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Review Article

Endoscopic Epilepsy Surgery: Systematic Review and Meta-Analysis

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Abstract

Endoscopic epilepsy surgery is a fast emerging minimally invasive alternative to open surgery. The approach minimizes the extent of bone and brain resection and reduces surgical morbidity. This systematic review and meta-analysis sought to evaluate the favorable outcome of seizure improvement in patients undergoing endoscopic epilepsy surgery. The search was conducted by two independent researchers using PubMed and Web of Science until January 2023 to find studies reporting results of patients who underwent endoscopic epilepsy surgery. We extracted data on the clinical profile and outcomes of the patients from the eligible studies. Fifteen studies yielded 340 patients, of which 293 underwent endoscopic epilepsy surgery. The patient cohort consisted of 189 (55.6%) males. A total of 171 (58.3) patients had a favorable outcome of either Engel I or II or $>90\%$ seizure control. Thirteen studies were included in our meta-analysis, and demonstrated improved seizure control after endoscopic epilepsy surgery, with a pooled seizure freedom rate of 58% (95% CI: 0.43–0.71, $I^2 = 77.1\%$, $\tau^2 = 0.6836$). Studies focusing on pediatric populations reported a higher proportion of positive outcomes, with a rate of 73.27% (95% CI: 62–82%, $I^2 = 0.0\%$). In comparison, mixed-age populations showed a lower success rate of 48% (95% CI: 32–65%, $I^2 = 79.0\%$). Furthermore, there was significant difference in treatment outcomes between the pediatric and mixed age groups ($p = 0.014$). The hypothalamic hamartomas (HH) patient population demonstrated a favorable outcome proportion of 61.71% (95% CI: 48.92–73.06%), with a moderate level of heterogeneity ($I^2 = 62.9\%$, $\text{tau}^2 = 0.4266$). Five patients developed postoperative complications, and there were three deaths. Our findings suggest that endoscopic epilepsy surgery is particularly effective in pediatric populations and among patients with HH, underscoring the importance of considering patient demographics and disease characteristics in clinical decision-

Keywords
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- hamartoma
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- callosotomy
- hemispherotomy

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making. The heterogeneity across studies necessitates cautious interpretation of the pooled results, advocating for tailored approaches in treatment planning. Prospective trials are required to establish class I evidence for the role of endoscopic epilepsy surgery compared with the recognized open surgical techniques.

Introduction

Endoscopic epilepsy surgery is a relatively new surgical procedure used for treating intractable epilepsy that has gained increasing popularity in recent years. This procedure involves using specialized endoscopes to access and remove epileptogenic foci in the brain through the nose, mouth, or small burr holes in the skull. This minimizes the extent of craniotomy and reduces surgical morbidity. This technique was first described in a cadaveric study by Bahuleyan et al in 2010.[1] The first utilization of endoscopic surgery for epilepsy surgery was done to disconnect or resect hypothalamic hamartomas (HH). Endoscopic disconnecting surgical treatment for HH was first described by Delalande and Fohlen in 2003.[2]

The use of endoscopic procedures is not only limited to the dissection and resection of epileptogenic foci. A novel minimally invasive device consisting of a channel for a flexible endoscope was used to implant subdural strip electrodes in patients with epilepsy.[3] Endoscopic procedures require expertise, and careful anatomical evaluation of the patient is essential for its success. Neuronavigation before the procedure plays a critical role in identifying the location of the burr hole and endoscope port to prevent excessive angulation during the procedure, as emphasized by Bahuleyan et al.[1,4]

The effectiveness of endoscopic epilepsy surgery in comparison to open epilepsy surgery is still a subject of debate among medical professionals. In this systematic review and meta-analysis, we aim to evaluate the body of evidence regarding endoscopic epilepsy surgery, with primary outcomes being seizure freedom and postoperative complications. In addition, we will assess the risk of bias in the included studies and conduct a meta-analysis to estimate the overall effect size. Our results will provide information on seizure outcomes postendoscopic epilepsy surgery that will help in informed clinical decision-making in clinicians.

Materials and Methods

This systematic review and meta-analysis were conducted and reported in conformity with the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) 2020 guidelines (►**Fig. 1**).[5] This systematic review was not registered.

Search Strategy and Information Source

A comprehensive literature search was conducted by two authors (J.C. and F.R.) separately using PubMed and Web of Science databases from their inception until January 17, 2023. The search terms included "Endoscopy" AND/OR "Endoscopic" AND "Epilepsy" OR "Seizure" AND "Surgery." Reference lists of included studies were also screened to identify relevant literature that may have been missed during the search. Articles retrieved from the search were exported to EndNote Reference Library (Clarivate), where duplicates were identified and removed.

Study Selection

Two authors (J.C. and F.R.) independently screened the titles and abstracts of articles for inclusion in the study. Subsequently, full-text articles were reviewed to check if they satisfied the inclusion criteria. Any discrepancies encountered were discussed among the authors until consensus was achieved. Articles included met the following prespecified eligibility criteria—(1) contained information on pathology, outcomes, and complications, (2) cohorts, case series, and case reports, and (3) published in English language. Studies without stratified baseline characteristics or outcomes or did not meet our inclusion criteria were excluded.

Data Extraction

Data extraction from articles included publication characteristics (i.e., first author name, publication year, country of studies, study design, number of patients), patient characteristics data (number of patients, age [year], sex), type of surgical procedure, epilepsy duration, and outcome measures (Engel's class). All data were extracted into a predesigned Excel spreadsheet.

Risk of Bias assessment

The Joanna Briggs Institute (JBI) Critical Appraisal checklist for case series, cohort study, and case reports, which are made up of 10, 11, and 8, yes/no/unclear or not applicable questions, respectively, were used to assess the standard of the included papers.[6] Publication bias was assessed using the funnel plot and Egger's test by using the metafor package in R Studio version 4.3.1 (R Foundation for Statistical Computing). Two authors (S.M. and M.G.) independently assessed the quality, and disagreements were resolved through consensus with a third investigator (J.C.).

Statistical Analyses

The demographics and clinical variables were reported using descriptive statistics. For continuous variables, we used median and interquartile range, and for dichotomous variables, we used frequencies and percentages. Patients that underwent surgical procedures other than endoscopic surgery were excluded from the analysis to better serve the scope of this review. A single author (F.R.) performed a meta-analysis to assess the efficacy of endoscopic epilepsy surgery,

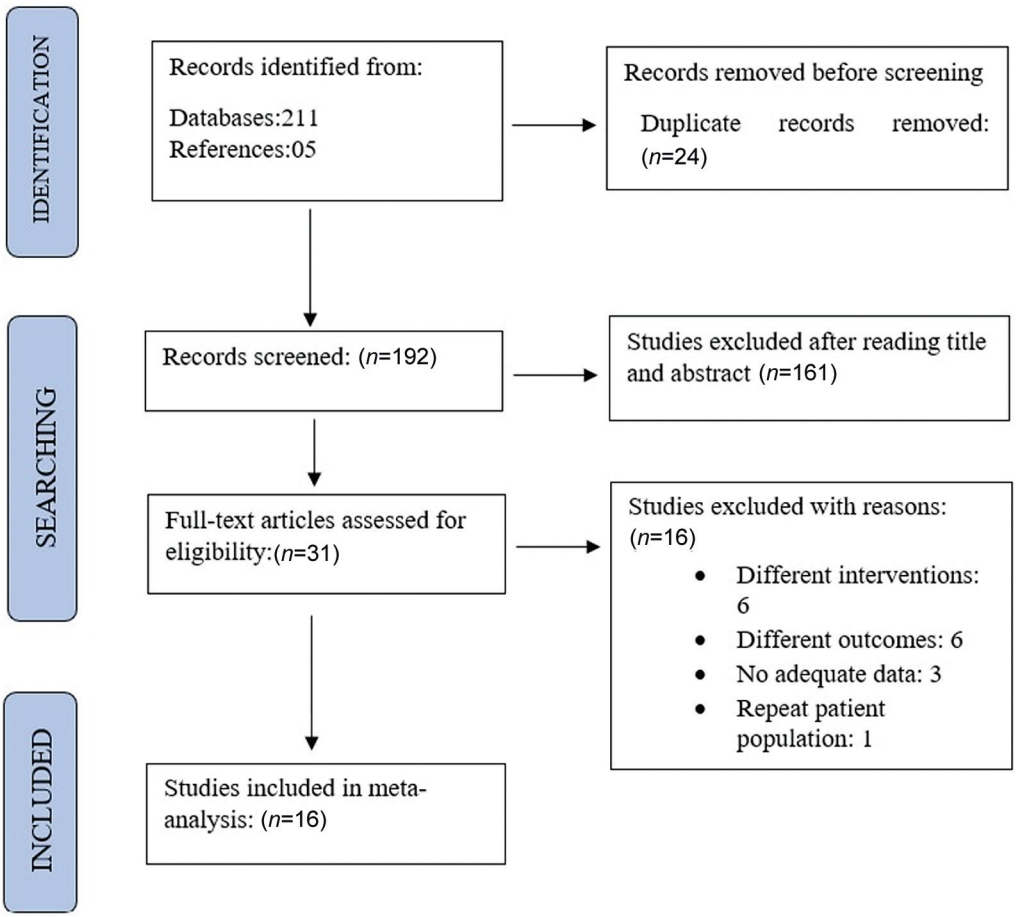

Fig. 1 Preferred Reporting Items for Systematic Review and Meta-Analyses flow diagram.

focusing on favorable outcomes, defined as Engel class I or II or > 90% seizure improvement and a focus on subgroup of children and patients with HH. The DerSimonian–Laird random-effect model meta-analysis was executed using R statistical software (version 4.3.1, R Foundation for Statistical Computing). We identified two studies that reported exclusively positive outcomes with a standard error (SE) of 0. The absence of variability in these reports presents a methodological concern, potentially skewing the overall analysis toward positive conclusions. We made the decision to exclude these two studies from our meta-analysis to ensure the reliability of our evidence. The random-effects model was chosen due to significant heterogeneity among study outcomes, quantified by the I^2 statistic. The restricted maximum-likelihood estimator for tau^2 and the Q-profile method for confidence intervals (CIs) were utilized to estimate the pooled effect sizes. The logit transformation was applied to the proportions to stabilize variances and facilitate the meta-analytical computations. Statistical significance was set at $p < 0.05$, with results presented as 95% CIs.

Results

Study Selection

A total of 216 articles were found through electronic search and references. After removing duplicate records, the reviewers (J.C. and F.R.) screened 192 articles by examining the titles and abstracts of all the articles. A total of 161 articles were excluded based on their titles and abstracts. The full-text articles of 31 studies were obtained and evaluated for eligibility. Through an independent assessment, 16 articles were eliminated due to specified reasons, leaving 15 articles for the current review as tabulated in ►**Table 1**. The PRISMA flow diagram (►**Fig. 1**) provides a visual representation of the study selection process and publication scrutiny.

Study Characteristics and Outcomes

►**Table 1** summarizes the major characteristics of the patients that were included in the review. The 15 included studies were published from 2001 to 2020 and were conducted in Italy ($n = 1$), India ($n = 2$), France ($n = 4$), China ($n = 1$), the United States ($n = 5$), Brazil ($n = 1$), and Korea ($n = 1$). Included studies consisted of 293 (86.2%) of 340 patients who underwent epilepsy surgery. Overall, 189 (55.6%) patients were male. The mean epilepsy duration was 13.05 years.

►**Table 2** summarizes surgical outcome of all the studies included in this meta-analysis. Note that 160 (54.6%) out of 293 patients that underwent endoscopic epilepsy surgery had a favorable outcome. In the endoscopic epilepsy surgery group, 68 (23.2%), 21 (7.2%), 51 (17.5%), and 30 (10.3%) patients were in Engel class I, II, III, and IV, respectively. Some studies reported seizure outcomes as decrease in

Table 1 Baseline characteristics of the studies

Author (year)	Country	Study design	Sample size ($n = 340$)	Male sex, *N* (%)	Mean age at diagnosis (y)	Epilepsy features	Intervention
Calisto et al (2014)[7]	Italy	Retrospective series	20	11 (55)	10.7	Monopolar coagulation vs. thulium laser • Mean epilepsy duration (6.9 vs. 4.9 years) • Mean number of weekly seizures (24.5 vs. 24.5)	• Monopolar coagulation$n = 13$ • Thulium laser disconnection = 7
Chandra et al (2016)[8]	India	Prospective, observational study	16	11 (68.8)	11.4	• Seizure onset ranged from birth to 5 years mean (22.48 ± 31.77 months) • Mean duration of epilepsy = 10.6 ± 6.4 years • Mean seizure frequency = 24.5 ± 19.8/day • Drop attack = present in all patients	• Both microscopic and endoscopic assistance = 11 • Endoscopic assistance only = 5
Chandra and Tripathi (2015)[9]	India	Prospective, observational study	34	15 (44.1)	EH – 9.4 CCWC-10 HH- NR	Drop attack = present in patient EH group The mean age of seizure onset was 1.52 ± 0.99 years (range 0.8–2.9 years) The mean frequency of seizures was 17.25 ± 16.1/day, excluding 1 patient who presented with status epilepticus CCWC group Seizure onset occurred within 1 month after birth in 3 patients. In others, it ranged from birth to 5.5 years (mean 24.37 ± 34.76 months) Mean duration of epilepsy was 9.2 ± 5.2 years Mean seizure frequency was 21.2 ± 17.3/day (range 1–45 days) HH group – NR	• Endoscopic hemispherotomy EH ($n = 11$) • Endoscopic corpus callosotomy with anterior and posterior commissurotomy group CCWC ($n = 16$) • Hypothalamic hamartoma group - Endoscopic-assisted transcallosal approach ($n = 4$) Pure endoscopic approach for HH ($n = 3$)
Chibbaro et al (2017)[10]	France	Prospective cohort	14	8 (57.1)	23.6	NR	Endoscopic assistance only
Choi et al (2004)[11]	China	Case report	4	2 (50)	15	Mean age at gelastic seizure onset – 8.5 months Mean age of complex partial seizure after gelastic seizure – 3.8 years	Endoscopic disconnection between hypothalamus and hamartoma
Delalande and Fohlen (2003)[2]	France	Prospective series	17	12 (70.6)	13.8	Mean seizure frequency was 21/day	Complete resection ($n = 1$) Conventional dissection

Table 1 (*Continued*)

Author (year)	Country	Study design	Sample size ($n = 340$)	Male sex, *N* (%)	Mean age at diagnosis (y)	Epilepsy features	Intervention
							($n = 8$) and endoscopic disconnection ($n = 2$) Combination of conventional dissection and endoscopic dissection ($n = 6$)
Drees et al (2012)[12]	USA	Prospective series	40	21 (52.5)	27.6	Mean duration of epilepsy = 26 years Mean seizure frequency was 5/day	Endoscopic ($n = 26$), open resection (pterional or orbitozygomatic resection) ($n = 10$), and Gamma Knife procedures ($n = 4$)
Kuzniecky and Guthrie (2003)[13]	USA	Prospective series	12	NR	6.5	NR	Stereotactic radiofrequency technique ($n = 8$) Endoscopic technique ($n = 4$)
Mandel et al (2017)[14]	Brazil	Prospective series	8	4 (50)	46	The mean duration of seizure = 18 years	Microscopy and endoscopy combined
Ng and Rekate (2007)[15]	USA	Prospective cohort	44	22 (50)	15	Median number of daily seizures = 6	Endoscopic disconnection (transventricular), $n = 44$
Pati et al (2013)[16]	USA	Prospective series	21	13 (61.9)	9 (median)	Median age of epilepsy onset prior to first surgery – 8 years	Endoscopic ($n = 12$), transcallosal ($n = 5$), orbitozygomatic ($n = 4$), radiosurgery ($n = 9$)
Procaccini et al (2006)[17]	France	Prospective series	33	24 (72.7)	10.5	NR	Frameless stereotactic disconnection procedure ($n = 26$) Complete resection ($n = 1$) Conventional disconnection only ($n = 6$)
Shim et al (2008)[18]	Korea	Prospective series	14	7 (50)	11.4	Mean age to initial seizure – 17.6 months Mean age of treatment 11.4 years	Endoscopic disconnection ($n = 9$), Gamma knife radiosurgery ($n = 4$), total resection ($n = 1$)
Sood et al (2015)[19]	USA	Prospective series	6	4 (66.7)	11	NR	Endoscopic technique (complete corpus callosotomy $n = 4$, bimanual endoscopic technique $n = 2$)
Sufianov et al (2020)[20]	France	Retrospective cohort study	57	35 (61.4)	1.5	NR	Endoscopic interhemispheric disconnection

Abbreviations: CCWC, corpus callosotomy with commissurotomy; EH, endoscopic hemispherotomy; HH, hypothalamic hamartoma; NR, not reported.

Table 2 Outcomes of the 13 studies included in the meta-analysis

Author	Total patient population in studies	No. of patients that underwent EES *n* (%)	Age group	Pathology	Outcomes in patients that underwent EES						Favorable outcomes in patients that underwent EES (Engel class I and II and/or > 90% seizure freedom) *n* (%)	Deaths
					Engel class I (*n*)	Engel class II (*n*)	Engel class III (*n*)	Engel class IV (*n*)	> 90 seizure freedom (*n*)	< 90 seizure freedom (*n*)		
Calisto et al, 2014[7]	20	20 (100)	Child	HH	8	6	5	1	NR	NR	14	NR
Chandra et al, 2016[8]	16	16 (100)	Mixed	Other	NR	NR	NR	NR	10	6	10	NR
Chandra and Tripathi, 2015[9]	34	34 (100)	Child	HH	14	3		1	11	5	28	NR
Chibbaro et al, 2017[10]	14	14 (100)	Mixed	HH	8	2	2	2	NR	NR	10	NR
Choi et al, 2004[11]	4	4 (100)	Child	HH	2	1		1	NR	NR	3	NR
Delalande and Fohlen, 2003[2]	17	8 (47)	Mixed	HH	2	NR	6	NR	NR	NR	2	NR
Drees et al, 2012[12]	40	36 (90)	Mixed	HH	NR	NR	NR	NR	11	22	11	3
Kuzniecky and Guthrie, 2003[13]	12	4 (33.3)	Mixed	HH	2	1	1	NR	NR	NR	3	NR
Ng and Rekate, 2007[15]	44	37 (84.1)	Mixed	HH	NR	NR	NR	NR	26	11	26	NR
Pati et al, 2013[16]	21	12 (57.1)	Child	HH	NR	NR	NR	NR	7	5	7	NR
Procaccini et al, 2006[17]	33	26 (78.8)	Mixed	HH	12	1	12	1	NR	NR	13	NR
Shim et al, 2008[18]	14	11 (78.6)	Child	HH	4		2	1	NR	NR	8	NR
Sufianov et al, 2020[20]	57	57 (100)	Mixed	Other	8	3	23	23	NR	NR	11	NR

Abbreviations: EES, endoscopic epilepsy surgery; HH, hypothalamic hamartoma; NR, not reported.

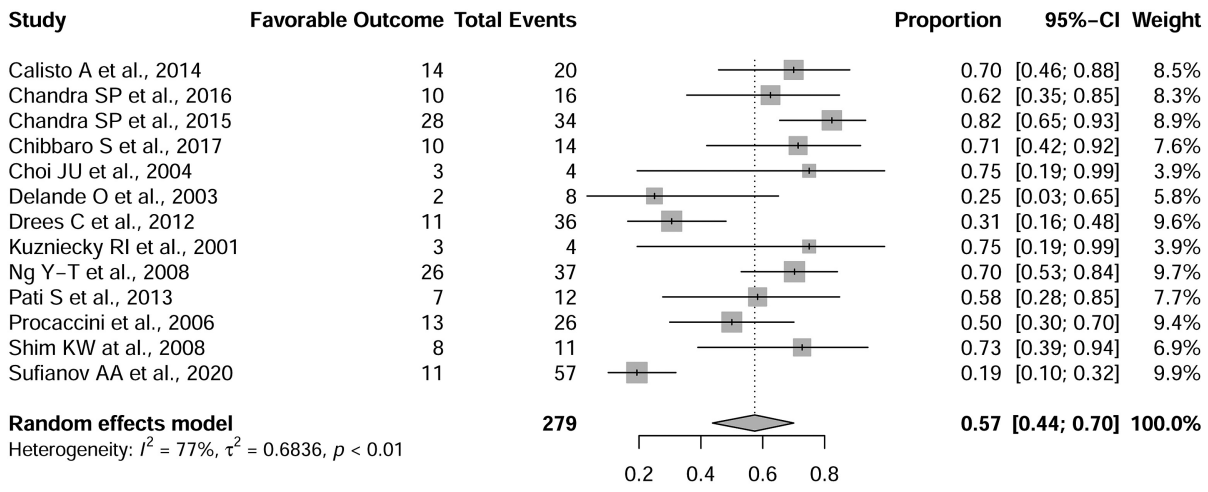

Fig. 2 Forest plot pooled random-effects meta-analysis.

seizure frequency: > 90% (71 [24.2%]) and < 90% (49 [16.7%]). Three (1%) patients died in the whole patient cohort of which two died because of intracranial hemorrhage[12] and one due to brainstem infarction.[13] The major postoperative complications reported in the various studies were: persistent hemianopia (1),[12] permanent short-term memory loss (3),[15] and bacterial meningitis (1).[9]

Meta-Analysis Results

The analysis included 13 studies encompassing 279 observations and 146 events. There was improved seizure control after endoscopic epilepsy surgery, with a pooled seizure freedom of 58% in patients (95% CI: 0.43–0.71) (►**Fig. 2**). The analysis displayed substantial heterogeneity ($I^2 = 77.1\%$, $\text{tau}^2 = 0.6836$), justifying the preference for the random effects model.

Subgroup Analysis: Age Group

The subgroup analysis based on the "age group" category showed significant differences in the proportion of favorable outcomes (►**Fig. 3**). Studies focusing exclusively on children reported a higher proportion of favorable outcomes of 0.73 (0.62–0.82 95% CI) (73.27%) compared with mixed age

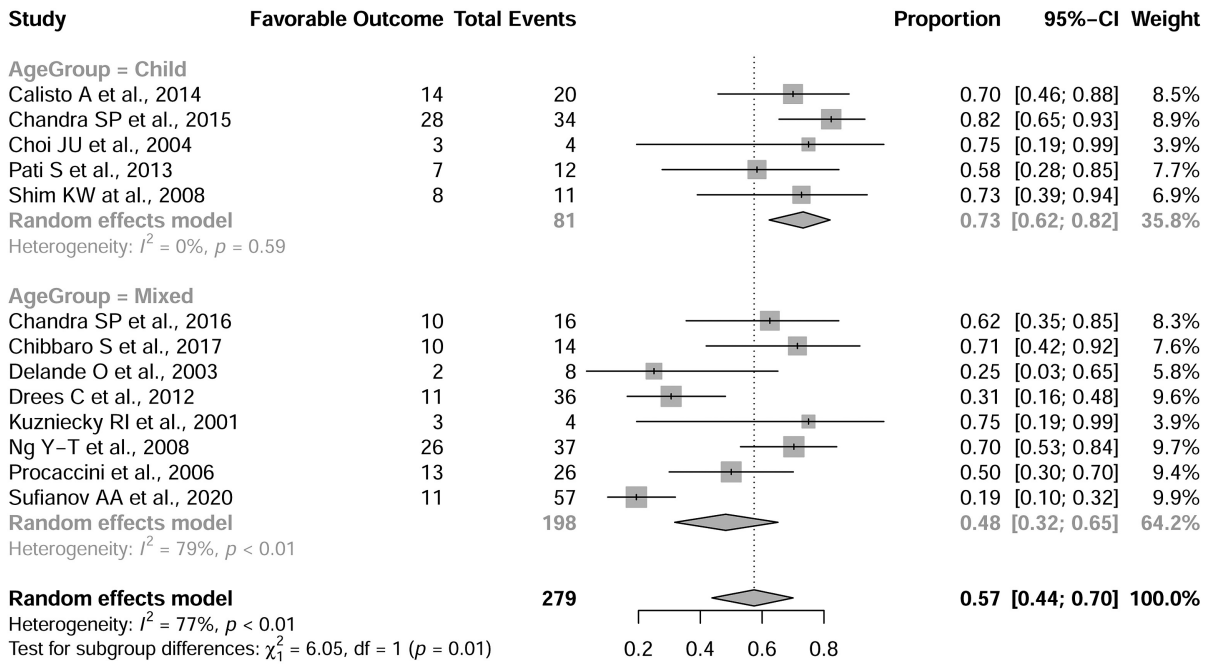

Figure 3-Forest plot AgeGroup subgroup analysis

Fig. 3 Forest plot of subgroup analysis by age group.

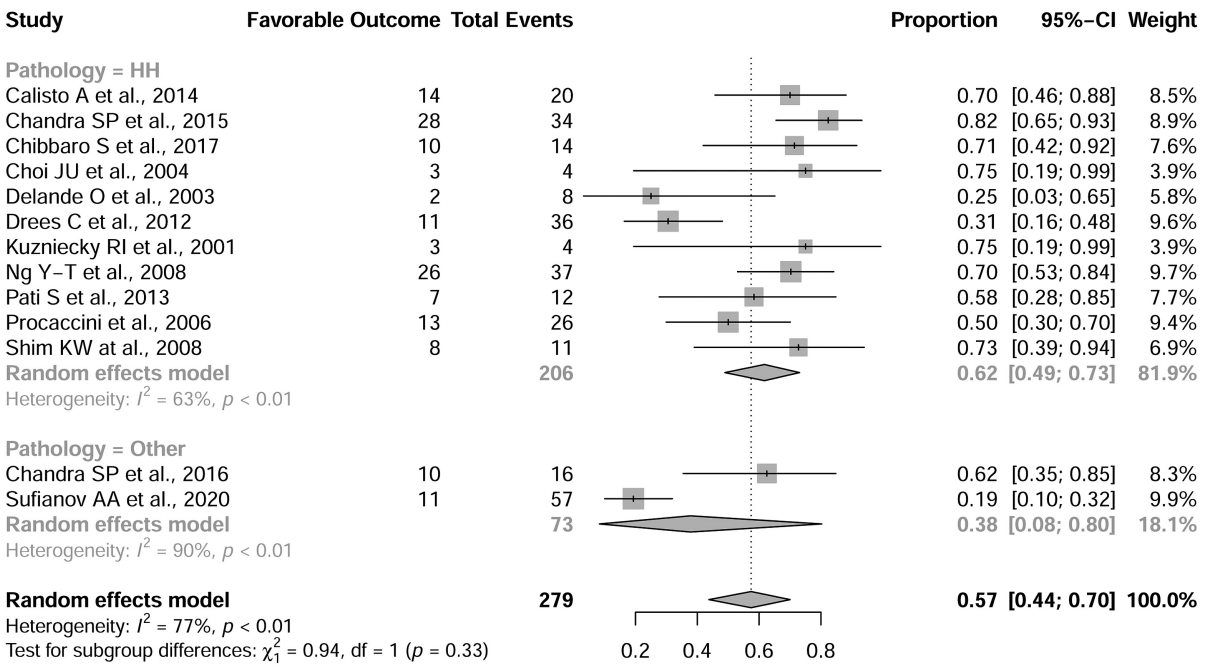

Fig. 4 Forest plot of subgroup analysis by pathology.

populations of 0.48 (0.32–0.65 95% CI) (48%). The heterogeneity within the "child" subgroup was negligible ($I^2 = 0.0\%$), whereas it remained substantial in the mixed age subgroup ($I^2 = 79.0\%$), suggesting consistent effects in pediatric populations.

Subgroup Analysis: Pathology

The studies involving participants with HH demonstrated a pooled proportion of favorable outcomes for the subgroup of HH, including 11 studies; the analysis showed a pooled proportion of favorable outcomes at 61.71% (95% CI: 48.92–73.06%), with moderate heterogeneity ($I^2 = 62.9\%$, $\text{tau}^2 = 0.4266$), indicating a relatively consistent beneficial effect across studies (►**Fig. 4**). Conversely, the "other" pathologies subgroup, though comprising only two studies, demonstrated a lower pooled proportion of favorable outcomes at 37.76% (95% CI: 8.31–80.24%), accompanied by substantial heterogeneity ($\text{tau}^2 = 1.6952$).

The tests for subgroup differences highlighted statistically significant variations in outcomes between subgroups both in the "child" category ($p = 0.0139$) and across different pathologies ($p < 0.0001$).

Heterogeneity and Publication Bias

We observed significant heterogeneity among pooled studies ($I^2 = 77.1\%$, $\tau^2 = 0.83$), which was statistically significant ($Q = 52.43$, degrees of freedom = 12, $p < 0.0001$). Further evaluation for publication bias using Egger's test showed that there is no statistical evidence of funnel plot asymmetry ($z = 0.87$, $p = 0.38$), with the limit estimate for the SE approaching 0 being –0.32 (CI: –2.01, 1.37). The funnel plot (►**Fig. 5**) generated did not display any obvious

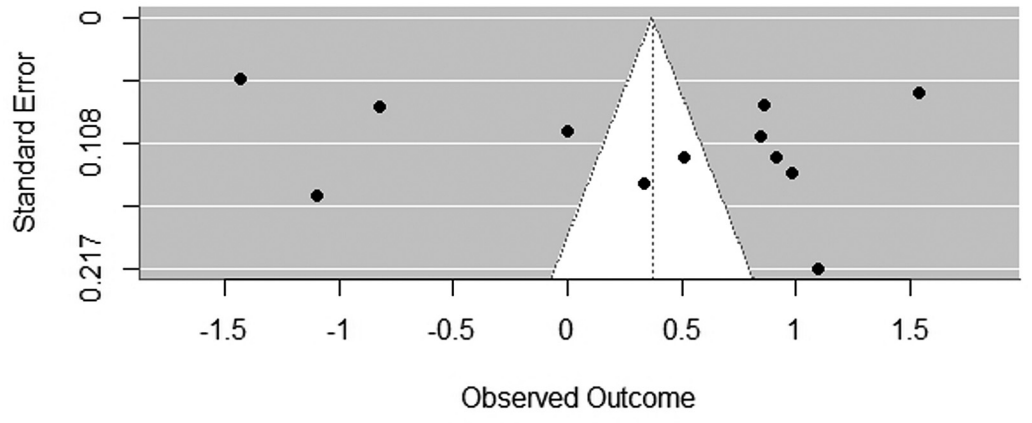

Fig. 5 Funnel plot for risk of bias among studies.

Table 3 Mean Joanna Briggs Institute (JBI) Critical Appraisal tool results and risk of bias in included studies

Study	Risk of bias	Bias percentage (%)
Chandra et al (2016)[8]	Low	75
Sufianov et al (2020)[20]	Moderate	50
Ng and Rekate (2007)[15]	Low	95
Delalande and Fohlen (2003)[2]	Moderate	50
Sood et al (2015)[19]	High	35
Choi et al (2004)[11]	Moderate	70
Fohlen M et al. (2003)[15]	Moderate	55
Calisto et al (2014)[7]	Low	80
Pati et al (2013)[16]	Moderate	70
Mandel et al (2017)[14]	Low	75
Chibbaro et al (2017)[10]	Moderate	55
Drees et al (2012)[12]	Low	80
Kuzniecky and Guthrie (2003)[13]	High	45
Procaccini et al (2006)[17]	Moderate	55
Shim et al (2008)[18]	Low	75
Chandra and Tripathi (2015)[9]	Moderate	73

Note: For a succinct assessment of the general quality of the included studies, these were categorized as follows: (1) low risk of bias (studies that met at least 75% of the standards for quality), (2) studies with a moderate risk of bias (compliant with 50–74% of the quality standards), and (3) studies with a high risk of bias (those that only complied with less than 49% of the standards for quality).

asymmetry, supporting the absence of publication bias in our meta-analysis. Additionally, the JBI checklist for bias revealed that out of the 16 studies, 6 studies were classified as having a low risk of bias (►**Table 3**).

Discussion

In the United States, between 2009 and 2014, only 4.2% of epilepsy patients underwent surgical intervention, highlighting the significant underutilization of epilepsy surgery despite its potential benefits.[11,21] Surgical methodologies for addressing seizures resistant to pharmacological treatment have evolved, with microsurgical techniques involving disconnection of abnormal neural circuits or removal of epileptogenic foci being the most commonly implemented. Minimally invasive techniques include personal or frontotemporal approaches and transcallosal or transcortical routes. They have been widely employed since the 2000s and are associated with good seizure control outcomes. However, they are associated with high rates of complications. Despite the growing popularity of endoscopic surgery in other specialties, its adoption in epilepsy surgery remains limited.[22]

Improved imaging methods allow for visualization of epileptogenic foci and assist in determining patients appropriate for surgical treatment. Endoscopic surgery has proven invaluable in resource-poor countries, such as low- and middle-income countries. To overcome the lack of diagnostic imaging, endoscopic visualization and real-time intraoperative diagnosis have been used to make endoscopic observations to guide and improve surgical planning intraoperatively.[12] Such modifications reduce reoperation, morbidity and mortality, and hospital costs.[12]

A favorable outcome was defined as postoperative Engel class I to II or $>90\%$ seizure control, while an unfavorable outcome included Engel class III and IV patients or patients with $<90\%$ seizure control. In this review, close to 60% of the patients had a favorable outcome. The meta-analysis of 13 studies demonstrated a highly significant overall effect in improving seizure control.[23] We performed a subgroup analysis of "age groups" and "pathology" to overcome high interstudy heterogeneity. The effectiveness of the intervention, especially among children (73.27% favorable outcome), as opposed to mixed age groups, highlights the potential for age-specific physiological or disease progression factors to influence treatment outcomes. This finding aligns with previous research suggesting that younger patients may have more plastic neural pathways, potentially rendering them more responsive to certain interventions.[24] The absence of heterogeneity within the child subgroup in contrast to the mixed age populations suggests a more uniform response to treatments in pediatric cohorts.

The studies involving participants with HH demonstrated a pooled proportion of favorable outcomes of 61.71%, indicative of a relatively high effectiveness of the interventions among this patient subgroup. However, the moderate heterogeneity observed within this subgroup indicates variability in response, possibly attributable to differences in lesion size, location, or the presence of comorbid conditions, emphasizing the need for individualized therapeutic approaches. Previous studies have supported the use of an endoscopic approach for HH-type lesions. One paper

reviewed outcomes of endoscopic resection of HH, highlighting that endoscopic surgery offers direct access to the lesion with reduced morbidity, leading to better seizure control and overall patient outcomes.[9] Another paper in 2011 found that the stereo endoscopic approach in treating HH reported favorable outcomes due to the minimally invasive nature of endoscopic surgery, which reduced the risk of damaging surrounding brain structures.[13]

There were statistically significant variations in outcomes between subgroups both in the "child" category ($p = 0.0139$) and across different pathologies ($p < 0.0001$), emphasizing the influence of patient age and specific pathologies on intervention effectiveness. This reinforces the importance of considering a range of factors, including age and specific pathology, in clinical decision-making.

Previous studies have shown that permanent complications are higher in patients who have undergone open microsurgery for epilepsy control. A systematic review discussed various complications associated with epilepsy surgery, highlighting that open microsurgical approaches were associated with a higher risk of permanent neurological deficits.[14] In this review, five (1.4%) patients developed permanent complications, namely, persistent hemianopia, short-term memory loss, and bacterial meningitis. Three deaths were reported in the patient cohort. Open microsurgical approaches lead to 47.2% of complications, which is much higher than those seen in endoscopic surgery.[15] Endoscopic surgery uses a small corridor for dissection and hence leads to lesser damage to surrounding brain tissue. Although endoscopic surgery has shown improved seizure outcomes with lower complications, the use of microsurgical techniques is not obsolete. The choice of surgical approach must be evaluated on a case-by-case basis.

Limitations

The studies analyzed in the review had limited data points, primarily consisting of retrospective case studies with small sample sizes or case reports. A significant limitation is the substantial heterogeneity observed in the pooled analysis ($I^2 = 77.1\%$), which suggests variability in study methodologies, intervention types, population characteristics, or outcome measures across the included studies.

The subgroup analyses, particularly for the "child" and "HH" categories, limit interpretation by the number of studies within each subgroup, potentially leading to overestimation or underestimation of the true effect sizes. Additionally, the negligible heterogeneity ($I^2 = 0.0\%$) observed in the "child" subgroup might not fully capture the variability within this group due to the small number of studies.

The generalizability of our findings may be limited by the specific populations and interventions studied (child subgroup and HH subgroup). Future prospective, multicenter studies with larger cohorts and clear predefined outcomes are needed to validate our results and to explore various individual characteristics that affect patient response to endoscopic surgery.

Conclusion

Our findings suggest that endoscopic epilepsy surgery is particularly effective in pediatric populations and among patients with HH, underscoring the importance of considering patient demographics and disease characteristics in clinical decision-making. The significant heterogeneity across studies necessitates cautious interpretation of the pooled results, advocating for tailored approaches in treatment planning. Prospective trials are required to establish class I evidence for the role of endoscopic epilepsy surgery compared with the recognized open surgical techniques.

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None.

Conflict of Interest
None declared.

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