Evidence-informed decision aid for fitness-to-dive assessment after otologic surgery

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Abstract
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Introduction: Fitness-to-dive after otologic surgery is often approached conservatively, with some procedures historically labelled as absolute contraindications despite limited empirical evidence. The available literature is heterogeneous and includes clinical reports, experimental pressure studies, guidance documents, and manufacturer specifications, leading to uncertainty in clinical counseling. We aimed to characterise the available evidence regarding fitness-to-dive after otologic surgery and to develop an evidence-informed clinical decision aid.
Methods: A scoping review was conducted in accordance with PRISMA-ScR guidance. PubMed/MEDLINE, Embase, Scopus, and relevant non-indexed sources were searched. Eligible sources included clinical reports and series, experimental or hyperbaric chamber studies, guidance or consensus documents, and manufacturer statements providing explicit pressure- or depth-related information. Data were charted descriptively by procedure type and evidence stream.
Results: The search identified 324 records; after removal of duplicates and screening, 40 sources were included. The evidence base was predominantly non-comparative. Across procedures, recommendations emphasised postoperative stability and reliable pressure equalisation rather than surgical history alone. Canal wall down mastoidectomy was consistently portrayed as incompatible with diving, whereas selected middle ear reconstructions and stapes surgery were commonly described as potentially compatible in appropriately selected individuals. For cochlear implantation, guidance was mainly conditional and based on hyperbaric testing, limited clinical diving reports, and manufacturer-specified pressure or depth limits. Communication emerged as an additional practical consideration in cases of significant hearing loss.
Conclusions: Relevant evidence is limited and heterogeneous, and does not consistently support blanket prohibitions for all otologic procedures. A function-based, individualised approach is supported, while specific higher-risk scenarios warrant restriction. Prospective registries and standardised outcome reporting are needed to refine procedure-specific recommendations.

Introduction

Exposure to pressure changes during scuba diving poses unique physiological challenges to the auditory and vestibular systems. Middle-ear pressure equalisation, inner-ear pressure transmission, and device integrity are critical considerations for diver safety.[1] As a result, a range of otologic conditions and prior surgical procedures have historically been considered contraindications to diving.[2,3] These recommendations are often conservative and variably defined, reflecting the limited empirical data available to support clear thresholds of risk.[4–6]

Otologic surgery encompasses a broad spectrum of procedures, including tympanoplasty and middle-ear reconstruction, ossiculoplasty, mastoidectomy, stapes surgery, and cochlear implantation. Patients undergoing these procedures increasingly seek guidance regarding return to recreational or occupational diving, where requirements may be more stringent in professional settings.[7] However, existing recommendations are inconsistent, ranging from absolute prohibition to conditional clearance based on healing status, Eustachian tube function, or device-specific considerations.[8,9]

Given the heterogeneity of the literature and the absence of randomised or large prospective studies, a scoping review is an appropriate methodological approach to map the available evidence, clarify the nature of existing recommendations, and identify gaps requiring further research. The present scoping review aims to systematically characterise the literature addressing fitness-to-dive after otologic surgery, with a focus on pressure exposure, reported otologic outcomes, and practical postoperative guidance.

Methods

STUDY DESIGN AND REPORTING

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).[10] A review protocol defining objectives, eligibility criteria, information sources, and planned data charting was finalised prior to screening and prospectively registered in the Open Science Framework.[11]

ELIGIBILITY CRITERIA

Eligibility criteria were defined using the Population-Concept-Context framework.

The pre-defined population of interest was individuals with a history of otologic surgery, including middle-ear reconstruction procedures and cochlear implantation. The concept explored was fitness-to-dive (recreational and occupational) and safety under pressure exposure, including scuba diving and controlled hyperbaric chamber exposure. Eligible sources addressed postoperative recommendations, depth or pressure limits, contraindications, or adverse otologic outcomes attributable to pressure changes.

Clinical studies (case reports, case series, and observational studies), experimental or hyperbaric chamber studies, clinical guidelines or expert consensus documents, and manufacturer documents were eligible for inclusion. Manufacturer documents were included only when they provided explicit statements regarding pressure exposure, depth limits, or device integrity relevant to diving. Publications unrelated to diving or pressure exposure, aviation-only contexts without relevance to diving, and sources without accessible full text were excluded.

In addition to sources meeting eligibility criteria and included in formal evidence charting, selected references (e.g., general reviews, physiology-focused studies, and broad guidance documents) were used to contextualise findings and support interpretation. These sources were not considered part of the included evidence dataset and are therefore not individually represented in procedure-specific tables.

INFORMATION SOURCES

The following bibliographic databases were searched: PubMed/MEDLINE, Embase, and Scopus. In addition, non-indexed sources relevant to diving medicine were reviewed, including Google Scholar, professional diving medicine resources, and selected manufacturer documentation when applicable.

SEARCH STRATEGY

Search strategies combined diving-related terms (e.g., scuba, diving, hyperbaric, pressure exposure, barotrauma) with otologic surgery terms (e.g., tympanoplasty, ossiculoplasty, stapedotomy, mastoidectomy, cochlear implant). Search strategies were adapted for each database. Google Scholar was queried using predefined search strings, and the first 200 results per query were screened. Reference lists of included sources were hand-searched to identify additional eligible records. The final search was completed on 4 February 2026.

SELECTION OF SOURCES OF EVIDENCE

Records were deduplicated prior to screening. Two reviewers independently screened titles and abstracts for relevance. Full-text review was performed for potentially relevant records. Discrepancies were resolved by consensus.

DATA CHARTING PROCESS

Data were extracted using a piloted standardised charting form. Extracted variables included: type of evidence (clinical, experimental, guidance, manufacturer), otologic procedure category, pressure exposure modality (scuba diving versus hyperbaric chamber), exposure characteristics (maximum depth or pressure when reported), timing from surgery to exposure, reported otologic outcomes, and postoperative recommendations related to diving.

DATA SYNTHESIS

Data were synthesised descriptively and organised by otologic procedure and evidence stream. Quantitative pooling or meta-analysis was not performed.

USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence tools (Microsoft Copilot) were used only to assist with language revision and did not contribute to study conception, methodology, data handling, or conclusions.

Results

SEARCH RESULTS

The search identified 324 records, including 177 from bibliographic databases and 147 from other sources. In the database search, 78 duplicate records and one record removed for other reasons were excluded before screening, leaving 98 records for title and abstract screening; 28 were excluded at this stage. Seventy reports were sought for retrieval, of which six were not retrieved, leaving 64 reports assessed for eligibility. In the other-sources search, 147 reports were sought for retrieval, of which 17 were not retrieved, leaving 130 reports assessed for eligibility. Overall, 194 reports were assessed for eligibility across both search approaches, and 40 met eligibility criteria for inclusion in data charting. The study selection process is summarised in the PRISMA flow diagram (Figure 1).

OVERVIEW OF INCLUDED EVIDENCE

Across the 40 included sources, the evidence base was heterogeneous and predominantly non-comparative. Clinical evidence consisted mainly of case reports, small case series, and retrospective surveys describing return to diving after otologic surgery.

Experimental evidence included hyperbaric chamber testing of cochlear implant devices and hyperbaric chamber exposure of patients with these devices implanted.[12] Additional sources comprised expert guidance documents from diving medicine organisations, narrative reviews addressing pressure-related otologic injury, and manufacturer specifications detailing pressure or depth tolerance of implantable devices.

An overview of the available evidence by surgical category and evidence stream is provided in Table 1, with detailed source-level information available in *Supplementary Tables S1–S3.

MIDDLE EAR SURGERY: TYMPANOPLASTY AND OSSICULOPLASTY

Evidence addressing fitness-to-dive after tympanoplasty and ossicular reconstruction was derived primarily from expert guidance and narrative clinical sources. Across these sources, the central determinant of dive fitness was not the surgical label itself but postoperative middle-ear stability. Procedures resulting in an intact, well-healed tympanic membrane, a dry ear, and preserved Eustachian tube function were generally considered compatible with a return to recreational diving.[6,13–15]

Ossicular reconstruction using partial ossicular replacement prostheses (PORP) was consistently described as having a pressure tolerance comparable to that of a non-operated ear when middle-ear aeration was adequate. In contrast, total ossicular replacement prostheses (TORP) were

Note: *Supplementary Tables S1–S3 can be found on our website: https://www.dhmjournal.com/index.php/journals?id=419

Figure 1
PRISMA flow diagram of the scoping review

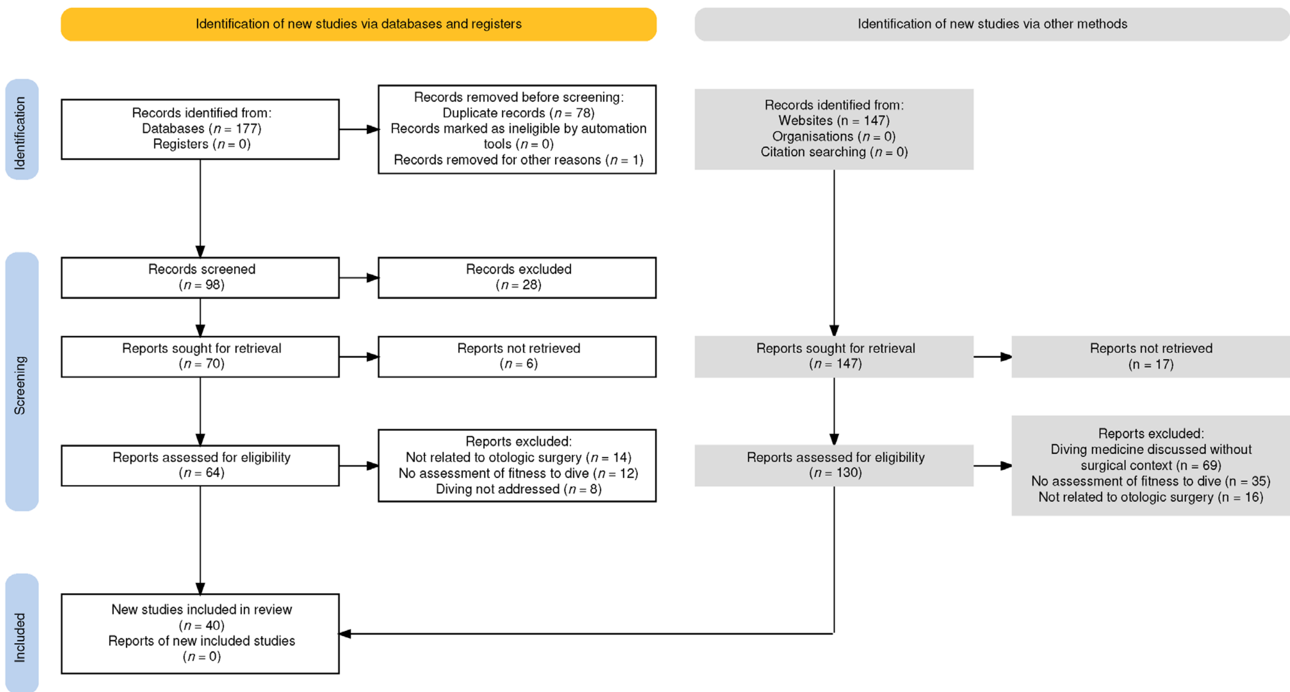


Table 1

Summary of evidence and fitness-to-dive considerations by otologic procedure; this table synthesises the available clinical, experimental, guidance, and manufacturer evidence regarding fitness to dive after different otologic procedures. For each procedure category, the predominant evidence base, key reported findings, and typical recommendations related to postoperative diving are summarised. Procedure and source-level details, including reported depth or pressure limits and device-specific considerations, are provided in *Supplementary Tables S1–S3. PORP – partial ossicular replacement prosthesis; TORP – total ossicular replacement prosthesis

Procedure category	Evidence base in this review	Key reported findings	Typical recommendations reported
Tympanoplasty/middle-ear reconstruction	Mainly expert guidance and narrative clinical sources	Fitness to dive relates primarily to postoperative stability rather than the surgical label.	Conditional clearance after healing; emphasis on intact tympanic membrane and reliable equalisation.
Ossiculoplasty (PORP)	Guidance and narrative sources	Generally described as pressure-tolerant when reconstruction and aeration are stable.	Conditional clearance after healing; individualised assessment.
Ossiculoplasty (TORP)	Guidance and narrative sources	Repeatedly described as potentially more vulnerable to pressure-related mechanical stress.	More conservative approach; greater caution and individualised restriction.
Mastoidectomy (canal wall up)	Guidance and narrative sources	Not usually considered an absolute contraindication once healing and ventilation are stable.	Conditional clearance after healing and dry ear status.
Mastoidectomy (canal wall down)	Guidance and narrative sources	Consistently framed as higher risk due to impaired pressure equilibration.	Generally considered unfit for scuba diving.
Stapes surgery	Retrospective surveys and small clinical series	Most reported divers resumed recreational diving without persistent sequelae when equalisation was adequate.	Not supported as an absolute contraindication; conditional clearance with precautions.
Cochlear implantation	Mixed: chamber testing, clinical reports, guidance, manufacturer data	Preserved device integrity/ function reported within specified pressure ranges.	Device-specific depth/pressure limits; conditional clearance.

repeatedly cited as more vulnerable to pressure-related mechanical stress, with expert sources suggesting lower rupture thresholds and recommending greater caution or restriction.[8,9,15,16]

Canal wall up (CWU) mastoidectomy, in which the posterior wall of the external auditory canal is preserved, and near-normal middle-ear anatomy is maintained, aims to restore a closed tympanomastoid system with physiological sound conduction and pressure transmission. In the available literature, CWU procedures were variably addressed but were generally not considered an absolute contraindication to diving once complete epithelialisation, stable tympanic membrane healing, and reliable middle-ear ventilation had been achieved.[8,9,15]

In contrast, canal wall down (CWD) mastoidectomy involves the removal of the posterior canal wall, creating a permanently open mastoid cavity that communicates directly with the external environment. This altered anatomy may impair effective pressure equalisation and increase exposure of the middle ear and mastoid cavity to water and thermal stress. For these reasons, CWD mastoidectomy has traditionally been regarded as a relative or absolute contraindication to diving.[8,9,15] However, some authors, as reported by Mallen et al., suggest that it may not represent an absolute contraindication in highly selected cases, provided additional functional assessment, including cold air or water testing, excludes vestibular sensitivity.[8]

STAPES SURGERY

Clinical evidence related to stapedectomy and stapedotomy consisted mainly of retrospective surveys and small clinical series describing divers who resumed scuba diving after surgery, as summarised in expert and guidance sources.[17–19] Across these reports, most individuals returned to recreational diving without persistent audiovestibular sequelae when middle-ear pressure equalisation was reliable.[8,15,20,21]

Reported adverse effects were generally mild and transient, including otalgia during descent or short-lived vertigo. Serious inner ear complications such as perilymphatic fistula were rarely documented and typically discussed as isolated events rather than systematic findings. None of the included sources provided robust evidence for an absolute contraindication to diving based solely on prior stapes surgery. Instead, recommendations emphasised individualised assessment, healed middle-ear status, and absence of vestibular symptoms.[16,17,22]

COCHLEAR IMPLANTATION

Evidence concerning cochlear implantation and diving was more structured and included both experimental and clinical data. Hyperbaric chamber testing reported preserved structural integrity and functional stability of cochlear implants exposed to pressures equivalent to depths of approximately 50 m (about six atmospheres absolute pressure), without mechanical damage to implant housings or electrode arrays. In vivo hyperbaric chamber studies involving implanted patients similarly reported no clinically relevant changes in device impedances or function, with only mild and transient discomfort reported.[23–26]

Clinical diving data were limited but consistent. Case reports and small series described implanted individuals completing multiple recreational dives at depths ranging from approximately 28 m to 43 m without deterioration of implant performance or auditory outcomes. These observations were reinforced by narrative reviews summarising manufacturer recommendations and available clinical experience.[24–26]

Manufacturer specifications varied by device platform but generally defined maximum pressure or depth limits rather than absolute prohibitions.[27–29] Across sources, recommendations for divers with cochlear implants were predominantly conditional, emphasising adherence to device-specific limits and the absence of surgical or vestibular complications rather than categorical exclusion from diving.[8,30]

HYPERBARIC AND PRESSURE-RELATED OTOLOGIC EVIDENCE

A limited number of included sources addressed otologic responses to pressure exposure in hyperbaric or experimental contexts without focusing on diving specifically. These studies provided a physiological framework for understanding middle and inner ear behavior under pressure, including the role of gas compression, intracochlear pressure transmission, and vulnerability of the round and oval windows.[20,31–33]

Although not designed to assess post-surgical dive fitness directly, this body of evidence supports the biological plausibility of pressure tolerance in stable postoperative ears and implant systems, while also highlighting mechanisms through which pressure-related injury may occur in the presence of impaired equalisation or structural instability.[15,20] Bone-anchored hearing systems were also considered within this review, with limited data suggesting a low risk of pressure-related complications, although they remain a relative contraindication due to the lack of robust evidence.[8,15]

Discussion

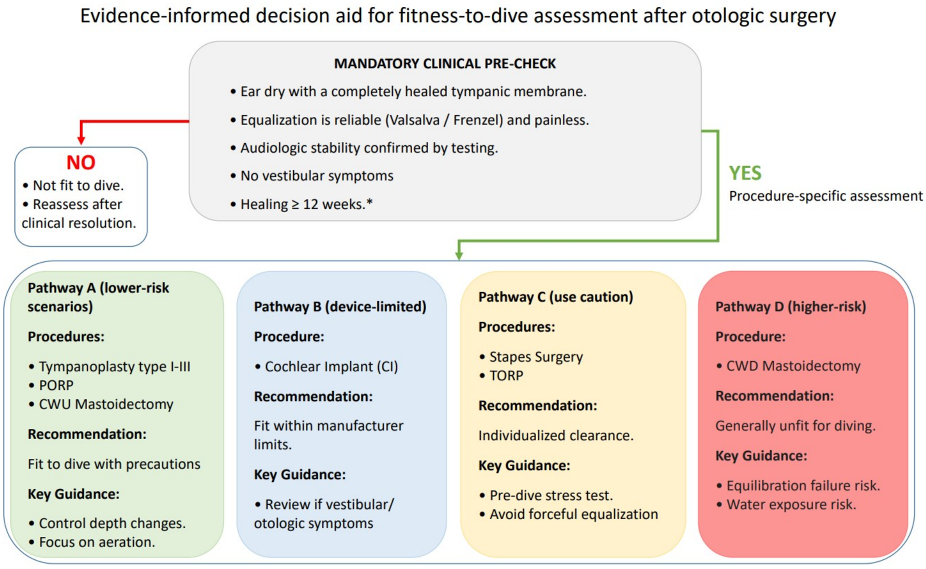
To our knowledge, this represents one of the first structured, evidence-informed clinical decision aids specifically addressing fitness-to-dive after otologic surgery. This scoping review highlights that fitness-to-dive after otologic surgery is rarely supported by evidence-based absolute contraindications.[34] Instead, the available literature consistently frames risk in functional and contextual terms rather than by surgical history alone.[35] Across procedure categories, postoperative stability, middle-ear ventilation, and the ability to equalise pressure reliably emerge as central determinants of safe diving.[8,15]

A key finding of this review is the disconnect between traditional exclusionary recommendations and the empirical evidence available. For several procedures commonly regarded as incompatible with diving, including stapes surgery and selected middle-ear reconstructions, the literature predominantly consists of small clinical series and retrospective surveys reporting return to recreational diving without persistent audiovestibular sequelae in carefully selected individuals. Although the quality of evidence remains limited, these observations do not support blanket prohibitions based solely on prior surgery. Across multiple sources, a consistent practical recommendation is to defer return to diving for approximately three months following middle ear surgery, provided that complete healing, normal tympanic membrane integrity, and adequate middle-ear ventilation are confirmed.[8,22,36,37]

Conversely, specific surgical scenarios are repeatedly identified as higher-risk contexts. CWD mastoidectomy is consistently described as incompatible with diving due

Figure 2

Evidence-informed decision aid for fitness-to-dive assessment after otologic surgery; this figure presents a structured clinical pathway for postoperative fitness-to-dive assessment based on functional criteria rather than surgical labels alone. It integrates mandatory clinical pre-checks, procedure-specific risk stratification, and device-related considerations to support individualised decision-making. CWD – canal wall down; CWU – canal wall up; PORP – partial ossicular replacement prosthesis; TORP – total ossicular replacement prosthesis



to impaired pressure equilibration and water exposure risk.[15,16] Similarly, certain ossicular reconstructions, particularly total ossicular replacement prostheses, are portrayed as potentially more vulnerable to pressure-related mechanical stress, warranting a more conservative and individualised approach.[5,8] These distinctions underline the importance of procedure-specific rather than surgery-generic counseling. In cases of uncertainty, a cautious return to diving under controlled conditions has been suggested, allowing assessment of pressure equalisation and symptom tolerance before resuming unrestricted diving activity.[35] In addition to clinical assessment, several sources recommend objective functional testing before return to diving following selected procedures, including stapes surgery or cochlear implantation. This may include tympanometry to confirm middle-ear status and vestibular evaluation, such as the video head impulse test or videonystagmography.[8,22]

Stapes surgery represents a distinct scenario within middle-ear procedures, given its direct interface with the inner ear and the associated theoretical risk of pressure-related complications.[21,38] However, available clinical reports suggest that return to recreational diving may be feasible in carefully selected individuals with stable postoperative status and normal vestibular function.[8,15–17] Some authors have suggested a cautious, stepwise return to diving under controlled conditions. This approach is conceptually similar to the 'pre-dive stress test' described after other otologic procedures and may include controlled pressure exposure in a hyperbaric chamber or a carefully supervised shallow-water dive to confirm symptom-free pressure tolerance before unrestricted diving is resumed.[13]

In light of these considerations, patients who are active or prospective divers should be counseled prior to middle-ear surgery regarding the potential implications for future diving, including procedure-specific risks and the possible need for restrictions or individualised clearance.[22]

For cochlear implantation, the evidence base differs in nature. Recommendations are informed by a combination of hyperbaric chamber testing,[23] limited clinical diving reports,[24,26,30] and manufacturer specifications.[27–29] Across sources, guidance is predominantly expressed as conditional clearance within device-specific pressure or depth limits rather than categorical exclusion from diving. This reinforces the concept that device integrity and postoperative stability, rather than the mere presence of an implant, should guide fitness-to-dive decisions.

To facilitate practical interpretation of these findings, we developed an evidence-informed decision pathway summarising procedure-specific considerations for postoperative diving clearance (Figure 2). While the preceding sections outline the variability in risks across surgical categories, the algorithm consolidates these distinctions into a structured, clinically usable framework. It emphasises functional markers such as middle-ear stability, reliable pressure equalisation, and device-specific pressure limits. The pathway also highlights higher-risk contexts, including CWD mastoidectomy and selected total ossicular replacement prostheses, where restriction or individualised assessment is warranted. Rather than replacing clinical judgment, the framework provides a pragmatic tool to support consistent, procedure-adapted decision-making in the postoperative diver. In this framework, a "*focus on* *aeration*" specifically refers to prioritising the confirmation of stable middle-ear ventilation, with the diver able to equalise pressure easily, repeatedly, and without symptoms.

An important practical aspect highlighted by this review, which is rarely addressed explicitly in the literature, relates to diver communication and situational awareness. In individuals with significant postoperative hearing loss, fitness-to-dive should not be considered in isolation. Effective communication with the dive buddy is a critical safety component in recreational diving. Buddies should be informed of hearing limitations and prepared to adapt communication strategies accordingly, particularly in low-visibility environments or emergencies. This consideration extends fitness-to-dive assessment beyond otologic risk alone and aligns it with real-world diving safety practices.

LIMITATIONS

Given the heterogeneity and limitations of the available evidence, the proposed decision aid should be interpreted as an evidence-informed clinical support tool rather than a formal guideline. Its purpose is to facilitate structured, individualised assessment and shared decision-making between clinicians and divers. Future research should focus on standardised outcome reporting and the development of prospective registries to better define procedure-specific risks and refine fitness-to-dive recommendations after otologic surgery.

Conclusions

The current evidence base suggests that fitness-to-dive after otologic surgery should be approached on an individualised basis rather than through absolute contraindications. While data remain limited, selected patients may safely return to diving under appropriate conditions. Further prospective research is needed to inform standardised clinical guidance.

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