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SURFER'S EAR – A HIDDEN CHALLENGE IN WATER SPORT: PATHOGENESIS, DIAGNOSIS AND TREATMENT STRATEGIES

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ABSTRACT

Background: External Auditory Canal Exostosis (EAE), or surfer's ear, is a benign yet progressive condition involving new bone formation within the external auditory canal, typically triggered by repeated exposure to cold water and wind. This review summarises current knowledge on the anatomy, pathogenesis, clinical presentation, and management of EAE, including preventive and surgical strategies.

Aim: The aim of this review is to evaluate the current understanding of the pathogenesis, clinical features, diagnostic methods, and therapeutic approaches to surfer's ear, and to provide a comprehensive synthesis to support clinical practice and guide future research.

Methodology: This literature review was conducted using PubMed, OVID and Google Scholar. Keywords included: "Surfer's ear", "Exostosis", "Exostosis in aquatic athletes" and "Canaloplasty". Studies were selected based on relevance and methodological quality.

Results: EAE prevalence is high among water sports participants, particularly those exposed to cold water. Reported rates range from 38% to 75.1%, with the latter observed in German wind- and kitesurfers, a population relevant to Polish athletes due to comparable climatic conditions. Severity of exostoses strongly correlates with cumulative exposure to cold water and wind. Symptoms typically include water trapping, pain and hearing loss. Various instruments are used for surgical removal. Microdrills, though common, are associated with suboptimal postoperative outcomes and potential complications. Osteotomies present a safer alternative: a large retrospective study showed that osteotome-only excision resulted in the lowest rates of postoperative symptoms and complications, including tinnitus.

Conclusion: EAE is a largely preventable condition driven by cumulative cold-water and wind exposure. Diagnosis is primarily clinical, with CT used for surgical planning. Consistent earplug use remains the most effective preventive measure. Increased awareness and preventive education in aquatic communities are needed. Future studies should refine risk assessment and evaluate newer surgical approaches.

KEYWORDS

Surfer's Ear, Exostosis, External Auditory Exostosis, Earplugs, Water Exposure

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1. Introduction:

Surfer's ear is the colloquial term for external auditory canal exostosis, a benign bony outgrowth of the temporal bone that narrows the external auditory canal. This condition is strongly associated with repeated exposure to cold water and wind, most commonly seen in individuals who participate in aquatic sports such as surfing, windsurfing, and kitesurfing. The pathogenesis is believed to involve chronic thermal irritation, which stimulates periosteal bone formation in the deep bony meatus of the ear canal (Kroon et al., 2002; Wegener et al., 2022; Wong et al., 1999). Clinically, surfer's ear may be asymptomatic in early stages but can progress to symptoms such as conductive hearing loss, recurrent otitis externa, water trapping, and a sensation of ear fullness. The severity of exostosis correlates with cumulative cold-water exposure, frequency, and duration of activity, with higher prevalence and more severe lesions observed in those surfing in colder waters and for longer periods (Kroon et al., 2002; Nakanishi et al., 2011; Simas et al., 2021; Vallée, 2024). Management is primarily preventive, with the use of earplugs shown to significantly reduce the risk of exostosis formation, while surf hoods offer less protection (Lambert et al., 2021). Surgical removal is reserved for cases with significant canal obstruction (>80%) and refractory symptoms, typically performed via transmeatal approach with specialized instruments (Ghavami et al., 2016; Whitaker et al., 1998). Awareness and early intervention are crucial to prevent progression and complications.

2. Methodology

2.1. Study design

This study is a literature review aimed at analysing existing research on the external auditory canal exostosis (EAE) among aquatic athletes. The review focuses on pathogenesis, risk factors, diagnosis, differential diagnosis and management strategies for EAE in athletes.

2.2. Search Strategy

A comprehensive search was conducted using electronic databases, including: PubMed, OVID and Google Scholar. The search covered publications focused on recent scientific research (2005-2025), but key academic works on the particular ailment from the earlier years could not be omitted. The following search terms, keywords and MeSH terms were used:

- “Surfer’s ear”
- “Exostosis”
- “External auditory canal exostosis”
- “Exostosis and Osteomas”
- “External ear canal diseases”
- “Prevalence of exostosis”
- “Pathophysiology of exostosis”
- “Surgical treatment of Surfer’s ear”
- “Surgical treatment of external auditory canal exostosis”
- “Piezoelectric Technique in treatment of external auditory canal exostosis”
- “Canaloplasty”
- “Anatomy of the external ear”
- “Temporal bone sutures”
- “Exostosis in aquatic athletes”

2.3. Inclusion and Exclusion Criteria

Inclusion criteria:

- Meta-analyses, systematic reviews, peer-review articles, clinical guidelines, academic books and case reports
- Research focusing on water sport athletes, especially aquatic athletes who have been participating in sports for many years
- Academic studies investigating the pathophysiology, prevalence, risk factors, diagnosis, differential diagnosis and management of EAE

Exclusion criteria:

- Articles not published in English or Polish
- Inadequate data quality in publications
- Poor methodological quality in publications

2.4. Data Collection:

A literature review was conducted independently by all authors. Abstracts were screened to assess the relevance. Full-text examination was performed for articles that met the inclusion criteria. Following the initial selection, data extraction was performed, capturing key variables such as study design, sample size, population demographics, methods of EAE diagnosis, and statistical analyses used. Data were then categorised into relevant themes, such as prevalence, risk factors, differences in particular aquatic sports, diagnosis and EAE management in athletes.

3. Anatomy of the external ear:

The external ear is composed of the cartilaginous auricle and the external acoustic meatus, a canal of mixed cartilage and bone that directs sound to the tympanic membrane. The auricle (pinna) constructed of a network of yellow elastic fibrocartilage, with its fleshy lobule being the only exception. Its prominent landmarks including the helix, antihelix, concha, tragus and antitragus are crucial for sound localisation (Alvord & Farmer, 1997).

Extending medially from the concha, the external acoustic meatus is an S-shaped canal approximately 2.5 cm long in adults. Its lateral one-third is cartilaginous and continuous with the auricle, while its medial two-thirds are bony, formed by the temporal bone. This dual composition contributes to the canal's protective and acoustic functions (Alvord & Farmer, 1997).

The bony external acoustic meatus is a composite structure formed by the tympanic, squamous, and mastoid parts of the temporal bone. The tympanic part is the primary contributor, forming the anterior wall, inferior wall (floor), and a portion of the posterior wall of the bony canal. The remaining boundaries are completed by contributions from the squamous and mastoid parts (Isaacson, 2018; Sobotta et al., 2018, pp. 36–40).

The specific contributions of each part to the meatus are as follows (Isaacson, 2018; Sobotta et al., 2018, pp. 36–40):

- **Tympanic part:** Forms the anterior wall, floor, and part of the posterior wall.
- **Squamous part:** Forms the roof and the anterosuperior aspect.
- **Mastoid part:** Forms the posterosuperior wall.

The junctions between these bony elements are demarcated by two key sutures. The tympanosquamous suture is located anteriorly, and the tympanomastoid suture is found posteriorly, marking the lines of fusion between the respective parts of the temporal bone (Isaacson, 2018; Sobotta et al., 2018).

4. Pathogenesis: The Role of Cold Water, Wind, and Evaporative Cooling

External Auditory Canal Exostosis (EAE) is a reactive osteogenesis resulting from chronic thermal irritation of the external auditory canal (EAC) periosteum, primarily driven by repeated exposure to cold water and wind. (Kroon et al., 2002; Vallée, 2024). This condition is an adaptive, protective response where the periosteum, the membrane covering the bone, is stimulated by prolonged cold exposure to deposit new bone, resulting in the typically presenting as multiple, bilateral lesions, they form broad-based protrusions into the external auditory canal and show histologically dense, concentric layers of subperiosteal bone arising near the tympanic ring. Their development is thought to result from the unique anatomical proximity of the canal's epidermis to the underlying temporal osseous tissue and the secondary vasodilatory effects associated with inflammation triggered by recurrent thermal irritant exposure (Shohet et al., 2023; Kroon et al., 2002).

The severity of EAE is significantly exacerbated by the influence of wind, which intensifies the thermal stress through evaporative cooling (Wegener et al., 2022). Evaporation of water trapped in the EAC rapidly lowers the temperature, providing a more potent and sustained stimulus for bone growth than cold water immersion alone (King et al., 2010).

This mechanism explains observed lateralisation patterns in surfers. Studies have shown that the ear exposed to the predominant coastal wind direction often develops more severe exostoses, confirming that wind-driven evaporative cooling contributes substantially to the condition's progression (King et al., 2010). Consequently, EAE growth is noted to occur faster in wind-dependent athletes, such as wind- and kitesurfers, compared to traditional surfers, underscoring the synergistic effect of cold water and wind (Wegener et al., 2022).

5.1. Quantitative Risk Factors: Surfing Duration and Frequency

The development and severity of EAE are strongly correlated with the cumulative duration and frequency of cold-water exposure. Early epidemiological studies established that the number of years spent surfing is a primary risk factor for both the presence and severity of EAE (Kroon et al., 2002; Wong et al., 1999).

Wong (1999) demonstrated that surfers active for more than 20 years had significantly higher rates of severe canal obstruction compared to those surfing 10 years or less. Quantifying this relationship, Kroon (2002) found that each additional year of surfing increased the risk of developing EAE by 12% and the risk of developing more severe lesions by 10%.

To better integrate both time and frequency, Nakanishi (2011) proposed the "**surfing index**," calculated as the product of the number of years surfing and the average frequency (number of surfing days per week). This composite metric showed a strong positive association with EAE severity, with surfers having an index exceeding 20 exhibiting significantly higher prevalences of moderate and severe exostoses (Nakanishi et al., 2011).

5.2. Environmental Risk Factors: Water Temperature and Geographic Location

While External Auditory Canal Exostosis (EAE) was historically linked almost exclusively to cold water exposure, recent epidemiological data demonstrates a significant prevalence of the condition in warm-water environments. Early research established EAE as a reactive osteogenesis driven by chronic thermal irritation, leading to the assumption that water temperatures below 19°C were the primary environmental prerequisite (Chaplin & Stewart, 1998; Kroon et al., 2002).

However, studies conducted in warmer geographic locations have challenged this strict temperature threshold. Simas (2021) investigated surfers in Australia, where mean water temperatures range from 19°C to

28°C, and reported an overall EAE prevalence of 71.8%. The high prevalence observed in warm-water surfers suggests that while cold water remains a strong risk intensifier, the pathogenesis of EAE is not restricted by a strict temperature boundary. Cumulative exposure and the synergistic effect of wind and evaporative cooling are critical pathogenic factors, independent of the baseline water temperature (Simas et al., 2021).

6. Prevalence in Different Water Sports

The prevalence of external auditory canal exostosis is consistently high among water sport enthusiasts, though rates can vary by study population and geography. The term "surfer's ear" was coined due to the particularly high incidence in the surfing population, but the condition is also common in swimmers, divers, sailors, kayakers, wind- and kitesurfers (Hetzler, 2007; Wegener et al., 2022; Ghavami et al., 2016). The prevalence of EAE among surfers was found to be 38%, of which 69% were graded as mild and the remaining 31% as moderate-severe (Kroon et al., 2002).

The prevalence of EAE among wind- and kitesurfers along the German coasts is notably high at 75.1%. Total exposure time and activity frequency, but not sex, influence the development of EAE, which appears to progress more rapidly in this population than in surfers (Wegener et al., 2022). This is evidenced by the results of studies conducted by Nakanishi (2011) on surfers, where the prevalence of EAE was 59.8%, and in studies conducted by Simas (2021) on surfers, where it was 71.8% (Nakanishi et al., 2011; Simas et al., 2021).

7. Clinical Presentation

The primary symptomatic consequence of External Auditory Canal Exostosis (EAE) is conductive hearing loss (CHL) resulting from the physical obstruction (stenosis) of the external auditory canal (EAC) by benign bony growths. These multinodular bony masses progressively narrow the EAC lumen, which is the direct anatomical cause of the hearing impairment (Barbon et al., 2017; Ursick & Fayad, 2013).

While the bony growth itself causes stenosis, the resulting conductive hearing loss is frequently triggered by secondary obstruction. The narrowed canal prevents the natural self-cleaning mechanism of the ear, leading to the accumulation and impaction of cerumen and desquamated keratin debris (DiBartolomeo, 1979; Montebello et al., 2022).

Dibartolomeo (1979) established that the CHL associated with exostoses is typically secondary to occlusion by impacted cerumen or acute external otitis. Turetsky (1990) documented a case of severe bilateral stenosis where hearing loss was directly attributed to impacted cerumen completely occluding the canal, with hearing normalising only after the cerumen was disimpacted. The progressive stenosis caused by EAE leads to relevant clinical issues (Barbon et al., 2017; DiBartolomeo, 1979; Kuczkowski et al., 2010; Nakanishi et al., 2011; Turetsky et al., 1990; Vallée, 2024):

- Conductive hearing loss
- Impaction of cerumen
- Sensation of fullness or water trapped in the ear
- Tinnitus
- Earache
- Itching
- Acute otitis externa

8.1. Otoscopic Diagnosis

Diagnosis is confirmed via otoscopic examination, which reveals firm, sessile, multinodular bony masses arising from the tympanic ring (DiBartolomeo, 1979; Montebello et al., 2022; Taylor et al., 2022). Severity is commonly graded based on the percentage of external auditory canal stenosis. The severity of symptoms in surfer's ear varies depending on the extent of the bony growths within the ear canal. The severity of EAC obstruction was graded on a standard clinical scale from one to three (Simas et al., 2021; Wong et al., 1999):

Table 1. Obstruction of the external auditory canal clinical scale in EAE

Grade	Patent Surface Area
0- normal	100%
1- mild	99% to 66%
2- moderate	65% to 33%
3- severe	Less than 33%

8.2. Advanced Diagnostic Imaging and Assessment Techniques

While otoscopy is the primary diagnostic tool, Computed Tomography (CT) remains the traditional gold standard for advanced assessment of EAE. CT imaging is crucial for confirming the diagnosis, precisely assessing the extent of the bony growth, and planning surgical intervention. It provides detailed visualisation of the multinodular masses and the exact residual luminal diameter (Barbon et al., 2017; Montebello et al., 2022; Turetsky et al., 1990)

However, CT is limited by its high cost and the patient's exposure to high-dose radiation, and it cannot typically be conducted during routine appointments. To overcome these drawbacks, novel, non-invasive methods are emerging. These techniques utilize image analysis software, such as ImageJ, applied directly to standard otoscopic images to accurately determine exostosis severity (Climstein et al., 2021).

9. Differential Diagnosis of External Auditory Canal Masses

External Auditory Canal Exostosis (EAE) must be differentiated from other bony and non-bony masses of the external auditory canal based primarily on its characteristic morphology and distribution. The differential diagnosis is critical because while EAE is managed conservatively until symptomatic, other lesions, particularly neoplasms, require immediate and distinct therapeutic interventions (Gidley, 2018):

- **Osteoma:** EAE is defined by multiple, broad-based, bilateral bony growths arising from the tympanic ring. The primary bony differential is the solitary osteoma. Unlike EAE, osteomas are usually unilateral, solitary, and often pedunculated, attaching near the tympanosquamous suture line (Baik et al., 2011; DiBartolomeo, 1979; Kuczkowski et al., 2010; S et al., 2021).
- **External Auditory Canal Cholesteatoma:** The lesion is characterised by bony erosion and invasion of squamous epithelium, associated with localised periostitis and bone sequestration (Spielmann et al., 2013).
- **Fibrous Dysplasia:** This benign, slowly progressive condition involves the replacement of normal bone with fibrous tissue and immature bone. When affecting the temporal bone, it frequently involves the EAC, causing bony protrusions or stenosis (Jethanamest & Roehm, 2011; J. S. Lee et al., 2012).
- **Schwannoma:** A rare, benign tumor of the nerve sheath that presents as a mass in the EAC (D. H. Lee et al., 2018).
- **Ceruminous Adenoma:** A rare, benign neoplasm arising from the ceruminous glands, presenting as a mass in the EAC (Markou et al., 2008).
- **Cartilaginous Choristoma:** This is a rare, small, white mass found in the bony EAC that should be included in the differential diagnosis alongside exostosis and osteoma (Yamahara et al., 2018).
- **Malignant Neoplasms (e.g., Squamous Cell Carcinoma, Basal Cell Carcinoma):** Neoplasms of the EAC must always be considered in the differential diagnosis of an unusual mass, especially if associated with earache, ulceration, facial palsy or bleeding (Gidley, 2018).

10. Prevention and Conservative Measures

The primary non-surgical strategy is **prevention** of the underlying cause: chronic cold water and wind exposure. This involves the consistent use of protective gear, such as earplugs, to minimize the thermal stimulus that drives the bony growth (Srinivasan et al., 2012; Timofeev et al., 2004). Awareness of EAE and the use of preventive measures vary among surfers. A study on windsurfers and kitesurfers in Germany found that 60% had 'good' or 'excellent' knowledge of EAE, and this knowledge was positively correlated with hours of exposure, otological complaints, and the frequency of ear canal protection use (Wegener et al., 2024).

For patients with established EAE, conservative management focuses on (DiBartolomeo, 1979; Srinivasan et al., 2012; Whitaker et al., 1998):

- **The aural toilet:** regular cleaning and removal of debris are essential to prevent hearing loss or to restore hearing function.
- **Treatment of the infection:** when acute otitis externa occurs, it is typically treated with antibiotic eardrops, topical steroids or topical antifungals to resolve the infection and inflammation.

11. Surgical Management (Canalplasty)

Surgical removal of the exostoses, known as **canalplasty**, is the definitive treatment for EAE. The goal is to restore the normal diameter of the external auditory canal to prevent water trapping, eliminate recurrent infections, and improve hearing.

11.1 Indications for Surgical Intervention

Surgical removal of external auditory canal exostoses is indicated primarily for patients whose symptoms are resistive to medical treatment. While most exostoses are asymptomatic, surgical candidacy is often determined by the presence of specific clinical signs and the failure of conservative management to resolve them (Whitaker et al., 1998).

According to Whitaker (1998), patients with severe exostoses may present with a constellation of symptoms that warrant consideration for surgery. The key clinical criteria that can lead to significant patient morbidity include:

- Canal obstruction greater than 80%
- Recurrent episodes of external otitis
- An associated conductive hearing loss

11.2. The Osteotome Technique

The osteotome technique is a well-established surgical method that uses chisels to fracture and remove exostoses. This procedure involves elevating a tympanomeatal flap to expose the exostosis. A sharp, thin chisel is then carefully positioned at the base of the bony growth, which is subsequently fractured and removed with a mallet tap (Hetzler, 2007).

The primary advantage of this method is the lower risk of iatrogenic sensorineural hearing loss in compare to the microdrilling technique (Swisher et al., 2023). The procedure can also be significantly faster than meticulous drilling, reducing overall surgical time.

However, the technique is not without significant risks, which are largely related to the application of force. The controlled fracture requires considerable skill to prevent complications (Ghavami et al., 2016). The potential complications include tympanic membrane perforation caused by a misdirected chisel or displaced bone fragment (Hetzler, 2007), temporomandibular joint injury, facial nerve palsy (Ghavami et al., 2016).

11.3. The Microdrilling Technique for Exostosis Removal

The microdrilling technique is a widely used surgical method for removing EAE, though it has been increasingly compared with the osteotome (chisel) method (Grinblat et al., 2016; Swisher et al., 2023). The procedure involves using a high-speed powered drill, typically with diamond burs, to precisely abrade the bony growths (Grinblat et al., 2016). The surgery is often performed via a retroauricular (post-auricular) approach, which involves an incision behind the ear to allow a full view of the ear canal. After elevating the skin of the ear canal, the surgeon uses the drill to progressively remove the exostoses (Grinblat et al., 2016). Copious irrigation with suction is used throughout the drilling process to manage bone dust and prevent thermal injury to the surrounding tissues (Shohet et al., 2023).

Despite its precision, the technique is associated with notable complications. The transmission of high-frequency drill vibrations to the inner ear is a primary cause of iatrogenic sensorineural hearing loss (SNHL)- a 2023 meta-analysis by Swisher et al. found that drill canalplasty was associated with a significantly higher rate of SNHL (4.3%) compared to the osteotome technique (0.69%) (Swisher et al., 2023). Furthermore, trauma to the canal skin during drilling can lead to postoperative stenosis caused by scarring (cicatricial stenosis). The same meta-analysis reported a stenosis rate of 4.1% for the drill group, compared to just 1.1% for the osteotome group (Grinblat et al., 2016; Swisher et al., 2023). On the other hand the meta-analysis by Swisher et al. found a tympanic membrane perforation rate of 3.8% for the drill group, which was statistically lower than the 5.3% rate for the osteotome group (Swisher et al., 2023).

11.4. The Piezoelectric Technique

The piezoelectric technique offers a novel approach that selectively cuts bone while preserving adjacent soft tissues, combining precision with enhanced safety. This method utilizes ultrasonic frequency generated by a specialised surgical instrument. The frequency of these vibrations is calibrated to act exclusively on hard, mineralized tissue, allowing for the precise removal of the exostosis without damaging the delicate canal skin, tympanic membrane, or other nearby soft structures (Puttasiddaiah & Browning, 2018).

While piezoelectric surgery offers significant theoretical advantages for soft tissue preservation, a recent large-scale study found it was associated with worse postoperative outcomes for tinnitus compared to the osteotome-alone technique (Shohet et al., 2023). A retrospective study by Shohet (2023) on 472 ears found that the osteotome with piezoelectric (OP) group had a significantly higher incidence of postoperative tinnitus compared to the osteotome-alone (OA) group. The OP group also showed trends toward higher rates of prolonged pain and otorrhea, although these were not statistically significant (Shohet et al., 2023).

12. Conclusions:

External Auditory Canal Exostosis is a preventable condition driven by the cumulative thermal stress of cold water and wind exposure. This review underlines that EAE is a physiological bony response that progresses from being asymptomatic to causing significant symptoms like water trapping, recurrent otitis externa, and hearing loss once canal occlusion is severe. The management strategy is staged and directly tied to symptom severity and the degree of stenosis. Key findings from this review underscore that:

- **Risk is dose-dependent:** The prevalence and severity of EAE are directly correlated with the cumulative duration and frequency of cold water exposure
- **Progression leads to complications:** While often asymptomatic initially, significant canal narrowing can cause water trapping, recurrent external otitis, and conductive hearing loss.
- **Diagnosis is clinical:** Otoscopy confirms diagnosis, while CT imaging is vital for pre-operative planning in symptomatic cases requiring surgery.
- **Prevention:** Consistent use of earplugs is the most effective strategy.

The most crucial issue is to place greater emphasis on education and preventive measures in aquatic communities at risk of this problem. Future research should focus on improving risk quantification beyond the surfing index and comparing the long-term results of modern surgical techniques, such as piezoelectric canaloplasty. It is also worth conducting research on the population of Polish water sports athletes, whose numbers are growing every year, especially in the Baltic coastal regions.

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All authors have read and agreed with the published version of the manuscript. All authors have reviewed and agreed to the publication of the final version of the manuscript.

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