

# Differentiating Acute Otitis Media and Acute Mastoiditis in Hospitalized Children

Anu Laulajainen-Hongisto<sup>1,2</sup> · Antti A. Aarnisalo<sup>1</sup> · Jussi Jero<sup>1</sup>

Published online: 10 September 2016  
© Springer Science+Business Media New York 2016

**Abstract** Acute otitis media is a common infection in children. Most acute otitis media episodes can be treated at an outpatient setting with antimicrobials, or only expectant observation. Hospital treatment with parenteral medication, and myringotomy or tympanostomy, may be needed to treat those with severe, prolonged symptoms, or with complications. The most common intratemporal complication of acute otitis media is acute mastoiditis. If a child with acute mastoiditis does not respond to this treatment, or if complications develop, further examinations and other surgical procedures, including mastoidectomy, are considered. Since the treatment of complicated acute otitis media and complicated acute mastoiditis differs, it is important to differentiate these two conditions. This article focuses on the differential diagnostics of acute otitis media and acute mastoiditis in children.

**Keywords** Acute otitis media · Acute mastoiditis · Pediatric · Ear infection

## Introduction

Acute otitis media (AOM) is one of the most common infections in children. Since spontaneous resolution of AOM occurs in

80 % within 2–3 days of symptom onset, children with no known risk for complications can simply be followed [1]. Small children are, however, known to benefit from antimicrobial treatment which reduces symptoms, shortens the duration of middle ear effusion (MEE), and leads to fewer hearing problems [2–6]. Antimicrobial treatment of AOM may also reduce the risk of complications of otitis media [7, 8].

Complications (such as mastoiditis, facial nerve paresis, and labyrinthitis) may develop following untreated or incompletely treated AOM, in cases with infection caused by resistant bacteria, but also despite adequate treatment. Hospital treatment with parenteral medication, and myringotomy or tympanostomy, may be needed to treat children with complications of AOM, but also those with severe, prolonged symptoms of AOM [9, 10]. If severe complications are suspected, or if no response to the initial treatment is seen within 48 h of its onset, imaging and operative treatment are considered. Since the treatment of complicated AOM and complicated acute mastoiditis (AM) is different, it is important to differentiate these two conditions.

## Acute Otitis Media

Acute otitis media is an acute inflammation of the middle ear, which is very common in children. By the age of 3 years, most children (83 %) have experienced at least one episode of AOM [11]. Middle ear effusion (MEE) can be a sign of AOM, but also of non-acute otitis media with effusion (OME), for which no antimicrobial treatment is needed. Pneumatic otoscopy and tympanometry are used to detect MEE. Changes in the translucency (translucent-semiopaque-opaque) or color (gray-yellow-white-red) of the tympanic membrane (TM) are used to evaluate patients with AOM. However, especially, a bulging of the TM is an important sign of AOM [12••]. According to the American Academy of Pediatrics, the diagnosis of AOM should be based

---

This article is part of the Topical Collection on *Otitis*

✉ Anu Laulajainen-Hongisto  
anu.laulajainen-hongisto@hus.fi

<sup>1</sup> Department of Otorhinolaryngology, University of Helsinki and Helsinki University Hospital, Kasarmikatu 11-13, P.O. Box 263, Fin-00029 HUH Helsinki, Finland

<sup>2</sup> Department of Allergy, University of Helsinki and Helsinki University Hospital, P.O. Box 160, FI-00029 HUH Helsinki, Finland

on acute symptoms, presence of MEE, and signs of acute middle ear inflammation, especially with a bulging of the TM [12••]. Otorrhea may be a sign of AOM in children with prior tympanostomy tubes, but also a sign of severe AOM in patients with spontaneous perforation of the TM.

### Acute Mastoiditis

Acute mastoiditis is a suppurative infection of the mastoid air cells, which can develop as a complication of acute, sub-acute, or chronic middle ear infections. The initial diagnosis of mastoiditis is clinical. Imaging, with either computed tomography (CT) or magnetic resonance imaging (MRI), is used in prolonged or complicated cases and can help in diagnostics. Also, an intraoperative diagnosis of AM is possible. No consensus exists on the exact diagnostic criteria of AM. The most commonly used diagnostic criteria are a recent episode of (sub)acute OM with at least two of the following symptoms: protrusion of the pinna, retroauricular swelling, retroauricular erythema, retroauricular tenderness, or abscess of the external auditory canal; or an intraoperative finding of acute mastoiditis (purulent secretion or acute infection in the mastoid process) [13••, 14••, 15, 16].

### Pathogenesis of Acute Otitis Media and Acute Mastoiditis

The middle ear is situated within the temporal bone, of which the mastoid bone is a part (Figs. 1 and 2). The upper part of the middle ear connects to the air-filled cells of the mastoid bone. The lower part of the middle ear connects to the nasopharynx

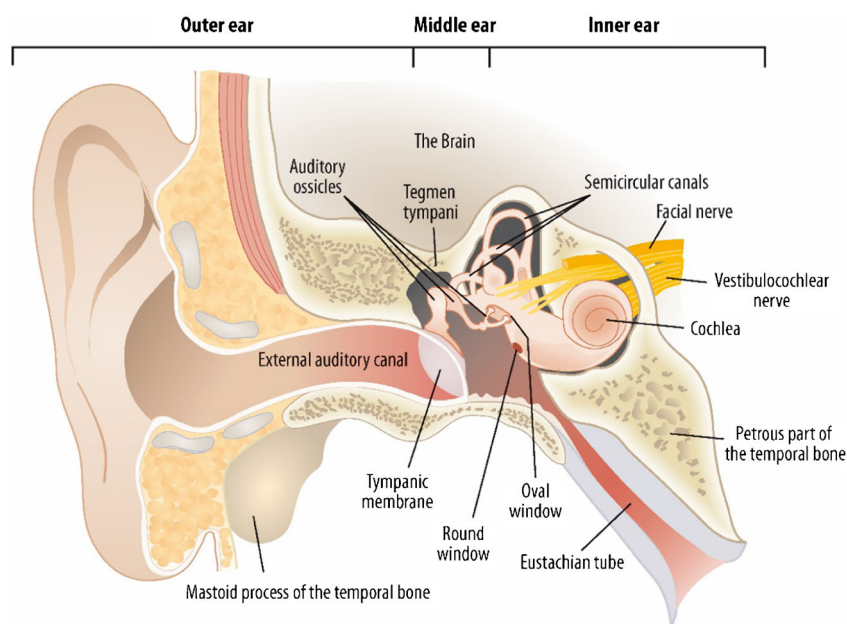
by the Eustachian tube (ET), which helps in pressurizing the middle ear and in removing MEE.

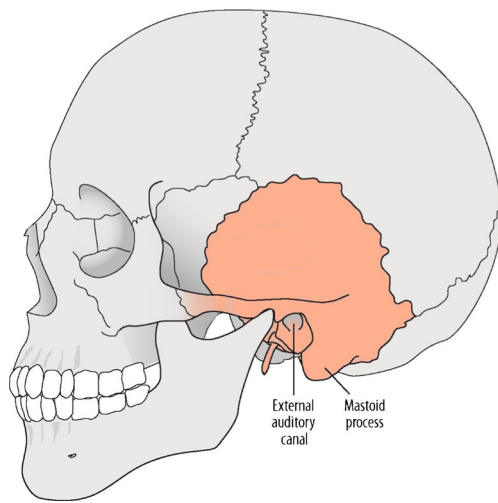
Viral upper respiratory tract infections usually precede AOM; they may result in inflammation of the nasopharynx and ET, and in an increased bacterial colonization of the nasopharynx. ET dysfunction leads to negative pressure of the middle ear, which allows bacteria and viruses to enter and cause inflammatory changes in the middle ear mucosa. This results in accumulation of MEE.

AOM complications may develop following untreated or incompletely treated infections, in cases with infection caused by bacteria that are resistant to antibiotics, but also for unknown reasons in cases with adequate antimicrobial treatment. The thinner bony structures of children may more easily be resorbed by infection, but also congenital malformations and anatomical or immunological conditions may predispose a patient to complications [18]. Suppurative AOM complications are uncommon; their rate has been reported at 0.12–0.24 % [1]. The annual incidence of OM complications in children has been reported at 1–4/100,000 [15, 19–21].

Acute mastoiditis may develop if middle ear infection spreads into the mastoid air cells leading to mucosal swelling, local acidosis, ischemia, resorption of the bone, and destruction of the bony mastoid septa [22]. Hypoxemia and metabolic changes lead to the selection of pathogens that survive in these conditions. Also, other intratemporal complications such as facial nerve paresis and labyrinthitis are possible if middle ear infection spreads toward these structures [9, 10]. AOM and its intratemporal complications can lead through periosteitis to further extratemporal (e.g., subperiosteal abscess, abscess of the external auditory canal)

**Fig. 1** Anatomy of the ear (image by, and modified by, Helena Schmidt; from Laulajainen-Hongisto et al. 2012 [17], with permission of Duodecim)





**Fig. 2** The temporal bone (image by Helena Schmidt)

or intracranial (e.g., meningitis, intracranial abscess, sinus thrombosis) complications.

The most common pathogens of uncomplicated AOM in children are *S. pneumoniae* (23–26 %), *M. catarrhalis* (18–23 %), and *H. influenzae* (16–23 %) [23, 24].

The clinical picture of AOM is affected by its bacterial etiology, and the bacteriology of common outpatient AOM and complicated OM differs [25–28]. Bacterial cultures must always be taken in complicated cases.

*S. pneumoniae* is a common pathogen, involved both in complicated AOM and AM, and has been associated with fever, earache, and clear signs of infection of the TM [24, 29]. AOM caused by non-encapsulated *H. influenzae* has been

associated with bilateral and recurrent AOM, older age, and conjunctivitis, but not with severe complications [24, 30–32]. *M. catarrhalis* is not common in complications of AOM [33]. *S. pyogenes* is uncommon in young children, and has been associated with complicated infections with labyrinthitis and hearing loss, TM perforations, and mastoiditis [34–36]. In our study including children in southern Finland, the most common pathogens in children hospitalized due to AOM and AM were *S. pneumoniae*, *P. aeruginosa*, and *S. pyogenes*; *P. aeruginosa* and *S. pyogenes* were, however, only seen in children older than 2 years [15, 28].

### Diagnostics and Treatment of Acute Otitis Media

Because spontaneous resolution of AOM without antimicrobial treatment is common, occurring in 80 % within 2–3 days, the expectant observational approach is accepted for most older children with mild disease in high-income countries [1, 37, 38••]. Introduction of the expectant observational approach as an alternative treatment for AOM has not resulted in an increase in the incidence of AM in children [16, 39].

It is, however, known that children under the age of two benefit from antimicrobial treatment, which reduces symptom burden and shortens the time to symptom resolution [3–5]. Antimicrobial treatment is also known to reduce the duration of MEE and of the resulting hearing impairment [6]. Children with bilateral AOM are more likely to have persistent symptoms if not treated with antimicrobials [31]. The risk of mastoiditis is reduced by antimicrobial treatment; the number

**Table 1** Clinical findings and symptoms of children hospitalized due to AM or AOM [13••, 15, 21, 28]

	AM (Groth et al.)	AM (van den Aardweg et al.)	AM (Laulajainen-Hongisto et al.)	AOM, hospitalized (Laulajainen-Hongisto et al.)
AOM (%)	97	80	100	100
Median CRP (mg/l)	70	Not available	66	29
Otalgia (%)	Not available	67	88	86
Fever (%)	60	76	71	66
Otorrhea (%)	25	53	34	50
Dizziness (%)	Not available	50	7	25
Nausea (%)	Not available	30 (vomiting)	7	11
Head ache (%)	Not available	31	9	5
Hearing problem (%)	Not available	67	9	9
Facial paresis (%)	Not available	6	5	27
Retroauricular redness (%)	87	83	79	23
Retroauricular pain (%)	50	81	80	16
Retroauricular swelling (%)	67	85	55	14
Retroauricular fluctuation (%)	9	Not available	18	0
Protrusion of the pinna (%)	87	79	66	7
Subperiosteal abscess (%)	20	58	18	0

needed to treat AOM to avoid one case of AM, however, is high (approximately 4800) [7, 8•]. Antimicrobial treatment of AOM should of course cover its most common pathogens *S. pneumoniae*, *M. catarrhalis*, and *H. influenzae*.

Thorough examination with bacteriological cultures is required if a child with AOM does not recover and has high fever, severe general symptoms of infection, secretion from the infected ear, retroauricular signs of infection, hearing problems, dizziness, or neurological symptoms. Because the bacterial etiology of complicated AOM, and AM, is more complicated than that of uncomplicated AOM, bacterial cultures of the MEE must always be taken in complicated cases [25, 27]. Intravenous antimicrobial treatment, corticosteroids, topical ear drops, and myringotomy or tympanostomy should be considered. Hospitalization may be needed in severe cases of AOM [40].

### Diagnosics and Treatment of Acute Mastoiditis

The most commonly used diagnostic criteria for AM are as follows: a recent episode of (sub)acute OM with postauricular swelling, erythema, tenderness, and protrusion of the pinna [13••, 14••]. High fever, leukocyte count (WBC), and C-reactive protein (CRP) levels may be signs of complicated AM [41].

Imaging should be considered in patients with acute infection of the middle ear and signs of mastoid infection that do not respond to conservative treatment (within 48 h), when surgical treatment is considered, or when complications are suspected [42•, 43]. The choice of modality should be based on the anatomical structure in question. CT has traditionally been the initial imaging technique for AM and is efficient in evaluating bony structures. MRI is, however, superior in evaluating soft tissues and intracranial structures [44–47].

When treating patients with AM, antimicrobial treatment is often combined with myringotomy or tympanostomy tube insertion. Retroauricular puncture may be attempted in children with a subperiosteal abscess [25, 42•, 48, 49]. Mastoidectomy, however, still remains the most reliable and efficient procedure, and is therefore suggested in patients who do not respond to more conservative treatment, or those who have intracranial complications [42•, 49, 50].

In our institution, children with AM are treated with tympanostomy tube insertion and antimicrobial treatment consisting of either intravenous cefuroxime or penicillin (in infections caused by *S. pyogenes*), or according to the results of bacteriological cultures. Topical ear drops (usually ciprofloxacin-hydrocortisone) are administered, and steroids are used to reduce inflammation and tissue swelling. Imaging is only performed when complications

are suspected, and in cases resistant to treatment, when mastoidectomy is also considered [51].

### Acute Mastoiditis, Diagnostic Criteria—How to Differentiate Acute Otitis Media and Acute Mastoiditis

The symptoms of AOM and AM overlap. The diagnosis of AM is clinical and is based on the following symptoms and findings: intraoperative finding of acute mastoiditis (purulent secretion or acute infection in the mastoid process), or a recent episode of (sub)acute OM with at least two of the following symptoms: protrusion of the pinna, retroauricular swelling, erythema, or tenderness, and/or abscess of the external auditory canal [13••, 14••, 15, 16].

Based on study results (Table 1), these criteria seem appropriate; fever, otorrhea, and otalgia, however, do not seem to differentiate children with AOM and AM [13••, 15, 21, 28].

### Conclusions

AOM is a common infection in children; its treatment consists of antimicrobials, or in some cases, only expectant observation. Some cases of AOM may, however, lead to complications and to the need for hospital treatment. Since the bacteriological etiology of complicated AOM differs from that of outpatient AOM, bacteriological cultures are mandatory. Complicated cases of AOM are usually treated with myringotomy or tympanostomy, intravenous antimicrobials, topical ear drops, and in some cases, with corticosteroids. The symptoms of AOM and AM overlap, and similar initial treatment is used to treat children with complicated AOM and its intratemporal complications. When severe complications of AOM are suspected, or when no response to their initial treatment is seen within 48 h of its onset, imaging and surgical treatment must be considered. The diagnosis of AM is clinical and based on an intraoperative finding of acute mastoiditis (purulent secretion or acute infection in the mastoid process), or a recent episode of (sub)acute OM with at least two of the following symptoms: protrusion of the pinna, retroauricular swelling, erythema, or tenderness, and/or abscess of the external auditory canal.

### Compliance with Ethical Standards

**Conflict of Interest** Drs. Laulajainen-Hongisto, Aarnisalo, and Jero declare no conflicts of interest relevant to this manuscript.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.



## References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Rosenfeld RM, Kay D. Natural history of untreated otitis media. *Laryngoscope*. 2003;113(10):1645–57.
2. Klein JO. Is acute otitis media a treatable disease? *N Engl J Med*. 2011;364(2):168–9. doi:10.1056/NEJMe1009121.
3. Tahtinen PA, Laine MK, Huovinen P, Jalava J, Ruuskanen O, Ruohola A. A placebo-controlled trial of antimicrobial treatment for acute otitis media. *N Engl J Med*. 2011;364(2):116–26.
4. Hoberman A, Paradise JL, Rockette HE, et al. Treatment of acute otitis media in children under 2 years of age. *N Engl J Med*. 2011;364(2):105–15.
5. Hoberman A, Ruohola A, Shaikh N, Tahtinen PA, Paradise JL. Acute otitis media in children younger than 2 years. *JAMA Pediatr*. 2013;167(12):1171–2. doi:10.1001/jamapediatrics.2013.3068.
6. Tapiainen T, Kujala T, Renko M, et al. Effect of antimicrobial treatment of acute otitis media on the daily disappearance of middle ear effusion: a placebo-controlled trial. *JAMA Pediatr*. 2014;168(7):635–41. doi:10.1001/jamapediatrics.2013.5311.
7. Petersen I, Johnson AM, Islam A, Duckworth G, Livermore DM, Hayward AC. Protective effect of antibiotics against serious complications of common respiratory tract infections: retrospective cohort study with the UK general practice research database. *BMJ*. 2007;335(7627):982.
- 8.• Thompson PL, Gilbert RE, Long PF, Saxena S, Sharland M, Wong IC. Effect of antibiotics for otitis media on mastoiditis in children: a retrospective cohort study using the United Kingdom general practice research database. *Pediatrics*. 2009;123(2):424–30. doi:10.1542/peds.2007-3349. **Study with information regarding the protective effect of antimicrobial treatment of acute otitis media on acute mastoiditis.**
9. Bluestone CD. Clinical course, complications and sequelae of acute otitis media. *Pediatr Infect Dis J*. 2000;19(5 Suppl):S37–46.
10. Kitsko DJ, Dohar JE. Inner ear and facial nerve complications of acute otitis media, including vertigo. *Curr Allergy Asthma Rep*. 2007;7(6):444–50.
11. Teele DW, Klein JO, Rosner B. Epidemiology of otitis media during the first seven years of life in children in greater Boston: a prospective, cohort study. *J Infect Dis*. 1989;160(1):83–94.
- 12.•• Lieberthal AS, Carroll AE, Chonmaitree T, et al. The diagnosis and management of acute otitis media. *Pediatrics*. 2013;131(3):e964–99. **Up-to-date information regarding the management of acute otitis media.**
- 13.•• van den Aardweg MT, Rovers MM, de Ru JA, Albers FW, Schilder AG. A systematic review of diagnostic criteria for acute mastoiditis in children. *Otol Neurotol*. 2008;29(6):751–7. **Systematic review of diagnostic criteria for acute mastoiditis.**
- 14.•• Stalfors J, Enoksson F, Hermansson A, et al. National assessment of validity of coding of acute mastoiditis: a standardised reassessment of 1966 records. *Clin Otolaryngol*. 2013;38(2):130–5. **Valuable information regarding diagnostic criteria for acute mastoiditis.**
15. Laulajainen-Hongisto A, Saat R, Lempinen L, Markkola A, Aarnisalo AA, Jero J. Bacteriology in relation to clinical findings and treatment of acute mastoiditis in children. *Int J Pediatr Otorhinolaryngol*. 2014;78(12):2072–8. doi:10.1016/j.ijporl.2014.09.007.
16. 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):1496–501. doi:10.1016/j.ijporl.2011.08.015.
17. Laulajainen-Hongisto A, Lempinen L, Jero J. Complications of acute otitis media. *Duodecim*. 2012;128(9):959–68.
18. Stenfeldt K, Enoksson F, Stalfors J, Hultcrantz M, Hermansson A, Groth A. Infants under the age of six months with acute mastoiditis. A descriptive study of 15 years in Sweden. *Int J Pediatr Otorhinolaryngol*. 2014;78(7):1119–22. doi:10.1016/j.ijporl.2014.04.027.
19. Van Zuijlen DA, Schilder AG, Van Balen FA, Hoes AW. National differences in incidence of acute mastoiditis: relationship to prescribing patterns of antibiotics for acute otitis media? *Pediatr Infect Dis J*. 2001;20(2):140–4.
20. Leskinen K, Jero J. Complications of acute otitis media in children in southern Finland. *Int J Pediatr Otorhinolaryngol*. 2004;68(3):317–24.
21. 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):1494–500. doi:10.1016/j.ijporl.2012.07.002.
22. Juliano AF, Ginat DT, Moonis G. Imaging review of the temporal bone: part I. Anatomy and inflammatory and neoplastic processes. *Radiology*. 2013;269(1):17–33.
23. Kilpi T, Herva E, Kaijalainen T, Syrjanen R, Takala AK. Bacteriology of acute otitis media in a cohort of Finnish children followed for the first two years of life. *Pediatr Infect Dis J*. 2001;20(7):654–62.
24. Palmu AA, Herva E, Savolainen H, Karma P, Makela PH, Kilpi TM. Association of clinical signs and symptoms with bacterial findings in acute otitis media. *Clin Infect Dis*. 2004;38(2):234–42.
25. Luntz M, Brodsky A, Nusem S, et al. Acute mastoiditis—the antibiotic era: a multicenter study. *Int J Pediatr Otorhinolaryngol*. 2001;57(1):1–9.
26. Leskinen K. Complications of acute otitis media in children. *Curr Allergy Asthma Rep*. 2005;5(4):308–12.
27. Benito MB, Gorricho BP. Acute mastoiditis: increase in the incidence and complications. *Int J Pediatr Otorhinolaryngol*. 2007;71(7):1007–11.
28. Laulajainen-Hongisto A, Saat R, Lempinen L, Aarnisalo AA, Jero J. Children hospitalized due to acute otitis media: how does this condition differ from acute mastoiditis? *Int J Pediatr Otorhinolaryngol*. 2015;79(9):1429–35. doi:10.1016/j.ijporl.2015.06.019.
29. Rodriguez WJ, Schwartz RH. Streptococcus pneumoniae causes otitis media with higher fever and more redness of tympanic membranes than Haemophilus influenzae or Moraxella catarrhalis. *Pediatr Infect Dis J*. 1999;18(10):942–4.
30. Leibovitz E, Jacobs MR, Dagan R. Haemophilus influenzae: a significant pathogen in acute otitis media. *Pediatr Infect Dis J*. 2004;23(12):1142–52.
31. McCormick DP, Chandler SM, Chonmaitree T. Laterality of acute otitis media: different clinical and microbiologic characteristics. *Pediatr Infect Dis J*. 2007;26(7):583–8.
32. Pichichero ME, Casey JR, Hoberman A, Schwartz R. Pathogens causing recurrent and difficult-to-treat acute otitis media, 2003–2006. *Clin Pediatr (Phila)*. 2008;47(9):901–6. doi:10.1177/0009922808319966.
33. Leskinen K, Jero J. Acute mastoiditis caused by Moraxella catarrhalis. *Int J Pediatr Otorhinolaryngol*. 2003;67(1):31–3.
34. Segal N, Givon-Lavi N, Leibovitz E, Yagupsky P, Leiberman A, Dagan R. Acute otitis media caused by Streptococcus pyogenes in children. *Clin Infect Dis*. 2005;41(1):35–41.
35. 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):878–82.

36. Shulman ST, Tanz RR. Streptococcal otitis media: from epidemiology to pathogenesis. *Clin Infect Dis*. 2005;41(1):42–4.
37. Stevanovic T, Komazec Z, Lemajic-Komazec S, Jovic R. Acute otitis media: to follow-up or treat? *Int J Pediatr Otorhinolaryngol*. 2010;74(8):930–3.
38. Venekamp RP, Sanders S, Glasziou PP, Del Mar CB, Rovers MM. Antibiotics for acute otitis media in children. *Cochrane Database Syst Rev*. 2013;1:000219. **Systematic review regarding antimicrobial treatment for acute otitis media.**
39. Stenfeldt K, Hermansson A. Acute mastoiditis in southern Sweden: a study of occurrence and clinical course of acute mastoiditis before and after introduction of new treatment recommendations for AOM. *Eur Arch Otorhinolaryngol*. 2010;267(12):1855–61.
40. Kvaerner KJ, Austeng ME, Abdelnoor M. Hospitalization for acute otitis media as a useful marker for disease severity. *Pediatr Infect Dis J*. 2013;32(9):946–9.
41. Bilavsky E, Yarden-Bilavsky H, Samra Z, Amir J, Nussinovitch M. Clinical, laboratory, and microbiological differences between children with simple or complicated mastoiditis. *Int J Pediatr Otorhinolaryngol*. 2009;73(9):1270–3. doi:10.1016/j.ijporl.2009.05.019.
42. Psarommatis IM, Voudouris C, Douros K, Giannakopoulos P, Bairamis T, Carabino C. Algorithmic management of pediatric acute mastoiditis. *Int J Pediatr Otorhinolaryngol*. 2012;76(6):791–6. **Well-structured article regarding the management of acute mastoiditis in children.**
43. Marom T, Roth Y, Boaz M, et al. Acute mastoiditis in children: necessity and timing of imaging. *Pediatr Infect Dis J*. 2016;35(1):30–4. doi:10.1097/INF.0000000000000920.
44. Minks DP, Porte M, Jenkins N. Acute mastoiditis—the role of radiology. *Clin Radiol*. 2013;68(4):397–405. doi:10.1016/j.crad.2012.07.019.
45. Dobben GD, Raofi B, Mafee MF, Kamel A, Mercurio S. Otogenic intracranial inflammations: role of magnetic resonance imaging. *Top Magn Reson Imaging*. 2000;11(2):76–86.
46. Saat R, Laulajainen-Hongisto AH, Mahmood G, et al. MR imaging features of acute mastoiditis and their clinical relevance. *AJNR Am J Neuroradiol*. 2015;36(2):361–7. doi:10.3174/ajnr.A4120.
47. Saat R, Mahmood G, Laulajainen-Hongisto A, et al. Comparison of MR imaging findings in paediatric and adult patients with acute mastoiditis and incidental intramastoid bright signal on T2-weighted images. *Eur Radiol*. 2015. doi:10.1007/s00330-015-4113-5.
48. Bakhos D, Trijolet JP, Moriniere S, Pondaven S, Al Zahrani M, Lescanne E. Conservative management of acute mastoiditis in children. *Arch Otolaryngol Head Neck Surg*. 2011;137(4):346–50. doi:10.1001/archoto.2011.29.
49. Psarommatis I, Giannakopoulos P, Theodorou E, Voudouris C, Carabino C, Tsakanikos M. Mastoid subperiosteal abscess in children: drainage or mastoidectomy? *J Laryngol Otol*. 2012;126(12):1204–8. doi:10.1017/S0022215112002332.
50. Quesnel S, Nguyen M, Pierrot S, Contencin P, Manach Y, Couloigner V. Acute mastoiditis in children: a retrospective study of 188 patients. *Int J Pediatr Otorhinolaryngol*. 2010;74(12):1388–92. doi:10.1016/j.ijporl.2010.09.013.
51. Kajosaari L, Sinkkonen ST, Laulajainen-Hongisto A, Jero J. Acute mastoiditis in children. *Duodecim*. 2014;130(3):251–7.