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Original Article

Pediatric Acute Mastoiditis: Which Factors Influence CT Scan Prescription and Surgical Intervention? A Multivariate Analysis

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BACKGROUND: The aim of this study is to investigate factors associated with computed tomography (CT) scan prescription and surgical intervention in pediatric patients with acute mastoiditis (AM).

METHODS: Children with AM admitted to Modena University Hospital over a 10-year period were retrospectively divided into 3 groups: those who did not undergo a CT scan nor surgery (Group A); those who underwent a CT scan but not surgery (Group B); and those who underwent CT scan and surgery (Group C). A multivariate analysis was performed to determine possible differences among groups in terms of clinical and laboratory variables.

RESULTS: In total, 80 patients were included (57 Group A, 22 Group B, 13 Group C). Factors independently associated with CT scan prescription and surgical intervention were WBC count ($P = .015$ and .041, respectively), CRP ($P = .001$ and .003, respectively), and at-home antibiotic administration ($P = .008$ and .039, respectively).

CONCLUSION: Laboratory parameters may be helpful in guiding pediatric AM management. Antibiotic treatment prior to admission is associated with a worse clinical picture.

KEYWORDS: Mastoiditis, Otitis media, computerized tomography, children, middle ear, middle ear surgery.

INTRODUCTION

Since the introduction of antibiotics, the incidence of acute mastoiditis (AM) as a complication of otitis media has reduced substantially.[1] However, AM still represents the most common extracranial complication of otitis media during childhood and the rate of hospital admittance and need for surgical treatment is still high.[2,3,4] Suggested reasons include the emergence of antibiotic resistance with consequent selection of more virulent pathogens, for example, *Fusobacterium necrophorum*, *Pseudomonas aeruginosa*, *Staphylococcus aureus,* and *Streptococcus pyogenes* Group A,[5] associated with the incorrect and sometimes abusive use of antibiotics.[6]

In virtually all cases of otitis media, purulent or exudative material spreads from the middle ear to the mastoid via the aditus ad antrum. However, acute mastoiditis (AM) only occurs when mastoid drainage is inhibited, typically due to blockage of the aditus ad antrum by granulation tissue or mucosal swelling. In some cases, the infection may extend from the mastoid through the lateral bony cortex via emissary veins, leading to the formation of a subperiosteal abscess behind the ear. Less commonly, the infection may extend

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cranially, potentially causing meningitis, temporal lobe abscesses, or septic thrombosis of the lateral sinus; or into the neck, eroding the tip of the mastoid medially to the attachment of the sternocleidomastoid muscle. The extent and duration of antrum blockage, together with high bacterial virulence and decreased immune defenses, are crucial factors for the development of these complications.[7]

To date, there are no commonly accepted guidelines for the management of AM. In particular, the need to perform a CT scan has been an object of discussion among experts. Non-contrast CT imaging is the first imaging modality of choice in patients with AM, as it reveals most of the above-mentioned complications. Most authors agree on performing a CT scan only for patients presenting with clinical signs and symptoms suspicious for an impending complication, with the aim to determine the need and extent of surgery.[5] However, others advocate the need to perform a CT scan as an integral part of the work-up for every children with AM, as they claim that intracranial complications can be clinically silent and insidious in onset.[6,8] The well-known association between CT scan-related radiation exposure during childhood and cancer, however, raises doubts as to whether a CT scan is really necessary in all cases and calls for a more in-depth reflection on the topic.

The aim of this study was to present a 10-year experience in managing pediatric patients with AM at a tertiary referral center. Furthermore, the authors sought to retrospectively assess which clinical and laboratory parameters at the time of symptoms' onset were associated with subsequent CT scan prescription and surgical intervention.

MATERIALS AND METHODS

The present retrospective single-center study was conducted on children who were consecutively admitted to the pediatric emergency room for AM between January 2010 and December 2020 at Modena University Hospital, a tertiary referral center. Diagnosis was based in all cases on the following signs: otoscopic evidence of acute otitis media, presence of post-auricular swelling, redness or tenderness, and protrusion of the auricular pinna. Exclusion criteria were: age > 18 years, patients presenting with AM secondary to cholesteatoma, and patients whose clinical documentation was not available. All patients were examined by both a pediatrician and an otolaryngologist, and were all hospitalized. Intravenous (IV) antibiotic therapy was promptly initiated upon hospitalization. Antibiotic regimens included cephalosporins or meropenem in association with clindamycin or vancomycin. Clinical evaluation of the patients was carried out on a daily basis in all cases during hospitalization. A CT scan was performed in those patients who did not improve after medical treatment or when the presence of a complication was suspected. Surgery was performed in the subgroup of patients who underwent CT scan if the latter showed evidence of complications.

Medical charts of all patients were reviewed retrospectively, with a focus on demographic factors, prior medical conditions and treatments, presenting signs and symptoms, blood test results, radiological and surgical findings, and management.

Patients were divided into 3 groups: those who did not undergo either radiological assessment or surgical intervention (Group A), those who were subjected to a CT scan but were ultimately not surgically treated (Group B), and those who underwent CT scan and subsequent surgery (Group C). Clinical and anamnestic characteristics of the 3 groups were compared, and differences among them were assessed.

The statistical analysis of the results was performed using SPSS for Windows, version 29 (IBM SPSS Corp.; Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). Student's t-test was used for continuous variables with a normal distribution, while the Mann-Whitney *U* test was adopted for continuous variables without a normal distribution. Comparisons between groups were performed by Pearson's chi-square or Fisher exact test for discrete variables, as appropriate. For comparison of > 2 groups, a 1-way ANOVA was performed. The strength of the correlation between the parameters was obtained by Pearson's correlation test.

Finally, a multivariate analysis using a linear regression model was performed to evaluate the association between the different independent variables and the 2 main dependent variables: indication for CT scan and surgical intervention. Results were considered significant for P values < .05 with a confidence interval of 95%.

This study was approved by the Institutional Review Board of Modena University Hospital on May 15, 2022 (CER Emilia Romagna 0002183/22) and was carried out in accordance with the Declaration of Helsinki. Verbal informed consent was obtained from the subjects who agreed to take part in the study.

RESULTS

Eighty-three patients were initially enrolled, and, according to the exclusion criteria, data analysis was performed on 80 patients. Two patients were excluded for cholesteatoma, and one patient for incomplete clinical documentation. The mean age of the overall group was

MAIN POINTS

- Acute mastoiditis (AM) is the most common extracranial complication of otitis media during childhood, and the rate of hospital admittance and surgical treatment for AM is still high despite the introduction of antibiotic treatment.
- There is no consensus among experts as to whether a CT scan should be prescribed to all children with acute mastoiditis as opposed to those whose symptoms do not improve with medical therapy alone and/or in cases where complications are suspected.
- In the authors' cohort, where the latter strategy was implemented, the authors observed that patients who underwent CT scans (with or without subsequent surgical intervention) had higher WBC counts and higher CRP levels with respect to those who did not, suggesting that an alteration of these laboratory parameters often coincides with a more severe clinical picture.
- Furthermore, antibiotic administration prior to hospitalization was found to be an independent predictor of CT scan prescription (with or without subsequent surgical intervention) in the authors' cohort study, likely due to the selection of more virulent pathogens and/or masking of AM symptoms.
- In light of these results, it may be possible to prescribe a CT scan to children with AM based also on laboratory parameters and previous antibiotic administration, especially when the clinical picture is unclear.

4.53 years (±3.3 months; range: 2-120 months); 55 patients were male (68.75%) and 25 were female (31.25%). The right side was affected in 47 cases (58.7%), while the left side in 33 cases (41.3%). Two patients had a previous history of AM (medically managed). At presentation, one patient had signs of central nervous system (CNS) involvement with suspected meningitis, and one patient had incomplete facial nerve palsy. Forty-seven patients (58.7%) had fever, with a mean temperature of 38.3 °C (± 0.5; range: 37.6-39.5). At presentation, the mean white blood cell (WBC) count was 15.180 x 10^3/mm^3 (± 5.800; range: 0.620-35.400), the mean neutrophil count was 62.45% (±15.3; range: 20.8-88.5), and the mean C-reactive protein (CRP) was 7.8 mg/dL (±8; range: 0.1-43.1). Thirty-eight patients (47.5%) had already been treated with oral antibiotics at home for a mean duration of 3.2 days (±2.4; range: 1-8).

Group A consisted of 57 patients (71.25%). Twenty-two patients (Group B; 27.5%) had a CT scan prescribed during hospitalization, 12 of whom at presentation. The median time between hospital admission and CT scan performance was 24 hours (range: 0-72 hours). Clinical parameters prompting physicians to prescribe a CT scan were lack of clinical improvement with medical therapy (n = 13); prominent retro-auricular swelling with variable degrees of fluctuation (n = 9); facial nerve palsy (n = 1); suspicion of CNS involvement (n = 1).

Thirteen patients (Group C; 16.2%) were operated on, 6 of whom at presentation. The median time between hospital admission and surgical intervention was 48 hours (range: 0-120 h). Surgical intervention consisted of 3 cases of simple myringotomy ± tube placement and in the remaining 10 cases of tympano-mastoidectomy. Intra-operatively, the drainage of an abscess was required in 6 cases, and transverse sinus/jugular bulb thrombosis was observed in 3 cases. In 2 patients, a dural dehiscence was recognized and one patient had a post-operative cerebrospinal fluid leak that resolved spontaneously 3 days later. Patients with cerebral sinovenous thrombosis were treated with anticoagulation with low-molecular-weight heparin. The remaining 9 patients, who underwent CT scan but no surgical intervention, had preserved mastoid cells, no signs of bone erosion, or other complications on CT.

A clinical flowchart is described in Figure 1.

Mean length of hospitalization was 11.8 days (± 5.3; range: 7-22), and mean duration of antibiotic therapy (including at-home therapy upon discharge) was 15.8 days (± 5.3; range: 7-27).

When the clinical and laboratory parameters were compared among groups, the only statistical differences were found in CRP value and length of hospital stay. CRP value was significantly lower in Group A vs. both Group B and C (6.2 vs. 11.9 and 12.8, respectively; $P < .05$). Hospital stay was significantly longer in both Group B and C versus Group A (9.5 days and 11.8 days vs. 5.1 days; $P < .001$). Table 1 depicts differences in the aforementioned clinical parameters among the 3 groups.

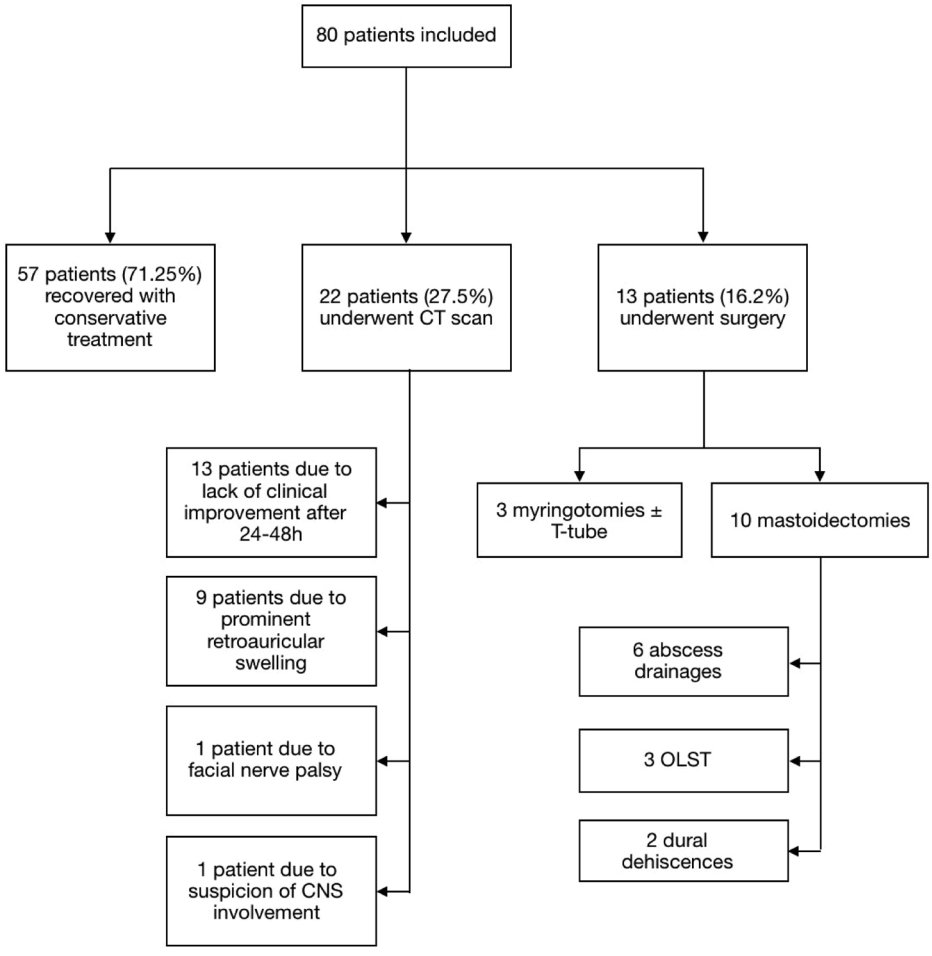

Figure 1. Clinical flowchart of included patients. OLST, otogenic Lateral sinus thrombosis.

Table 1. Clinical Parameters in the 3 Groups

Clinical Parameter	Group A	Group B	Group C	*P*
Mean age in years (SD; range)	4.9 (±3.5; 1-12)	3.4 (±2.4; 2- 11)	3.7 (± 2.6; 2-11)	.260
Male-to-female ratio	2.1	2.6	3.3	.809
Patients admitted with fever (%)	52.6	72.7	61.5	.264
Mean body temperature at admission in °C (SD; range)	38.4 (±0.6; 37.6-39.5)	38.4 (±0.4; 37.8-39.3)	38.4(±0.3; 38-39)	.961
Mean WBC in n°x10^3/mm^3 (SD; range)	15.2 (± 5; 7.1-32.2)	15.3 (±7.7; 0.62-35.4)	14.7 (±7.7; 0.62-26.5)	.957
Mean CRP in mg/dL (SD; range)	6.22 (±6; 0.1-25)	11.9 (±11.7; 0.22-43.1)	12.8 (12±; 0.22-43.1)	.045*
Mean neutrophil percentage	63.3 (±14; 20-88.5)	61 (±17; 33-87.4)	63 (±0.17; 33-87)	.954
Patients with previous home therapy (%)	51	36	46	.514
Mean length of hospitalization in days (SD; range)	5.1 (± 1.8; 3-11)	9.5 (±4.9; 4-22)	11.8 (±5.3; 7-22)	.0001*
Mean duration of antibiotic therapy in days (SD; range)	10.3 (± 2.9; 6-19)	13.8 (±4.9; 7-27)	15.8 (±5.3; 7-27)	.544

CRP, cationic reactive protein; WBC, white blood cell. *Statistically significant value.

Finally, in the multivariate analysis, the variables significantly associated with CT scan prescription and surgical intervention were: WBC count (*P* = .015 and .041, respectively), CRP value (*P* = .001 and .003, respectively), and at-home antibiotic administration (*P* = .008 and .039, respectively). Tables 2 and 3 depict results from the multivariate analysis.

DISCUSSION

No clear-cut indications exist in the literature regarding the indication to perform a CT scan in pediatric patients with AM. Some centers have an early CT scan as an integral part of their management protocol, while others reserve imaging studies for complicated cases.

Of note, the diagnosis of acute mastoiditis is based on clinical findings in the vast majority of ENT practices. Typical diagnostic criteria include fever, otalgia, otorrhea, protrusion of the auricle, external auditory canal and retroauricular swelling and erythema, and otoscopic evidence of concurrent or recent acute otitis media.[6-16] Therefore, IV antibiotic therapy, which is the mainstay of AM treatment, can and should be initiated even in the absence of radiologic confirmation. More to the point, most cases of uncomplicated acute mastoiditis resolve with medical management alone.[15,17,18] Surgical management (including myringotomy, myringotomy plus ventilation tube insertion, and cortical mastoidectomy[19]) of uncomplicated cases was not associated with more rapid recovery rates with respect to conservative treatment in a study by Zanetti and Nassif.[20] Recently, even the indication to perform minor surgical interventions, such as myringotomy, in patients with uncomplicated AM has been questioned.[21] For these reasons, in line with most data from the scientific literature, routine CT scan is not included in the diagnostic work-up of acute mastoiditis at the author's center.

Criteria that prompt physicians to urge a CT scan in children with acute mastoiditis include: lack of clinical improvement after 24-48 hours of intravenous antibiotic therapy; new onset of focal neurological signs; deterioration of general health status (e.g., lethargy, headache, and vomiting), all findings that are highly suggestive of an underlying complication; and also clinically diagnosed subperiosteal abscess and suspect of cholesteatoma.[6,9,15,16,18-24] To be more precise, with regard to subperiosteal abscesses, some authors have even suggested that a CT scan may be postponed until failure of a conservative approach with abscess puncture and drainage,[17,18,25] while others favor a CT scan in all cases where post-auricular signs or symptoms (pain, tenderness, and/or erythema) are present.[26]

Despite a tendency toward less interventional management of AM, some authors still claim that complications of acute mastoiditis, especially intracranial ones, can be insidious in onset, yet potentially lethal, and that their clinical presentation can be further silenced by antibiotic treatment. Thus, they advocate blanket imaging investigation with CT scans in all patients with AM.[11,13,27-31] As a matter of fact, in a series by Scorpecci et al, more than half of the children with otogenic lateral sinus thrombosis did not manifest external signs of AM,

Table 2. Multivariate Analysis of Possible Factors Associated with CT Scan Prescription

	Non-standardized Coefficients		Standardized Coefficients Beta	*t*	Significance	Confidence Interval 95%	
	B	Standard Deviation error				Inferior Limit	Superior Limit
Constant	0.947	4.821		0.196	0.845	−8.751	10.645
Age	−0.019	0.020	−0.122	−0.963	0.340	−0.059	0.021
Gender	−0.166	0.137	−0.155	−1.212	0.232	−0.442	0.110
WBC	−0.029	0.012	−0.388	−2.517	0.015*	-0.053	−0.006
CRP	0.026	0.007	0.514	3.452	0.001*	0.011	0.040
Body temperature	−0.018	0.125	−0.018	−0.147	0.884	−0.270	0.233
Previous antibiotic therapy	0.405	0.146	0.357	2.777	0.008*	0.112	0.698

CRP, cationic-reactive protein; WBC, white blood cell. *Statistically significant value.

Table 3. Multivariate Analysis of Possible Factors Associated with Surgical Intervention

	Non-standardized Coefficients		Standardized Coefficients Beta	*t*	Significance	Confidence Interval, 95%	
	B	Standard Deviation error				Inferior Limit	Superior Limit
Constant	0.408	4.609		0.089	0.930	−8.864	9.680
Age	−0.007	0.019	−0.046	−0.348	0.729	−0.045	0.032
Gender	−0.177	0.131	−0.189	−1.350	0.184	−0.0441	0.087
WBC	−0.024	0.011	−0.338	−2.105	0.041*	−0.046	−0.001
CRP	0.022	0.007	0.484	3.126	0.003*	0.008	0.036
Body temperature	−0.006	0.120	−0.006	−0.048	0.962	−0.247	0.235
Previous antibiotic therapy	0.296	0.139	0.284	2.120	0.039*	0.015	0.576

CRP, cationic-reactive protein; WBC, white blood cell. *Statistically significant value.

and mastoid involvement was detected only by neuroimaging.[32] It is worth mentioning, however, that unenhanced CT scan has a sensitivity of around 60% for detecting lateral sinus thrombosis,[33] which may be too low to be used as a screening test in patients with no clinical suspicion of this complication.

This hard-to-untangle debate gave rise to a number of studies aiming at identifying clinical predictors of acute mastoiditis complications, so as to limit the use of CT scans while avoiding serious complications going undiagnosed. For instance, Mansour and colleagues observed that patients with higher CRP on admission had a higher risk of developing intracranial complications from acute mastoiditis than their peers.[12] Higher CRP was found to be a risk factor for intracranial complications by other authors as well.[13,34] In line with these findings, Kvestad et al. observed CRP above 150 g/L and WBC count above 20×10^9/L at the time of hospital admission to be significant predictors for subsequent mastoidectomy.[35] Similarly, in a study comparing patients with acute mastoiditis who were surgically treated to a control group of patients who were successfully managed with conservative therapy alone, Stern Shavit and colleagues showed significantly higher average temperature, WBC, neutrophil count, and CRP at the time of hospital admission in the former group.[5]

In the present sudy's cohort, the authors observed a significant difference at multivariate analysis in total WBC count and CRP between patients who ultimately underwent a CT scan (with or without subsequent surgical treatment) and those who did not, suggesting that laboratory parameters often coincide with clinical features suggestive of complications and the need for surgical intervention. Given these premises, it may be reasonable to rely on clinical parameters to guide the management of pediatric patients with AM. Laboratory findings may come in handy to strengthen the indication to perform a CT scan, especially in borderline cases. When clinical findings do not clearly point to a complication, the presence of elevated WBC count and CRP may prompt the pediatrician and otolaryngologist to request a CT scan, as these parameters show a statistical association with complicated AM. Based on the above-mentioned considerations regarding CT scan sensitivity in diagnosing lateral sinus thrombosis, the authors suggest performing a contrast-enhanced CT scan in all cases where radiology is deemed necessary.

It has been suggested elsewhere that inappropriate antibiotic treatment prior to hospitalization may be associated with an increased risk of developing complications from AM.[12,28] The authors' findings may add some elements regarding this topic, as the authors observed that patients who were prescribed a CT scan and those who were ultimately surgically treated for complications had significantly higher rates of at-home antibiotic treatment administration prior to hospital admission compared to cases where a CT scan was not deemed necessary. Pre-hospitalization antibiotic treatment, especially when inappropriate and/or underdosed, may be responsible for masking the symptoms of AM, thereby delaying diagnosis and allowing the infection to spread. When these patients are finally referred to the otolaryngologist, their clinical picture may already be already advanced, thus requiring more aggressive management. Interestingly, in the present series, about 50% of patients who had a CT scan prescribed did so at presentation. Finally, broad-spectrum antibiotics may favor the selection of more virulent pathogens, thus increasing the risk of complications. Studies have shown that there are differences in the microbiology of acute mastoiditis with and without intracranial complications,[28] as well as between surgically treated patients and those who recovered with conservative treatment alone.[5]

This study suffers from some limitations, the main one being its retrospective nature. CT scans were not prescribed to patients with rapid clinical recovery upon conservative management and no signs or symptoms of intracranial complications, thereby making it impossible to compare CT scan and intra-operative findings among groups. Moreover, no information on the antibiotic home therapy was available. More data would be necessary to determine whether, in patients who were administered at-home antibiotics, the clinical picture eventually worsened in association with previous inappropriate antibiotic treatment.

In conclusion, at the authors' tertiary referral center, CT scans are prescribed to children with AM based on the basis of clinical criteria indicating an impending complication. Surgical intervention is planned according to the results of the imaging study. In the present study's' cohort, patients who were prescribed a CT scan and those who underwent surgical intervention had higher WBC count and CRP on admission than patients who did not require a CT scan nor surgical intervention. Laboratory parameters may be helpful in deciding AM management strategy in children, especially in borderline cases. In addition, the authors observed a significantly higher rate of antibiotic administration prior to hospitalization in patients who required CT (with or without subsequent surgical intervention) than in those

who did not, suggesting that at-home antibiotic use may mask initial signs of AM complications and favor the selection of more virulent pathogens.

Data Availability Statement: The data that support the findings of this study are available upon request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of Modena and Reggio Emilia (Approval no: 0002183/22, Date: May 15, 2022).

Informed Consent: Verbal informed consent was obtained from the subjects who agreed to take part in the study.

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