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Review

A scoping review of the management of acute mastoiditis in children: What is the best approach?

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ABSTRACT

Background. Acute mastoiditis (AM) is a severe infection of the mastoid air cells that occurs in cases of acute, sub-acute, or chronic middle ear infections. No definitive consensus regarding the management of AM has been identified. The current guidelines include a conservative approach (parenteral antibiotics alone, antibiotics plus minor surgical procedures such as myringotomy with a ventilation tube inserted or drainage of the subperiosteal abscess through retro-auricolar incision or needle aspiration) or surgical treatment (mastoidectomy). The main aim of this review was to evaluate and summarize the current knowledge about the management of pediatric AM by analyzing the current evidence in the literature.

Methods. We examined the following bibliographic electronic databases: Pubmed and the Cochrane Library, from the inception date until February 2023. The search was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISM). The key words used for the search across electronic databases were: 'mastoiditis' and 'management'; 'mastoiditis' and 'surgery'; 'mastoiditis' and 'conservative'; 'mastoiditis' and 'antibiotics'; 'mastoiditis' and 'myringotomy'; 'mastoiditis' and 'grommet'; 'mastoiditis' and 'drainage'; and 'mastoiditis' and 'mastoidectomy'.

Results. We selected 12 articles involving 1124 episodes of mastoiditis. Some of these studies considered medical therapy alone as a valid first step, whereas others considered a minor surgical intervention as an initial approach along with antibiotic therapy. Considering the studies that evaluated medical therapy as the initial sole treatment option, the success rate of antibiotics alone was 24.6%. Overall, the success rate of minor surgical procedures, excluding mastoidectomy, was 87.7%, whereas the mastoidectomy success rate was 97%.

Conclusions. Overall, there is no shared consensus on the diagnostic or therapeutic approach to mastoiditis. Conservative therapy has gained considerable ground in recent times, quite limiting the predominant role of mastoidectomy. Further studies will be necessary to definitely develop standardized protocols shared in the scientific community.

Key words: mastoiditis, children, management, antibiotics, mastoidectomy.

Acute mastoiditis (AM) is a severe infection of the mastoid air cells that occurs in cases of acute, sub-acute or chronic middle ear infections.[1] Even though the introduction of antibiotics has reduced the incidence of AM, it remains the main intratemporal complication of acute otitis media (AOM).[2] It involves about 1/400 cases (0.24%) of AOM, with an incidence varying from 1.2 to 6.1 per 100.000 children aged 0–14 years and a peak occurring at 2–3 years.[3,4] Clinical signs and symptoms are the first tool to identify AM and most authors agree that its diagnosis is clinical.[1] The diagnostic clinical criteria include characteristic findings: postauricular tenderness, erythema, swelling with loss of the postauricular crease, fluctuance and protrusion of the auricle, tympanic membrane modifications.[5-7] Ear

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pain is sometimes replaced by irritability or lethargy in younger children, and fever and ear discharge may also occur.[8,9] Radiological imaging should be considered in patients with compromised general conditions and altered laboratory findings, in patients not responding to conservative treatment within 48 hours, if surgery is considered, or in the suspicion of complications.[3,9-11] Computerized tomography (CT) has traditionally been the initial imaging technique for AM, especially for bony structures, while magnetic resonance imaging (MRI) is more commonly applied to evaluate soft tissues and intracranial structures.[12-14] CT examinations are widely used because of their speed, accessibility, and high quality. Generally, they do not require sedation. MRI is more expensive, requires longer time to execute, and is not available in all medical centers.[10] Despite these drawbacks, MRI is the gold standard for suspected intracranial complications (ICCs), especially for extra-axial fluid collections and associated vascular lesions. Furthermore, it is useful to evaluate the equivocal lesions found on a CT scan.[8,15,16] In the last few years, several studies have investigated the necessity of imaging in diagnosing AM versus solely using clinical criteria. No definitive consensus regarding the role of imaging in the diagnosis of AM has been identified.[17] No definitive consensus on the treatment of AM has been established either. The current guidelines include a conservative approach (parenteral antibiotics alone, antibiotics plus minor surgical procedures such as myringotomy with a ventilation tube inserted or drainage of the subperiosteal abscess through retro-auricolar incision or needle aspiration) or surgical treatment (mastoidectomy).[4] AM generally requires parenteral antimicrobial therapy for 7 to 10 days and then transition to oral antibiotics to complete a four-week course.[7,17] Empiric therapy is based on epidemiological data, a history of recurrent AOM or recent antibiotic therapy. When cultures and microbiologic results are obtained, antimicrobial therapy should be adjusted consequently.[4] Drainage procedures consist of myringotomy, with or without placement of tympanostomy tubes (TTs), and retro-auricular needle aspiration or incision. Myringotomy implicates a surgical perforation of the tympanic membrane, along with the TTs placement, allowing effective drainage over a longer duration than myringotomy alone. Retro-auricular needle aspiration or incision is an effective modality for the drainage of subperiosteal abscesses. Mastoidectomy is the surgical removal of the mastoid cortical bone and underlying air cells.[7] In the last few years, a conservative approach has been preferred over surgical treatment, even if surgery remains the main choice in the management of AM, especially if no improvement is observed within 48 hours.[4,18-20] The main aim of this review was to evaluate and summarize the current knowledge about the management of pediatric AM by comparing and analyzing the current evidence in the literature.

Materials and Methods

Data sources

We examined the following bibliographic electronic databases: Pubmed and the Cochrane Library, from the inception date until February 2023. The search was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISM) and was limited to English-language papers that focused on AM in pediatric patients.[21] To be considered eligible for the review, papers had to include the following criteria: (1) children with a diagnosis of AM; (2) who received conservative or surgical treatment; and (3) outcomes based on follow-up assessment. We excluded: 1) non-English language papers; 2) studies in which "conservative" or "surgical" options were not specified; and 3) studies involving patients with co-existing cholesteatoma, chronic mastoiditis, or cochlear implants. The key words used for the search across electronic databases were: 'mastoiditis' and 'management'; 'mastoiditis' and 'surgery'; 'mastoiditis' and 'conservative'; 'mastoiditis' and 'antibiotics'; 'mastoiditis' and 'myringotomy'; 'mastoiditis' and 'grommet';

'mastoiditis' and 'drainage'; and 'mastoiditis' and 'mastoidectomy'. The abstracts of the papers were assessed by two reviewers (LDS and IC), who strictly applied the inclusion and exclusion criteria mentioned above in order to decide whether a paper was eligible for full review. Each paper that met the eligibility criteria was reviewed and analyzed in full text by two authors (LDS and IC), and any discrepancies among them were solved by debate.

Study selection

Overall, we identified 480 records through database searching. As a first step, we excluded 50 articles not in English, 10 records whose related articles were not available, 5 articles concerning ongoing trials, and 200 duplicate papers. As a second step, we eliminated 175 records by evaluating only titles and abstracts because they did not match the inclusive criteria mentioned above. Of the remaining 40 studies, we excluded 28 through a further discussion among authors regarding the reliability of the data. Thus, 12 selected articles were included in the review.

The detailed selection of literature is shown in Fig. 1.

A wide and extensive summary of the results is shown in Tables I and II.

Data extraction

The data extracted from each eligible paper included: study population sample, mean age, sex prevalence, study design, radiological imaging performed, type of AM treatment, type of complications, microbiological cultures, and antibiotics adopted. Studies were grouped into those that evaluated medical therapy as the initial sole treatment and those that evaluated surgery as the initial treatment option along with medical therapy.

In this review, we analyzed the current literature on the management of AM in children. Thus, ethical approval was not required.

Results

The papers included 1124 episodes of mastoiditis. The CT scan examination rate greatly differs among the different papers, varying from 0.4% to 100%, with a mean percentage of 29.09%. MRI was used only in four studies, with a percentage of 29%, 8.5%, 7.7%, and 0.9%, respectively.

Some of these studies considered medical therapy alone as a valid first step, whereas others considered a surgical intervention, either drainage or mastoidectomy, since the beginning along with antibiotic therapy.[11,20,22-31] In the first group, the percentage rate of episodes treated with antibiotic therapy alone as the first step was 48% (278 episodes). Focusing on the first therapeutic approach, the overall percentage rates concerning different drainage procedures (including myringotomy or myringotomy with placement of the tympanostomy tube and retro-auricolar needle aspiration or incision) and mastoidectomy were respectively 38.6% (434 episodes) and 36.4% (409 episodes).

Considering the studies that evaluated medical therapy as the initial sole treatment option, the success rate of antibiotics alone was 24.6%. Overall, the success rate of minor surgical procedures, excluding mastoidectomy, was 87.7% whereas the mastoidectomy success rate was 97% among the included papers.

Concerning the microbiological cultures obtained, *Streptococcus pneumoniae* was the most common bacterium identified (31.3%), alone or in association with other pathogens. At lower rates, *Streptococcus pyogenes (9.8%), Staphylococcus aureus (2.6%), Haemophilus influenzae (3.9%)* and *Pseudomonas aeruginosa (4%)* were commonly detected as well. Considering the high incidence of *Streptococcus pneumoniae* and its susceptibility to beta-lactam antibiotics, cephalosporins such as ceftriaxone sodium and cefotaxime were mostly adopted.[23,28] Subsequent changes or the addition of another type of antibiotic, especially in polymicrobial infections, were made according to cultures and antibiograms.

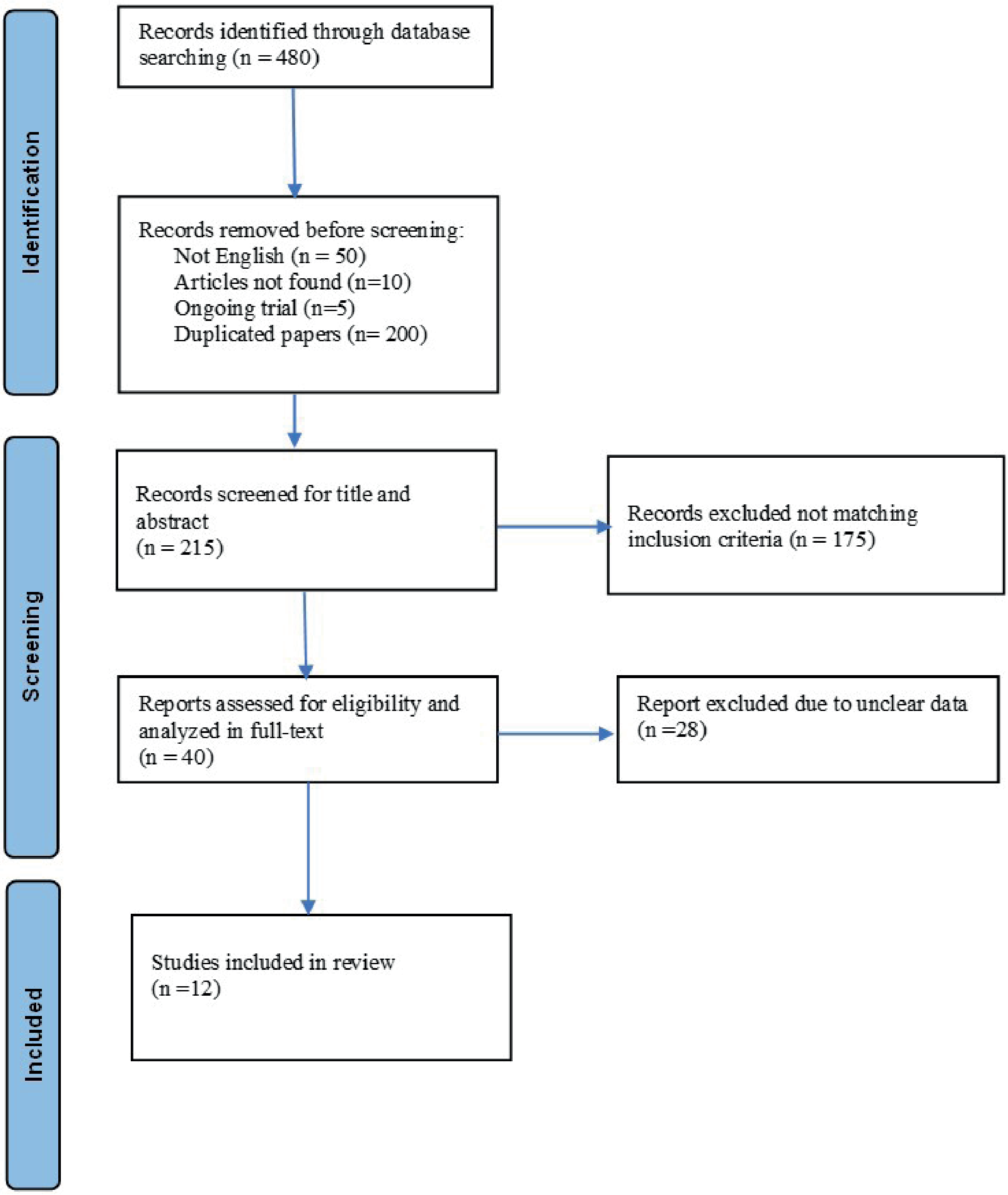

Fig. 1. The detailed summary of the literature search.

Table I. Studies that evaluated medical therapy as the initial sole treatment option.

Study	Sample size and sex (N) Mean age Imaging, n (%)	Treatment	Cultures	Antibiotics adopted	Complications
Gorphe et al. (2011)*	36 31.8 mo CT 36 (100%)	1 IV AB (2.8%), 8 IV AB + TT (22.2%), 3 IV AB + TT + puncture (8.3%), 24 IV AB + TT + mastoidectomy (66.7%)	13 *S. pneumoniae* (36.1%), 5 *S. pyogenes* (13.9%), 5 *S. epidermidis* (13.9%), 3 *P. aeruginosa* (8.3%), 3 *F. necroforum* (8.3%), 1 *H. influenzae* (2.8%)*	CTX and FOS (+ AG if anaerobic infection; + MET in case of *F. necroforum*)	26 subperiosteal abscess (72.2%), 1 Bezold syndrome (2.7%), 4 lateral sinus thromboses (11.1%), 2 subdural empyema (5.5%)
Quesnel et al. (2010)	188 (M: 108, F: 80) 15 mo CT 68 (36.2%)	120 AB alone (monotherapy in 74.5% and a bitherapy in 25.5%), 68 surgery (36.2%): 62 Mastoidectomy (91.2%), 6 Simple drainage of retro auricular abscess (8.8%)	87 *S. pneumoniae* (51%), 20 *S. pyogenes* (11.5%), 3 Other streptococci (1.8%), 11 Anaerobes (6.5%), 13 CNS (7.6%), 8 *H. influenzae* (4.5%), 8 *P. aeruginosa* (4.5%), 7 GNB (4%), 6 *S. aureus* (3.5%), 4 Corynebacteria (2.5%), 4 *T. otitidis* (2.5%)	186 β-lactam AB (100%): 159 CTR (85.5%), 24 CTX (13%), 1 CTZ (0.5%), 2 AMC (1%); 119 AG (64%), 50 FOS (27%), 34 MET (19%), 12 CLI (6.4%), 8 RIF (4.3%), 1 VAN (0.5%)	6 lateral sinus thrombosis (3.2%), 1 Transient balance disorder (0.5%)
Duygu et al. (2020)	28 (M: 16, F: 12) 80.4 mo CT 28 (100%), MRI 8 (29%) in suspected intracranial complications	3 Medical (10.7%), 8 Ventilation tube (28.6%), 8 Ventilation tube + Drainage (28.6%) , 9 Ventilation tube + Mastoidectomy (32.1%)	9 None (32.1%), 12 *S. pneumoniae* (42.9%), 2 *S. pyogenes* (7.1%), 1 *S. maltophilia* (3.6%), 1 *P. aeruginosa* (3.6%), 1 *P. mirabilis* + *E. coli* (3.6%), 1 Enterococci (3.6%), 1 Aspergillus spp. (3.6%)	16 CTR as monotherapy (57.1%); VAN, depending on clinical symptoms or culture results.	8 Subperiosteal abscess (28%), 7 Facial paralysis (25%), 5 Meningitis (17%), 2 Meningitis and sigmoid sinus thrombosis (7.1%), 1 Meningitis and cerebellar abscess (3.5%)

All listed studies were retrospective except for that by Shrestha et al. (2021), which was a prospective observational study.
*Antimicrobial susceptibility was mentioned in the study by Gorphe et al (2011) as follows: *S. pneumoniae* PEN G: 9 sensitive (69%) 4 resistant (31%); AMO: 13 sensitive (100%); CTX: 13 sensitive (100%); ERY: 3 sensitive (23.1%), 10 resistant (76.9%); PRI: 10 sensitive (77%), 3 resistant (23%). *S. pyogenes* Sensitive to: PEN G, AMO, RIF, VAN; Resistant to: TMP-SMX. *S. epidermidis* Sensitive to: AG, RIF, FOS, OFL, VAN, TMP-SMX; Resistant to: PEN G and INN. *F. necroforum* Sensitive to: AMO, AMC, MET. Resistant to: VAN. *P. aeruginosa* Sensitive to: PIP, CTZ, AG, TIC and TIM. Resistant to: FOS.
AB: antibiotics, AG: aminoglycosides, AMC: amoxicillin-clavulanic acid, AMO: amoxicillin, CLI: clindamycin, CN: cranial nerve, CNS: coagulase-negative staphylococci, CRX: cefuroxime, CTR: ceftriaxone, CTX: cefotaxime, CT: computerized tomography, CTZ: ceftazidime, Dexa: dexamethasone, ERY: erythromycin, F: female, FOS: fosfomycin, GEN: gentamycin, GNB: Gram-negative bacilli, INN: methicillin, IV: intravenous, M: male, MET: metronidazole, mo: months, MRI: magnetic resonance imaging, OFL: ofloxacin, PEN: penicillin, PIP: piperacillin, PRI: pristinamycin, RIF: rifampicin, TIC: ticarcillin, TIM: ticarcillin-clavulanic acid, TMP-SMX: trimethoprim-sulfamethoxazole, TT: tympanostomy tube, VAN: vancomycin.

Table I. Continued.

Study	Sample size and sex (N) Mean age Imaging, n (%)	Treatment	Cultures	Antibiotics adopted	Complications
Shrestha et al. (2021)	79 (M: 49, F: 30) 111.84 mo CT 13 (16.4%)	41 Parenteral AB alone (51.9%), 25 Myringotomy or incision and drainage (31.6%), 13 Mastoidectomy along with injectable antibiotics and myringotomy or incision and drainage (16.5%)	16 *S. pneumoniae* (53%), 8 *P. aeruginosa* (26%), 3 *S. pyogenes* (10%), 3 *S. aureus* (10%)	3rd-gen cephalosporin with or without MET	21 Subperiosteal abscess (26%), 1 Facial nerve palsy (1.2%)
Mierzwiński et al. (2019)	73 (M: 35, F: 38) Mean age and imaging numbers not mentioned. Imaging only in case of suspicion of intracranial complications.	9 Medical therapy (11%), 10 Tympanostomy / Myringotomy (12%), 56 Mastoidectomy + Tympanostomy (67%), 8 Mastoidectomy only (10%)	28 *S. pneumoniae* (33.7%), 13 *S. pyogenes* (15.7%), 3 *P. aeruginosa* (3.6%), 3 *H. influenzae* (3.6%), 2 *C. albicans* (2.4 %), 1 *E. coli* (1.2%), 1 *A. baumannii* (1.2%) 1 *E. faecalis* (1.2%), 1 *S. aureus* (1.2%), 1 *M. catarrhalis* (1.2%)	3rd-gen cephalosporin (CTR or CTX) with CLI or MET	1 Epidural abscess (1.2%), 4 Sigmoid sinus Thrombophlebitis (5%), 1 Petrositis (1.2%), 1 Facial paralysis (1.2%)

All listed studies were retrospective except for that by Shrestha et al. (2021), which was a prospective observational study.

*Antimicrobial susceptibility was mentioned in the study by Gorphe et al (2011) as follows: *S. pneumoniae* PEN G: 9 sensitive (69%) 4 resistant (31%); AMO: 13 sensitive (100%); CTX: 13 sensitive (100%); ERY: 3 sensitive (23.1%), 10 resistant (76.9%); PRI: 10 sensitive (77%), 3 resistant (23%). *S. pyogenes* Sensitive to: PEN G, AMO, RIF, VAN; Resistant to: TMP-SMX. *S. epidermidis* Sensitive to: AG, RIF, FOS, OFL, VAN, TMP-SMX; Resistant to: PEN G and INN. *F. necroforum* Sensitive to: AMO, AMC, MET. Resistant to: VAN. *P. aeruginosa* Sensitive to: PIP, CTZ, AG, TIC and TIM. Resistant to: FOS.

AB: antibiotics, AG: aminoglycosides, AMC: amoxicillin-clavulanic acid, AMO: amoxicillin, CLI: clindamycin, CN: cranial nerve, CNS: coagulase-negative staphylococci, CRX: cefuroxime, CTR: ceftriaxone, CTX: cefotaxime, CT: computerized tomography, CTZ: ceftazidime, Dexa: dexamethasone, ERY: erythromycin, F: female, FOS: fosfomycin, GEN: gentamycin, GNB: Gram-negative bacilli, INN: methicillin, IV: intravenous, M: male, MET: metronidazole, mo: months, MRI: magnetic resonance imaging, OFL: ofloxacin, PEN: penicillin, PIP: piperacillin, PRI: pristinamycin, RIF: rifampicin, TIC: ticarcillin, TIM: ticarcillin-clavulanic acid, TMP-SMX: trimethoprim-sulfamethoxazole, TT: tympanostomy tube, VAN: vancomycin.

Table I. Continued.

Study	Sample size and sex (N) Mean age Imaging, n (%)	Treatment	Cultures	Antibiotics adopted	Complications
Mather et al. (2020)	47 (sex not mentioned) 42 mo CT alone 10 (21.2%), MRI alone 1 (2.12%), CT and MRI 3 (6.38%), Ultrasound alone 1 (2.12%) (CT not tolerated)	20 Pharmacological treatment alone (40%), 9 Cortical mastoidectomy with myringotomy and grommet insertion (18%), 9 Cortical mastoidectomy alone (18%), 6 incision and drainage (12%), 2 myringotomy and grommet alone (4%), 3 combined approaches with neurosurgical input (6%)	3 *P. aeruginosa* (6%), 4 *S. pyogenes* (8%), 3 *S. pneumoniae* (6%), 3 *F. necrophorum* (6%), 2 *H. influenzae* (4%), 1 *S. haemolyticus* + *S. mitis* (2%), 1 *S. aureus* alone (2%), 1 Group A streptococci in blood culture only (2%)	14 AMC alone, 5 AMC & Dexa drops, 2 AMC & GEN drops, 2 AMC and MET with OFL drops, 18 Other combination, 8 Not documented	3 Sigmoid sinus thrombosis (6.1%), 2 Extradural abscess (4.1%), 1 7th CN palsy (2%), 1 Internal jugular vein thrombus (2%), 1 Cerebellar abscess (2%), 1 Masseter abscess (2%), 1 Wound granulation (2%), 1 Wound dehiscence (2%), 1 Wound infection, 1 Meningitis (2%), 1 Temporal lobe abscess (2%), 1 Submastoid empyema (2%), 1 Sensorineural hearing loss (2%)
Katz at al. (2003)	101 (M: 61, F: 40) 25 mo CT 54 (47 %)	72 Pharmacological therapy alone (62%), 32 Mastoidectomy (27.5%), 12 Ventilation tube placement (12%)	13 *S. pneumoniae* (38%), 9 *S. pyogenes* (26%), 6 *H. influenzae* (18%), 4 *P. aeruginosa* (12%), 2 *E. coli* (6%)	CRX (49%), CTR (30%), AMC (15%), MET (8%), CTZ (7%)	8 Subperiosteal abscess (7%), 2 Lateral sinus thrombosis (2%)

All listed studies were retrospective except for that by Shrestha et al. (2021), which was a prospective observational study.
*Antimicrobial susceptibility was mentioned in the study by Gorphe et al (2011) as follows: *S. pneumoniae* PEN G: 9 sensitive (69%) 4 resistant (31%); AMO: 13 sensitive (100%); CTX: 13 sensitive (100%); ERY: 3 sensitive (23.1%), 10 resistant (76.9%); PRI: 10 sensitive (77%), 3 resistant (23%). *S. pyogenes* Sensitive to: PEN G, AMO, RIF, VAN; Resistant to: TMP-SMX. *S. epidermidis* Sensitive to: AG, RIF, FOS, OFL, VAN, TMP-SMX; Resistant to: PEN G and INN. *F. necroforum* Sensitive to: AMO, AMC, MET. Resistant to: VAN. *P. aeruginosa* Sensitive to: PIP, CTZ, AG, TIC and TIM. Resistant to: FOS.
AB: antibiotics, AG: aminoglycosides, AMC: amoxicillin-clavulanic acid, AMO: amoxicillin, CLI: clindamycin, CN: cranial nerve, CNS: coagulase-negative staphylococci, CRX: cefuroxime, CTR: ceftriaxone, CTX: cefotaxime, CT: computerized tomography, CTZ: ceftazidime, Dexa: dexamethasone, ERY: erythromycin, F: female, FOS: fosfomycin, GEN: gentamycin, GNB: Gram-negative bacilli, INN: methicillin, IV: intravenous, M: male, MET: metronidazole, mo: months, MRI: magnetic resonance imaging, OFL: ofloxacin, PEN: penicillin, PIP: piperacillin, PRI: pristinamycin, RIF: rifampicin, TIC: ticarcillin, TIM: ticarcillin-clavulanic acid, TMP-SMX: trimethoprim-sulfamethoxazole, TT: tympanostomy tube, VAN: vancomycin.

Table II. Studies that evaluated surgery as the initial treatment option along with the medical therapy.

Study	Sample size and sex (N) Mean age Imaging, n (%)	Treatment	Cultures	Antibiotics adopted	Complications
Bakhos et al. (2011)	50 (M: 29, F: 21) 32 mo CT 43 (86%)	16 Mastoidectomy (34%), 34 AB combined with retroauricular puncture and grommet insertion (37%)	6 No growth (19%), 19 *S. pneumoniae* (61%), 4 *S. pyogenes* (12%), 1 *S. chromogenes* (3%), 1 *F. necroforum* (3%)	CTR was the most used (64%) combined with FOS or MET	31 subperiosteal abscess (62%), 3 sigmoid sinus thrombosis (6%), 1 subdural empyema (2%), 1 facial palsy (2%)
Anthonsen et al (2013)*	214 (M: 112, F: 102) 25.2 mo CT 1 (0.4%)	183 explorative myringotomy (simple drainage) (86%), 66 insertion of a ventilation tube (31%), 67 mastoidectomy (31%)	63 No growth (29%), 46 *S. pneumoniae* (21.6%), 29 Skin flora (13.6%), 15 *P. aeruginosa* (7%), 15 *S. pyogenes* (7%), 10 *S. aureus* (4%), 10 *H. influenzae* (4%), 9 Corynebacteria (4%), 3 Other streptococci (1.4%), 1 Aspergillus (0.5%), 12 Other (5.5%)	62 PEN (29%), 55 AMP (26%), 43 CRX (20%)	68 subperiosteal abscesses (32%), 1 vertigo (0.5%), 1 facial nerve paresis (0.5%), 1 spreading of the infection to the eye and facial region (0.5%), 1 larger perforation of the tympanic membrane (0.5%)
Enoksson et al (2015)	115 34.5 mo, 38.7 mo and 49.5 mo in Group 1, 2, and 3 resp. CT 45 (39%)	115 AB during hospitalization, 0 AB alone Group 1 – 33 needle aspiration (17 only needle aspiration, 10 aspiration and incision, 6 only incision) and/or incision of the abscess (28%) Group 2 – 67 mastoidectomy (47 with previous myringotomy) (58%) Group 3 - 15 needle aspiration and mastoidectomy (13%)	16 *S. pyogenes* (19%), 46 *S. pneumoniae* (56%), 26 Negative (32%)	Not mentioned	3 perforations of the eardrum (2.6%), 3 mild sensorineural hearing loss (2.6%)

All listed studies were retrospective.
*Anthonsen et al (2013) reported antibiotic sensitivity as: 94% sensitive to penicillin, 93% sensitive to Amp
**Zavras et al (2020) reported antibiotic sensitivity of *S. pneumoniae* as PEN-sensitive in 4 (80%) samples, Pen-resistant and cefotaxime-sensitive in 1 (20%) sample.
AB: antibiotics, AMC: amoxicillin-clavulanic acid, AMP: ampicillin, AMS: ampicillin-sulbactam, AZT: aztreonam, CLI: clindamycin, CNS: coagulase-negative staphylococci, CRX: cefuroxime, CT: computerized tomography, CTR: ceftriaxone, CTX: cefotaxime, F: Female, FOS: fosfomycin, M: male, MET: metronidazole, mo: months, MRI: magnetic resonance imaging, MRV: magnetic resonance venography, PEN: penicillin.

Table II. Continued.

Study	Sample size and sex (N) Mean age Imaging, n (%)	Treatment	Cultures	Antibiotics adopted	Complications
Psarommatis et al. (2012)	155 (M: 106, F: 49) 36.7 mo CT 18 (11.6%), MRI 7 (4.5%), CT and MRI/MRV 5 (3.2%)	112 Myringotomy alone (72.3%), 21 abscess drainage (13.5%), 22 Myringotomy + simple mastoidectomy (14.1%), 43 Mastoidectomy as further intervention due to poor response to myringotomy or drainage (37%)	63 *S. pneumoniae* (40.6%), 25 CNS (16.1%), 16 *S. pyogenes* (10.3%), 14 *H. influenzae* (9%), 9 Anaerobes (5.8%), 8 *S. aureus* (5.2%)	149 3rd-gen cephalosporin: (CTX or CTR) and CLI (The 3rd-gen cephalosporin was replaced by AZT in three penicillin allergic children and the combination AMC + CLI was used in two children.), 3 AMC, 2 AMS,1 2nd gen cephalosporin	34 Subperiosteal abscesses (29.5%), 3 Epidural abscess (1.9%), 1 Brain abscess (0.6%), 2 Sigmoid sinus thrombosis (1.2%), 1 Brain abscess plus epidural abscess (0.6%), 1 Brain abscess plus perisinus abscess/ sigmoid sinus thrombosis (0.6%), 1 Epidural abscess plus sigmoid sinus thrombosis (0.6%), 4 Facial nerve paralysis (2.4%)
Zavras et al. (2020)**	11 (M: 6, F: 5) 4.7 mo	11 Myringotomy and ipsilateral needle aspiration of the post-auricular area (100%), 4 Antrotomy (18.2%), 4 Incisional drainage (18.2%)	5 *S. pneumoniae* (45.5%), 4 *S. pyogenes* (36.3%)	CTX and CLI	8 Subperiosteal abscess (36.4%)

All listed studies were retrospective.
*Anthonsen et al (2013) reported antibiotic sensitivity as: 94% sensitive to penicillin, 93% sensitive to Amp
**Zavras et al (2020) reported antibiotic sensitivity of *S. pneumoniae* as PEN-sensitive in 4 (80%) samples, Pen-resistant and cefotaxime-sensitive in 1 (20%) sample.
AB: antibiotics, AMC: amoxicillin-clavulanic acid, AMP: ampicillin, AMS: ampicillin-sulbactam, AZT: aztreonam, CLI: clindamycin, CNS: coagulase-negative staphylococci, CRX: cefuroxime, CT: computerized tomography, CTR: ceftriaxone, CTX: cefotaxime, F: Female, FOS: fosfomycin, M: male, MET: metronidazole, mo: months, MRI: magnetic resonance imaging, MRV: magnetic resonance venography, PEN: penicillin.

Discussion

Acute mastoiditis is a complication of acute AOM, in which there is inflammation of the mastoid periosteum and air cells.[32] Despite the widespread use of antibiotics and vaccines, AM is still a growing complication in children because of rising antibiotic resistance. The introduction of a pneumococcal conjugate vaccine in 2000, rapidly substituted by a polyvalent version, has widely lowered the rate of pneumococcal AOM.[33] In contrast to these data, no reduction has been recorded in the rate of pneumococcal AM.[3] As a matter of fact, *Streptococcus pneumoniae* remains the main pathogen detected in this review as well. Koutouzis et al.[34] in a retrospective study involving 334 children, compared the rate of pneumococcal mastoiditis before and after the introduction of PCV7 and PCV13, documenting no significant differences, probably due to a possible pneumococcal serotype replacement. In the papers analyzed in this review, no specific data on the pneumococcal vaccination status of patients was available. Since these studies were set in different timeframes and countries, we were not able to assess the impact of pneumococcal vaccination on the prevention of mastoiditis.

As mentioned above, there is no gold standard for the management of pediatric AM in terms of the radiological examination performed and treatment. The use of CT scans in the diagnostic process is still a controversial issue today. In the studies we analyzed, the CT scan examination rate greatly differed among papers, implying a heterogeneous radiological approach. Pediatric patients are particularly susceptible to radioactivity, and a CT scan enhances the risk of developing a tumor in a considerable way. This is why some pediatricians, especially in Denmark, desist from using this examination as a routine.[29] Other authors suggest that CT should be a standard procedure in the diagnosis of every AM. In fact, Vassbotn et al.[35] showed in their retrospective study in 2002 that clinical examination revealed only 50% of the cases with surgically proven subperiostal abscesses, recommending a CT scan of every patient treated conservatively. The majority of authors, however, support the opinion that imaging exams should be limited to selected circumstances: neurologic signs, deterioration of the general state, suspicion of intracranial complications, and unresponsiveness to conservative treatment.[28]

Third-generation cephalosporins have been the main antibiotics prescribed among the mentioned papers.[23,28,36] These data are in line with others reported in the literature.[37,38] Edwards et al.[39] in a retrospective study in 2022, emphasized how broad-spectrum antibiotics have been used in this clinical scenario in contrast with microbiological evidence. As a matter of fact, in their paper, vancomycin was widely adopted, even though methicillin-resistant *Staphylococcus aureus* was detected in a negligible number of cultures. In this regard, appropriate antibiotic stewardship with microbiological cultures is an essential tool to treat the underlying pathogen and avoid antibiotic resistance. A major contribution to antibiotic resistance could be due to AOM home therapy. Despite the fact that amoxicillin alone is considered the first line in patients with AOM, Balsamo et al. pointed out how the majority of cases are treated at home with amoxicillin plus clavulanic acid. The abuse of amoxicillin and clavulanic acid in non-hospitalized patients might have triggered a rise in resistant pathogens. However, more studies are needed to confirm this correlation.

As regards treatment, historically, the surgical approach in terms of mastoidectomy has been the most applied, but more recently, many authors have supported the conservative approach considering the surgical complications amongst children.[35] Parenteral antibiotic therapy alone is reported to be successful in some reports.[18,23] In other patients, antimicrobial therapy alone may not be sufficient, especially in the later stages of the disease, when it becomes more challenging to reach adequate antibiotic levels in deep bony tissues.

By tradition, there seems to be an established consensus on performing mastoidectomy if a subperiosteal abscess is encountered, but it still remains a matter of controversy.[28-31] Shrestha et al.[25] and Psarommatis et al.[11] in their studies, treated subperiosteal abscesses mostly by adopting a conservative approach.

Furthermore, there is no solid evidence regarding factors predicting the severity or evolution of AM complications.[32] Subsequently, management decisions cannot be based on a specific validated algorithm. Actually, treatment is based on the decision of the pediatrician; some of them predilect surgery right away, whereas others opt for medical therapy before considering surgery. In this review, medical therapy as the initial sole treatment showed a success rate of 24.6%. In this cluster of studies, medical therapy alone was probably preferred because of a less severe disease, and this could have overestimated this percentage. The success rate of minor surgical procedures, excluding mastoidectomy, was 87.7% in line with other data reported in the literature.[32] Mastoidectomy had almost a 100% success rate, both as a first-line treatment and as a second step after pharmacological therapy or minor procedures. One crucial issue is which treatment is best for AM in terms of efficacy and safety. The current data is not sufficient to answer this question. There is not enough evidence on efficacy to recommend for or against any of these techniques.

Although a validated standardized protocol is not available, according to our data, medical therapy with or without myringotomy as an initial treatment seems to be appropriate in good clinical conditions. As soon as the patient's conditions get clinically worse, a mastoidectomy can be performed.

The drawbacks of our review are included in the limits of the articles involved. The main limitations are the heterogeneity of study designs, the divergence among the different types of interventions, and the different durations of follow-up.

Overall, there is no shared consensus either on the diagnostic approach nor on the therapeutic one of mastoiditis. Conservative therapy has gained considerable ground in recent times, quite limiting the predominant role of mastoidectomy.

Further studies including a wide range of patients will be necessary to definitely develop standardized protocols shared in the scientific community.

Ethical approval

No ethical approval was required.

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: Lorenzo Di Sarno, Ignazio Cammisa and Antonio Chiaretti, data collection: Lorenzo Di Sarno and Ignazio Cammisa, analysis and interpretation of results: Lorenzo Di Sarno and Ignazio Cammisa, draft manuscript preparation: Lorenzo Di Sarno, Ignazio Cammisa, Gemma Eftimiadi, Antonio Gatto, Antonietta Curatola, Valeria Pansini. All authors reviewed and approved the final version of the manuscript.

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Conflict of interest

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