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REVIEWS

Chronic Suppurative Otitis Media: Current Diagnostic Strategies and Contemporary Surgical Management

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Abstract

Background. Chronic suppurative otitis media (CSOM) remains a major public health concern affecting both children and adults, particularly in low- and middle-income countries. The disease requires complex medical and surgical management and imposes a substantial socioeconomic burden because of its association with hearing impairment and potentially life-threatening complications.

Material and Methods. A comprehensive literature search was conducted using the PubMed, HINARI, SpringerLink, National Center for Biotechnology Information (NCBI), and MEDLINE databases. Publications published between 2000 and 2024 were identified using the keywords *"chronic otitis media"* and *"chronic suppurative otitis media"* combined with terms related to surgical treatment, mastoidectomy, canal wall-down, canal wall-up, canal wall-intact, canal wall reconstruction, tympanoplasty, and ossiculoplasty. Relevant studies meeting predefined selection criteria were critically reviewed and synthesized.

Results. Chronic suppurative otitis media is a chronic inflammatory disease of the middle ear cleft characterized by persistent or intermittent otorrhea, permanent tympanic membrane perforation, and progressive conductive or mixed hearing loss. Prevalence is below 1% in high-income countries but ranges from 7% to 46% in low-income regions. Diagnosis is based on clinical history, otoscopic examination, audiological assessment, microbiological investigations, and high-resolution imaging when indicated. Surgical management includes canal wall-down (CWD) and canal wall-up (CWU) techniques. CWD provides excellent surgical exposure and superior cholesteatoma eradication but is associated with open cavity-related disadvantages. CWU better preserves external auditory canal anatomy and hearing outcomes, although residual and recurrent cholesteatoma are more common. Contemporary strategies increasingly incorporate mastoid obliteration and canal wall reconstruction to minimize postoperative cavity-related complications.

Conclusions. CSOM management should be individualized according to disease extent, anatomical and radiological findings, hearing status, associated pathology, complications, and patient-related factors to optimize disease control and functional outcomes.

Keywords: chronic suppurative otitis media; hearing loss; diagnosis; surgical management; mastoidectomy; canal wall reconstruction; tympanoplasty; ossiculoplasty.

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INTRODUCTION

Chronic suppurative otitis media (CSOM) remains a major public health concern affecting both children and adults, particularly in low- and middle-income countries. The disease represents not only a complex clinical condition requiring multidisciplinary medical and surgical management but also a substantial socioeconomic burden because of its association with hearing impairment, disability, and potentially life-threatening complications[1,2,5,6,11].

Globally, CSOM is among the most prevalent infectious diseases of childhood, largely owing to the immaturity of the immune system and inadequate hygiene practices, particularly in resource-limited settings[2,6,11]. According to the World Health Organization (WHO), approximately 3.0–4.7% of the world's population is affected by CSOM, and nearly 60% of these individuals experience moderate-to-severe hearing impairment[6].

Hearing loss associated with CSOM has profound consequences for intellectual, linguistic, psychosocial, and emotional development[2,5,6,11]. In children, it adversely affects speech and language acquisition, educational achievement, communication skills, and social integration. In adults, hearing impairment is associated with reduced occupational performance, impaired interpersonal relationships, social isolation, depression, cognitive decline, dementia, and a diminished quality of life[2,5,6,11].

Surgical intervention is generally considered when conservative management fails to achieve disease control[2,5,10,11].In patients with persistent CSOM, surgery is indicated after unsuccessful systemic therapy and persistence of otorrhea despite appropriate antimicrobial treatment, with the primary objectives of eliminating chronic infection, preventing complications, and restoring middle ear function whenever feasible [10,21].

The principal objective of surgical management in CSOM with cholesteatoma is complete eradication of the disease while creating a safe, dry, and self-cleaning ear with a minimal risk of recurrence. Secondary objectives include preservation or reconstruction of the ossicular chain to improve hearing and maintenance of the normal anatomical architecture of the middle ear whenever possible[10,21].

A wide spectrum of surgical techniques has been developed for the treatment of middle ear and mastoid diseases. Mastoidectomy and tympanoplasty, performed with or without ossicular chain reconstruction, remain the cornerstone procedures for the definitive management of CSOM[21,27–36]. The choice of surgical technique depends on multiple factors, including the extent of disease, the presence of cholesteatoma, middle ear anatomy, hearing status, and surgeon experience[31–36].

The aim of this narrative review is to summarize the most recent evidence regarding the etiology, pathogenesis, epidemiology, diagnosis, complications, and contemporary surgical management of chronic suppurative otitis media, with particular emphasis on the indications, advantages, limitations, and clinical outcomes of current surgical techniques.

MATERIALS AND METHODS

To achieve the objective of this narrative review, a comprehensive literature search was conducted using the PubMed, HINARI (Health InterNetwork Access to Research Initiative), SpringerLink, National Center for Biotechnology Information (NCBI), and MEDLINE databases.

The search strategy focused on contemporary publications addressing the etiology, pathogenesis, epidemiology, diagnosis, complications, and surgical management of chronic suppurative otitis media (CSOM). The following keywords were used individually and in various combinations to maximize search sensitivity: *"chronic otitis media," "chronic suppurative otitis media," "etiology," "pathogenesis," "epidemiology," "classification," "diagnosis," "complications," "prognosis," "surgical treatment," "mastoidectomy," "canal wall-down," "canal wall-up," "canal wall-intact," "canal wall reconstruction," "tympanoplasty,"* and *"ossiculoplasty."*

For the advanced selection of relevant publications, the following eligibility criteria were applied: full-text articles, publications written in English, studies published between 2000 and 2024;

original research articles, narrative reviews, systematic reviews, editorials, and meta-analyses

containing contemporary evidence on the etiology, pathogenesis, epidemiology, diagnosis,

complications, and surgical management of CSOM.

In addition to the electronic database search, the reference lists of all eligible articles were manually screened to identify further relevant studies that had not been retrieved during the initial search process.

RESULTS

The information extracted from the selected publications was systematically collected, categorized, critically evaluated, and synthesized to provide a comprehensive overview of current concepts regarding the etiopathogenesis, diagnosis, and surgical management of chronic suppurative otitis media.

To minimize the risk of systematic bias, an extensive search strategy was implemented to identify the largest possible number of relevant publications. Only studies meeting predefined methodological and scientific validity criteria were included, while articles that failed to satisfy the eligibility criteria were excluded from the review.

Following the initial database search, a large number of publications addressing the management of CSOM were identified. After title screening, potentially relevant studies underwent full-text assessment for eligibility. Articles that did not address the objectives of the present review, duplicate publications, inaccessible full-text papers, and studies unavailable through the HINARI program or the Scientific Medical Library of the Nicolae Testemițanu State University of Medicine and Pharmacy were excluded. The final bibliography comprised studies considered representative of the current evidence regarding the diagnosis and surgical management of chronic suppurative otitis media.

Definition. Chronic suppurative otitis media (CSOM) is a chronic inflammatory disease involving the middle ear cleft that usually develops following an episode of acute otitis media. It is clinically characterized by the classic triad of persistent or intermittent purulent otorrhea through a permanent tympanic membrane perforation and progressive conductive or mixed hearing loss of varying severity.

Despite its widespread use, there is currently no universal consensus regarding the minimum duration of symptoms required to establish the diagnosis of CSOM. According to the World Health Organization (WHO), CSOM is defined as persistent inflammation of the middle ear and mastoid cavity associated with tympanic membrane perforation and recurrent or continuous otorrhea lasting for more than two weeks[1, 2, 10, 11]. In contrast, most otologists consider a longer disease duration, ranging from six weeks to three months, to be more clinically appropriate[6,10].

Etiology. In the majority of patients with chronic suppurative otitis media (CSOM), polymicrobial bacterial flora is identified. Aerobic bacteria predominate in tubotympanic (mucosal) disease, whereas anaerobic microorganisms are more commonly associated with atticoantral (squamous) disease [9]. According to studies published over the past 10–15 years, the microbial spectrum of CSOM includes both aerobic and anaerobic pathogens. The most frequently isolated aerobic organisms are *Pseudomonas aeruginosa* (21.6–44.0%), *Staphylococcus aureus* (17.0–42.5%), *Klebsiella pneumoniae* (4–7%), *Proteus mirabilis* (3–20%), *Escherichia coli* (1–21%), and *Streptococcus pyogenes* (1–3%). The predominant anaerobic bacteria include *Bacteroides* spp. (4–8%), *Clostridium* spp. (3–6%), and *Prevotella* spp. (1–3%). Among these pathogens, *Pseudomonas aeruginosa* is considered the most clinically significant because of its remarkable ability to form biofilms, develop antimicrobial resistance, and induce progressive destruction of the middle ear and mastoid structures through the production of virulence factors, including exotoxins and proteolytic enzymes[1,4,6,12,13,15–17].

In regions with specific geographical and climatic conditions, as well as among immunocompromised individuals, fungal pathogens such as *Aspergillus* spp. (3–20%) and *Candida* spp. (0.9–23%) may contribute to disease progression. Furthermore, fungal colonization may occur secondary to prolonged topical antibiotic therapy, which suppresses the normal bacterial flora and promotes fungal overgrowth[1,4,6,11–13,15–18].

Recent microbiological studies have reported positive culture results in 77.2–97.3% of CSOM cases, with polymicrobial infections identified in 5–10% of patients. In contrast, negative culture results have been reported in 3.63–15.5% of specimens. It is noteworthy that while several studies identified *Staphylococcus aureus* as the predominant pathogen isolated from patients with CSOM, others reported *Pseudomonas aeruginosa* as the most frequently recovered microorganism [4,15,17,19]. Bacterial biofilms have been demonstrated on the mastoid mucosa in patients with CSOM, both in the presence and absence of cholesteatoma. Biofilms were detected in 61.5–85.0% of patients with middle ear cholesteatoma, 70–92% of patients with CSOM, and 16% of patients with tympanic membrane perforation. These findings indicate that bacterial biofilm formation is a common feature of both CSOM and middle ear cholesteatoma and likely plays a pivotal role in the persistence of chronic infection, resistance to antimicrobial therapy, and disease recurrence[18].

Classification. Chronic suppurative otitis media (CSOM) is classified as either active or inactive disease. The term active CSOM refers to a tympanic membrane perforation associated with persistent infection and otorrhea, whereas a chronic tympanic membrane perforation in the absence of active infection is classified as inactive CSOM [10]. Based on the histopathological characteristics of the middle ear mucosa and the margins of the tympanic membrane (TM) perforation, CSOM is classified into mucosal and squamous disease. According to the anatomical location of the tympanic membrane perforation, CSOM is further subdivided into the following categories:

Tubotympanic (mucosal, "safe," or "benign") CSOM (approximately 86.0% of cases), characterized by a pars tensa perforation, a relatively low risk of complications, and occurring with similar frequency in both sexes.

Atticoantral (squamous, "unsafe," or "malignant") CSOM (approximately 14.0% of cases), involving the posterosuperior compartment of the middle ear, including the epitympanum, mastoid antrum, and mastoid air-cell system. It is characterized by a marginal or pars flaccida perforation, retraction pocket formation, and subsequent development of cholesteatoma. This form is associated with a substantially higher risk of extracranial and intracranial complications and is more frequently diagnosed in male patients. These complications result from granulation tissue and cholesteatoma, which cause progressive bone erosion and osteonecrosis and may involve critical anatomical structures, including the facial nerve, inner ear, ossicular chain, and intracranial contents [9,17,19,20].

Nevertheless, several authors consider the terms "safe" and "unsafe" CSOM to be inaccurate and potentially misleading, as serious complications may develop in any patient with active chronic otitis media, regardless of the underlying pathological subtype [1].

Cholesteatoma represents the end stage of progressive retraction of either the pars tensa or pars flaccida, resulting from chronic negative middle ear pressure. It is characterized by the abnormal growth and expansion of keratinizing stratified squamous epithelium within the middle ear and/or mastoid process, accompanied by progressive bone erosion that may lead to both intratemporal and intracranial complications. One of the most common forms of temporal bone cholesteatoma is acquired attic cholesteatoma. If left untreated, acquired attic cholesteatoma frequently extends into the mastoid antrum and mastoid air-cell system and, as it progressively involves the ossicular chain, may further spread into the hypotympanum and tympanic sinus[21].

Despite apparently complete surgical excision, cholesteatoma may recur, and recurrence may be associated with persistent or recurrent infection, chronic otorrhea, conductive and sensorineural hearing loss, facial nerve paralysis, vertigo, tinnitus, otalgia, headache, and meningitis. Reported recurrence rates range from 5% to 15%, although rates as high as 61% have been described, particularly following canal wall-up (CWU) mastoidectomy. Once diagnosed, surgical treatment of cholesteatoma is mandatory because of its progressive destructive behavior and its substantial potential to cause irreversible functional impairment and life-threatening complications [22].

Diagnosis. The contemporary diagnostic approach to chronic suppurative otitis media (CSOM) comprises the following key components:

Comprehensive assessment of the patient's symptoms, including persistent or intermittent painless purulent otorrhea through a perforated tympanic membrane, hearing loss, tinnitus, otalgia, aural fullness, headache, and fever. In more advanced cases, the presence of vertigo, severe headache, or facial nerve paralysis should raise suspicion of intratemporal or intracranial complications.

Detailed medical history, including the onset of the disease, identification of possible etiological factors, disease duration, duration and characteristics of otorrhea, previous medical or surgical treatment, treatment response, and the frequency and duration of remission periods.

Otoscopic examination, evaluating the presence, character, quantity, and odor of ear discharge, the location and size of the tympanic membrane perforation, the condition of the middle ear mucosa, and the presence of granulation tissue or cholesteatoma[1,2,6,9,19,23].

Clinical examination usually allows accurate differentiation of the various forms of chronic suppurative inflammation of the middle ear. However, additional diagnostic investigations are required to establish the exact disease subtype, determine the extent and reversibility of pathological changes, select the most appropriate therapeutic strategy, and assess the patient's prognosis. A more detailed evaluation of the middle ear can be achieved by optical otoscopy, otomicroscopy, and otoendoscopy using rigid endoscopes with different viewing angles, which provide superior visualization of hidden anatomical recesses of the middle ear [1,9,21,23]. Comprehensive evaluation of auditory function includes voice audiometry (whispered and conversational voice testing), tuning fork tests, and pure-tone audiometry, allowing determination of both the type and severity of hearing impairment[1,9,19,23].

Audiological assessment plays a pivotal role in the diagnosis of CSOM. The affected ear typically demonstrates conductive hearing loss, characterized by an air-conduction threshold elevation of approximately 50–60 dB, while bone-conduction thresholds remain relatively preserved on pure-tone audiometry. Classical tuning fork findings include a negative Rinne test, prolonged Schwabach test, and Weber test lateralizing to the affected ear[7]. Microbiological examination of middle ear secretions remains an essential component of the diagnostic work-up in CSOM. Identification of the causative microorganisms and determination of their antimicrobial susceptibility patterns provide the basis for appropriate, targeted, and rational antibiotic therapy[9].

Recent advances in imaging techniques, particularly high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI), have significantly improved the diagnosis and management of CSOM.

High-resolution computed tomography of the temporal bone provides excellent visualization of the osseous anatomy and accurately defines the extent of disease. HRCT enables detailed assessment of the mastoid air-cell system, identification of inflammatory changes such as soft-tissue opacification, fluid accumulation, osteolysis, and destruction of bony septa, as well as evaluation of ossicular chain erosion. Furthermore, HRCT is invaluable for preoperative surgical planning and for minimizing the risk of postoperative complications[7,22]. Magnetic resonance imaging (MRI) offers superior soft-tissue characterization, allowing reliable differentiation between inflammatory fluid, granulation tissue, and cholesteatoma. In addition, MRI represents the imaging modality of choice for the diagnosis of intracranial complications, particularly cerebral venous sinus thrombosis [22].

Overall, the diagnosis of CSOM relies on a combination of clinical history, otoscopic findings, and audiological evaluation. Conventional radiography may provide useful information regarding temporal bone anatomy and structural abnormalities; however, high-resolution computed tomography has become the imaging modality of choice for assessing disease extent and identifying complications such as cholesteatoma and mastoiditis. Chronic tympanic membrane perforations, cholesteatoma, retraction pockets, and middle ear adhesions represent different manifestations within the spectrum of CSOM. Microbiological analysis of ear discharge assists in identifying causative pathogens and guiding targeted antimicrobial therapy, while recent advances in otoendoscopy and advanced imaging modalities have further improved diagnostic accuracy and surgical decision-making [1,20].

Mastoidectomy is a surgical procedure of the temporal bone that involves opening the postauricular pneumatic cell system by removing the thin bony septa separating these air cells. This technique remains the cornerstone of treatment for malignant/atticoantral chronic suppurative otitis media (CSOM) [27–30]. A systematic review of the literature indicates that, overall, the rate of achieving a "dry ear" is reported in 70–95% of cases, while the incidence of ears free of recurrent or residual cholesteatoma ranges between 55% and 97% of surgically treated patients [28].

There are four traditional surgical procedures: 1). simple mastoidectomy (cortical or complete mastoidectomy); 2). radical mastoidectomy; 3).modified radical mastoidectomy; 4). mastoidectomy with tympanoplasty.

The objectives of the latter procedure, in addition to disease eradication, include preservation or reconstruction of the posterior-superior wall of the external auditory canal (EAC), restoration of the tympanic membrane (tympanoplasty), and reconstruction of the ossicular chain (ossiculoplasty) [31]. The aforementioned procedures can be classified into two main categories: canal wall down (CWD) and canal wall up (CWU) or canal wall intact (CWI) techniques, with or without middle ear reconstruction, each presenting distinct advantages and disadvantages [31–35]. These two approaches differ primarily in the preservation or removal of the external auditory canal wall.

The CWD technique is considered the most effective method for cholesteatoma eradication because it provides wide exposure and direct visualization of the mastoid and middle ear structures. However, the creation of a small, self-cleaning mastoid cavity is not always achievable. These limitations are largely avoided with the CWU technique, as the anatomical integrity of the external auditory canal is preserved. Nevertheless, residual disease and recurrence rates are higher with CWU procedures, whereas hearing outcomes are generally superior compared with CWD techniques [36].

Simple mastoidectomy (cortical or complete mastoidectomy)

Simple mastoidectomy (cortical or complete mastoidectomy) or antrostomy involves removal of the mastoid cortex and selected mastoid air cells, depending on the extent of the disease process [21,37].

Radical mastoidectomy is a **canal wall down (CWD)** procedure involving exteriorization of the middle ear. It includes removal of the superior and posterior walls of the external auditory canal (EAC), the tympanic membrane, and the ossicular chain, without any attempt at reconstruction[21].

Modified radical mastoidectomy refers to the procedure introduced by Gustave Bondy in 1910, designed for cases in which the disease is limited to the epitympanum. The epitympanic disease is exteriorized by removing the posterior and superior canal walls while preserving the lateral epitympanic wall, either partially or completely, without disturbing the intact tympano-ossicular system (pars tensa and ossicular chain). The posterior wall of the EAC is lowered to the level of the facial nerve, and the mastoid cavity floor is merged with the floor of the EAC, creating a common cavity consisting of the mastoid, epitympanum, and external auditory canal.

This technique is indicated for epitympanic cholesteatoma with an intact ossicular chain, normal pars tensa, and preserved hearing, with the goal of creating a safe ear and preventing intracranial complications. The advantages of this technique include the possibility of performing a single-stage procedure, lower rates of residual and recurrent cholesteatoma, fewer revision surgeries, and improved functional outcomes[10,21,38–41].

The technique provides a relatively safe surgical approach for the removal of chronic disease affecting the middle ear and mastoid, with reproducible results. However, several studies have suggested that hearing outcomes may not be comparable to those achieved with canal wall up (CWU) or canal wall intact (CWI) procedures[41,42].

Canal wall down mastoidectomy (CWD) includes radical and modified radical mastoidectomy procedures and involves complete removal of mastoid air cells, mastoid cortical margins, and the superior and posterior walls of the EAC, followed by meatoplasty to create an open cavity. This results in the formation of a single cavity comprising the mastoid, middle ear space, and external auditory canal, with significant alterations in the anatomy and physiology of the middle ear and mastoid. At present, mastoid obliteration and meatoplasty should be considered integral components of CWD mastoidectomy in order to achieve a complete and functionally optimized surgical outcome[10,21,30–32,34,43,44].

The CWD technique is generally performed in cases of extensive infection, large cholesteatoma involving the mastoid and tympanic cavities, severe to profound hearing loss, erosion and destruction of the ossicular chain, or the presence of complications[5]. The main advantages of CWD procedures include excellent intraoperative exposure with wide access to the mesotympanum and epitympanum, facilitating more effective eradication of middle ear cholesteatoma; lower recurrence rates of cholesteatoma (2–17%); easier detection of recurrence; and reduced rates of postoperative complications[29,30,34,42–46]. A meta-analysis comparing recurrent disease (recurrent and/or residual cholesteatoma) demonstrated that recurrence rates ranged from 5–17% for CWD procedures and from 9–70% for CWU procedures[47].

However, CWD tympanomastoidectomy is associated with several well-recognized disadvantages, including cosmetic concerns related to an enlarged meatus, suboptimal functional outcomes, intolerance and restriction of water exposure to prevent complications, caloric or pressure-induced vertigo, difficulties with fitting conventional hearing aids, and impaired self-cleaning capacity of the cavity. Persistent otorrhea and granulation tissue formation may require regular specialist follow-up, mastoid cavity cleaning, and medical treatment aimed at controlling infection[32,34,39,43,44,46,48,49].

Even with appropriate postoperative care, a significant proportion of patients (20–60%) may develop a painful mastoid cavity with persistent otorrhea, predisposing them to recurrent infections and additional complications, with a considerable negative impact on quality of life [34,44].

Currently, CWD mastoidectomy is performed less frequently, but remains indicated in situations where complete cholesteatoma removal cannot otherwise be achieved [21]. To minimize the disadvantages associated with the CWD cavity, surgeons have increasingly adopted CWU mastoidectomy, CWD mastoidectomy with mastoid cavity obliteration, canal wall reconstruction (CWR), and cavity ablation (decavitation) techniques[35].

Therefore, the historical strategy of performing an open cavity procedure without reconstruction, regardless of disease severity, is now considered outdated. Optimal management should be individualized and determined on a case-by-case basis, taking into account the patient's goals and priorities, the surgeon's experience and technical expertise, careful preoperative assessment of disease extent, and intraoperative findings[45].

Mastoid Obliteration and Canal Wall Up Mastoidectomy

Mastoid obliteration, introduced by Mosher in 1911, was proposed as an attempt to overcome the disadvantages associated with both mastoidectomy techniques—canal wall down (CWD) and canal wall up (CWU) procedures. The main advantages of mastoid cavity obliteration include:

- reduction of the nitrogen-absorbing mucosal surface within the mastoid cavity, which may prevent cholesteatoma recurrence in patients with Eustachian tube dysfunction;
- elimination of the open mastoid cavity, preventing accumulation of squamous epithelium and reducing the risk of mastoid cavity infection[32,44,48].

Currently, mastoid obliteration represents a preferred strategy for the management of problematic mastoid cavities and may be performed either as a primary procedure during CWD mastoidectomy or as a secondary procedure during revision surgery[32,34].

Various materials have been used for mastoid obliteration, including soft tissues (granulation techniques, free soft tissue grafts), cartilage (autologous cartilage and homografts), bone (autologous grafts, homografts, and heterografts), as well as synthetic non-resorbable and biocompatible biomaterials (hydroxyapatite cement, silicone, Proplast, calcium phosphate, and bioactive glass ceramics such as Ceravital). Since no ideal material or technique currently exists for mastoid reconstruction or obliteration, combinations of different approaches are frequently used to achieve the most favorable outcomes[32,34,44,48,50].

Several studies have reported satisfactory outcomes following mastoid obliteration, with a high proportion (82%) of patients achieving a dry, safe, and self-cleaning ear with a reduced mastoid cavity. The most controversial aspect of mastoid obliteration remains the potential risk of "silent" cholesteatoma recurrence within the obliterated cavity. Following CWD mastoidectomy with canal wall reconstruction, recurrence rates ranging from 0–16.7% have been reported. Currently, advanced imaging modalities, such as diffusion-weighted magnetic resonance imaging (DWI-MRI), are available and facilitate the detection of cholesteatoma within obliterated or reconstructed cavities[34].

Canal Wall Up (CWU) Mastoidectomy (also referred to as canal wall intact, CWI mastoidectomy), introduced by Jansen in 1958, is performed by removing pathological tissue while preserving the posterior and superior bony walls of the external auditory canal (EAC)[10,21,30,31,34,40,51].

The objectives of this procedure are:

- avoidance of mastoid cavity exteriorization whenever possible;
- performing surgery as a staged procedure when required (in approximately 70% of patients);
- second-look exploration of the mastoid and middle ear for detection and removal of residual cholesteatoma when indicated[27,30,34,51].

CWU mastoidectomy is indicated in patients with CSOM associated with limited epitympanic cholesteatoma, an intact ossicular chain, adequate ventilation and drainage of the mastoid and tympanic cavities, and absence of intracranial complications [5,51].

As part of the CWU approach for attic cholesteatoma, the following procedures may be performed: atticotomy, reconstruction of the lateral epitympanic wall, cartilage/perichondrial tympanoplasty with or without ossiculoplasty, canaloplasty, and cortical mastoidectomy[51,52].

The major advantages of CWU mastoidectomy include preservation of the normal anatomical structure of the EAC with reduced structural alteration, improved potential for hearing reconstruction, avoidance of open cavity-related problems, easier wound healing, and improved postoperative hearing aid fitting.

However, CWU mastoidectomy is associated with a residual disease rate of 20–39% and a cholesteatoma recurrence rate ranging from 3.8–50%, predominantly occurring in the anterior epitympanum (an area that is difficult to visualize intraoperatively). Therefore, a planned second-stage procedure is often recommended, ideally performed 6–12 months after the initial surgery, to ensure complete eradication of disease and, when necessary, reconstruction of the conductive hearing mechanism[29,31,34,42,45,46,51,53].

Contraindications for CWU mastoidectomy include: revision or residual cholesteatoma, intracranial complications, non-reconstructable defects of the posterior EAC wall, poor patient compliance, and unresectable cholesteatoma matrix involving the labyrinth, facial nerve, dura mater, or tympanic sinus[51].

Atticotomy refers to the removal of the lateral wall of the epitympanum, improving access to and visualization of the epitympanic space and facilitating the removal of cholesteatoma or a retracted tympanic membrane. This technique allows excision of middle ear or attic lesions without the need for mastoidectomy. Furthermore, removal of the middle or inferior portion of the medial aspect of the posterior wall of the external auditory canal (EAC) enhances exposure of the hypotympanum and tympanic sinus[33].

Atticotomy techniques may also be performed during canal wall up (CWU) mastoidectomy procedures when additional exposure is required for complete disease eradication. Partial atticotomy, performed as part of the CWU approach, can significantly improve exposure and access to the middle ear, epitympanum, tympanic sinus, hypotympanum, and the round and oval windows. In addition, cholesteatoma removal through attico-antrotomy followed by obliteration or reconstruction using bone or cartilage may significantly reduce recurrence rates[29,52,53].

The canal wall reconstruction (CWR) technique, involving removal and reconstruction of the posterior wall of the external auditory canal, combines the excellent surgical exposure provided by the canal wall down (CWD) approach with preservation of the EAC anatomy characteristic of the canal wall up (CWU) technique. The main goal is to optimize cholesteatoma eradication while obliterating the attic space, thereby reducing the risk of recurrence, postoperative complications, and retraction pocket formation.

The CWR technique was introduced by Mercke in 1987 and is performed together with mastoid obliteration using osteoperiosteal flaps, ceramic alloplastic materials, bone cement grafts, and cartilage grafts (tragal or costal cartilage) [27,34,46,50,54,55]. CWR may be performed as a primary procedure, carried out as a single-stage operation in combination with CWD mastoidectomy, or as a secondary procedure during revision mastoid surgery[34].

The canal wall reconstruction technique associated with tympano-ossicular allograft transplantation allows reconstruction of the mastoid cavity, resulting in an almost normal anatomical ear and favorable outcomes, including: 76.25–85.0% anatomical surgical success rate; 9.5% functional surgical failure rate; 67.0% improvement in overall functional hearing outcomes[46,55].

Considering the previously mentioned evidence, the management of cholesteatomatous chronic suppurative otitis media (CSOM) requires an individualized approach for each patient. The selection of the surgical technique should be based on anatomical, biological, radiological, and social factors.

Currently, it is widely accepted that cholesteatoma surgery should be tailored according to the location and extent of the cholesteatoma, the presence and severity of posterior EAC wall defects, associated complications, degree of hearing impairment, and the patient's general medical condition [37].

REVISION MASTOIDECTOMY

One of the most effective treatment strategies for persistent or recurrent middle ear pathology following previous radical surgery is revision mastoidectomy. Along with complete eradication of disease, several procedures aimed at preventing recurrence may be performed, including meatoplasty, canaloplasty, mastoid obliteration techniques, canal wall reconstruction, tympanoplasty, and ossiculoplasty[22,48,49,56–59]. Revision surgery is indicated after failure of one or more primary objectives of CSOM surgery: eradication of progressive disease in order to achieve a safe and dry ear; modification of the tympanomastoid compartment anatomy to prevent recurrent disease; reconstruction of the hearing mechanism. Additionally, revision mastoidectomy is performed in cases of recurrent cholesteatoma, recurrent otorrhea, recurrent tympanic membrane perforation, and residual or recurrent conductive hearing loss[49,56–60]. According to multiple studies, the most frequent causes of failure following previous CSOM surgery include: insufficient lowering of the facial ridge (43–98%); inadequate removal of mastoid air cells (**62–100%**); residual or recurrent cholesteatoma (46–66%); inadequate meatoplasty with a narrow meatus (24–84%); persistence of the malleus head (40%)[60].

Specific surgical procedures relevant to revision mastoid surgery can be divided into two main categories:

procedures aimed at complete eradication of disease;

modifications of soft tissues or bone structures intended to prevent further recurrence[57].

Surgical management of revision mastoid cavities initially focuses on elimination of recurrent and/or residual disease, treatment of complications, and correction of technical surgical failures. Subsequently, when required, additional procedures such as meatoplasty, canaloplasty, mastoid obliteration, posterior EAC wall reconstruction, tympanic membrane reconstruction, and ossicular chain reconstruction may be performed, significantly improving patients' quality of life[46,48,49,57,58,60].

Tympanoplasty, introduced by Zöllner and Wullstein in 1952, is a surgical procedure performed to repair the tympanic membrane (TM), with or without reconstruction of the ossicular chain (ossiculoplasty). The objectives of surgery for chronic otitis media (COM) are eradication of disease, creation of a safe and dry ear with an intact tympanic membrane, restoration of the vibratory surface area of the TM, improvement of hearing function, and prevention of recurrent infection[33,61–67].

According to the Wullstein classification (1956), tympanoplasty types are differentiated according to the method of ossicular reconstruction and are based on two main parameters:

- the remaining middle ear structures after eradication of pathology;
- the manner in which sound is transmitted to the oval window[21,63,67,68].

Currently, the most widely used classification is the modification of the original Wullstein system proposed by Nadol and Schuknecht, in which tympanoplasty types are defined according to the method of ossicular reconstruction:

Type I tympanoplasty – simple myringoplasty. The middle ear and ossicular chain are normal; the procedure consists of reconstruction of the tympanic membrane alone.

Type II tympanoplasty. The tympanic membrane graft or reconstructed TM is placed in contact with the incus and stapes. This procedure involves repair of the TM and middle ear in cases of minor ossicular chain defects causing minimal conductive hearing loss. The lever mechanism is restored by placing the graft between the long process of the incus and the stapes head.

Type III tympanoplasty – myringostapediopexy: The tympanic membrane graft or reconstructed TM is placed directly onto the stapes suprastructure, producing a columella effect. It is subdivided into three reconstruction types: (a) stapes columella, where the TM graft is placed directly on the intact stapes head; (b) minor columella, where an interposition prosthesis is placed between the TM graft and the stapes head; (c) major columella, where the prosthesis is positioned between the TM graft and the stapes footplate.

Type IV tympanoplasty – cavum minor: The ossicular chain is absent, and the tympanic membrane graft is placed directly onto the mobile stapes footplate. This technique involves a CWD approach, with a graft covering only the round window and the opening of the Eustachian tube.

Type V tympanoplasty – fenestration procedure: A staged procedure performed after failure of type III or IV tympanoplasty, in which the stapes footplate is removed, the tympanic membrane graft covers the hypotympanum, and a surgically created fenestra is made in the horizontal semicircular canal[21,63,67–69].

The size of tympanic membrane perforations has been classified as small (<50%), medium (50–75%), or large (>75%) [62]. The main objective of tympanoplasty is improvement of hearing through reconstruction of the TM and/or middle ear ossicles, as well as prevention of recurrent otorrhea. Any reduction in the air–bone gap (ABG) after surgery, which represents an effective measure of conductive hearing loss, may be considered a clinical improvement. However, closure of the ABG to within 10 dB hearing level is considered an optimal outcome[70–74].

Tympanoplasty is an effective procedure that can prevent infection of the tympanic cavity, recurrent otorrhea, and cholesteatoma formation, while improving hearing function, with reported functional success rates ranging from 57% to 99%[65,75].

Over the years, various techniques have been developed to improve tympanoplasty outcomes, including: overlay (lateral graft) technique; underlay (medial graft) technique; medio-lateral technique; cartilage shield technique; cartilage palisade technique; cartilage island technique; butterfly cartilage technique; sandwich technique[75,78,80,81].

Although each technique has specific advantages and limitations, two fundamental approaches remain widely used for TM reconstruction: the overlay (lateral graft) technique; the underlay (medial/substrate graft) technique[21,61,78].

The standard definition of tympanoplasty success includes anatomical positioning of the graft in the correct location, complete graft integration, and improvement of hearing outcomes at one year after surgery [82]. Several studies have reported primary tympanoplasty success rates ranging from 60–99% in adults and 35–94% in children with CSOM[65,76,79,80,82].

However, complications may occur following primary tympanoplasty. The most frequently reported complications include graft failure (3.6–4.2%), persistent conductive hearing loss (1.9%), recurrent tympanic membrane perforation (1.0%), and the need for intraoperative or postoperative ventilation tube placement[63].

Ossiculoplasty represents the reconstruction of the auditory conductive mechanism (ossicular chain) using either an autologous graft (tragal cartilage and perichondrium) or a prosthetic device, with the aim of restoring the connection between the tympanic membrane (TM) and the oval window. The procedure may be performed using partial ossicular replacement prostheses (PORP) or total ossicular replacement prostheses (TORP), depending on the condition of the remaining ossicular structures after complete removal of diseased tissue[33,61,62,68,83–85].

According to the results of a study evaluating 279 ears after surgery for chronic suppurative otitis media (CSOM), ossicular chain erosion was identified in 23.66% of cases. Ossicular erosion was significantly more frequent in ears with cholesteatoma (69.3%) compared with ears without cholesteatoma (13.9%). The most commonly affected ossicle was the incus (22.2%), followed by the stapes (11.1%) and malleus (4.7%). The presence of cholesteatoma was associated with a higher prevalence of ossicular erosion, involving the incus (65.3%), stapes (63.3%), and malleus (22.5%), including cases with simultaneous involvement of two or more ossicles[83]. Currently, the most widely used classification of ossicular status is the Austin–Kartush classification: Class 0: normal ossicular chain (M+I+S+); Class A: absent incus (M+S+); Class B: absent incus and stapes (M+S−); Class C: absent malleus and incus (M−S+) Class D: absent ossicles (M−S−) [81]. Historically, ossicular chain reconstruction has been performed using a wide variety of materials, including autologous bone grafts, ceramics, gold, hydroxyapatite, and polyethylene. Titanium prostheses were introduced in the early 1990s and rapidly gained popularity. Many authors recommend tragal cartilage and perichondrium as graft materials for ossicular reconstruction due to their easy availability, biocompatibility, lack of toxicity, minimal extrusion rates, reduced risk of contraction and lateralization, and cost-effectiveness[68,84].

A recent meta-analysis evaluating the influence of prosthesis material on outcomes failed to demonstrate significant differences in audiometric results or extrusion rates when comparing titanium and non-titanium prostheses. Nevertheless, titanium prostheses remain widely used because of their low weight, rigid structure, and low acoustic impedance, which provide favorable acoustic properties. Furthermore, the small size and design characteristics of titanium prostheses facilitate improved surgical visualization and more accurate placement[84,85].

In studies involving non-titanium prostheses, the mean long-term postoperative air–bone gap (ABG) ranges from 12 to 21 dB, with successful outcomes (ABG ≤20 dB) reported in 37–65% of cases. For titanium prostheses, success rates range from 60–73%. According to published data, the overall prosthesis extrusion rate is 0–4%, suggesting that titanium prostheses remain stable within the middle ear environment over many years[85]. Based on long-term outcomes (1–3 years follow-up), all four types of tympanoplasty demonstrated hearing improvement, reflected by a significant reduction in the mean postoperative ABG ($p < 0.001$). However, hearing improvement appeared to be less durable following reconstruction with PORP compared with TORP [86]. Despite favorable functional outcomes, long-term studies (with at least 3 years of postoperative follow-up) have reported clinically significant complication rates requiring additional surgical intervention. These included complications in 10.3% of patients, with: 8.2% requiring revision surgery; 10.2% requiring secondary ventilation tube placement; 3.6% experiencing recurrent conductive hearing loss; 4.1% presenting tympanic membrane graft failure; 1.5% developing recurrent cholesteatoma[87].

DISCUSSION

Chronic suppurative otitis media (CSOM) remains a major global health problem despite substantial advances in antimicrobial therapy, diagnostic imaging, and microsurgical techniques. The literature reviewed in the present study confirms that the epidemiology of CSOM varies considerably according to socioeconomic conditions, with the highest disease burden reported in low- and middle-income countries, where overcrowding, malnutrition, recurrent upper respiratory tract infections, poor hygiene, and limited access to healthcare contribute to disease persistence and delayed treatment[2,6,11–15]. These findings are consistent with the World Health Organization reports and recent epidemiological studies demonstrating that CSOM continues to represent an important cause of preventable hearing loss worldwide.

The reviewed evidence also demonstrates that the microbiological profile of CSOM remains dominated by *Pseudomonas aeruginosa* and *Staphylococcus aureus*, although geographical variations in bacterial distribution and antimicrobial susceptibility have been reported. Recent studies indicate increasing antimicrobial resistance and emphasize the importance of microbiological culture and susceptibility testing, particularly in patients with persistent otorrhea or recurrent disease[4,12,13]. Furthermore, the growing recognition of bacterial biofilm formation provides an explanation for the chronicity of infection, treatment failure, and postoperative recurrence, highlighting the limitations of antibiotic therapy alone.

One of the principal findings of this review is the continuing evolution of diagnostic strategies. While clinical examination remains the cornerstone of diagnosis, high-resolution computed tomography and diffusion-weighted magnetic resonance imaging have significantly improved the assessment of disease extent, ossicular destruction, cholesteatoma, and intracranial complications. These imaging modalities also facilitate surgical planning and reduce the risk of unexpected intraoperative findings, supporting their routine use in selected patients[7,22].

The greatest controversy in contemporary otologic surgery continues to concern the choice between canal wall-down (CWD) and canal wall-up (CWU) mastoidectomy. The literature consistently demonstrates that CWD procedures provide superior visualization and lower rates of residual or recurrent cholesteatoma, whereas CWU techniques preserve normal external auditory canal anatomy and generally achieve better functional hearing outcomes. However, the increased risk of residual disease after CWU frequently necessitates planned second-look surgery or postoperative imaging surveillance[29,31,34,42,45–47,51]. Consequently, neither technique can be considered universally superior, and the choice should be individualized according to disease extent, anatomical characteristics, hearing status, patient compliance, and surgeon experience.

Recent advances in mastoid obliteration and canal wall reconstruction have attempted to combine the advantages of both traditional approaches. Several studies included in this review report encouraging anatomical and functional outcomes with these reconstructive techniques, together with lower cavity-related morbidity and satisfactory disease control. Nevertheless, long-term follow-up remains essential because residual cholesteatoma may develop even after apparently successful reconstruction, particularly in obliterated cavities[34,44,46,48,50].

The literature further confirms that tympanoplasty and ossiculoplasty remain effective procedures for hearing rehabilitation in patients with CSOM. Functional success depends on multiple factors, including the status of the middle ear mucosa, Eustachian tube function, extent of ossicular destruction, graft material, prosthesis type, and surgical technique. Titanium prostheses continue to demonstrate excellent biocompatibility, low extrusion rates, and satisfactory audiological outcomes, although recent meta-analyses suggest that overall hearing results are comparable with those achieved using other prosthetic materials [84,85]. Similarly, cartilage grafts remain widely recommended because of their long-term stability and resistance to retraction. In selected patients with persistent conductive or mixed hearing loss despite successful eradication of disease, implantable hearing devices such as Bonebridge and Vibrant Soundbridge represent effective rehabilitation options, providing significant functional hearing improvement and better quality of life[89].

When surgical hearing restoration is incomplete or contraindicated, conventional hearing aids remain an effective option for auditory rehabilitation, significantly improving speech perception, communication abilities, and quality of life in patients with conductive or mixed hearing loss[88].

Overall, the evidence reviewed supports a modern, patient-centered approach to CSOM management. Contemporary treatment should not rely on a single standardized surgical procedure but rather on individualized decision-making based on disease severity, cholesteatoma extension, anatomical findings, radiological evaluation, hearing status, and patient-related factors. The integration of advanced imaging techniques, modern reconstructive procedures, and long-term postoperative surveillance has substantially improved both disease control and functional outcomes. Future prospective multicenter studies with standardized outcome measures and longer follow-up are required to further optimize surgical decision-making and establish evidence-based recommendations for the management of chronic suppurative otitis media.

CONCLUSION

Chronic suppurative otitis media (CSOM) is a chronic inflammatory process localized within the middle ear system, resulting from an initial episode of acute otitis media. It is characterized by persistent or intermittent purulent otorrhea, a permanent tympanic membrane perforation, and progressive conductive or mixed hearing loss. The incidence of CSOM varies considerably worldwide: in developed countries, the prevalence is relatively low (<1%), whereas in low-income countries it ranges from 7% to 46%.

The causative pathogens involved in CSOM include aerobic bacteria such as *Pseudomonas aeruginosa* (21.6–44.0%), *Staphylococcus aureus* (17.0–42.5%), *Klebsiella pneumoniae* (4–7%), *Proteus mirabilis* (3–20%), *Escherichia coli* (1–21%), and *Streptococcus pyogenes* (1–3%); anaerobic bacteria including *Bacteroides* spp. (4–8%), *Clostridium* spp. (3–6%), and *Prevotella* spp. (1–3%); as well as fungal pathogens such as *Aspergillus* spp. (3–20%) and *Candida* spp. (0.9–23%). The diagnosis of CSOM is based on a combination of clinical history, otoscopic examination, and audiological assessment. CSOM causes mild conductive hearing loss (approximately 10–20 dB increase in hearing thresholds) to moderate conductive hearing loss (approximately 50–70 dB increase in hearing thresholds) in 50–60% of cases. Hearing impairment is primarily caused by tympanic membrane perforation, reduced tympanic membrane mobility, middle ear effusion, and/or ossicular chain discontinuity. Complications of CSOM are classified into extracranial and intracranial complications. Extracranial complications include chronic otitis externa, meatal stenosis, ossicular erosion and discontinuity, middle ear adhesions, tympanosclerosis, facial nerve paralysis, mastoiditis, serous or suppurative labyrinthitis, petrous apicitis, and labyrinthine fistula. Intracranial complications include sinus thrombosis, meningitis, extradural, subdural, or intracerebral abscess formation, and otogenic hydrocephalus.

Four traditional surgical procedures are used in the treatment of CSOM: simple mastoidectomy (cortical or complete mastoidectomy); radical mastoidectomy; modified radical mastoidectomy; mastoidectomy with tympanoplasty. These procedures can be classified into two major categories: canal wall down (CWD) and canal wall up (CWU) or canal wall intact (CWI) techniques.

The CWD technique represents the most effective method for cholesteatoma eradication because it provides wide-angle visualization and access to mastoid and middle ear structures. However, it results in the creation of a large mastoid cavity associated with several functional and anatomical disadvantages. These limitations are largely avoided with the CWU technique, in which the anatomy of the external auditory canal is preserved. Nevertheless, residual and recurrent disease occurs more frequently after CWU procedures, whereas hearing outcomes are generally superior compared with CWD techniques.

Currently, CWD mastoidectomy is performed less frequently, but remains indicated when complete cholesteatoma eradication cannot be achieved by other methods. To avoid the disadvantages associated with the open mastoid cavity, surgeons increasingly use CWU mastoidectomy or CWD mastoidectomy combined with mastoid cavity obliteration, canal wall reconstruction (CWR), or cavity ablation procedures.

Five main types of tympanoplasty are recognized: Type I – simple myringoplasty; Type II – tympanic membrane graft or reconstructed tympanic membrane in contact with the incus and stapes; Type III – myringostapediopexy; Type IV – cavum minor; Type V – fenestration procedure.

Successful tympanoplasty is defined as anatomical placement of the graft in the correct position, complete graft integration, and improvement of hearing function at one year after surgery. The reported success rate of primary tympanoplasty ranges from 60–99% in adults and 35–94% in children with CSOM. The most widely used classification of ossicular status is the Austin–Kartush classification: Class 0: normal ossicles (M+I+S+); Class A: absent incus (M+S+); Class B: absent incus and stapes (M+S–); Class C: absent malleus and incus (M–S+); Class D: absent ossicles (M–S–). The reported success rate of ossicular reconstruction, defined as an air–bone gap (ABG) ≤20 dB, ranges from 37–65% in studies using non-titanium prostheses and from 60–73% in studies using titanium prostheses. The overall prosthesis extrusion rate is reported to be 0–4%, confirming the long-term stability and biocompatibility of modern ossicular prostheses. Patients with persistent postoperative conductive or mixed hearing loss should be considered for hearing-aid fitting as part of comprehensive auditory rehabilitation[88].

Auditory rehabilitation should be considered an integral component of CSOM management. While tympanoplasty and ossiculoplasty remain the primary methods for hearing restoration, patients with residual conductive or mixed hearing loss may benefit from conventional hearing aids or active middle-ear and bone-conduction implants (Bonebridge and Vibrant Soundbridge), depending on the anatomical and audiological findings[89].

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Availability of data and materials: The data used and/or analyzed throughout this study are available from the corresponding author upon reasonable request.
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