication rate for acute paediatric mastoiditis varies from 32.7%[17] to 1.9%,[11] with our figure of 15.7% falling in the middle. Complications in our population were largely due to intracranial sequelae (14.0%), similar to published series.[2,17,20-22]

Both blood inflammatory marker levels (white cell counts and CRP) and the rate of intracranial complications and adverse events were lower in period 2. This difference is likely due to the lack of a winter effect during the pandemic: *P. aeruginosa* has previously been found to be associated with lower inflammatory markers,[16,18] and in our series was not associated with any intracranial complications. There is also evidence for lower inflammatory markers[15] and fewer complications in comparative older age groups.[13,18,23]

4.4 | The COVID-19 pandemic has led to changes in the management of acute paediatric mastoiditis

A systematic review of retrospective paediatric mastoiditis series[24] demonstrated 95.9% cure with medical treatment alone, 96.3% with conservative surgery (ventilation tube insertion and/or abscess drainage without mastoidectomy) and 89.1% with more extensive surgery. Similarly, this study has identified few patients requiring delayed or second surgery (overall 6.3%), and low recurrence rates at 30 days (overall 2.1%), suggesting outcomes were not affected by COVID-19-associated changes in mastoiditis or its management.

Our data demonstrate a significant decrease in surgical management in period 2, with several possible explanations for this difference. Firstly, children in period 2 were more likely to have milder, uncomplicated mastoiditis, lending themselves to more conservative management. Secondly, within the UK and elsewhere, guidance on the management of acute mastoiditis changed, to prioritise more conservative interventions.[8] There is however little evidence of the latter promoting the change, as incision and drainage / curettage techniques reduced similarly to 'higher-risk' interventions, such as high-speed drill mastoidectomy, discouraged in many COVID-19-related guidelines owing to its aerosol-generating potential.

The published rate of failure to improve, requiring mastoidectomy, following initial conservative treatment is 4.3%,[24] and in our study, the figure was 2.8% for medical treatment and 28.6% for needle aspiration, though the sample size for aspiration was too small to draw conclusions. Our data confirm that medical management alone is appropriate for more than half of children who are admitted with acute mastoiditis, though the observational nature of this study prevents an understanding of the complex clinical assessment that goes into management planning. The only significant differences identified related to management choice were lower CRP and older age in the conservative treatment group, but neither is likely to be a primary driver of clinical decision-making.

4.5 | Lessons for the future

It is impossible to conclude from our data whether surgical management is currently over-adopted. No iatrogenic adverse events were identified, and given the potential for complications with severe acute mastoiditis, many surgeons feel surgery is justified. There has been a shift towards more conservative management and delayed surgical management[12] with evidence that needle aspiration can provide effective management of subperiosteal abscesses in some children.[19,25] It was thought that the COVID-19 pandemic may force changes in mastoiditis management, providing lessons for future guidelines; however, findings instead appear to reflect a change in the nature of mastoiditis cases presenting.

4.6 | Limitations of the study

This study was completed primarily to capture emergency changes to practice and new presentations relating to COVID-19 and therefore adopted a relatively short time period and simplified dataset to ease the burden on clinicians. As a consequence, some data were lacking that could be of use, such as pre-COVID-19 seasonal variation and more in-depth medical histories for each case (eg relating to previous ear disease). Furthermore, the low incidence of acute mastoiditis and its associated adverse events limits the certainty of comparison between periods and treatments, as well as the statistical tests that can be applied.

While *P. aeruginosa* can often be isolated from ear canal or middle ear samples, it is infrequently isolated from subperiosteal abscesses[25] or the mastoid.[11] This may be because it is less likely to cause disease requiring invasive intervention, or alternatively more peripheral samples may represent contamination/colonisation. Analysis excluded samples taken in primary care, but the site (ear canal, mastoid etc.) was not recorded. It is possible sampling methods changed in period 2 due to reduced surgery and concerns over viral exposure.

Our dataset was retrospective, and so decision-making and criteria applied for surgical treatment are unknown. Treatment decisions are based on patient history, examination, test findings and personal or local clinical experience, and so there will be substantial unknown differences between groups, in addition to those that are reported herein.

Finally, it should be noted that while this study presents data from tertiary and smaller centres across the UK, there could be a bias in those choosing to participate. Furthermore, the findings may not relate to other countries, due to differing childhood immunisation schedules, mastoiditis management protocols and/or COVID-19 social measures.

5 | CONCLUSIONS

The COVID-19 pandemic led to a significant change in the presentation and case mix of acute paediatric mastoiditis in the UK, with fewer cases overall, a loss of the usual winter peak and a change in the affected population.

ACKNOWLEDGEMENTS

Funding was received from ENTUK (the professional membership body representing Ear, Nose and Throat surgery in the United Kingdom), the British Society of Otology, the British Association for Paediatric Otolaryngology and the North West ENT Research Fund.

Contributions to the collaborative work are outlined below. All authors meet ICMJE criteria.

Steering Committee, Writing Matthew E. Smith, Huw Jones, Jaya Nichani, Sadie Khwaja, Iain Bruce, Peter Rea.

Data analysis Matthew E. Smith, Huw Jones, John C Hardman.

Site leads / Data collection (Hospital: Trainee Lead, Consultant Lead). Addenbrooke's Hospital, Cambridge: Samuel Dewhurst, Manohar L Bance. Alder Hey Children's Hospital, Liverpool: Emma J Whitehall, Madhankumar Krishnan. Altnagelvin Area Hospital, Londonderry: Gavin Donaldson, Cathy Smyth. Barnet Hospital, London: Noshin Siddiqi, Cheka Spencer. Birmingham Children's Hospital, Birmingham: Nicola Wooles, Birmingham City Hospital, Birmingham: Srinish Gopala Krishnan, Yohanna Takwoingi. Bradford Royal Infirmary, Bradford: David Selwyn, David Strachan. Bristol Royal Infirmary, Bristol: James D Constable, Philip J Robinson. Broomfield Hospital, Chelmsford: Billy Wong, Laura Harding.

Countess of Chester Hospital, Chester: Ahmed Yousef, Robert Temple. Doncaster Royal Infirmary, Doncaster: Beverley Yu, Jayant Dugar. Great Ormond Street Hospital, London: Fiona McClenaghan, Robert Nash. Heartlands Hospital, Birmingham: Andrew Mowat, Arshad Janjua. James Cook University Hospital, Middlesbrough: Mohamed Elmorsy, George Thomas. John Radcliffe Hospital, Oxford: Marina Brimioulle, Ian Bottrill. Leicester Royal Infirmary, Leicester: Georgios Sakagiannis & Bassem Mettias, Peter Rea. Lister Hospital, Stevenage: Olivia Kenyon, Ananth Vijendren. Luton and Dunstable University Hospital, Luton: Anna I Kaleva, Pranay Singh. Manchester Children's Hospital, Manchester: Anna Harrison, Jaya Nichani. Milton Keynes University Hospital, Milton Keynes: Elizabeth Mathew, Alison Hunt. Musgrove Park Hospital, Taunton: Oliver J Wright, Alistair Mitchell-Innes. Ninewells Hospital, Dundee: Richard A Steven, Patrick M Spielmann. Norfolk and Norwich University Hospital, Norwich: Rachael Collins, John Phillips. Northampton General Hospital, Northampton: Darren Yap, Mrinal Supriya. Northwick Park Hospital, London: Priya Sethukumar, Anooj majithia. Queen Alexandra Hospital, Portsmouth: Aria Amir Ghasemi, Eleanor Sproson. Queen's Hospital Burton, Burton-on-Trent: Alison Conybeare, Patrick Lee. Queen's Hospital, Romford: Guled M. Jama, Gaurav Kumar. Royal Berkshire Hospital, Reading: Alison Liu, Dilip Nair. Royal Hospital for Sick Children, Edinburgh: Lucy Qian Li & Anas Gomati, Alok Sharma. Royal Hospital for Sick Children, Glasgow: William Flynn & Christopher Connon, David Wynne. Royal Stoke University Hospital, Stoke: Soo Oh, Sanjiv Kumar Bhimrao. Royal Victoria Hospital, Belfast: Brendan Wright, Conor Jackson. Royal Victoria Infirmary, Newcastle: Craig James McCaffer, Claire McLarnon. Russells Hall Hospital, Dudley: Hannah R Lancer, Matthew Weller. Salisbury District Hospital, Salisbury: Emily Lowe, Marcel Geyer. Sheffield Children's Hospital, Sheffield: Dylan Chew, Sanjeev Gupta. Southampton General Hospital, Southampton: Dimitrios Ioannidis, Timothy Mitchell. Stepping Hill Hospital, Greater Manchester: Anastasha Herman, Mamoona Khalid-Raja. The Royal London Hospital, London: Arshad Zubair, Kay Seymour. University College London Hospital, London: Cillian T Forde, Azhar Shaida. University Hospital Coventry and Warwickshire, Coventry: Emma Watts, Emma Hoskison. University Hospital Monklands, Airdrie: Anna Loroch, Arunachalam Iyer. University Hospital of Wales, Cardiff: Laura Burton, Andrew Hall. Walsall Manor Hospital, Walsall: Alexander Yao, Mark Simmons. Warrington Hospital, Warrington: Hannah Emerson, Ahmed Allam. Wythenshawe Hospital, Greater Manchester: Safdar Sarwar, Sadie Khwaja. Ysbyty Gwynedd Hospital, Bangor: Faiza Ali, Phillip Moore.

DATA AVAILABILITY STATEMENT

Data are not publicly available due to small numbers at each hospital site permitting case identification despite pseudonymisation.

ORCID

Matthew E. Smith https://orcid.org/0000-0001-8147-1549
John C. Hardman https://orcid.org/0000-0002-6591-5119

REFERENCES

1. Mattos JL, Colman KL, Casselbrant ML, Chi DH. Intratemporal and intracranial complications of acute otitis media in a pediatric population. *Int J Pediatr Otorhinolaryngol*. 2014;78(12): doi:10.1016/j.ijporl.2014.09.032
2. Mansour T, Yehudai N, Tobia A, et al. Acute mastoiditis: 20 years of experience with a uniform management protocol. *Int J Pediatr Otorhinolaryngol*. 2019;125:187-191. doi:10.1016/j.ijporl.2019.07.014
3. Frazier KM, Hooper JE, Mostafa HH, Stewart CM. SARS-CoV-2 Virus Isolated From the Mastoid and Middle Ear. *JAMA Otolaryngol Head Neck Surg*. 2020;146(10):964. doi:10.1001/jamaoto.2020.1922
4. Enrique G-L, Margarita B-B, Ángel M-J, Saturnino S-S, María Jesús D-GR. COVID-19 and severe ENT infections in pediatric patients. IS there a relationship? *Int J Pediatr Otorhinolaryngol*. 2021;145:110714. doi:10.1016/j.ijporl.2021.110714
5. Kuitunen I, Ponkilainen VT, Launonen AP, et al. The effect of national lockdown due to COVID-19 on emergency department visits. *Scand J Trauma Resusc Emerg Med*. 2020;28(1). doi:10.1186/s13049-020-00810-0
6. Torretta S, Capaccio P, Coro I, et al. Incidental lowering of otitis-media complaints in otitis-prone children during COVID-19 pandemic: not all evil comes to hurt. *Eur J Pediatr*. 2021;180(2):649-652. doi:10.1007/s00431-020-03747-9
7. van de Pol AC, Boeijen JA, Venekamp RP, et al. Impact of the COVID-19 pandemic on antibiotic prescribing for common infections in the netherlands: a primary care-based observational cohort study. *Antibiotics*. 2021;10(2):196. doi:10.3390/antibiotics10020196
8. ENTUK (The professional membership body for Ear Nose and Throat surgery and related specialties in the UK). https://www.entuk.org/guidance-undertaking-otological-procedures-during-covid-19-pandemic-0. Accessed July 1 2021.
9. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi:10.1016/j.jclinepi.2007.11.008
10. Wright SP. Adjusted P-values for simultaneous inference. *Biometrics*. 1992;48:4. doi:10.2307/2532694
11. Anthonsen K, Høstmark K, Hansen S, et al. Acute mastoiditis in children. *Pediatr Infect Dis J*. 2013;32(5):436-440. doi:10.1097/INF.0b013e31828abd13
12. Groth A, Enoksson F, Hermansson A, Hultcrantz M, Stalfors J, Stenfeldt K. Acute mastoiditis in children in Sweden 1993–2007—No increase after new guidelines. *Int J Pediatr Otorhinolaryngol*. 2011;75(12):1496-1501. doi:10.1016/j.ijporl.2011.08.015
13. Palma S, Fiumana E, Borgonzoni M, Bovo R, Rosignoli M, Martini A. Acute mastoiditis in children: The "Ferrara" experience. *Int J Pediatr Otorhinolaryngol*. 2007;71(11):1663-1669. doi:10.1016/j.ijporl.2007.06.018
14. Stockmann C, Ampofo K, Hersh AL, et al. Seasonality of acute otitis media and the role of respiratory viral activity in children. *Pediatr Infect Dis J*. 2013;32(4):314-319. doi:10.1097/INF.0b013e31827d104e
15. Groth A, Enoksson F, Hultcrantz M, Stalfors J, Stenfeldt K, Hermansson A. Acute mastoiditis in children aged 0–16 years—A national study of 678 cases in Sweden comparing different age groups. *Int J Pediatr Otorhinolaryngol*. 2012;76(10):1494-1500. doi:10.1016/j.ijporl.2012.07.002
16. Camanni G, Bianchini S, Neglia C, et al. Acute mastoiditis associated with pseudomonas aeruginosa in the pediatric population of the Umbria Region, Italy. *Pathogens*. 2019;8(4):180. doi:10.3390/pathogens8040180

[Correction added on 13 April 2022, after first online publication: In Acknowledgment section, the collaborator's surname listed under Site leads/Data collection was corrected from 'Mattias' to 'Mettias' so it reads as 'Bassem Mettias' in this version.]

17. Mather M, Powell S, Yates PD, Powell J. Acute mastoiditis in children: contemporary opportunities and challenges. *J Laryngol Otol*. 2020;134(5):434-439. doi:10.1017/S0022215120000833
18. Nussinovitch M, Yoeli R, Elishkevitz K, Varsano I. Acute mastoiditis in children: epidemiologic, clinical, microbiologic, and therapeutic aspects over past years. *Clin Pediatr*. 2004;43(3):261-267. doi:10.1177/000992280404300307
19. Bartov N, Lahav Y, Lahav G, et al. Management of acute mastoiditis with immediate needle aspiration for subperiosteal abscess. *Otol Neurotol*. 2019;40(6):e612-e618. doi:10.1097/MAO.0000000000002231
20. Attlmayr B, Zaman S, Scott J, Derbyshire SG, Clarke RW, De S. Paediatric acute mastoiditis, then and now: is it more of a problem now? *J Laryngol Otol*. 2015;129(10):955-959. doi:10.1017/S0022215115002078
21. Luntz M, Bartal K, Brodsky A, Shihada R. Acute mastoiditis: The role of imaging for identifying intracranial complications. *Laryngoscope*. 2012;122(12):2813-2817. doi:10.1002/lary.22193
22. Bakhos D, Trijolet J-P, Morinière S, Pondaven S, Al zahrani M, Lescanne E. Conservative management of acute mastoiditis in children. *Arch Otolaryngol Head Neck Surg*. 2011;137(4):346. doi:10.1001/archoto.2011.29
23. Katz A, Leibovitz E, Greenberg D, et al. Acute mastoiditis in Southern Israel: a twelve year retrospective study (1990 through 2001). *Pediatr Infect Dis J*. 2003;22(10):878-883. doi:10.1097/01.inf.0000091292.24683.fc
24. Loh R, Phua M, Shaw C-KL. Management of paediatric acute mastoiditis: systematic review. *J Laryngol Otol*. 2018;132(2):96-104. doi:10.1017/S0022215117001840
25. Lahav J, Handzel O, Yehuda M, Gertler R, Halperin D. Postauricular needle aspiration of subperiosteal abscess in acute mastoiditis. *Ann Otol Rhinol Laryngol*. 2005;114(4):323-327. doi:10.1177/000348940511400412

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Smith ME, Jones GH, Hardman JC, et al; The INTEGRATE (The UK ENT Trainee Research Network) UK Acute Paediatric Mastoiditis Audit Collaborators. Acute paediatric mastoiditis in the UK before and during the COVID-19 pandemic: A national observational study. *Clin Otolaryngol*. 2022;47:120–130. https://doi.org/10.1111/coa.13869