Volume 4, Issue 3, March 2026 ISSN (E): 2938-3765

ENHANCING SURGICAL EFFICIENCY THROUGH ARTIFICIAL INTELLIGENCE IN THE SURGICAL MANAGEMENT OF CONGENITAL EXTERNAL AUDITORY CANAL ATRESIA

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Abstract

Congenital external auditory canal atresia is a complex developmental malformation of the external and middle ear that causes conductive hearing loss and presents substantial surgical challenges because of aberrant anatomy of the ossicular chain, facial nerve, middle ear space, tegmen, sigmoid sinus, and adjacent temporal bone structures. High-resolution temporal bone CT remains the cornerstone of preoperative assessment, while candidacy for atresiaplasty is commonly guided by grading systems such as the Jahrsdoerfer score. Contemporary surgical reviews state that surgery is generally not recommended for patients with Jahrsdoerfer scores of 6 or lower, whereas patients with scores of 7 or higher often achieve favorable short-term hearing outcomes, with 80% to 90% reaching a postoperative speech reception threshold of 30 dB HL or better. At the same time, newer evidence shows that the Jahrsdoerfer score alone does not adequately capture all surgically relevant temporal bone abnormalities, including low tegmen position, anterior sigmoid sinus displacement, and vascular variants.

Artificial intelligence has recently emerged as a promising adjunct in temporal bone imaging. Recent reviews indicate that AI-driven CT analysis can improve automatic segmentation, anatomical measurement, anomaly detection, and personalized surgical planning in ear disease. Although direct AI studies specifically dedicated to congenital aural atresia remain limited, computer-enhanced 3D virtual surgery in congenital atresia has already shown that advanced image processing can closely reflect actual intraoperative anatomy and may even help avoid surgery in anatomically unfavorable cases. In addition, newer radiologic work has shown that advanced temporal bone imaging modalities can improve visualization of the ossicular chain and other structures that are critical for operative planning.

The aim of this modeled study was to evaluate whether an AI-assisted surgical workflow could improve preoperative planning, intraoperative efficiency, and 12-month postoperative outcomes in 85 patients with congenital external auditory canal atresia treated at the TDTU ENT Department. The modeled protocol combined standard otologic assessment with AI-assisted temporal bone CT interpretation, automated anatomical risk mapping, AI-supported virtual surgical corridor simulation, and postoperative restenosis-risk stratification. Synthetic results suggested that AI support improved diagnostic concordance, shortened time to final operative planning, reduced operative time, lowered intraoperative change of strategy, and improved postoperative canal patency and hearing-related outcomes.

Keywords: Congenital aural atresia, congenital external auditory canal atresia, artificial intelligence, temporal bone CT, atresiaplasty, canalplasty, Jahrsdoerfer score, virtual surgery, hearing outcome, surgical planning.

Introduction

Congenital aural atresia is one of the most challenging malformations in otologic surgery because the anatomical abnormalities extend far beyond simple canal absence. In addition to conductive hearing loss, affected patients may present with abnormal tegmen position, anterior sigmoid sinus displacement, aberrant facial nerve course, hypoplastic middle ear space, and ossicular malformations. High-resolution CT is therefore essential before treatment selection is made, and it remains the key imaging study for determining surgical candidacy and operative risk.

Modern surgical management has become more selective. Current surgical reviews emphasize that careful preoperative selection is crucial, that surgery is generally avoided in patients with Jahrsdoerfer scores of 6 or below, and that short-term hearing results are best in patients with scores of 7 or higher. Earlier outcome studies similarly showed that patients with higher Jahrsdoerfer scores achieve significantly better postoperative hearing than those with lower scores. At the same time, newer anatomical work indicates that the Jahrsdoerfer score alone may not adequately reflect surgically important skull-base and vascular anomalies, meaning that more refined imaging analysis is required for personalized operative planning.

Artificial intelligence is increasingly relevant in temporal bone CT because of the small size, high density, and complex spatial relationships of ear structures. Recent reviews report that AI-driven segmentation and measurement tools can improve precision and personalization in surgical planning for ear disease, including congenital malformations. Although direct AI evidence in congenital aural atresia remains limited, computer-aided virtual surgery has already demonstrated that enhanced 3D CT reconstructions can accurately represent atretic ear anatomy and help identify cases in which surgery should be avoided.

For this reason, congenital aural atresia is a logical setting in which to test an AI-assisted workflow. Such a workflow may improve surgery not by replacing the otologic surgeon, but by improving candidate selection, identifying anatomical danger zones, defining the safest drilling corridor, and anticipating the likelihood of canal restenosis or suboptimal hearing gain.

Aim

To assess, in a modeled 85-patient cohort from the TDTU ENT Department, whether an AI-assisted surgical workflow can improve preoperative accuracy, intraoperative efficiency, and postoperative outcomes in patients undergoing surgery for congenital external auditory canal atresia.

Materials and Methods

This manuscript was designed as a modeled prospective comparative study. A total of 85 patients with unilateral or bilateral congenital external auditory canal atresia were included. All modeled patients had conductive hearing loss, temporal bone CT suitable for preoperative planning, and anatomy considered potentially amenable to reconstructive ear canal surgery. Because current literature supports careful candidate selection using CT-based evaluation and grading systems, the modeled inclusion framework was based on standard preoperative otologic assessment combined with radiologic candidacy evaluation.

The modeled cohort was divided into two groups. Group A, the conventional pathway, included 42 patients assessed with standard otologic examination, audiometry, and expert temporal bone CT review. Group B, the AI-assisted pathway, included 43 patients assessed by the same standard workflow plus four modeled AI components:

1. automated temporal bone CT segmentation of the atretic plate, ossicular mass, facial nerve canal, middle ear space, sigmoid sinus, and tegmen;
2. AI-supported anatomical risk mapping highlighting potentially hazardous drilling zones;
3. AI-assisted virtual canalplasty simulation and predicted operative corridor;
4. machine-learning prediction of postoperative canal patency and hearing improvement based on preoperative imaging and audiologic variables.

These AI components were modeled on the basis of published evidence showing that AI-driven segmentation and measurement tools improve temporal bone CT analysis, and that computer-enhanced virtual surgery in congenital aural atresia can reflect actual intraoperative anatomy with high fidelity.

All modeled patients underwent surgery by the same otologic team. Canalplasty or canal-tympanoplasty with meatoplasty was planned in anatomically suitable cases, with ossicular reconstruction performed selectively when needed. The primary endpoints were preoperative diagnostic concordance, time to final operative decision, mean operative time, intraoperative change of plan, and 12-month anatomical success. Secondary endpoints included postoperative air-bone gap improvement, canal restenosis, dry ear status, revision-free survival, and surgeon-rated anatomical confidence.

Results

Table 1. Baseline Characteristics of the Modeled Cohort

Variable	Group A: Conventional Pathway (n=42)	Group B: AI-Assisted Pathway (n=43)
Mean age, years	13.8 ± 4.6	14.1 ± 4.9
Male, n (%)	24 (57.1)	25 (58.1)
Female, n (%)	18 (42.9)	18 (41.9)
Unilateral atresia, n (%)	34 (81.0)	35 (81.4)
Bilateral atresia, n (%)	8 (19.0)	8 (18.6)
Mean preoperative air-conduction PTA, dB HL	63.1 ± 8.5	62.4 ± 8.1
Mean preoperative bone-conduction PTA, dB HL	13.2 ± 5.4	12.8 ± 5.1
Mean air-bone gap, dB	49.9 ± 7.9	49.6 ± 7.4
Jahrsdoerfer score ≥7, n (%)	31 (73.8)	32 (74.4)
Suspected aberrant facial nerve course on CT, n (%)	9 (21.4)	10 (23.3)
Low tegmen and/or anterior sigmoid sinus on CT, n (%)	11 (26.2)	12 (27.9)

The modeled baseline distribution reflects the contemporary understanding that most surgical candidates are selected from the subgroup with more favorable CT anatomy, while a meaningful proportion still harbor skull-base or vascular anomalies that complicate surgery. Recent studies confirm that such abnormalities are common in congenital aural atresia and are not fully predicted by the Jahrsdoerfer score alone.

Table 2. Modeled Preoperative Diagnostic and Planning Performance

Metric	Group A: Conventional Pathway	Group B: AI-Assisted Pathway
Diagnostic concordance with intraoperative anatomy, n (%)	34 (81.0)	40 (93.0)
Mean time to final operative decision, days	4.1 ± 1.5	2.3 ± 0.9
Additional radiology review required, n (%)	10 (23.8)	3 (7.0)
Mean CT interpretation time per case, min	13.7 ± 3.5	7.8 ± 2.1
Correct preoperative identification of major anatomical hazard, n (%)	29 (69.0)	39 (90.7)
Surgeon-rated confidence before surgery /10	7.2 ± 1.1	8.6 ± 0.8

The modeled improvement in preoperative planning is plausible because advanced CT processing and AI-supported measurement are specifically described as tools that can enhance personalized planning in ear disease. Likewise, historical virtual surgery data in congenital aural atresia showed that enhanced 3D CT reconstructions could accurately predict anatomy and influence case selection.
The modeled hearing results are compatible with contemporary surgical literature indicating that selected congenital aural atresia cases can achieve favorable 1-year hearing outcomes after canal-tympanoplasty, while restenosis and long-term deterioration remain important concerns. Recent case-series data reported serviceable hearing in all patients at 3 months and in 85% at 1 year, with the air-bone gap improving from about 39 dB preoperatively to about 19 dB at 1 year.
The present modeled study suggests that artificial intelligence may improve congenital aural atresia surgery mainly by refining the preoperative stage. This is clinically important because the operation is highly dependent on subtle anatomical relationships, especially the position of the facial nerve, sigmoid sinus, tegmen, and middle ear space. Recent work from 2024 demonstrated that congenital aural atresia patients have a higher prevalence of low tegmen and anterior sigmoid sinus, and that these abnormalities are not adequately captured by the Jahrsdoerfer score alone. That finding strongly supports the need for more sophisticated CT-based planning tools.
The modeled diagnostic advantage of AI is also plausible in light of recent temporal bone imaging reviews, which state that AI has already improved automatic segmentation, measurement, and anomaly detection in ear CT. In congenital malformations, these functions are especially useful because conventional visual review can underestimate the true spatial complexity of the atretic ear.
Another major modeled benefit was improved operative efficiency. Congenital aural atresia surgery can fail or become hazardous when the true drilling corridor is not fully appreciated before surgery. Historical computer-assisted virtual surgery showed that enhanced 3D CT could accurately represent ossicles, facial nerve, and otic capsule relationships in atretic ears, and even helped avoid surgery in

anatomically unfavorable cases. The AI-assisted pathway in the present modeled study extends that same principle into a modern segmentation and risk-mapping framework.

The modeled reduction in restenosis and revision is also reasonable. Canal restenosis is one of the major long-term challenges of aural atresia surgery, and hearing outcomes vary substantially depending on anatomy and postoperative healing. Surgical reviews emphasize that careful patient selection and meticulous technique remain the main determinants of success, while newer radiologic approaches improve visualization of the ossicular chain and other relevant structures. AI is most likely to help by improving the consistency and personalization of those same steps.

At the same time, direct AI evidence specifically for congenital aural atresia surgery is still limited. Much of the currently available literature supports AI in temporal bone CT analysis more broadly rather than in atresiaplasty alone. Therefore, the present manuscript should be interpreted as a translational scientific template grounded in current imaging and surgical evidence, not as proof that AI has already been validated as a routine standard in congenital aural atresia surgery.

Conclusion

In this modeled 85-patient study, an AI-assisted workflow improved the surgical management pathway for congenital external auditory canal atresia by increasing preoperative concordance, shortening time to operative planning, reducing operative time, lowering intraoperative changes in strategy, and improving 12-month canal patency and hearing-related outcomes.

The most realistic near-term role of AI in congenital aural atresia surgery is as an integrated support tool for temporal bone CT interpretation, anatomical hazard mapping, virtual surgical corridor planning, and individualized prediction of postoperative outcome. A real-world prospective TDTU ENT study would be required to determine whether these modeled benefits can be reproduced in routine otologic practice.

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