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Long-term surgical outcomes of drug-resistant mesial temporal lobe epilepsy in a multicenter collaborative program in Vietnam: a retrospective cohort study

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Abstract

Background

Evidence on long-term effectiveness and safety of mesial temporal lobe epilepsy (mTLE) surgery in resource-limited settings remains scarce. This study aimed to evaluate seizure outcomes, complications, and potential outcome predictors in adults with drug-resistant mTLE within a multicenter collaborative program in Vietnam.

Methods

This retrospective cohort study used prospectively collected data from adults with drug-resistant mTLE who underwent standard anterior temporal lobectomy between 2019 and 2025 with at least 12 months of follow-up. The primary outcome was Engel class I at last follow-up. Secondary outcomes included seizure status at predefined intervals, antiseizure medication (ASM) tapering, neurological deficits, and surgical complications.

Results

Forty-six patients were included (mean age at surgery, 32.1 ± 8.8 years; mean follow-up, 39.0 ± 19.8 months). Engel class I was achieved in 38 patients (82.6%) at last follow-up and in 71.7% (33/46), 84.8% (39/46), 94.6% (35/37), and 85.7% (6/7) at 6, 12, 24, and 60 months, respectively. ASMs were reduced in 31 patients (67.4%) and completely withdrawn in one (2.2%). Visual field deficits were detected in 16 patients (34.8%) but were symptomatic in only one (2.2%); memory decline occurred in three (6.5%), infection in two (4.3%), and cerebrospinal fluid leakage in one (2.2%). In exploratory multivariable Firth logistic regression, hemispheric interictal epileptiform discharges were associated with lower odds of Engel class I (adjusted OR, 0.067; 95% CI, 0.006–0.718; p = 0.025).

Conclusions

In this resource-limited multicenter collaborative program, surgery for adult drug-resistant mTLE was associated with favorable seizure outcomes, reduced ASM burden, and infrequent symptomatic complications.

Introduction

Epilepsy is a major chronic neurological disorder associated with substantial individual, societal, and healthcare burdens worldwide [9]. Approximately one-third of people with epilepsy continue to have seizures despite adequate trials of at least two appropriately chosen and tolerated antiseizure medications (ASMs), thereby fulfilling the International League Against Epilepsy (ILAE) definition of drug-

resistant epilepsy (DRE) [12]. Among focal epilepsies, mesial temporal lobe epilepsy (mTLE), particularly when associated with hippocampal sclerosis (HS) or other concordant structural abnormalities, represents a well-established surgically remediable epilepsy syndrome.

For appropriately selected patients with drug-resistant temporal lobe epilepsy (TLE), randomized controlled trials have shown that surgery provides better seizure control than continued medical therapy [7, 20]. Furthermore, a shorter epilepsy duration before surgery is associated with a higher likelihood of seizure freedom, supporting referral for presurgical evaluation without delay [4]. Beyond seizure control, successful epilepsy surgery may allow ASM reduction or withdrawal [6, 16] and improve quality of life [17].

Despite its established efficacy, epilepsy surgery remains substantially limited in many low- and middle-income countries (LMICs), particularly across Southeast Asia [14, 19]. Underutilization in the region has been attributed mainly to a lack of expertise, facilities, and funding, with limited availability of advanced noninvasive and invasive presurgical investigations [19]. Where standalone, fully equipped epilepsy surgery centers are not yet feasible, inter-institutional collaboration integrating neurological, neurosurgical, and neurophysiological expertise offers a pragmatic alternative to expand access to surgical treatment. In Vietnam, a multicenter collaborative epilepsy surgery program has previously demonstrated the feasibility of such an organizational model and reported encouraging short-term clinical outcomes [13]. However, evidence regarding the durability of seizure control, changes in ASM requirements, and postoperative complications following epilepsy surgery in this setting remains limited.

Long-term follow-up is imperative because seizures may recur after an initially favorable response [6, 16], and postoperative neurological deficits and changes in ASM use influence long-term function and treatment decisions. Identifying presurgical clinical and electroencephalographic characteristics associated with seizure outcome may also help refine patient selection and counseling, but evidence on such prognostic factors from resource-limited settings is scarce. Therefore, this study aimed to evaluate long-term seizure outcomes and postoperative complications in adults with drug-resistant mTLE who underwent standard anterior temporal lobectomy (ATL) within a multicenter collaborative epilepsy surgery program in Vietnam. We evaluated Engel seizure outcomes at the last follow-up and at predefined postoperative intervals, changes in ASM use, and postoperative neurological and surgical complications. Furthermore, we explored potential clinical, electroencephalographic, imaging, and histopathological factors associated with favorable seizure outcomes.

Methods

Study design and ethical approval

This was a retrospective cohort study based on prospectively collected clinical data from patients with drug-resistant mTLE who underwent epilepsy surgery within a multicenter collaborative program between 2019 and 2025 in Ho Chi Minh City, Vietnam. The network was established as a collaborative

model involving neurologists, neurosurgeons, neuropsychologists, psychiatrists, electroencephalography (EEG) specialists, nursing staff, and allied specialists from participating hospitals, including Nguyen Tri Phuong Hospital and University Medical Center, Ho Chi Minh City. The structure and presurgical workflow of the program have been described previously [13]. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Medicine and Pharmacy at Ho Chi Minh City (approval number: 4037/ĐHYD-HĐĐĐ).

Study population

Patients were eligible if they met all of the following criteria: (1) age ≥ 18 years at surgery; (2) diagnosis of DRE according to the ILAE definition [12], defined as failure of adequate trials of at least two appropriately chosen and tolerated ASMs, whether as monotherapy or in combination, to achieve sustained seizure freedom; (3) clinical, electroencephalographic, and imaging evidence supporting mTLE; (4) standard ATL with mesial temporal resection; and (5) at least 12 months of follow-up after surgery.

Patients were excluded if they had generalized epilepsy or non-temporal epilepsy, underwent tailored temporal resection or lesionectomy, had incomplete baseline presurgical data, or had insufficient postoperative follow-up for outcome classification.

Presurgical evaluation and surgical procedures

All patients underwent standardized presurgical evaluation according to our previously reported protocol [13]. The purpose of presurgical evaluation was to determine whether seizure semiology, scalp EEG findings, and neuroimaging were sufficiently concordant to define a unilateral mesial temporal epileptogenic zone and to assess the risk-benefit profile of surgery.

Patients with concordant findings across seizure semiology, scalp interictal or ictal EEG, and structural neuroimaging were considered suitable for surgery after multidisciplinary discussion. Presurgical concordance was defined as agreement of at least two of the three main presurgical modalities (seizure semiology, EEG lateralization/localization, and lesion on magnetic resonance imaging [MRI]) supporting the potential epileptogenic zone in the mesial temporal lobe. Patients were categorized as having concordant, partially concordant, or discordant presurgical data based on multidisciplinary review. In patients with incomplete or partially concordant noninvasive data, additional investigations, including fluorodeoxyglucose positron emission tomography (FDG-PET), further MRI review, functional imaging, or intraoperative electrocorticography (ECoG) to guide the extent of resection, were considered according to availability and clinical need. The final surgical decision was made by consensus during a multidisciplinary team meeting. The operation was standard ATL with mesial temporal resection, as described in the Early Randomized Surgical Epilepsy Trial (ERSET) protocol [7]. Intraoperative ECoG was used selectively when the extent of the epileptogenic cortex was uncertain. Patients who underwent

tailored temporal resection or lesionectomy outside the standard ATL protocol were excluded from the present analysis.

Patients were followed up clinically after surgery according to routine practice at the participating centers. Follow-up data were collected from outpatient visits, hospital records, telephone interviews, and available clinical documentation.

Variables and outcome assessment

Baseline and surgical variables included age at surgery, sex, age at epilepsy onset, duration of epilepsy before surgery, seizure type, seizure frequency before surgery, history of febrile seizures, family history of epilepsy, preoperative number of ASMs, MRI findings, scalp EEG findings, side of surgery, use of intraoperative ECoG, and histopathological diagnosis.

Interictal scalp EEG findings were classified according to the lateralization and localization of interictal epileptiform discharges (IEDs) as (1) unilateral temporal, (2) unilateral hemispheric, or (3) bilateral temporal with unilateral predominance; the presence of temporal intermittent rhythmic delta activity (TIRDA) was recorded separately.

MRI findings were categorized as hippocampal sclerosis (HS), focal cortical dysplasia (FCD), low-grade epilepsy-associated tumors (LEATs), vascular lesions/other lesions, or MRI-negative/indeterminate.

Histopathological diagnoses were recorded and classified as HS, FCD, LEATs, gliosis/chronic inflammation, vascular lesion/other lesion, or nonspecific findings. Dual pathology was recorded when the histopathological report contained two diagnoses.

Outcomes were assessed at approximately 6, 12, 24, and 60 months after surgery. The primary outcome was Engel class I at last follow-up. Engel class I was defined as seizure freedom or freedom from disabling seizures. Engel classes II-IV were considered non-Engel class I outcomes for binary analyses. Secondary time-point outcomes included Engel class I status at approximately 6, 12, 24, and 60 months when data were available. Time-point outcomes reflected the patient's seizure status at each scheduled assessment, whereas the primary outcome reflected the Engel classification at last follow-up, which considers the entire postoperative course; time-point proportions may therefore differ from the proportion classified as Engel class I at last follow-up. Secondary outcomes included change in the number of ASMs from preoperative baseline to last follow-up, ASM reduction or tapering, complete ASM discontinuation when documented, postoperative neurological deficits, and surgical complications. ASM reduction was defined as any decrease in the number of ASMs or clinically meaningful dose reduction compared with the preoperative regimen. Complete ASM discontinuation was defined as being off all ASMs at the last follow-up.

Postoperative complications were classified as minor or major [3]. A complication was defined as minor if the adverse event or deficit resolved completely within 3 months without persistent sequelae. A major

complication was defined as a deficit that lasted longer than 3 months and negatively affected the patient's activities of daily living. Any significant neurological deficit was classified as a major complication. Visual fields were assessed using automated perimetry at least three months after surgery.

Statistical analysis

Continuous variables were summarized as mean and standard deviation or median and interquartile range, depending on distribution. Categorical variables were presented as frequencies and percentages. Baseline characteristics were compared between patients with Engel class I and Engel class II-IV outcomes using Fisher's exact test for categorical variables and the independent-samples t test or Mann-Whitney U test for continuous variables, as appropriate. Changes in the number of ASMs between baseline and last follow-up were compared using the Wilcoxon signed-rank test.

No formal a priori sample-size calculation was performed because this was a retrospective cohort including all consecutive eligible patients in the program during the study period. Analyses of factors associated with seizure outcomes were considered exploratory. Because only eight patients had non-Engel class I outcomes, multivariable modeling was restricted to a small number of clinically plausible variables, and Firth penalized logistic regression was used to reduce small-sample and sparse-event bias.

Missing data were reported by variable. Time-point outcomes were analyzed among patients with available data at each time point. All statistical tests were two-sided, and $p < 0.05$ was considered statistically significant. Analyses were performed using Stata, version 19 (StataCorp LLC, College Station, TX, USA).

Results

Patient characteristics

Patient selection and follow-up of the 46 included patients are shown in Fig. 1.

Baseline demographic and clinical characteristics of the patients are summarized in Table 1.

Table 1
Baseline demographic and presurgical characteristics

Feature	Total (n = 46)
Age at surgery, years (min - max)	32.1 ± 8.8 (18–62)
Sex (female) (%)	27 (58.7%)
Age at seizure onset, years (min - max)	16.2 ± 9.0 (2–34)
Age at seizure onset < 18 years	29 (63.0%)
Duration of epilepsy before surgery, years (min - max)	15 [6–23] (1–42)
Initial precipitating injury	13 (28.3%)
• Febrile seizure	8 (17.4%)
• Meningitis / Encephalitis	4 (8.7%)
• Other precipitating injury	1 (2.2%)
Comorbidities	5 (10.9%)
Seizure types	
• Focal to bilateral tonic-clonic seizure	27 (58.7%)
Preoperative seizure frequency	
• Daily	5 (10.9%)
• Weekly	17 (37.0%)
• Monthly	24 (52.2%)
Preoperative neuropsychological assessment	
• Memory deficit	6 (13.0%)
• Normal findings	16 (34.8%)
• Not performed	24 (52.2%)
Preoperative MRI findings	
• HS	39 (84.8%)
• FCD	2 (4.3%)
• LEATs	2 (4.3%)
• Vascular lesions/others	3 (6.5%)
Preoperative interictal EEG abnormalities	
• TIRDA	28 (60.9%)

Feature	Total (n = 46)
• IEDs lateralization	
- Unilateral temporal abnormalities	33 (71.7%)
- Unilateral hemispheric abnormalities	4 (8.7%)
- Bilateral temporal abnormalities with lateral predominance	9 (19.6%)
PET/CT hypometabolism performed	2 (4.3%)
Number of preoperative ASMs ≥ 3	23 (50.0%)

Values are presented as mean ± standard deviation, median [interquartile range], or n (%), as appropriate. ASM, antiseizure medication; EEG, electroencephalography; IED, interictal epileptiform discharge; HS, hippocampal sclerosis; FCD, focal cortical dysplasia; LEATs, low-grade epilepsy-associated tumors; MRI, magnetic resonance imaging; PET/CT, positron emission tomography/computed tomography; TIRDA, temporal intermittent rhythmic delta activity.

Surgical characteristics, seizure outcomes, and complications

Surgical procedures were performed at both participating centers during the same period. Surgical characteristics, seizure outcomes, and complications are shown in Table 2.

Table 2
Surgical characteristics, seizure outcomes, antiseizure medication changes, and postoperative complications

Feature	Total (n = 46)
Side of surgery, left	27 (58.7%)
Operating center	
Nguyen Tri Phuong Hospital	25 (54.3%)
University Medical Center	21 (45.7%)
Intraoperative ECoG	15 (32.6%)
Histopathological findings[a]	
HS	18 (39.1%)
FCD	14 (30.4%)
LEATs	4 (8.7%)
Gliosis/chronic inflammation	6 (13.0%)
Vascular lesions/others	3 (6.5%)
Nonspecific histopathological findings	4 (8.7%)
Dual pathology	3 (6.5%)
Length of hospital stay, days (min - max)	7 [6–8] (3–19)
Operation duration, minutes (min - max)	200.5 [180–240] (142–360)
Blood loss, mL (min - max)	200 [100–200] (50–300)
Duration of postoperative follow-up, months (min - max)	39.0 ± 19.8 (12–86)
Engel class I outcomes	
At last follow-up	38 (82.6%)
At 6 months	33 (71.7%)
At 12 months	39 (84.8%)
At 24 months (n = 37)	35 (94.6%)
At 60 months (n = 7)	6 (85.7%)
Engel class at last follow-up	
IA	31 (67.4%)
IB	3 (6.5%)

Feature	Total (n = 46)
IC	4 (8.7%)
II	7 (15.2%)
III	0 (0%)
IV	1 (2.2%)
ASM reduction after surgery	
ASM tapering	31 (67.4%)
Unchanged	13 (28.3%)
Additional ASM	2 (4.3%)
Complete ASM discontinuation	1 (2.2%)
Number of ASMs, preoperative	2.67 ± 0.79
Number of ASMs, at last follow-up[b]	1.67 ± 0.73
Neurological deficits	19 (41.3%)
Visual field deficit	16 (34.8%)
Symptomatic visual field deficit	1 (2.2%)
Memory decline	3 (6.5%)
Postoperative complications	
Infection	2 (4.3%)
CSF leakage	1 (2.2%)

[a] A total of 49 histopathological diagnoses were recorded across 46 patients; categories are not mutually exclusive because three patients had dual pathology. [b] $p < 0.001$ versus preoperative (Wilcoxon signed-rank test). Values are presented as mean ± standard deviation, median [interquartile range], or n (%), as appropriate. Percentages for 24- and 60-month Engel outcomes were calculated among patients with available follow-up data at each time point. ASM, antiseizure medication; CSF, cerebrospinal fluid; ECoG, electrocorticography; HS, hippocampal sclerosis; FCD, focal cortical dysplasia; LEATs, low-grade epilepsy-associated tumors.

Factors associated with Engel class I outcome

Univariable analysis showed that the distribution of IED patterns differed between patients with Engel class I outcomes and those with Engel class II-IV outcomes ($p = 0.013$) (Table 3). Other demographic,

clinical, imaging, surgical, pathological, and follow-up variables were not significantly associated with Engel class I outcome.

In the exploratory multivariable Firth logistic regression analysis, hemispheric IEDs were associated with lower odds of Engel class I outcome (adjusted OR 0.067; 95% CI 0.006–0.718; p = 0.025) (Fig. 2). Age at surgery and histopathological HS were not statistically significant predictors in the adjusted model.

Table 3
Univariable analysis of factors associated with Engel class I outcome at last follow-up

Feature	Engel I (n = 38)	Engel II-IV (n = 8)	p value
Demographic and clinical characteristics			
Age at surgery, years	33.2 ± 8.8	27.1 ± 7.4	0.078
Sex (female)	23 (60.5%)	4 (50.0%)	0.700
Age at seizure onset < 18 years	24 (63.2%)	5 (62.5%)	1.000
Duration of epilepsy before surgery, years	17 [6–24]	11 [6.5–17]	0.334
Initial precipitating injury			0.343
Febrile seizure history	7 (18.4%)	1 (12.5%)	
Meningitis/encephalitis history	2 (5.3%)	2 (25.0%)	
Normal history	28 (73.7%)	5 (62.5%)	
Other	1 (2.6%)	0 (0%)	
Neurological comorbidity	4 (10.5%)	1 (12.5%)	1.000
Focal to bilateral tonic-clonic seizure	23 (60.5%)	4 (50.0%)	0.700
Daily or weekly seizure frequency	17 (44.7%)	5 (62.5%)	0.451
Preoperative ASMs ≥ 3	18 (47.4%)	5 (62.5%)	0.699
Presurgical evaluation findings			
MRI findings			0.352
HS	33 (86.8%)	6 (75.0%)	
FCD	1 (2.6%)	1 (12.5%)	
LEATs	2 (5.3%)	0 (0%)	
Vascular/other lesion	2 (5.3%)	1 (12.5%)	
TIRDA	24 (63.2%)	4 (50.0%)	0.693
IED pattern			0.013
Unilateral temporal abnormalities	28 (73.7%)	5 (62.5%)	
Unilateral hemispheric abnormalities	1 (2.6%)	3 (37.5%)	
Bilateral temporal abnormalities with lateral predominance	9 (23.7%)	0 (0%)	

Feature	Engel I (n = 38)	Engel II-IV (n = 8)	p value
Surgical and pathological characteristics			
Left-sided surgery	24 (63.2%)	3 (37.5%)	0.246
HS	17 (44.7%)	1 (12.5%)	0.124
FCD	12 (31.6%)	2 (25.0%)	1.000
Dual pathology	2 (5.3%)	1 (12.5%)	0.444
Follow-up duration, months	34.5 [24–51]	29 [26.5–47.5]	0.603

Values are presented as mean ± standard deviation, median [interquartile range], or n (%), as appropriate. p values are exploratory and were not adjusted for multiple comparisons. Categorical variables were compared using Fisher's exact test; continuous variables were compared using the independent-samples t test or Mann-Whitney U test, as appropriate. ASM, antiseizure medication; EEG, electroencephalography; HS, hippocampal sclerosis; FCD, focal cortical dysplasia; IED, interictal epileptiform discharge; LEATs, low-grade epilepsy-associated tumors; MRI, magnetic resonance imaging; TIRDA, temporal intermittent rhythmic delta activity.

Because only eight patients had non-Engel class I outcomes, this model was exploratory and restricted to a small number of clinically plausible predictors. OR > 1 indicates higher odds of Engel class I outcome; 95% CIs are Wald intervals. CI, confidence interval; HS, hippocampal sclerosis; IED, interictal epileptiform discharge; OR, odds ratio.

Discussion

In this cohort of 46 adults with drug-resistant mTLE treated within a multicenter epilepsy surgery program in Vietnam, Engel class I outcome was achieved in 38 patients (82.6%) at last follow-up. Time-point outcomes were also favorable, with Engel class I observed in 39 of 46 patients (84.8%) at 12 months and 35 of 37 patients (94.6%) at 24 months. Of the seven patients with available 60-month data, six (85.7%) remained in Engel class I. ASM tapering was documented in 31 patients (67.4%). Visual field deficit was recorded in 16 patients (34.8%), but symptomatic visual field deficit occurred in only one patient (2.2%); memory decline, infection, and cerebrospinal fluid leakage were uncommon, and no hemiparesis or death was observed.

The seizure outcome observed in the present cohort is consistent with other mTLE surgery reports. Drexler et al. [5] reported favorable seizure outcomes (ILAE class 1–2) in 83.6% of cases at 12 months and in 79.0% at last follow-up in a global multicenter mTLE surgery cohort. Similar efficacy was reported by Mathon et al. [15], with Engel class I outcomes in 83.7% of patients after ATL or selective amygdalohippocampectomy (SAH) for mTLE-HS (mean follow-up, 8.7 years), and by Sindou et al. [18],

with Engel class I outcomes in 85% of 100 consecutive adults after tailored temporo-mesial resections. Pereira Dalio et al. [16] reported Engel class I outcome in 73.6% of a large adult TLE-HS cohort at last follow-up, and Elsharkawy et al. [6] reported Engel I outcomes in 76.2% at 6 months and 69.4% at 16 years after adult TLE surgery. Although direct comparisons are inherently limited by heterogeneity in case selection, histopathology, surgical approach, outcome definitions, and follow-up duration, our results were within the range reported in these series, suggesting that comparable seizure control is achievable within a collaborative, resource-limited framework.

In our cohort, Engel class I was observed in 94.6% (35/37) of patients at the 24-month assessment. Because time-point outcomes reflect seizure status at each assessment rather than the entire postoperative course, this proportion exceeds the Engel class I rate at last follow-up (82.6%). Similarly, the increase in Engel class I status from 71.7% at 6 months to 84.8% at 12 months among the same 46 patients indicates that disabling seizures in the early postoperative period did not necessarily persist. The 2-year time point is clinically important because among patients who were seizure-free 2 years after surgery, the reported probability of remaining seizure-free at 16 years was 90% [6]. A 23-year follow-up study found that while 73.6% of patients were free from disabling seizures overall, this outcome was successfully maintained in approximately 65% of patients followed for more than 20 years [16]. Late recurrences have been attributed to de novo epileptogenesis, whereas early failures more often reflect incomplete localization or resection of the epileptogenic focus [2].

The favorable outcomes in our cohort may partly reflect careful patient selection, as surgical candidacy was decided by multidisciplinary consensus on concordant semiology, scalp EEG, and MRI findings, with additional investigations when noninvasive data were incomplete or partially concordant. Adopting standard ATL with mesial temporal resection across all participating centers was a deliberate strategy during program development to minimize procedural heterogeneity and establish a consistent baseline for outcome evaluation. This approach is supported by previous studies demonstrating the effectiveness of conventional temporal lobe resection. Drexler et al. [5] found favorable outcomes after mTLE surgery in a global multicenter cohort in which most patients underwent anterior temporal lobe resection with amygdalohippocampectomy. Pereira Dalio et al. [16] reported Engel class I outcomes in 78.6% of patients after standard ATL, which includes temporal pole resection, compared with 67.2% after subtemporal SAH, which preserves the temporal pole, suggesting that the epileptogenic network may extend beyond the mesial temporal structures. Kohlhase et al. [11] reported higher Engel class I proportions after conventional ATL and SAH than after minimally invasive ablation in their meta-analysis. However, Mathon et al. [15] found no significant association between surgical approach and long-term seizure outcomes in their mTLE-HS cohort, and the optimal resection strategy remains debated. Surgical strategy should therefore be individualized according to presurgical localization, anatomical considerations, and the experience of the treating center.

Our cohort contributes long-term data on mTLE surgery in a resource-limited multicenter program and extends our previous report of short-term outcomes [13]. Mansouri et al. [14] reported pooled seizure freedom of 68% and favorable seizure outcome of 79% after ATL with or without

amygdalohippocampectomy in studies from LMICs, while emphasizing the need to improve timely access to epilepsy surgery in these regions. Our Engel class I rate at last follow-up (82.6%) compares favorably with these pooled LMIC estimates. Although establishing dedicated epilepsy surgery centers throughout the country is logistically difficult, our findings suggest that favorable seizure control can be achieved in carefully selected patients with drug-resistant mTLE through a structured multicenter program coordinated by a regional hub.

ASM reduction is a clinically relevant benefit of epilepsy surgery, particularly for patients who have experienced prolonged drug resistance and exposure to multiple medications. In our cohort, 31 patients (67.4%) achieved postoperative ASM reduction, and the mean number of ASMs decreased significantly from 2.67 ± 0.79 before surgery to 1.67 ± 0.73 at the last follow-up ($p < 0.001$). These findings suggest that favorable seizure control following ATL may be accompanied by a meaningful reduction in pharmacological treatment burden. A long-term study found that complete discontinuation of ASMs after two years of postoperative seizure freedom was not associated with an increased risk of long-term seizure recurrence [6]. The extent of medication reduction also appears to depend on the surgical approach: Abe et al. reported a significant reduction in the mean number of ASMs after ATL, whereas the number of ASMs remained unchanged after multiple hippocampal transection [1]. This conservative discontinuation rate reflects both cautious clinician-patient preferences and the follow-up duration of our cohort, as ASM withdrawal in comparable programs typically begins after 2 years of seizure freedom with a median time to discontinuation of 4.2 years [6].

The association between hemispheric IEDs and lower odds of Engel class I outcome in our cohort is clinically plausible because non-focal or widespread electrographic abnormalities may indicate an extensive epileptogenic network. The presence of bilateral interictal sharp waves or bitemporal EEG abnormalities has been identified as an independent predictor of seizure relapse and poor overall surgical outcome, particularly in patients with HS [6]. Extratemporal ictal abnormalities on video-EEG [8] were associated with unfavorable long-term outcomes after temporal resection. However, these studies used different EEG variables and differently defined endpoints. Moreover, our estimate was based on only four patients with hemispheric IEDs, three of whom did not achieve Engel class I, and its confidence interval was wide. Therefore, the EEG association observed in our study should be considered hypothesis-generating and requires validation in larger prospective cohorts.

The safety of ATL remains an important consideration, particularly when evaluating surgical programs in resource-limited settings. Postoperative neurological deficits were recorded in 19 patients (41.3%) in the present cohort, mainly visual field deficits, but only one patient had a symptomatic visual field deficit and three had memory decline. Reported rates of visual field deficits range from 1.8% to 69%, depending on how rigorously patients are tested postoperatively; superior homonymous quadrantanopia is the most common deficit [10]. Our relatively high rate of visual field deficits likely reflects systematic perimetric screening rather than clinically meaningful impairment. The discrepancy between objectively detected abnormalities and patient-reported symptoms highlights that subclinical deficits do not necessarily impair daily functioning, which may explain why reported complication rates vary widely when transient

or asymptomatic findings are grouped with disabling morbidity. Drexler et al. [5] reported complications or neurological deficits in 14.4% of patients and no in-hospital mortality in a global mTLE cohort, whereas Kohlhase et al. [11] reported overall and major complication rates of 31.3% and 10.9%, respectively, and homonymous quadrantanopia in 13.9% after ATL in their meta-analysis. Although surgical mortality is rare, other adverse events, such as postoperative hematoma, meningitis, or anterior choroidal artery ischemia resulting in mild permanent hemiparesis, remain documented risks associated with resective procedures [18]. Our findings support the feasibility of performing standard ATL within a coordinated multicenter program, provided that appropriate surgical expertise, perioperative care, and postoperative surveillance are maintained.

Our study benefits from consecutive enrollment, a standardized presurgical evaluation protocol and surgical procedure across the participating centers, and long-term follow-up of up to 86 months. Nonetheless, the retrospective design introduces a risk of information bias and non-uniform assessment intervals. The small subset of patients with complete 60-month data limits the precision of long-term estimates, and the modest sample size and low event rate restricted multivariable prognostic modeling to an exploratory analysis. Cognitive evaluations were constrained by the initial absence of locally validated comprehensive neuropsychological testing. Furthermore, the gap between MRI-detected (84.8%) and histologically confirmed (39.1%) HS may reflect variable tissue retrieval, constraining pathological correlations. Lastly, outcomes from this highly selected cohort may not extend to nonlesional epilepsies, discordant cases, or settings lacking an integrated multidisciplinary epilepsy network.

Conclusion

In this multicenter cohort from Vietnam, standard ATL was associated with favorable seizure outcomes in adults with drug-resistant mTLE, with 82.6% achieving Engel class I at the last follow-up and frequent ASM tapering during follow-up. Visual field deficits were common, but rarely symptomatic, and major surgical complications were uncommon. Hemispheric interictal epileptiform discharges showed a potential association with unfavorable seizure outcomes. Overall, these results support the feasibility of a coordinated multidisciplinary epilepsy surgery program as a practical model for delivering surgical treatment in resource-limited healthcare settings. Prospective multicenter studies with standardized long-term outcome assessment are warranted to confirm the durability and generalizability of these findings.

Declarations

Funding No funding was received for this study.

Competing interests The authors declare no competing interests.

Ethics and consent to participate All procedures performed in this study involving human participants were in accordance with the ethical standards of the Ethics Committee of the University of Medicine and

Pharmacy at Ho Chi Minh City (approval number: 4037/ĐHYD-HĐĐĐ) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The requirement for informed consent was waived by the Ethics Committee because of the retrospective design of the study.

Data availability The de-identified data may be available from the corresponding author upon reasonable request and subject to institutional approval.

Author contributions D.H.N., V.T.L., and T.A.P. conceived and designed the study. D.H.N., M.A.T.L., V.T.L., V.T.H.V., L.N.P.T., T.N.T.H., T.T. Tran, and T.T. Truong contributed to the investigation and data collection, and H.T.T.N. performed the histopathological examination. M.A.T.L., V.T.L., V.T.H.V., L.N.P.T., T.N.T.H., T.T. Tran, T.T. Truong, and T.A.P. provided study resources. D.H.N. curated the data, performed the statistical analysis, prepared the figures, administered the project, and wrote the main manuscript text. V.T.L., and T.A.P. supervised the study. All authors reviewed and edited the manuscript and read and approved the final version.

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Figures

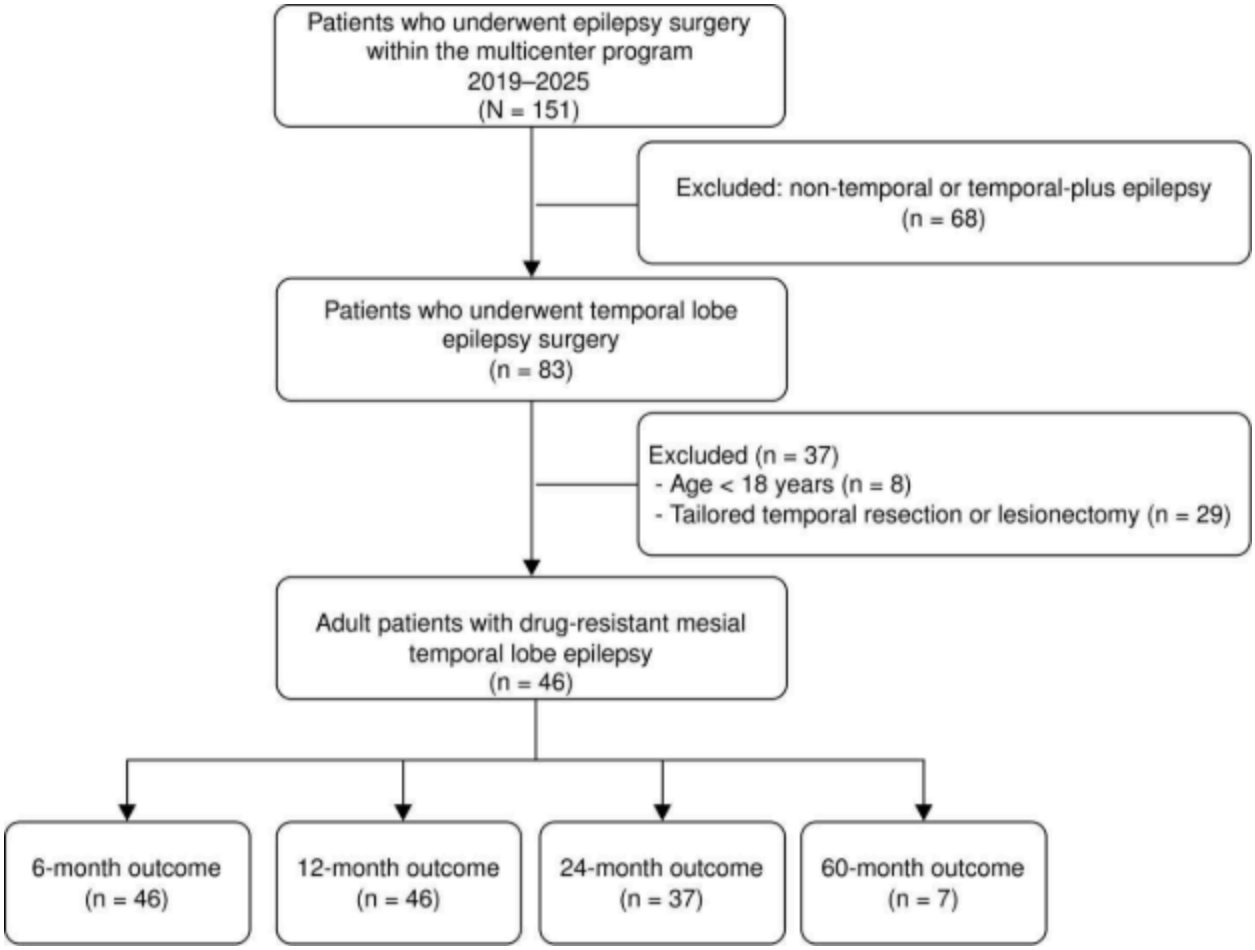


Figure 1

Flowchart of participants and follow-up availability

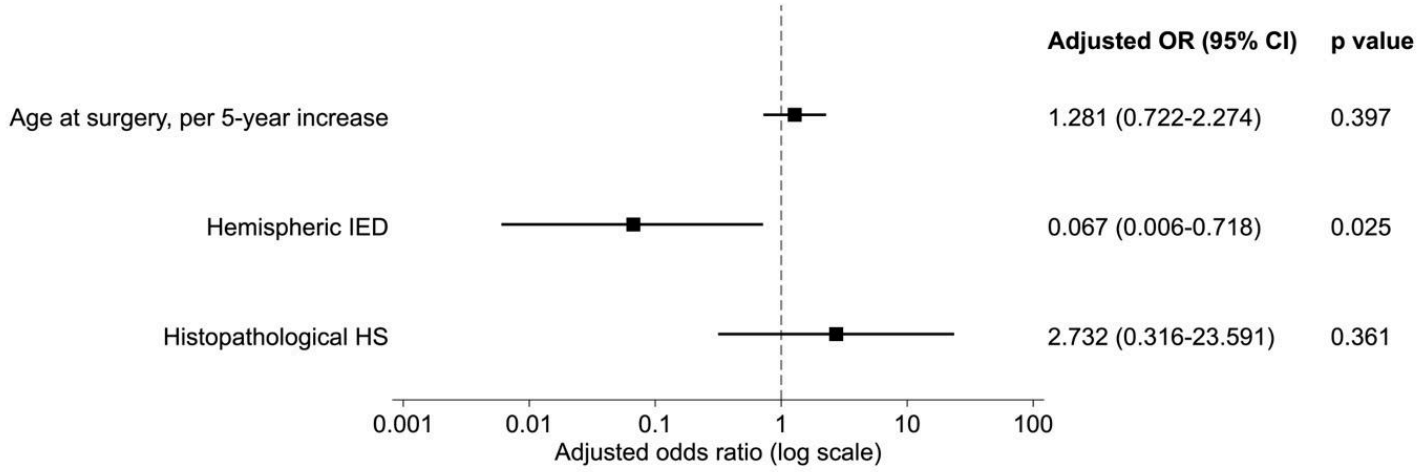


Figure 2

Exploratory multivariable Firth logistic regression for Engel class I outcome

Because only eight patients had non-Engel class I outcomes, this model was exploratory and restricted to a small number of clinically plausible predictors. OR >1 indicates higher odds of Engel class I outcome; 95% CIs are Wald intervals. CI, confidence interval; HS, hippocampal sclerosis; IED, interictal epileptiform discharge; OR, odds ratio.