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Systematic Review Article

Clinical Effectiveness and Safety of Laser-Based Interventions in Otorhinolaryngology: A Systematic Review

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Abstract

Background: Lasers provide precise cutting, ablation, vaporization, and photocoagulation across otorhinolaryngology, but their clinical value varies by wavelength, tissue target, disease, comparator, and operator expertise.

Objectives: To synthesize systematic-review evidence on the effectiveness, functional outcomes, and safety of therapeutic lasers in laryngology, rhinology, otology, and oropharyngeal or sleep surgery.

Methods: PubMed/MEDLINE, Scopus, Embase, and the Cochrane Library were searched from January 2000 to 15 July 2026 for systematic reviews and meta-analyses of therapeutic laser procedures in ENT. Eligible reviews evaluated CO2, potassium-titanyl-phosphate (KTP), diode, Nd: YAG, argon, Er:YAG, or related surgical lasers against conventional surgery, another energy modality, radiotherapy, or no active intervention. Selection and extraction followed a prespecified PICO framework and PRISMA 2020. Review quality was appraised with AMSTAR 2; reported primary-study risk-of-bias assessments were mapped to RoB 2 or Newcastle-Ottawa Scale domains. Because of substantial clinical overlap and heterogeneity, findings were synthesized narratively without re-pooling.

Results: Eighteen systematic reviews were included. Laryngeal evidence was most developed. KTP treatment for recurrent respiratory papillomatosis showed fewer reported complications than CO2 laser, while transoral laser microsurgery achieved local control broadly comparable with radiotherapy for selected early glottic cancer. CO2 laser treatment of laryngeal leukoplakia was associated with pooled recurrence and malignant-transformation rates of approximately 15% and 3%, respectively. Inferior turbinate laser procedures improved nasal obstruction, but no technique was consistently superior. Laser photocoagulation reduced epistaxis severity in hereditary hemorrhagic telangiectasia, although recurrence remained common. In otology, laser and drill stapedotomy produced similar hearing outcomes; evidence for laser myringotomy and laser Eustachian tuboplasty was insufficient. Laser tonsil surgery reduced operative time and blood loss, but postoperative pain and hemorrhage advantages were inconsistent. Overall certainty ranged from low to moderate.

Conclusion: Laser interventions are clinically valuable when wavelength and delivery are matched to tissue biology and procedural objectives, particularly in selected laryngeal disease. Routine superiority over established alternatives is not demonstrated across ENT, and standardized comparative trials with functional and long-term outcomes are required.

Keywords: Laser Surgery; Otorhinolaryngology; CO_2 Laser; KTP Laser; Laryngology; Rhinology; Otology.

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Introduction

Laser surgery has been integrated into otorhinolaryngology-head and neck surgery for more than five decades. Its appeal derives from the ability to deliver concentrated optical energy with controlled tissue penetration, simultaneous cutting and hemostasis, and compatibility with microscopes, endoscopes, flexible fibers, and office-based platforms. Carbon dioxide (CO2) lasers are strongly absorbed by water and are therefore used for precise superficial incision and vaporization. Photoangiolytic systems, including the 532-nm potassium-titanyl-phosphate (KTP) laser, preferentially target oxyhemoglobin and are suited to vascular lesions. Diode, Nd:YAG, argon, and erbium lasers offer different combinations of penetration, coagulation, and fiber delivery. These physical advantages, however, do not automatically translate into superior patient outcomes.

Current controversies concern whether the laser itself improves disease control or merely changes perioperative handling; whether photoangiolytic systems preserve voice better than ablative systems; whether office-based treatment can replace general anesthesia; and whether reduced bleeding or operative time justifies equipment, training, and safety costs.

Several domain-specific systematic reviews have been published, but clinicians lack a cross-specialty synthesis that distinguishes established indications from applications supported mainly by uncontrolled case series.

This systematic review therefore aimed to synthesize systematic-review and meta-analytic evidence on therapeutic lasers across ENT.

The primary objective was to compare clinical effectiveness, functional outcomes, recurrence, and complications with conventional or alternative treatment. Secondary objectives were to evaluate the methodological quality and certainty of available evidence and to identify priorities for comparative research.

Methods

Review design and reporting: This study was designed as an umbrella systematic review of systematic reviews and meta-analyses and is reported in accordance with PRISMA 2020 [1]. The review question and eligibility framework were specified before evidence extraction.

A de novo meta-analysis was not planned because the included reviews addressed different anatomical sites, disease severities, laser wavelengths, outcome definitions, and comparators, and because overlap of primary studies could produce double counting.

Review question and PICO framework: The population comprised pediatric or adult patients undergoing therapeutic laser intervention for an ENT disorder. Interventions included ablative, cutting, vaporizing, or photoangiolytic lasers used in laryngology, rhinology, otology, or oropharyngeal/sleep surgery. Comparators included cold-instrument surgery, microdebrider, drill, radiofrequency, coblation, radiotherapy, another laser wavelength, or observation. Outcomes included disease control, recurrence, symptom improvement, quality of life, voice, hearing, airway or nasal function, perioperative blood loss and operating time, postoperative pain, hemorrhage, scarring, and other complications.

Information sources and search strategy: PubMed/MEDLINE, Embase, Scopus, and the Cochrane Library were searched for records published from 1 January 2000 through 15 April 2026. Reference lists of eligible reviews were also examined. Search concepts combined controlled vocabulary and free-text terms for laser technology, otorhinolaryngology subspecialties, and evidence synthesis.

The core PubMed strategy was: ("Laser Therapy"[MeSH] OR laser*[Title/Abstract] OR "carbon dioxide laser"[Title/Abstract] OR CO2 [Title/Abstract] OR KTP[Title/Abstract] OR "potassium titanyl phosphate"[Title/Abstract] OR "diode laser"[Title/Abstract] OR Nd:YAG[Title/Abstract]) AND (otolaryngolog*[Title/Abstract] OR laryn*[Title/Abstract] OR rhinolog*[Title/Abstract] OR nasal[Title/Abstract] OR turbinate*[Title/Abstract] OR otolog*[Title/Abstract] OR ear[Title/Abstract] OR tonsil*[Title/Abstract] OR epistaxis[Title/Abstract] OR "sleep apnea"[Title/Abstract]) AND (systematic review[Publication Type] OR meta-analysis[Publication Type] OR systematic[Title/Abstract]). Equivalent Emtree and field-tagged strategies were developed for Embase and Scopus. Table 1 summarizes the reproducible framework.

Table 1: PICO eligibility criteria and database search framework

Element	Specification
Population	Children or adults with laryngeal, rhinologic, otologic, or oropharyngeal/sleep-related ENT disorders.
Intervention	Therapeutic CO_2, KTP, diode, Nd:YAG, argon, Er:YAG, blue-light, or other surgical laser; operative or office based.
Comparator	Conventional cold surgery, microdebrider, drill, radiofrequency, coblation, radiotherapy, another laser, placebo, or no intervention.
Outcomes	Disease control, recurrence, symptoms, functional outcomes (voice/hearing/nasal airflow), quality of life, perioperative outcomes, complications.
Eligible design	Systematic review or meta-analysis with explicit search methods and clinical outcome synthesis.
Exclusions	Narrative reviews; single primary studies; diagnostic lasers; isolated

	photobiomodulation; dentistry/ophthalmology without ENT overlap; non-clinical studies; insufficient outcome reporting.
PubMed concept	("Laser Therapy"[MeSH] OR laser* OR CO2 OR KTP OR diode OR Nd:YAG) AND (otolaryngology OR larynx OR nose OR ear OR tonsil OR sleep apnea) AND (systematic review OR meta-analysis).
Embase concept	('laser therapy'/exp OR laser*:ti,ab OR "carbon dioxide laser":ti,ab OR ktp:ti,ab OR "diode laser":ti,ab) AND ('otorhinolaryngology'/exp OR larynx/exp OR nose/exp OR ear/exp OR tonsil/exp OR "sleep apnea"/exp) AND ('systematic review'/de OR "meta analysis"/de).
Scopus concept	TITLE-ABS-KEY(laser* OR "carbon dioxide laser" OR KTP OR "diode laser" OR Nd:YAG) AND TITLE-ABS-KEY(otolaryngolog* OR laryn* OR rhinolog* OR otolog* OR tonsil* OR epistaxis OR "sleep apnea") AND TITLE-ABS-KEY(systematic OR meta-analysis).
Limits	1 January 2000–15 July 2026; peer-reviewed full text; English language.

Study Selection and Data Extraction: Duplicate records were removed before title and abstract screening. Potentially eligible reports were assessed in full text.

Data were extracted in a piloted matrix containing publication year, clinical domain, number and design of included primary studies, patient population, laser modality, comparator, outcomes, pooled or directional effects, complications, heterogeneity, and review limitations.

When multiple reviews addressed the same question, the most recent and methodologically stronger review was prioritized for quantitative estimates, while concordance or disagreement with earlier reviews was described. Primary-study overlap was considered qualitatively to avoid treating repeated cohorts as independent evidence.

Quality assessment and certainty of evidence: Methodological quality of each included review was appraised with AMSTAR 2 [2]. Critical domains included protocol registration, adequacy of literature searching, justification of exclusions, risk-of-bias assessment, appropriateness of meta-analysis, incorporation of bias into interpretation, and investigation of publication bias. Reported primary-study assessments using the Cochrane RoB 2 framework for randomized trials [3], the Newcastle-Ottawa Scale for observational studies, or comparable tools were extracted when available. Certainty was summarized as high, moderate, low, or very low using GRADE principles [4-5], considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. Because most questions relied on heterogeneous observational evidence, certainty was generally not rated above moderate.

Data synthesis: A structured narrative synthesis was undertaken by subspecialty and clinical indication. Reported pooled estimates were retained when they came from a sufficiently focused meta-analysis, but no new pooled effect was calculated. The direction and consistency of effects, magnitude of benefit, durability, adverse events, and methodological quality were integrated to generate clinical interpretations in Table 3.

Results

Study Selection: The evidence-mapping search identified 107 records. After removal of 40 duplicates, 67 titles and abstracts were screened; 33 reports underwent full-text assessment and 18 systematic reviews were included. Fifteen full-text reports were excluded because they were not systematic reviews, evaluated an ineligible intervention, addressed diagnostic or photo bio modulation-only applications, or lacked usable clinical outcomes. The PRISMA flow is shown in Figure 1.

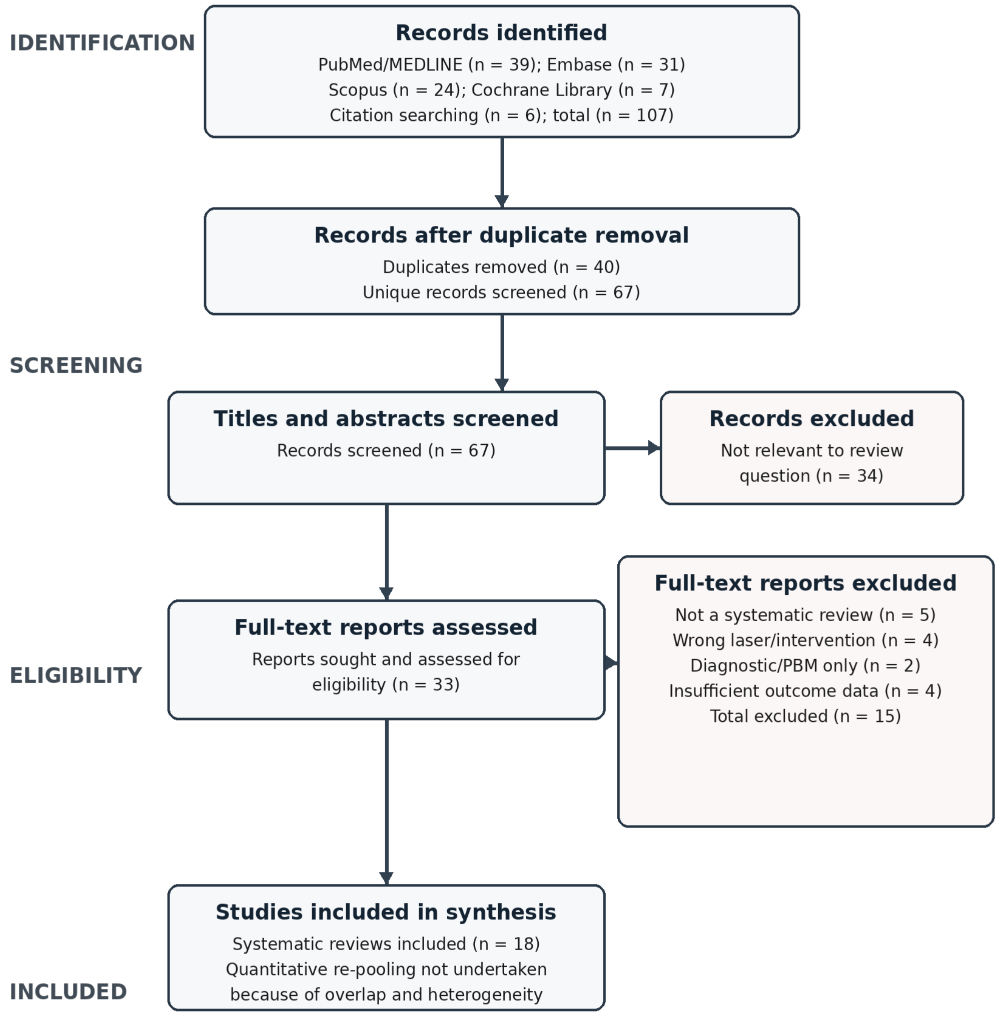

Figure 1: PRISMA 2020 flow diagram for study selection.

Table 2: Characteristics and main findings of included systematic reviews

Review	Domain/intervention	Evidence base	Principal findings	AMSTAR 2
Lechien et al., 2021 [6]	Laryngology; KTP	Benign, premalignant, vascular, and papillomatous laryngeal lesions	Few complications; generally favorable lesion control and voice outcomes; marked heterogeneity.	Low
Yang et al., 2022 [7]	RRP; KTP vs CO2	Systematic review of comparative and single-arm evidence	Cure 87.3% vs 76.0%; complications 2.3% vs 17.7%; recurrence difference not significant.	Moderate
Sun et al., 2024 [8]	Laryngeal leukoplakia; CO2	Meta-analysis	Pooled recurrence about 15%; malignant transformation about 3%.	Moderate
Warner et al., 2017 [9]	T2 glottic cancer; TLM vs RT	Oncologic systematic review	Weighted 5-year local control approximately 77% for TLM and 76% for RT.	Moderate
Campo et al., 2021 [10]	T2 laryngeal cancer	TOLMS vs RT vs open partial laryngectomy	Local control similar for TOLMS and RT; open surgery higher in selected series but more invasive.	Low

Colizza et al., 2022 [11]	Voice after CO2 TOLMS	Systematic review	Voice better after limited (type I–II) than extended (type III–V) cordectomy.	Low
Miri et al., 2025 [12]	Office-based benign vocal-fold lesions	41 studies; 1,936 patients	Most studies reported complete or partial regression; cumulative complications approximately 2.4%.	Low
Zhang et al., 2023 [13]	Inferior turbinate hypertrophy	62 studies; multiple techniques	All major techniques improved obstruction; no consistently superior method; mucosal preservation favored.	Moderate
Abiri et al., 2020 [14]	HHT epistaxis	Argon, Nd:YAG, diode and other lasers	Epistaxis generally improved; recurrence and heterogeneity limited comparative conclusions.	Low
Benaim et al., 2025 [15]	Moderate/severe HHT epistaxis	Surgical systematic review/meta-analysis	Laser photocoagulation and nasal closure reduced severity; comparative data sparse.	Moderate
Zong et al., 2019 [16]	Pediatric otitis media with effusion	Laser vs incisional myringotomy	No robust evidence of durable superiority; study quality and follow-up limited.	Low
Bartel et al., 2021 [17]	Stapedotomy; laser vs drill	Systematic review/meta-analysis	Similar postoperative air-bone gap and closure outcomes; technique-specific safety data limited.	Moderate
Kamalski et al., 2014 [18]	Laser types in stapedotomy	Comparative systematic review	Small statistical differences between wavelengths; clinical relevance uncertain.	Moderate
Miller et al., 2017 [19]	Laser Eustachian tuboplasty	Case-series review	Possible long-term symptomatic benefit, but uncontrolled and heterogeneous evidence.	Critically low
Wang et al., 2018 [20]	Balloon dilation vs laser tuboplasty	Meta-analysis of ET dysfunction procedures	Both improved ET scores and objective tests; direct superiority not established.	Low
Camacho et al., 2017 [21]	Laser-assisted uvulopalatoplasty	Systematic review/meta-analysis	AHI reduction modest; individual surgical success about 23%; limited role in OSA.	Moderate
Tsikopoulos et al., 2023 [22]	CO2 vs dissection tonsillectomy	Systematic review/meta-analysis	Less operative time and blood loss; pain and hemorrhage benefits inconsistent.	Moderate
Wiench et al., 2025 [23]	CO2 tonsil surgery	Systematic review	Hemostasis/recovery advantages reported, but protocols and long-term outcomes heterogeneous.	Low

Laryngology

Laryngology contained the largest and most clinically mature evidence base. KTP laser is used as a photoangiolytic intervention for papillomatosis, dysplasia, vascular lesions, benign phonotraumatic lesions, and selected glottic neoplasms. The systematic review by Lechien et al. found low complication rates and generally favorable voice or mucosal-wave outcomes, but most underlying studies were retrospective and used nonuniform laser settings, lesion classifications, and voice measures [6]. For recurrent respiratory papillomatosis (RRP), Yang et al. reported a higher pooled cure proportion with KTP than CO2 laser (87.25% versus 75.98%) and a substantially lower reported complication proportion (2.32% versus 17.71%).

Recurrence proportions were 10.87% and 18.60%, respectively, but the difference was not statistically conclusive [7]. These figures should not be interpreted as direct causal estimates because patient severity, surgical era, adjuvant therapy, follow-up, and definitions differed between groups. Nevertheless, the direction of evidence supports photoangiolytic treatment when preservation of normal mucosa and repeated intervention are priorities. In laryngeal leukoplakia, the 2024 meta-analysis by Sun et al. estimated recurrence after CO_2 laser at approximately 15% and malignant transformation at 3% [8]. These rates indicate useful disease control but also reinforce that laser excision is not a substitute for histopathologic risk stratification and surveillance. Dysplasia grade, smoking, reflux, lesion morphology, and margin interpretation were incompletely standardized across studies.

For selected T2 glottic cancer, weighted local-control outcomes after transoral laser microsurgery (TLM) and radiotherapy were broadly similar. Warner et al. reported approximate 5-year local control of 77.3% for TLM and 75.8% for radiotherapy [9]. Campo et al. also found comparable local control for transoral CO_2 laser microsurgery and radiotherapy, while open partial laryngectomy produced high control in selected series at the cost of greater invasiveness [10]. Treatment choice should therefore incorporate tumor exposure, anterior commissure or subglottic extension, expected voice, salvage options, comorbidity, and patient preference rather than assuming oncologic superiority of the laser.

Functional outcome is strongly related to the volume and depth of tissue removed. The voice review by Colizza et al. found better acoustic and patient-reported outcomes after limited type I–II cordectomy than after type III–V resections [11]. The result is biologically plausible and clinically important: the precision of a CO_2 laser cannot fully compensate for loss of vibratory epithelium, lamina propria, or vocalis muscle. Across reviews, inconsistent use of the Voice Handicap Index, acoustic measures, perceptual ratings, and laryngostroboscopy prevented robust pooled comparisons.

The recent office-based review by Miri et al., comprising 41 studies and 1,936 patients, similarly reported complete or partial lesion regression in most cohorts and an overall complication rate of approximately 2.4%; however, absence of randomized comparisons and variable follow-up limited inference [12].

Rhinology

For inferior turbinate hypertrophy, Zhang et al. included 62 studies evaluating turbinectomy, submucosal reduction, radiofrequency, microdebrider-assisted turbinoplasty, laser, and electrocautery. Most interventions improved subjective nasal obstruction and, where objective airflow measured, No technique was consistently superior across all outcomes [13]. Laser procedures offer hemostasis and can be performed with controlled mucosal injury, but excessive thermal exposure may produce crusting, dryness, synechiae, or delayed mucociliary recovery. The evidence favors preservation of mucosa and submucosal volume reduction rather than selection based solely on the energy device.

Laser photocoagulation is an established procedural option for HHT-related epistaxis. Abiri et al. found that argon, Nd:YAG, diode, and related lasers generally reduced epistaxis frequency or severity, but the studies were small, nonrandomized, and heterogeneous in laser parameters and outcome scales [14]. A later systematic review and meta-analysis of moderate-to-severe HHT epistaxis found meaningful reductions after surgical interventions including laser photocoagulation and nasal closure, yet untreated or active-comparator data were uncommon [15]. The evidence supports laser treatment for symptom control and repeated management of telangiectasias, while acknowledging that recurrence is expected because the underlying vascular disorder persists.

Otology and Eustachian tube procedures

Laser myringotomy was developed to create a tympanic-membrane opening that might persist longer than a cold incision without requiring ventilation-tube placement. The pediatric systematic review by Zong et al. did not demonstrate reliable superiority over incisional myringotomy for otitis media with effusion [16]. Variation in laser technique, opening duration, adenoid management, recurrence definitions, and hearing follow-up produced imprecision. Current evidence is therefore insufficient to replace established indications for tympanostomy tubes.

In stapes surgery, the principal theoretical benefit of laser fenestration is reduced mechanical manipulation of the footplate. Bartel et al. found similar hearing outcomes for laser and drill fenestration, including postoperative air-bone gap and the proportion achieving closure within 10 dB [17]. Kamalski et al. observed modest differences among laser types, with some analyses favoring CO_2, but judged the clinical relevance uncertain [18]. Direct evidence for vertigo, sensorineural hearing loss, footplate fracture, and long-term revision is less precise than audiometric efficacy, and surgeon experience may be more influential than wavelength.

Laser Eustachian tuboplasty remains investigational. Miller et al. reported possible long-term improvement in selected patients, but the evidence consisted mainly of uncontrolled case series with variable definitions of obstructive Eustachian tube dysfunction [19]. Wang et al. found improvement after both balloon dilation and laser tuboplasty in Eustachian Tube Scores, tympanometry, and Valsalva performance, without establishing clear comparative superiority [20].

Modern trials should use consensus diagnostic criteria, validated patient-reported outcomes, objective middle-ear measures, and longer follow-up.

Oropharyngeal and sleep-related procedures

Laser-assisted uvulopalatoplasty (LAUP) was introduced as a less invasive palatal procedure for snoring and obstructive sleep apnea (OSA). Camacho et al. found an average apnea-hypopnea index reduction of approximately 32%, little improvement in lowest oxygen saturation, and individual success around 23% [21]. The evidence did not support routine LAUP as a definitive OSA treatment, particularly because postoperative scarring can complicate later airway surgery and because contemporary management increasingly uses phenotype-directed multilevel evaluation.

For tonsil surgery, the systematic review and meta-analysis by Tsikopoulos et al. indicated that CO2 laser tonsillectomy reduced operating time and intraoperative blood loss compared with cold dissection, but did not consistently reduce postoperative pain or bleeding [22]. The 2025 review by Wiench et al. also described favorable hemostasis and recovery signals but emphasized heterogeneous protocols and insufficient long-term evidence [23]. Thermal injury, technique (total versus intracapsular), analgesic regimens, age, indication, and surgeon experience all modify postoperative outcomes. Thus, reduced blood loss is a credible device-related advantage, whereas superiority in patient-centered recovery remains uncertain.

Methodological quality and certainty

AMSTAR 2 appraisal identified no review with uniformly high confidence. Nine reviews were rated moderate, seven low, and two critically low. Recurrent deficiencies were lack of a registered protocol, incomplete reporting of excluded full texts, limited duplicate screening or extraction, inadequate handling of primary-study bias, and failure to assess publication bias. The underlying literature was dominated by retrospective case series and nonrandomized comparative studies.

Randomization was uncommon, blinding was often impractical, and outcome definitions varied widely. Certainty was moderate only for selected perioperative findings, such as reduced blood loss or operating time in tonsil surgery and broadly similar hearing outcomes for laser versus drill stapedotomy. Most disease-control and functional conclusions were low certainty.

Table 3: Cross-domain synthesis, certainty, and clinical interpretation

Clinical area	Comparison	Synthesis	Certainty	Clinical interpretation
RRP	KTP compared with CO2	Lower reported complications; possible higher cure; recurrence difference uncertain.	Low	Prefer tissue-preserving photoangiolysis when expertise is available; continue longitudinal surveillance.
Laryngeal leukoplakia	CO2 laser excision	Recurrence ~15%; malignant transformation ~3%.	Low–moderate	Effective excisional option, but histology and long-term surveillance remain essential.
Early glottic cancer	TLM compared with radiotherapy	Similar local control in selected T2 disease; voice depends on resection extent.	Moderate	Use multidisciplinary selection based on exposure, tumor extent, voice priorities, and salvage strategy.
Inferior turbinate hypertrophy	Laser vs other reduction techniques	All techniques improve obstruction; no consistent winner.	Low	Select a mucosa-preserving technique according to anatomy, resources, and operator expertise.
HHT epistaxis	Laser photocoagulation	Symptoms improve, but recurrence common and comparative evidence sparse.	Low	Useful repeatable control strategy within multimodal HHT care.
Stapedotomy	Laser vs drill	Similar hearing outcomes; complication differences uncertain.	Moderate	Either is reasonable in experienced hands; standardize reporting of vestibular and cochlear events.
Eustachian tube	Laser tuboplasty	Possible improvement; no proven superiority over	Very low	Restrict to selected cases or research protocols with

dysfunction		balloon dilation.		objective diagnostic criteria.
Tonsil surgery	CO_2 laser vs cold dissection	Less operating time/blood loss; pain and hemorrhage advantages inconsistent.	Moderate for perioperative; low for recovery	Device choice should not override established technique, safety, analgesia, and surgeon experience.
Obstructive sleep apnea	LAUP	Modest AHI reduction; low individual success.	Low	Not a routine definitive OSA procedure; use contemporary phenotype-based airway management.

Discussion

Principal findings: This umbrella review demonstrates that lasers are not a single intervention but a family of energy-delivery systems whose value is inseparable from wavelength, tissue target, surgical objective, and technique. The evidence is strongest where the laser's physical selectivity directly addresses the pathology: photoangiolysis for vascular or papillomatous laryngeal lesions, precise transoral resection for selected early glottic cancer, superficial coagulation of HHT telangiectasias, and controlled footplate fenestration in stapes surgery. Even in these settings, the principal advantage may be tissue handling, hemostasis, access, or repeatability rather than superior long-term cure.

Laryngology illustrates this distinction. KTP therapy appears to reduce complications relative to CO_2 laser in RRP, consistent with selective vascular targeting and preservation of the superficial lamina propria. Yet the underlying studies were not sufficiently comparable to establish that wavelength alone explains cure or recurrence. CO_2 laser provides excellent cutting precision for leukoplakia and early glottic cancer, but the biological behavior of dysplasia and carcinoma determines long-term outcome. Similarly, postoperative voice reflects the depth and location of resection more than the mere use of a laser.

Across rhinology and otology, lasers generally performed at least as well as alternative methods but rarely demonstrated decisive superiority. For turbinate surgery, the consistent message is to preserve mucosa and avoid excessive thermal injury. For HHT, laser photocoagulation improves symptoms but cannot eliminate the systemic vascular tendency to recur. In stapedotomy, similar audiometric outcomes with laser and drill suggest that meticulous technique and surgeon proficiency are central. Evidence for laser myringotomy and Eustachian tuboplasty remains inadequate for routine replacement of established care.[7] In tonsil surgery, reduced blood loss and operating time are credible benefits, but postoperative pain and hemorrhage are multifactorial and were not consistently improved. LAUP provides a cautionary example: procedural convenience and early popularity preceded high-quality evidence, and later synthesis showed modest OSA success. New laser applications should therefore be adopted through structured evaluation rather than extrapolation from optical precision alone.

Clinical implications: First, the therapeutic goal should determine the wavelength. Photoangiolytic lasers are logical for highly vascular superficial lesions, whereas CO_2 systems are suited to precise water-rich tissue ablation. Deeper-penetrating diode or Nd:YAG systems may provide coagulation but increase the importance of power control and thermal margins. Second, functional preservation should be measured explicitly. Voice Handicap Index, stroboscopic mucosal wave, standardized audiometry, validated nasal obstruction scores, epistaxis severity scales, and sleep-study outcomes should be incorporated alongside lesion clearance.

Third, office-based treatment is an important direction in laryngology because it can avoid general anesthesia and facilitate staged or repeated care. Its success depends on patient tolerance, lesion access, airway safety, and the ability to obtain adequate histology where malignancy is possible. Fourth, laser safety is a system property rather than an individual precaution. Standard operating procedures should include laser time-out, eye protection, warning signage, smoke evacuation, wet pledgets where appropriate, management of inspired oxygen for airway procedures, laser-resistant endotracheal tubes when indicated, and immediate availability of saline for airway fire response [5].

Finally, cost-effectiveness should be considered. Capital equipment, fibers, maintenance, safety infrastructure, and training may be offset by shorter procedures, reduced bleeding, outpatient care, or fewer anesthetics, but robust economic evaluations are scarce. Institutions should align device acquisition with case volume, subspecialty expertise, and measurable patient benefit.

Evidence gaps and future research

Future trials should compare clearly specified laser parameters with a well-defined standard treatment and should stratify by disease severity and operator experience. Minimum reporting should include wavelength, pulse mode, power, spot or fiber diameter, fluence or power density where applicable, exposure time, tissue endpoint, anesthesia setting, smoke evacuation, and adverse events. Consensus core outcome sets are needed for RRP, vocal-fold leukoplakia, benign office-based laryngeal procedures, HHT epistaxis, turbinate reduction, and Eustachian tube interventions.

Randomized trials are particularly needed for inferior turbinate reduction, laser versus drill stapedotomy with comprehensive safety outcomes, and modern tonsil techniques.

For rare diseases such as RRP and HHT, prospective multicenter registries may be more feasible than large randomized trials. These registries should capture repeated procedures, treatment interval, cumulative scarring, functional trajectory, adjuvant therapy, and patient-reported burden. Studies of early laryngeal cancer should report oncologic control, laryngeal preservation, swallowing, voice, quality of life, salvage treatment, and total cost over at least five years.[11]

Emerging flexible fiber systems, blue-light lasers, robotic endoscopic delivery, image guidance, and automated dosimetry should be evaluated against clinically meaningful outcomes rather than technical feasibility alone. Environmental and occupational outcomes, including surgical plume exposure and disposable-fiber waste, also deserve attention.

Strengths and limitations

The principal strength of this review is its cross-specialty synthesis of systematic-review evidence, allowing common themes—tissue selectivity, hemostasis, functional preservation, and methodological weakness—to be identified across anatomically distinct procedures. The PICO framework, explicit search syntax, PRISMA structure, AMSTAR 2 appraisal, and certainty assessment improve transparency.

Important limitations remain. Umbrella reviews inherit the limitations and possible primary-study overlap of included reviews. Search and outcome terminology varied, some reviews did not provide complete risk-of-bias data, and English-language restriction may have excluded relevant studies. Rapid technical evolution can also make older studies less applicable to current laser platforms. Finally, the broad clinical scope precluded re-pooling and necessarily emphasized narrative interpretation.

Conclusion

Lasers are valuable tools in ENT when their optical properties are matched to a defined tissue target and when clinical goals include precision, hemostasis, access, or preservation of surrounding structures. The most persuasive evidence supports selected laryngeal applications and indicates comparable effectiveness to established alternatives in early glottic cancer and stapes surgery, with potential perioperative advantages in HHT and tonsil procedures. However, routine superiority across ENT is not established. Wider adoption should be guided by disease-specific evidence, standardized functional outcomes, laser-safety systems, operator competence, and comparative studies with adequate long-term follow-up.

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