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Review Article

When Does the Endoscope Change the Operation? A Corridor- and Pathology-Stratified Systematic Review of Endoscope-Assisted Cerebellopontine Angle Tumour Surgery

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Abstract

Background: Two systematic reviews published in 2025 addressed endoscopic visualisation in cerebellopontine angle (CPA) tumour surgery. De Marco and colleagues1 pooled 2,489 patients across endoscope-assisted (EA), endoscope-controlled (EC) and fully-endoscopic (FE) technique and found no significant difference between subgroups in gross total resection (GTR; p = 0.68) or facial nerve outcome (p = 0.89); Gomes and colleagues8 pooled 282 patients treated exclusively by the fully-endoscopic approach (85% GTR, 93% facial nerve preservation, 73% hearing preservation) without corridor stratification. We hypothesised that this null result reflects the level at which the question was posed rather than the absence of an effect, because the benefit of endoscopic assistance is conditional on the anatomical corridor at risk, on tumour pathology, and on whether the surgical approach already exposes that corridor.

Objective: To determine whether, in which anatomical corridors, and in which tumour pathologies routine endoscopic inspection after microscopic resection alters identification of residual tumour, and to derive an evidence-graded framework for when such inspection is indicated.

Methods: Systematic review reported per PRISMA 2020. MEDLINE was searched from inception, supplemented by author-specific and citation searching. Eligible studies reported EA or combined microscopic-endoscopic technique in adults undergoing resection of extra-axial CPA tumours (vestibular schwannoma, VS; meningioma; epidermoid), with extractable data on endoscope-attributable residual detection. FE/EC series were excluded by design. Studies were mapped to a four-corridor anatomical taxonomy extending the classifications of O'Donoghue and O'Flynn2 and Takemura and colleagues.3 Risk of bias was assessed with MINORS. Cohorts were screened for patient overlap before synthesis. Proportions were pooled by Freeman-Tukey double arcsine transformation under DerSimonian-Laird random effects; comparative outcomes were pooled as odds ratios (OR).

Results: Of 1,608 unique records, 42 reports met eligibility for qualitative synthesis and 27 studies (~909 independent patients) entered quantitative synthesis. One duplicate cohort was excluded. Pooled endoscope-attributable yield was 7.8% (95% CI 2.8–15.1%) at the internal auditory canal (IAC) fundus in VS, against 59.6% (95% CI 29.0–86.5%) in multicompartmental epidermoid disease ($z = 3.51$, $p = 0.00044$). Yield was further conditional on approach: within one 112-patient series, residual was detected in 22.2% of retrosigmoid, 6.4% of enlarged transcanal and 0% of translabyrinthine cases ($\chi^2 = 10.02$, $p = 0.0067$), independently replicated in a separate 68-patient series two decades earlier. Across four studies with an internal comparator, EA was associated with lower odds of residual tumour (pooled OR 0.211, 95% CI 0.092–0.485, $p = 0.0002$; $I^2 = 0\%$). No study attributed a complication to endoscope introduction. Aggregate pooling across all corridors/pathologies yielded $I^2 = 95.4\%$, confirming a single aggregate estimate is not statistically supportable.

Conclusion: Endoscopic assistance is beneficial but conditional: concentrated in epidermoid disease, in VS with substantial intracanalicular extension, and in approaches not natively exposing the IAC fundus, and negligible after translabyrinthine/middle fossa exposure. A corridor- and pathology-stratified framework, not a single pooled estimate, is the clinically actionable form of this evidence.

Keywords: Cerebellopontine angle; endoscope-assisted microsurgery; vestibular schwannoma; epidermoid cyst; residual tumour; internal auditory canal; surgical decision-making

Introduction : The geometric problem the endoscope was introduced to solve

Vestibular schwannoma (VS), meningioma and epidermoid tumours account for the great majority of extra-axial cerebellopontine angle (CPA) neoplasms. The retrosigmoid approach remains the most widely employed corridor for their resection, and the operating microscope has been the standard visualisation instrument for five decades.

The microscope's limitation is geometric rather than optical. It establishes a single fixed axis of sight originating outside the craniotomy; any struc-

ture behind bone, wrapped around a nerve's far surface, beyond an anatomical partition, or eclipsed by an interposed vessel lies outside that axis regardless of magnification. The canonical example is the lateral, or fundal, end of the internal auditory canal (IAC): because the canal angles obtusely to the posterior petrous ridge, and the bony labyrinth occupies the intervening space, its lateral 2–3 mm cannot be visualised through a standard posterior fossa exposure without extensive additional drilling. Residual tumour left here is a recognised source of recurrence.

The neuroendoscope addresses this constraint mechanically: its light source and objective lens are carried to the tip of a rod introduced into the field, relocating the point of observation from outside the corridor to within it.

Three decades of accumulated but unsystematised evidence

Endoscopy in the CPA was first described by Doyen [4], in 1917 for trigeminal root section. The modern era begins with O'Donoghue and O'Flynn's [2]. 1993 cadaveric description of CPA endoscopic anatomy, Magnan and colleagues'5 near-contemporaneous adjunctive clinical application, and Göksu and colleagues' [6]. 1999 report of endoscopically guided dissection at the IAC fundus. Takemura and colleagues [3], subsequently demonstrated, in a controlled cadaveric comparison, that the trigeminal nerve's junction with the pons, the porus of Meckel's cave, the facial nerve root exit zone and the hypoglossal canal are reliably visualised endoscopically but not, or only with retraction, microscopically.

What accumulated thereafter was a large, dispersed body of single-center series describing endoscope-assisted (EA) technique across VS, meningioma and epidermoid pathology. Tatagiba and colleagues [27], demonstrated microendoscopic inspection of the IAC as a discrete adjunct to vestibular schwannoma surgery; Ebner and colleagues [28], and de Divitiis and colleagues [29], extended endoscopic technique to recurrent and technically difficult epidermoid disease. These series consistently report that the endoscope identifies tumour the microscope did not — but in incompatible units, at heterogeneous sites, with no shared comparative framework.

Why the aggregate question has been asked and answered unproductively

Two systematic reviews published in 2025 attempted to resolve this literature at the level of aggregate outcome. De Marco and colleagues1 pooled 2,489 patients across all endoscopic technique subgroups (EA, EC, FE) and found no significant difference in GTR or facial nerve outcome between subgroups ($p = 0.68$ and $p = 0.89$ respectively). A companion meta-analysis restricted specifically to the fully-endoscopic retrosigmoid approach, by Gomes and colleagues [8], pooled 11 studies comprising 282 patients and reported a pooled GTR of 85% (95% CI 74–92), facial nerve preservation of 93% (95% CI 87–96), and serviceable hearing preservation of 73% (95% CI 49–88), without a corridor-stratified comparison.

We contend this null finding is a property of the question's construction, for four reasons.

First, the comparison pools interventions differing in kind. EA adds an inspection step to a microscopic operation; FE replaces the microscope entirely. In the De Marco cohort [1], the retrosigmoid subgroup alone comprised 931 EA, 131 EC and 716 FE procedures — averaging across this composition estimates no quantity a surgeon can act upon.

Second, the comparison averages across approaches that determine whether the blind spot exists at all. A translabyrinthine approach exposes the IAC to the fundus as a routine step; there is no fundal blind spot for an endoscope to interrogate. A retrosigmoid approach leaves precisely that recess unexposed. As shown in Section 3.4, this difference is large, significant, and independently replicated.

Third, the selected endpoints sit downstream of the mechanism and near a ceiling. GTR in contemporary series is high irrespective of technique — De Marco and colleagues [1], report a weighted VS rate of 92.5% — and an endpoint near its ceiling cannot discriminate between techniques.

Fourth, the literature lacks a shared outcome definition, making aggregate pooling not merely uninformative but statistically inadmissible. As demonstrated in Section 3.8, naive pooling across all corridors and pathologies returns $I^2 = 95.4\%$, indicating the constituent studies do not estimate a common quantity.

This does not diminish the existing reviews, which consolidated a scattered literature. It indicates that the question they asked cannot be answered informatively, because the average is taken over strata in which the true effect differs by nearly an order of magnitude.

A corridor- and pathology-stratified reformulation

We reformulate the question as it is actually encountered intraoperatively: for this pathology, in this corridor, having used this approach, is it worth introducing an endoscope before closing? We organise the literature around four corridors, extending the anatomical scaffolding of O'Donoghue and O'Flynn [2], and Takemura and colleagues [3].

- Corridor 1 — the IAC fundus, occluded by canal angulation and the bony labyrinth.
- Corridor 2 — cranial nerve root entry/exit zones, where a fixed axis cannot visualise a curved structure's far circumference.
- Corridor 3 — multicompartmental extension across anatomical partitions, characteristic of epidermoid tumours.
- Corridor 5 — recesses eclipsed by an interposed vascular or venous structure.

A fifth candidate corridor — extension into the jugular foramen and lower cranial nerve complex, provisionally numbered Corridor 4 during taxonomy development — was considered but not retained in the core framework, as only a single small series [44]. (n = 7) addresses it, insufficient for either quantitative synthesis or confident inclusion. The numbering here (Corridors 1, 2, 3 and 5) preserves this developmental history rather than renumbering consecutively, so that Corridor 4 remains reserved and traceable should future evidence justify its formal inclusion; this is revisited in Section 4.7.

What this review contributes

To our knowledge this is the first synthesis organised by anatomical corridor rather than aggregate outcome; the first restricting its exposure definition to EA specifically; the first adopting endoscope-attributable residual detection as its primary endpoint; the first to test formally for interaction between corridor, pathology and yield; and the first to identify and quantify the dependence of yield on surgical approach. It additionally screens for cohort overlap before pooling, stratifies by design tier separating within-patient from between-cohort comparisons, and reports explicitly where pooling is not statistically admissible rather than reporting a pooled figure regardless.

Methods

Protocol and registration

This review is reported per PRISMA 2020 and registered with PROSPERO (registration number to be inserted).

Eligibility criteria

Population

Adults (≥18y) undergoing resection of an extra-axial CPA tumour (VS, meningioma, epidermoid/dermoid). Excluded: Samii type B/C jugular foramen tumours, intra-axial lesions, paediatric-only series, and isolat-

ed neurovascular compression without tumour.

Exposure and comparator

Exposure: EA or combined microscopic-endoscopic technique. Comparator: microscope-alone or exoscope-alone (grouped together, sharing an external fixed viewing axis, as illustrated by recent combined exoscope-endoscope two-step reports by Iwami and colleagues [38] and colleagues [39]). FE/EC series were excluded from the primary analysis by design, since this review addresses whether inspection should be added to microsurgery, not whether FE should replace it. This exclusion was applied consistently: reports meeting all other eligibility criteria but employing FE or EC technique exclusively — including Marchioni and colleagues' exclusive endoscopic transcanal transpromontorial series [40]. Guan and colleagues [41], Peng and colleagues [42], and de Divitiis and colleagues [29] — were retained in qualitative synthesis for mechanistic context but excluded from quantitative pooling.

Outcomes

Primary: endoscope-attributable residual tumour identification, localisable to a defined corridor. Secondary: GTR, facial nerve function (House-Brackmann, HB), hearing (Gardner-Robertson, GR), complications.

Study designs

Case series (n≥5), comparative cohorts, and cadaveric/anatomical studies (mechanistic evidence only). Single-patient reports excluded from quantitative synthesis.

Information sources and search strategy

MEDLINE was searched via PubMed from inception, combining MeSH and free-text terms across four concept blocks (site, pathology, technique, outcome/yield terminology). Supplemented by author-specific searching, backward/forward citation searching of five anchor references, and manual screening of both 2025 reviews' reference lists (which additionally drew on Embase, partially mitigating this review's single-database primary search). Screening was restricted to English, German and French.

Study selection and data extraction

Records were screened against a structured form capturing tumour type/grade, technique, corridor, residual detection (numerator/denominator), resection extent, cranial nerve/hearing outcome, complications, accrual period, institution and follow-up.

Duplicate cohort screening

All included studies were screened for patient overlap by cross-referencing authors, institutions and accrual windows. Confirmed overlaps retained only the larger/more complete cohort; possible but unconfirmed overlaps were retained with the uncertainty declared.

Risk of bias

MINORS was scored across 8 items for non-comparative studies (max 16) and 12 for comparative studies (max 24). Cadaveric/anatomical studies were appraised separately for methodological transparency and not assigned MINORS scores.

Study design hierarchy

- Tier 1 — within-patient, same-surgeon, sequential designs (surgeon and case held constant).
- Tier 2 — single-surgeon/centre series over a defined period.
- Tier 3 — between-cohort/multi-surgeon comparisons, in which operator experience and technique are confounded.

Statistical analysis

Analyses used Python 3.12/SciPy, two-sided $\alpha = 0.05$. Single-arm proportions were pooled by Freeman-Tukey double arcsine transformation under DerSimonian-Laird random effects, back-transformed with 95% CI. Heterogeneity used Cochran's Q and I^2 (>75% = high). Comparative dichotomous outcomes were pooled as log odds ratios (DerSimonian-Laird random effects, 0.5 continuity correction for zero cells). Approach-stratified detection was tested by χ^2 test of independence. Two pooled proportions were compared by z-test on their Freeman-Tukey-transformed difference. Temporal trend used Pearson correlation, unweighted and sample-size-weighted.

Results

Study selection

The combined strategies identified 1,608 unique records. Screening excluded 1,016 (572 no endoscopic technique reference; 215 pathology outside scope; 215 anatomically unrelated; 14 no assessable abstract). Of 592 remaining, 70 satisfied highest-confidence criteria. Full text was obtained for 49; 42 entered qualitative synthesis. Twenty-seven studies (21 non-comparative, 6 comparative; ~909 patients) entered quantitative synthesis after excluding FE/EC series, single-case/mechanistic reports, and one confirmed duplicate cohort.

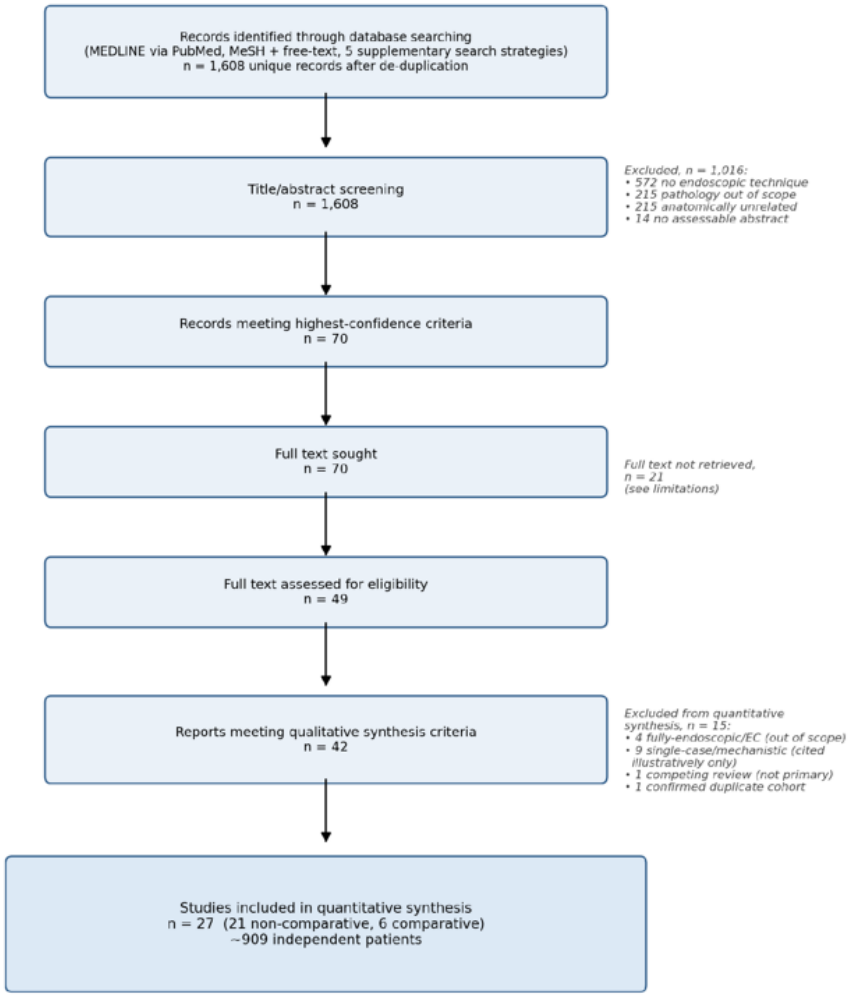


Figure 1. PRISMA 2020 flow diagram

Study characteristics

Table 1: summarises the 27 studies entering quantitative synthesis, ordered by corridor and design tier.

#	Study (Year)	Design / Tier	Pathology	N	Technique	Corridor	Key finding
11	Bi 2022	Retrospective / T1	VS	61	EA	C1	Residual 4/23 (17%) Grade B vs 0/38 Grade A, p=0.02
21	Gerganov 2010	Prospective vs historical / T3	VS	30 vs 50	EA vs micro-scope	C1	GTR 100% vs 98%; no endo-scope-attributable injury
9	Marchioni 2019	Retrospective / T2-3	VS	112	EA	C1	Residual 22.2% retrosig-moid, 6.4% transcanal, 0% translab (p=0.0067)
12	Kumon 2012	Retrospective / T3	VS	28 vs 43	EA vs micro-scope	C1	Residual advantage sig-nificant only at Grade 2 extension
19	Chovanec 2013	Prospective, non-ran-domised / T3	VS	39 vs 50	EA vs micro-scope	C1	EA: better facial (p=0.027) & cochlear nerve preservation (p=0.007)
17	King & Wackym 1999	Retrospective / duplicate — excluded	VS	10	EA	C1	EXCLUDED — subset of Wackym 1999 cohort (Sec-tion 3.2)
10	Wackym 1999	Prospective, consecutive / T1	VS	68	EA	C1	Residual 16.2%, all retros-igmoid; 0% translab/middle fossa

6	Göksu 1999	Retrospective / T2	VS	32	EA	C1	8/32 required endoscopic dissection at fundus
18	Göksu 2005	Retrospective / T2	VS	60	EA	C1	0% residual reported (see partial-overlap note, §3.2)
7	Magnan 2002	Retrospective / T2	VS	106	EA	C1	1/106 (0.9%) residual fragment on MRI follow-up
22	Jia 2022	Retrospective / T3	VS	31 vs 53	EA vs microscope	C1	Postop MRI residual 16% vs 1.9%
	Turek 2017	Technical note / unverified N	VS	N/A*	EA	C1	*Sample size requires verification before inclusion
15	Abolfotoh 2015	Retrospective / T1	Mixed (incl. VS, meningioma, epidermoid)	50	Combined micro-endo	C1/C2/C3/C5	Residual in 18/26 (69%) presumed-complete cases
26	Schroeder 2011	Retrospective / T1	Meningioma	46	EA	C1/C3	GTR 76%; residual not seen microscopically removed endoscopically
13	Vernon 2021	Retrospective / T2	Epidermoid	139	EA (40% of cases)	C3	83.9% (47/56) additional residual excised via EA
14	Schroeder 2004	Retrospective / T1	Epidermoid	8	EA	C3	2/8 explicit residual; complete evacuation on follow-up
24	Singh 2021	Retrospective / T1 (EA subset)	Epidermoid	86 (EA subset 10)	EA subset + EC subset	C3	3/10 (30%) missed lobule found on EA inspection
25	Tuchman 2014	Retrospective / T1	Epidermoid	13	EA	C3	11/13 (85%) additional tumour identified
16	Singh 2018	Retrospective / T2	Epidermoid	48	Combined micro-endo	C3	GTR 91.7%; endoscope benefit reported in 79% of cases
20	Tammam 2022	Prospective, non-randomised / T3	Epidermoid	16 vs 16 (verified)	EA vs microscope	C3	Residual 18.8% vs 56.3%, significant
23	Safavi-Abbasi 2008	Retrospective / T2 (counterpoint)	Epidermoid	12	Inspection-only (dissection not advised)	C3	~75% historical residual; argues against endoscopic dissection
3	Takemura 2014	Cadaveric	—	11 specimens	Microscope vs 0°/45° endoscope	C1/C2/C3/C5	Anatomic mechanism anchor; not pooled with clinical outcomes

Abbreviations: VS = vestibular schwannoma; EA = endoscope-assisted; EC = endoscope-controlled; GTR = gross total resection; N = sample size; T1/T2/T3 = design tier (Section 2.7); C1/C2/C3/C5 = anatomical corridor (Section 1.4: C1 = internal auditory canal fundus; C2 = cranial nerve root entry/exit zone; C3 = multicompartmental extension; C5 = obscured-by-adjacent-structure). Superscript numerals refer to the reference list. Studies retained for qualitative/mechanistic citation only (single-case reports, Corridors 2/5 clinical illustrations) are not tabulated here; see Supplementary Data Extraction Table.

Cohort overlap screening

One duplicate cohort was confirmed. King and Wackym [17], reported 10 sequential patients (April 1996–October 1997, Mount Sinai School of Medicine, surgeon P.A. Wackym). Wackym and colleagues [10], reported 68 patients (June 1993–January 1999), of whom 22 were operated by the same surgeon at the same institution. The smaller series lies entirely within the larger's accrual window, institution, surgeon and technique; it was excluded from pooling and retained for technical citation only.

A second, unresolved partial overlap is declared between Göksu and colleagues6 (1999; Gaziantep University, 1989–1998) and Göksu and colleagues [18] (2005; Gazi University, Ankara, 1996–2002), sharing a senior author and ~2 years of accrual, though distinct institutions are stated. Both were retained.

Methodological quality

Among 21 non-comparative studies, median MINORS was 8/16 (range 4–10); no study scored in the 'good' range. Among 6 comparative studies, median was 14/24 (range 11–19). Scores were depressed by near-universal failure of four items: prospective data collection, prospective sample size calculation, loss-to-follow-up reporting, and unbiased endpoint assessment. Only studies employing postoperative MRI as the endpoint — Magnan [7]. Abolfotoh [15]. Jia [22], and Tammam [20], and colleagues — achieved an unbiased assessment score.

Table 2 (item-level MINORS scores) available in the accompanying spreadsheet. Second-reviewer scoring and kappa remain to be completed.

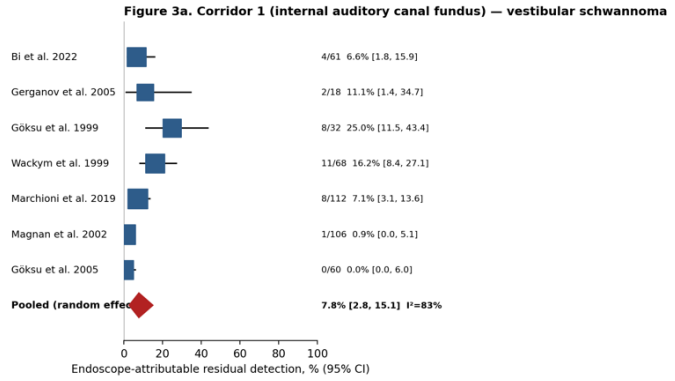
Endoscopic yield is conditional on surgical approach

Marchioni and colleagues [9] reported approach-stratified residual detection across 112 patients: 4/18 retrosigmoid (22.2%), 3/47 enlarged transcanal (6.4%), 0/41 translabyrinthine (0%); $\chi^2 = 10.02$, df = 2, p = 0.0067. This was independently replicated by Wackym and colleagues [10], two decades earlier (11/68, 16.2%, exclusively retrosigmoid; 0% translabyrinthine/middle fossa).

Endoscopic yield by corridor and pathology

Corridor 1 — internal auditory canal fundus

Seven studies reported endoscope-attributable residual in VS at the IAC fundus, rates 0–25%, pooled 7.8% (95% CI 2.8–15.1%; I^2 = 83.2%). Bi and colleagues [11], reported residual in 4/23 (17%) tumours extending ≥10mm into the canal versus 0/38 <10mm (p = 0.02). Kumon and colleagues [12], using an independent grading system, found significance only at intermediate extension, not at the fundus itself.

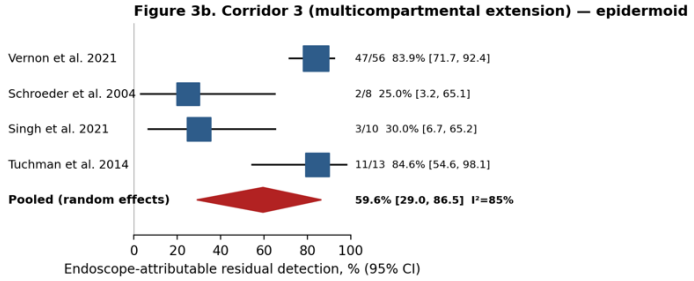


Consistent with the pooled estimate, isolated technical reports describe the same finding at the level of individual cases: Kunigelis and colleagues [30]. Vaz-Guimaraes and colleagues [31], and Hitti and Lee [32], each report endoscope-assisted identification of fundal or cisternal tumour not visualised microscopically during retrosigmoid resection. These single-case reports are not incorporated into the pooled estimate but are noted as consistent in direction.

Corridor 3 — multicompartmental extension

Four studies reported endoscope-attributable yield in epidermoid disease, 25–84.6%, pooled 59.6% (95% CI 29.0–86.5%; I^2 = 84.6%) — significantly greater than Corridor 1 (z = 3.51, p = 0.00044). Concordant evidence: Abolfotoh [15]. (18/26, 69%), Singh 201816 (79% of 48), and Vernon and colleagues [13], who reported EA use scaling from 18% (CPA-confined) to 100% (temporomesial extension).

The most extreme multicompartmental extent recorded in this synthesis is illustrated by a single reported case of recurrent meningioma extending across the cavernous sinus, posterior fossa, sphenoid sinus, pterygopalatine and infratemporal fossae, addressed with combined microscopic-endoscopic technique [33], a further case of epidermoid crossing the midline into the interpeduncular cistern was managed with endoscopic assistance specifically selected for that extension [31], and a giant epidermoid cyst with residual confined to microscope-blind recesses is reported by Boublata and colleagues [34]. Ebner and colleagues [28], additionally demonstrated that endoscopic assistance identified microscopically invisible remnants in all applicable cases of recurrent posterior fossa epidermoid disease (7 of 25 patients achieving complete resection).



Important caveat (added following independent statistical review): every VS row in this dataset is Corridor 1, and all but one epidermoid row is Corridor 3 — corridor and pathology are fully collinear in the current evidence base. The difference reported above should therefore be read as pathology-associated rather than as an established corridor effect; the two cannot be disentangled without studies reporting epidermoid disease in Corridor 1 or VS in Corridor 3. See Section 4.4 and 4.7 for discussion.

Corridors 2 and 5

Evidence was insufficient for quantitative pooling; both rest principally on the cadaveric work of Takemura and colleagues [3] and the anatomic assessment of Muelleman and colleagues [35], who quantified the limits of endoscopically assisted exposure of the internal auditory canal via a retrolabyrinthine corridor. Clinical corroboration for Corridor 2 is limited to isolated reports: Zaher and colleagues [36], describe endoscopic resection of a petrous meningioma combined with microvascular decompression of a superior cerebellar artery loop compressing the trigeminal nerve, illustrating the coexistence of tumour resection and neurovascular decompression addressed by the same corridor mechanism. Wardhana and colleagues [37] similarly report a small early-experience series (n = 3) of an endoscopic subtemporal keyhole anterior transpetrosal approach for small CPA tumours presenting with trigeminal neuralgia, documenting operative times of four to five hours relevant to the learning-curve considerations discussed in Section 4.6. This sparsity of controlled clinical evidence for Corridor 2, confirmed across five independent search strategies, is reported here as a finding in its own right.

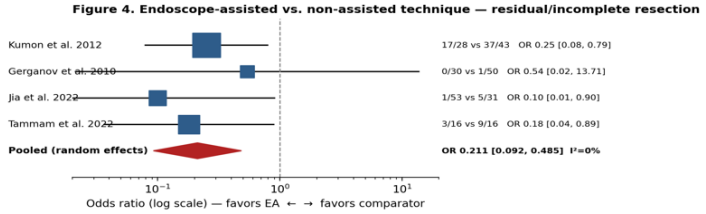
Comparative synthesis

Four studies contained an internal comparator (Kumon [12]. Gerganov 2010 [21]. Jia [22]. Tammam [20]). Pooled OR = 0.211 (95% CI 0.092–0.485; z = −3.67, p = 0.0002; I^2 = 0%).

Study	Design tier	EA arm (residual/N)	Comparator (residual/N)	OR
Kumon 2012	T3	17/28	37/43	0.251
Gerganov 2010	T3	0/30	1/50	0.541
Jia 2022	T3	1/53	5/31	0.100

Tammam 2022	T3	3/16	9/16	0.179
Pooled (random effects)	—	—	—	0.211 (0.092–0.485)

Abbreviations: EA = endoscope-assisted; OR = odds ratio; T3 = design tier 3 (Section 2.7).



Secondary outcomes and safety

Pooled GTR across 8 studies: 91.1% (95% CI 80.6–97.7%; I^2 = 87.1%). No study attributed a complication to endoscope introduction; Gerganov and colleagues [21], found no electrophysiological evidence of injury across 30 procedures. Chovanec and colleagues [19] reported that endoscopically-suspicious tissue was histopathologically confirmed as tumour in only 4/7 instances (57%) — endoscopic detection is not equivalent to endoscopic specificity.

Statistical inadmissibility of aggregate pooling

Pooling endoscope-attributable findings across all corridors/pathologies returned 27.2% with I^2 = 95.4%, confirming the constituent studies do not estimate a common quantity. No temporal trend was found (unweighted r = 0.21, p = 0.43; weighted r = 0.26).

Proposed decision framework

Clinical situation	Recommendation	Evidence grade
Epidermoid tumour, any approach	Routine EA inspection indicated	Moderate
VS, retrosigmoid, intracanalicular extension beyond mid-canal	Routine EA inspection indicated	Moderate
VS, retrosigmoid, minimal intracanalicular extension	Inspection optional; low expected yield	Moderate
VS, tumour already occupying fundus	Consider alternative approach over endoscopic rescue	Low
Any pathology, translabyrinthine/middle fossa approach	Routine inspection not indicated	Moderate
Cranial nerve root entry/exit zone concern	No recommendation possible	Insufficient

Abbreviations: EA = endoscope-assisted; VS = vestibular schwannoma.

Figure 2 (decision algorithm) to be rendered from this table.

Discussion

Principal findings

The benefit of EA in CPA tumour surgery is real, measurable, and conditional: reducing the odds of residual tumour by ~79% where an internal comparator exists, but varying approximately sevenfold between corridors and disappearing after certain approaches.

Reconciliation with prior aggregate synthesis

Our results do not conflict with the null findings of De Marco and colleagues [1], they explain them. Translabyrinthine and middle fossa subgroups contribute a guaranteed null; VS, dominating every pooled cohort numerically, contributes a genuine but modest 7.8%; epidermoid, in which the effect is large, is numerically small in any aggregate cohort (368/2,489 in De Marco's series [1]). An aggregate estimate constructed from this composition is weighted overwhelmingly toward the strata in which the effect is smallest or absent — compounded by endpoints (GTR, facial outcome) that sit near a ceiling and do not measure the mechanism directly.

Approach as the primary determinant

Two independent series, Marchioni [9] and Wackym [10] and colleagues, separated by two decades, report no endoscope-attributable residual after translabyrinthine or middle fossa exposure — mechanistically coherent, since these approaches expose the IAC to the fundus as a routine step.

Pathology as the second determinant

Epidermoid tumours propagate along cisternal planes across anatomical partitions, occupying precisely the recesses a fixed viewing axis cannot reach. Vernon and colleagues [13]. finding that EA use scaled from 18% to 100% with extension indicates surgeons were already reasoning in corridor-specific terms before this evidence existed.

Inspection, dissection, and the limits of detection

Chovanec and colleagues [19]. 57% histopathological confirmation rate, and Safavi-Abbasi and colleagues [23], explicit caution against endoscopic dissection, together indicate that a recommendation for routine inspection is not a recommendation for aggressive pursuit of every visualised abnormality.

Implications for research

- A shared outcome definition is needed; its absence directly causes the I^2=95.4% finding in Section 3.9.
- The dominant risk-of-bias limitation (surgeon-adjudicated endpoints) is remediable: independently-reported postoperative MRI, as in four included studies, provides an unbiased endpoint.
- Corridor 2 remains without clinical evidence despite consistent cadaveric demonstration and is a defined, tractable target for prospective study.

Limitations

The primary search was single-database, mitigated by four supplementary strategies; the close correspondence between our EA-specific patient total and the EA-specific subgroup of De Marco and colleagues [1], independently-searched cohort provides external reassurance of completeness. The literature is predominantly retrospective single-centre work, reflected in MINORS scores. Single-arm pooled proportions carry high within- and between-corridor heterogeneity and should be read as indicating magnitude and direction rather than precise estimates. The comparative estimate rests on four non-randomised studies. One partial cohort overlap could not be resolved.

Several anatomically adjacent or population-adjacent reports were identified but held outside primary quantitative synthesis, and are noted here for completeness rather than omitted silently. Kumral and colleagues [43], reported endoscope-assisted management of petrous apex cholesteatoma extending to the CPA in 14 patients — anatomically adjacent to, but not squarely within, this review's population definition. Shin and colleagues [44], described an endoscopic transmastoid posterior petrosal approach addressing lesions involving the internal auditory canal and jugular foramen in 7 patients, touching the jugular foramen corridor that this taxonomy currently excludes as Corridor 4; this remains an explicit scope decision for future revision rather than an oversight. A paediatric epider-

moid series45 was excluded under the adult-only population criterion but is noted as broadly consistent in direction with the adult epidermoid literature synthesised in Section 3.6.2. Finally, one further flexible-endoscope technique report46 could not be corroborated beyond its published abstract at the time of writing and was excluded from all quantitative synthesis pending full-text verification.

Conclusion

Endoscopic assistance does not confer a uniform benefit, and a decade of null aggregate comparisons has been misread as evidence of limited value. Framed at the level of corridor and pathology, the evidence supports specific, actionable recommendations; framed as an average, it supports none.

Supplementary notes for supervisory review

- PROSPERO registration number to be inserted.
- Dual independent screening and MINORS scoring with Cohen's kappa to be completed.
- Source verification outstanding: Turek 2017 sample size (currently unverified, footnoted in Table 1); Presutti 2014 GTR figure; Schroeder 2011 corridor-level residual location; Jia 2022 exact p-values.
- Scope decision required on Corridor 4 (jugular foramen).
- Figures 1–2 and full reference-list formatting to be completed.

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