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Stereo-EEG-guided radiofrequency thermocoagulation in patients with drug-resistant epilepsy: a systematic review

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ABSTRACT

Background. Radiofrequency thermocoagulation (RFTC) allows for destruction of epileptogenic zone during stereo-electroencephalographic (stereo-EEG) monitoring. This technique can serve therapeutic and diagnostic purposes in the treatment of patients with drug-resistant epilepsy (DRE).

Objective. A systematic review of literature data on RFTC, its technique, efficacy, and safety in patients with DRE.

Material and methods. This review was conducted according to the PRISMA 2020 criteria and registered in the PROSPERO registry. Two researchers selected studies in three stages using appropriate keywords. Studies with sample size ≥5 patients devoted to RFTC in patients with DRE were included. Studies demonstrating the effectiveness of RFTC for seizures with a minimum follow-up of 6 months were eligible. Case reports, reviews, manuscripts without available full text and non-eligible studies were excluded.

Results. The review included 41 articles and 1,417 patients. The main causes of RFTC during stereo-EEG were contraindications for resection, the need for additional information on location of ictal zone, coagulation as an additional method for epileptogenic zone destruction and treatment of seizures in patients with indications for resection. The overall complication rate ranged from 0% to 60% (in 5.3% of patients). Neurological deficit was transient in 64% of cases. Favorable outcomes (Engel I) after RFTC without additional treatment were achieved in 24.9% of patients with DRE.

Conclusion. Stereo-EEG navigated RFTC is a promising technique for examination and treatment of patients with DRE. It is safe and effective. However, standardization of coagulation parameters and prospective multiple-center studies are needed to obtain more accurate data.

Keywords: *radiofrequency thermocoagulation, radiofrequency thermal destruction, radiofrequency ablation, stereo-EEG, drug-resistant epilepsy, invasive monitoring.*

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Introduction

Stereo-electroencephalography (stereo-EEG), developed in the 1960s, is an important tool in diagnosis and treatment of focal drug-resistant epilepsy (DRE) [1]. Stereo-EEG is an invasive preoperative diagnostic method with deep intracerebral electrodes. Stereo-EEG offers unique capabilities for accurate analysis of ictal zones and propagation pathways, as well as indications for subsequent surgical treatment.

Stereo-EEG became widespread in the past decade with introduction of radiofrequency thermocoagulation (RFTC) [2]. This technique was proposed as an alternative or complementary treatment for patients with DRE. RFTC enables ictal zones destruction during stereo-EEG via brain matter coagulation through the deep electrode. This method was first described by Guenot M. in 2004. The author demonstrated effectiveness of RFTC and low risk of permanent neurological deficit [2]. However, many subsequent studies demonstrated significant limitations of this method and conflicting data regarding efficacy and safety [3]. The purpose of this study was a systematic review of literature data on RFTC, its technique, efficacy and safety in patients with DRE.

Material and methods

Study design

A systematic review was conducted in accordance with the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [4]. The study

protocol was developed prior to review and included key steps: objective, searching strategy, inclusion/exclusion criteria, data analysis methods, and risk of bias. This study is registered in the PROSPERO International Prospective Register of Systematic Reviews (registration number CRD4202511123398).

Searching strategy

We searched English- and Russian-language articles in electronic databases PubMed, Scopus, Web of Science and Google Scholar. Articles published through June 2025 were included. Two researchers independently searched for relevant articles in three stages **(Fig. 1)**. If disagreements regarding inclusion of study in systematic review arose, the decision was made collectively. The first stage involved searching with keywords «stereo-EEG», «stereoelectroencephalography», «radiofrequency thermocoagulation», «radiofrequency thermal destruction», «radiofrequency ablation», «invasive monitoring» and «deep electrodes» in Russian and English. The second stage involved screening of abstracts, exclusion of duplicates and non-eligible articles. The third stage involved analysis of full-text articles for eligibility, as well as references regarding additional relevant studies. The quality of studies was assessed using the National Institute of Health risk of bias assessment tool for observational studies without control group [5].

Eligibility criteria

We selected the studies according to predefined inclusion and exclusion criteria. Both prospective and retrospective studies with sample size ⩾5 patients dedicated to RFTC in stereo-EEG monitoring in patients with DRE were eligible. We enrolled only articles with available data on effectiveness of RFTC as a stand-alone method for the treatment of seizures and minimum 6-month follow-up after RFTC. Case reports, reviews, abstracts, articles without full text, duplicates, studies dedicated to thermocoagulation of hypothalamic hamartomas, RFTC of ictal zone without preliminary invasive monitoring and studies without data on effectiveness of RFTC were excluded.

Data processing

The main data extracted for analysis were sample size, patient age, follow-up, indications for RFTC, coagulation parameters, efficacy of RFTC according to the Engel scale, neurological complications associated with RFTC, ictal zone location and MRI data. If some data were missing, we did not request additional information from the authors. We also did not request primary data. Only those patients who underwent RFTC were included in analysis.

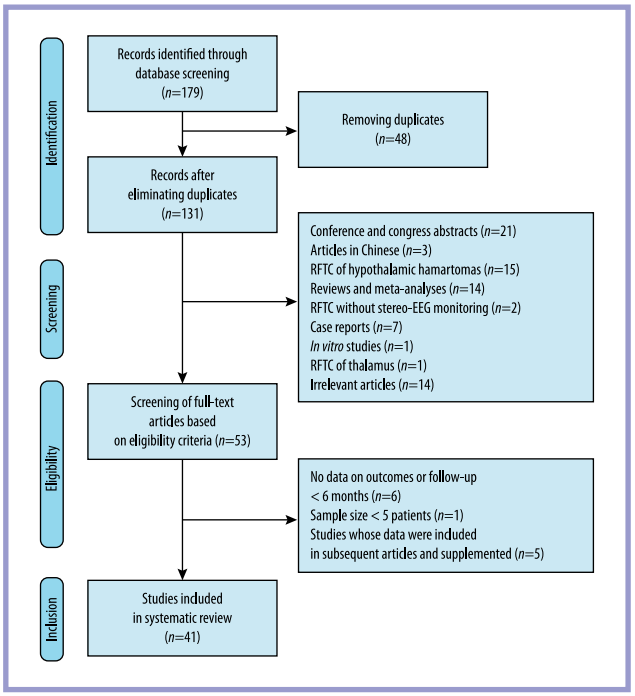

Fig. 1. **Study flowchart.**

We assessed efficacy of RFTC using the Engel classification at the last follow-up examination without additional treatments after coagulation. If studies did not describe RFTC efficacy according to this classification, we used the Engel surgical outcome that most closely corresponded to the outcome in the article (e.g., ILAE). A favorable clinical outcome was seizure control at the last follow-up visit (but not earlier than 6 months after coagulation) (Engel grade I). When available, we assessed the rate of complete freedom from seizures (Engel grade Ia). Responders had seizure rate reduction ⩾50% from baseline, including patients without seizures.

We evaluated all available data on coagulation parameters (monopolar/bipolar mode, current and voltage, power, exposure time, and target temperature in destruction zone). In case of no available data on coagulation parameters, but there was a reference to another RFTC protocol, we assumed that parameters fully complied with that protocol.

We assessed safety of RFTC considering neurological complications. Permanent neurological deficit was defined by appropriate symptoms at the last follow-up examination, transient neurological deficit — complete regression of disorders at the end of the follow-up. Expected neurological deficit was defined as impairments caused by coagulation in functionally significant brain areas or near those deep electrodes whose stimulation resulted in various motor or speech responses. Unexpected neurological deficit was defined as neurological impairments following coagulation in apparently safe area without prior anatomical or stimulation data indicating the possibility of such a deficit. Adverse events related to deep electrode implantation and stereo-EEG monitoring (intracranial he-

matomas, infectious complications) were not considered complications of RFTC. Various neurological phenomena that occurred only during coagulation and completely regressed later were not considered complications of RPTC.

Temporal lobe epilepsy implied EEG-verified ictal zone localization in temporal lobes. Extratemporal epilepsy involved other lobes in addition to temporal lobes. MR-negative epilepsy was characterized by no MR signs of structural epileptogenic pathology before stereo-EEG and RFTC.

Data at each stage were entered into a Microsoft Excel spreadsheet (Microsoft Corp., USA) and included in overall analysis.

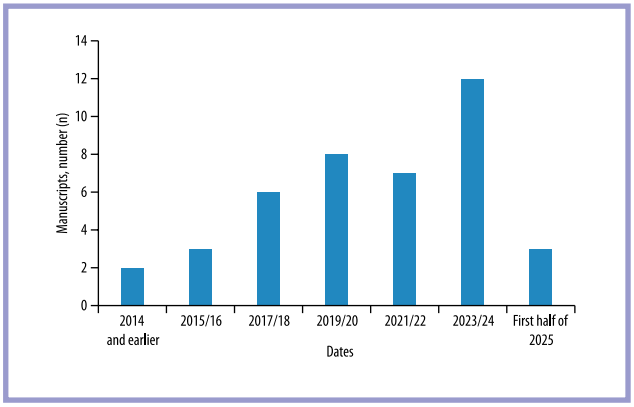

Fig. 2. **Year-adjusted distribution of publications.**

Results

Characteristics of articles

This review included 41 studies (38 retrospective, 3 prospective observational studies and 1 study with prospective and retrospective cohorts). All articles were English-language. We analyzed methodological quality of studies using the National Institute of Health scale: 34 (82.9%) studies were rated as good quality, while 7 (17.1%) were rated as satisfactory. Analysis of year-adjusted distribution of publications revealed a trend towards higher scientific interest in RFTC **(Fig. 2)**.

Patient characteristics

All studies included 1.417 patients with DRE who underwent RFTC during stereo-EEG monitoring. Mean age was 27.5 years. Twenty-two studies included adults and children, 3 studies included only children, and 16 studies included only adults (Appendix, **Table 1)**.

Thermocoagulation: indications

The indications for RFTC have not yet been definitively defined. Despite the only available guidelines for stereo-EEG (French Stereo-EEG Guidelines, 2018), specific indications for RFTC vary considerably across studies. According to these guidelines, an indication for RFTC during stereo-EEG monitoring is contraindications for resection in patients with DRE due to involvement of functionally significant brain areas in epileptogenic focus or presence of extensive epileptogenic focus [6]. If coagulation volume is sufficient for complete destruction of epileptogenic focus, RFTC can completely relieve the patient of seizures. Thus, RFTC may be an alternative treatment method in some situations [5, 7].

When multiple or bilateral epileptogenic focus is detected during stereo-EEG monitoring, RFTC is indicated as an alternative treatment method. Indeed, resection surgery is not indicated in such situations. In this case, the purpose of RFTC is destruction of some critical epileptic «nodes» to limit organization and spread of ictal activity [98].

If coagulation volume is insufficient for total destruction of the entire ictal zone and probability of favorable clinical outcome is minimal, RFTC may be indicated for diagnostic reasons. Disappearance or reduction of seizures, even temporary, as well as their modification after RFTC, is a prognostic factor for a favorable surgical outcome in patients with DRE after subsequent resection surgery [8].

Some authors also emphasize diagnostic value of RFTC when differentiation between several hypotheses regarding localization of ictal zone during stereo-EEG monitoring is difficult [9]. In this case, electrodes remain in place after RFTC in suspected ictal zone, and stereo-EEG monitoring continues to re-record epileptic activity. Subsequent analysis of the effect of RFTC on epileptic activity is valuable regarding validity of various hypotheses regarding localization of ictal zone and seizure pathways [9].

Coagulation zone

Selection of deep electrode contacts for RFTC was based on electrophysiological criteria after stereo-EEG. Selection criteria: 1) onset of ictal pattern manifested either as low-amplitude fast activity (beta-gamma range) or as rhythmic spike discharges or spike-wave complexes; 2) interictal activity as continuous epileptiform discharges; 3) location of deep electrode contacts within structural lesion according to MRI data; 4) initiation of typical seizures after stimulation from deep electrode contacts; 5) localization of deep electrode contact within early epileptic activity pathways [93.11].

Thermocoagulation: procedure

Deep electrode placement technique is crucial for subsequent RFTC. Accurate placement is currently ensured by robotic or stereotactic implantation systems. RFTC from a particular deep electrode requires certain criteria regard-

ing its position (within the intended ictal zone in avascular region) [10]. Most authors consider a 2-mm distance between electrode contact and the nearest vessel to be safe for RFTC. For better visualization of vessels, some authors recommend MR or CT angiography of the brain. However, thin-slice contrast-enhanced MRI is sufficient for this purpose in most cases [11].

The number of coagulation points is determined by ictal zone dimensions. RFTC may be performed in two modes. Bipolar coagulation occurs between two adjacent contacts of one or two electrodes. In case of monopolar coagulation, current is applied between the electrode contact point and neutral electrode on body surface. Both methods imply high-frequency alternating current to create a destructive focus in ictal zone. Forty studies used bipolar coagulation between adjacent contacts of a single electrode, while one study used monopolar coagulation [12]. In 1 study, the authors used alternating coagulation between adjacent electrode contacts («cross bonding»). This approach created confluent destructive foci between two deep electrodes with interelectrode distance of up to 7 mm.

Currently, there are no standardized RFTC parameters during stereo-EEG monitoring, that results in significant variability of techniques across studies [6]. Detailed RFTC parameters were reported in 35 (85.4%) articles. Their analysis revealed three main approaches to coagulation. The most common protocol was focused primarily on temperature. This method was first demonstrated by Guénot M. et al. According to their data in vitro, ~50 V and ~120 mA provide rapid tissue heating to a target temperature of 78—82°C and focal brain lesion with a diameter of 5—7 mm in 40—50 s. This report became the basis for many centers [2, 10, 11].

The second approach is a fixed voltage as the main coagulation parameter (usually 50—70 V) at a current of 25—120 mA. This allows for direct control of electric field density around the electrode [12]. The advantage of this method is more predictable and uniform energy distribution in tissue with certain resistance.

The third safe and most manageable RFTC strategy is power-controlled coagulation. A power of 7.5—8 W for 30—60 s to one point allows for predictable ablation zone with a diameter of 5—7 mm [13—15]. Unlike current and voltage varying due to tissue impedance, power remains relatively stable. Impedance varies depending on location of deep electrode contacts, characteristics of target structure and its vascularization. Tissue impedance can also increase throughout RFTC due to coagulated tissue clusters around the electrode [14].

Safety and complications of RFTC

Data on neurological complications are available in 35 (85.4%) articles. Permanent neurological deficit was recorded in 22 (1.5%) patients from 8 studies, transient deficit — in 54 (3.8%) patients from 15 studies. The overall complication rate in various studies ranged from 0 to 60% (percentage of patients with complications out of total number in the study). Nineteen studies described neither permanent no transient impairments. Thus, RFTC-associated complications developed in 76 (5.3%) out of 1417 patients.

Neurological deficit is predictable after RFTC in functionally significant areas. Patients are informed about this risk and give consent for procedure. Although most predictable impairments after RFTC are transient and regress within a few weeks or months, permanent deficit occurred in some cases. Bai J. et al. [3] described permanent impairment in 3.6% of patients who were warned in advance about the risk of motor dysfunction. In such cases, RFTC is advisable due to necessary seizure control despite the risk of potentially predictable complications when resection is impossible [15].

Importantly, adverse events such as intracranial hematomas or infectious processes are not complications of RFTC. They are related to deep electrode implantation and considered complications of invasive stereo-EEG monitoring [16, 17]. However, one study described intracranial hematoma not related to deep electrode implantation, but occurred immediately after RFTC. Interestingly, this was the only study where the authors used monopolar coagulation [13].

Efficiency of thermocoagulation

Mean follow-up after RFTC was 30.5 months. Engel Ia outcome was assessed in only 19 (46.3%) studies. There were 140 (14.8%) out of 948 patients with Engel grade Ia. Engel grade I was the most common criterion of a favorable outcome (in 26 (63.4%) studies). This grade was observed in 254 (35.9%) out of 707 patients. We considered Engel grade I with all subgroups as favorable outcomes. If there were no available data on other subgroups (Ib, Ic, Id) in addition to Ia, we assumed that the number of Ia outcomes corresponded to total number of favorable outcomes (Engel grade I). Thus, there were 353 (24.9%) out of 1417 patients with favorable outcomes after RFTC. The number of responders with seizure rate reduction ⩾50% after treatment was determined in 30 studies. A total of 493 (45.1%) out of 1.092 patients were responders, that demonstrated significantly lower incidence of seizures after RFTC.

Results of RFTC in patients with temporal and extratemporal epilepsy were presented in 26 (63.4%) studies. There were more patients with favorable outcomes after RFTC in the temporal epilepsy group. Engel grade I was achieved in 114 (30.6%) out of 372 patients with temporal lobe epilepsy and in 118 (20.3%) out of 580 patients with extratemporal epilepsy. Analysis of outcomes in MR- and MR-negative patients was based on 18 (43.9%) studies. Engel grade I was achieved in 144 (22.4%) out of 642 MR-positive patients and in 112 (26.2%) out of 427 MR-negative patients. Temporal lobe epilep-

sy may be associated with higher likelihood of favorable outcomes after RFTC. Moreover, efficacy of coagulation is comparable in MR-positive and MR-negative patients.

Conclusion

RFTC in patients with drug-resistant epilepsy undergoing stereo-EEG is a safe procedure with 1.5% incidence of permanent complications and 24.9% rate of favorable outcomes (Engel grade I). Effects of RFTC on functional outcomes are inferior to those of resection surgery. Nevertheless, RFTC is not a complete alternative to resection, but rather an independent technique with own indications, therapeutic and diagnostic purposes. Further analysis of effectiveness and indications for RFTC is needed. Identification of factors influencing outcomes in patients with drug-resistant epilepsy after RFTC is also important. First and foremost, standardized coagulation parameters are needed to summarize and analyze post-RFTC results in different hospitals.

Author contribution:
Concept and design of the study — Zuev A.A., Batmanova Yu.V., Alekseev I.M.
Collection and analysis of data — Batmanova Yu.V., Alekseev I.M.
Statistical analysis — Batmanova Yu.V., Alekseev I.M.
Writing the text — Batmanova Yu.V., Alekseev I.M.
Editing — Zuev A.A.

No conflict of interests to declare.

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Appendix

***Table*. Characteristics of studies and patient samples.**

No.	Authors, year	Study design	Sample size, *n*	Mean age, years	Coagulation parameters					Complications		
					I, mA	U, mV	t, °C	W	Time, s	Permanent impairment, *n*	Transient impairment, *n*	Total, *n* (%)
1	M. Guénot et al., 2004 [2]	Retrospective	20	31	120	50	78–82	No data	40–50	0	2	2 (10)
2	Z. Wu et al., 2014 [16]	Retrospective	7	29.6	No data	No data	75	No data	120	0	0	0 (0)
3	H. Catenoix, 2015 [18]	Retrospective	14	33.5	120	50	78–82	No data	10–30	1	1	2 (14.3)
4	M. Cossu et al., 2015 [7]	Retrospective	89	26.7	25	No data	78–82	8.3	60	2	1	3 (3.4)
5	J. Wellmer et al., 2016 [19]	Retrospective	7	41.1	No data	No data	No data	No data	No data	1	0	1 (14.3)
6	P. Bourdillon et al., 2017 [20]	Retrospective	162	28	120	50	78–82	No data	10–20	2	4	6 (3.7)
7	P. Dimova et al., 2017 [18]	Retrospective	23	22.4	75–110	40–50	80	No data	10–60	1	2	3 (13)
8	L. Mirandola et al., 2017 [11]	Retrospective	17	32.4	25	No data	78–82	8.3	60	0	0	0 (0)
9	F. Pizzo et al., 2017 [17]	Retrospective	10	28.5	No data	No data	No data	No data	No data	No data	No data	No data
10	Q. Zhao, 2017 [22]	Retrospective	12	29.2	No data	No data	75	No data	120	0	0	0 (0)
11	A. Moles et al., 2018 [22]	Retrospective	21	31.3	120	50	78–82	No data	No data	0	0	0 (0)
12	J. Bai et al., 2019 [15]	Retrospective	56	16.5	No data	No data	72–79	8–10	10–30	2	0	2 (3.6)
13	F. Cardinale et al., 2019 [23]	Retrospective	153	No data	120	50	78–82	8	10–20	3	0	3 (2)
14	M. Chipaux et al., 2019 [24]	Retrospective and prospective	46	8.2	120	50	78–82	No data	10–30	1	4	5 (10.9)
15	X. Fan et al., 2019 [12]	Retrospective	21	26.1	No data	No data	No data	3	60	0	0	0 (0)
16	C.Y. Lee et al., 2018 [25]	Prospective	7	42.7	No data	No data	78–80	No data	90	0	0	0 (0)
17	N. Mullatti et al., 2019 [26]	Retrospective	19	27.5	No data	No data	75	No data	60	0	8	8 (42.1)
18	R. Gao et al., 2020 [27]	Retrospective	35	21.8	120	50	78–82	6	60	No data	No data	No data
19	J.L. Méreaux et al., 2020 [28]	Retrospective	8	25	No data	No data	No data	No data	No data	0	0	0 (0)
20	M. Contento et al., 2021 [29]	Retrospective	38	19	No data	No data	No data	No data	No data	0	0	0 (0)
21	F.A. Mirza et al., 2021 [14]	Retrospective	14	34.4	No data	No data	No data	No data	No data	0	2	2 (14.3)
22	T. Luo et al., 2022 [30]	Prospective	9	4.2	No data	No data	78–82	3.5	15–45	0	1	1 (11.1)
23	L.P. Oliveira et al., 2022 [9]	Retrospective	31	38.2	120	50	78–82	No data	40–50	0	0	0 (0)
24	L. Wang et al., 2022 [6]	Retrospective	17	28.5	No data	No data	No data	7.5	30–30–30	0	0	0 (0)
25	Y. Xu et al., 2022 [8]	Retrospective	15	25	No data	No data	No data	3–5	60	1	8	9 (60)
26	W. Zhang et al., 2022 [32]	Retrospective	62	24.3	No data	No data	70–75	No data	60–120	0	0	0 (0)

Table*. Characteristics of studies and patient samples. *(End)

No.	Authors, year	Study design	Sample size, *n*	Mean age, years	Coagulation parameters					Complications		
					I, mA	U, mV	t, °C	W	Time, s	Permanent impairment, *n*	Transient impairment, *n*	Total, *n* (%)
27	Y. Dai et al., 2023 [10]	Retrospective	10	29.1	No data	No data	No data	3	60	0	4	4 (40)
28	H. Li et al., 2023	Retrospective	27	25.6	No data	70	75	6	30	0	4	4 (14.8)
29	J.A. Shields et al., 2023	Retrospective	49	35.9	No data	No data	No data	2–8	60	1	4	5 (10.2)
30	T. Cai et al., 2024	Retrospective	12	21.7	No data	No data	78–82	3–3.5	30–50	No data	No data	No data
31	C. Du et al., 2024	Retrospective	40	27.5	No data	No data	No data	7	40	0	4	4 (10)
32	Q. Huang et al., 2024	Retrospective	30	17.7	No data	No data	78–82	8.3	60	0	No data	No data
33	S. Jean et al., 2024	Retrospective	22	28.6	No data	No data	No data	7.5	40	4	0	4 (18.2)
34	H. Kreinter et al., 2024	Retrospective	13	35	No data	No data	No data	No data	No data	0	0	0 (0)
35	K. Li et al., 2024 [33]	Retrospective	28	25.7	No data	No data	No data	No data	60	0	0	0 (0)
36	K.T. Minkin et al., 2023 [13]	Retrospective	31	24	No data	No data	No data	4.5	60	1	2	3 (9.7)
37	R. Slegers et al., 2024 [41]	Prospective	24	32.5	No data	50	75–80	No data	30	2	2	4 (16.7)
38	Z. Xie et al., 2025 [42]	Retrospective	40	7	25	No data	78–82	8.3	60	0	4	4 (10)
39	Y. Gong et al., 2025 [43]	Retrospective	10	19.9	No data	No data	No data	3–5	60	0	5	5 (50)
40	J. Gula et al., 2025 [44]	Retrospective	10	33.2	No data	50	70–80	No data	30	No data	No data	No data
41	J. Yan et al., 2025 [45]	Retrospective	38	27	No data	No data	No data	7.5	60	No data	No data	No data

Patient outcomes in the study sample.

No.	Seizure rate reduction ⩾50%, *n* (%)	Engel grade		«MP-positive» patients		«MP-negative» patients		Temporal lobe epilepsy		Extratemporal epilepsy		Follow-up, months
		Engel I, *n* (%)	Engel II–IV, *n* (%)	Engel I, *n* (%)	Total, *n* (%)	Engel I, *n* (%)	Total, *n* (%)	Engel I, *n* (%)	Total, *n* (%)	Engel I, *n* (%)	Total, *n* (%)	
1	13 (65)	3 (15)	17 (75)	2 (11.1)	18 (90)	1 (50)	2 (10)	2 (22.2)	9 (45)	1 (9.1)	11 (55)	19
2	6 (85.7)	4 (57.1)	3 (42.9)	4 (57.1)	7 (100)	–	0 (0)	4 (57.1)	7 (100)	–	0 (0)	44.6
3	9 (64.3)	4 (28.6)	10 (71.4)	4 (28.6)	14 (100)	–	0 (0)	–	0 (0)	4 (28.6)	14 (100)	41.7
4	25 (28.1)	16 (18)	73 (82)	11 (25.6)	43 (48.3)	5 (10.9)	46 (51.7)	2 (13.3)	15 (16.9)	14 (18.9)	74 (83.1)	12
5	No data	4 (57.1)	3 (42.9)	4 (57.1)	7 (100)	–	0 (0)	–	0 (0)	4 (57.1)	7 (100)	22
6	78 (48)	11 (6.8)	151 (93.2)	No data	107 (66.1)	No data	55 (33.9)	No data	55 (33.9)	No data	107 (66.1)	12
7	8 (34.8)	1 (4.3)	22 (95.7)	0 (0)	8 (34.8)	1 (6.7)	15 (65.2)	0 (0)	4 (17.4)	No data	19 (82.6)	32.1
8	13 (76.5)	13 (76.5)	4 (23.5)	13 (76.5)	17 (100)	–	0 (0)	No data	No data	No data	No data	50
9	No data	2 (20)	8 (80)	2 (20)	10 (100)	–	0 (0)	–	0 (0)	4	10 (100)	10.8
10	No data	5 (41.7)	7 ()	1 (50)	2 (16.7)	4 (40)	10 (83.3)	5 (41.7)	12 (100)	–	0 (0)	34.1
11	10 (47.6)	0 (0)	21 (100)	0 (0)	16 (76.2)	0 (0)	5 (23.8)	0 (0)	21 (100)	–	0 (0)	12
12	No data	7 (12.5)	49 (87.5)	0 (0)	44 (78.6)	7 (58.3)	12 (21.4)	2 (15.4)	13 (23.2)	5 (11.6)	43 (76.8)	11.4
13	25 (16.3)	15 (9.8)	138 (90.2)	No data	No data	No data	No data	No data	No data	No data	No data	74
14	17 (37)	13 (28.3)	33 (71.7)	No data	33 (71.7)	No data	13 (28.3)	No data	4 (8.7)	No data	42 (91.3)	6
15	21 (100)	16 (76.2)	5 (23.8)	16 (76.2)	21 (100)	–	0 (0)	16 (76.2)	21 (100)	–	0 (0)	12
16	4 (57.1)	2 (28.6)	5 (71.4)	2 (28.6)	7 (100)	–	0 (0)	2 (28.6)	7 (100)	–	0 (0)	6
17	17 (89.5)	10 (52.6)	9 (47.4)	2 (50)	4 (21.1)	2 (13.3)	15 (78.9)	–	0 (0)	10 (52.6)	19 (100)	65.1
18	13 (37.1)	7 (20)	28 (80)	4 (25)	16 (45.7)	3 (15.8)	19 (54.3)	0 (0)	2 (5.7)	7 (21.2)	33 (94.3)	15
19	6 (75)	3 (37.5)	5 (62.5)	No data	No data	No data	No data	No data	No data	No data	No data	24
20	19 (50)	8 (21.1)	30 (78.9)	No data	32 (84.2)	No data	6 (15.8)	No data	13 (34.2)	No data	25 (65.8)	39
21	8 (57.1)	3 (21.4)	11 (78.6)	2 (25)	8 (57.1)	1 (16.7)	6 (42.9)	3 (42.9)	7 (57.1)	0 (0)	6 (42.9)	25.9
22	9 (100)	7 (77.8)	2 (22.2)	7 (77.8)	9	–	0 (0)	1 (100)	1 (11.1)	6 (75)	8 (88.9)	18.2
23	14 (45.2)	8 (25.8)	23 (74.2)	–	0 (0)	8 (25.8)	31 (100)	5 (27.8)	18 (58.1)	3 (23.1)	13 (41.9)	30.9
24	9 (52.9)	6 (35.3)	11 (64.7)	No data	No data	No data	No data	3 (27.3)	11 (64.7)	3 (50)	6 (35.3)	16.5
25	14 (93.3)	9 (60)	6 (40)	7 (53.8)	13 (86.7)	2 (100)	2 (13.3)	No data	No data	9 (60)	15 (100)	22.1
26	No data	32 (51.6)	30 (48.4)	–	0 (0)	32 (51.6)	62 (100)	32 (51.6)	62 (100)	–	0 (0)	24
27	10 (100)	7 (70)	3 (30)	2 (100)	2 (20)	5 (62.5)	8 (80)	–	0 (0)	7 (70)	10 (100)	38.7
28	No data	15 (55.6)	12 (44.4)	2 (50)	4 (14.8)	13 (56.5)	23 (85.2)	3 (33.3)	9 (33.3)	12 (66.7)	18 (66.7)	27.8
29	No data	12 (24.5)	37 (75.5)	12 (33.3)	36 (73.5)	0 (0)	13 (26.5)	No data	No data	No data	No data	34
30	No data	6 (50)	6 (50)	3 (50)	6 (50)	3 (50)	6 (50)	2 (40)	5 (41.7)	4 (57.1)	7 (58.3)	40.8
31	No data	8 (20)	32 (80)	6 (15)	21 (52.5)	2 (5)	19 (47.7)	No data	No data	No data	No data	28.2
32	20 (66.7)	11 (36.7)	19 (63.3)	–	0 (0)	11 (36.7)	30 (100)	0 (0)	1 (3.3)	11 (37.9)	29 (96.7)	31.1
33	No data	17 (77.3)	5 (22.7)	6 (54.5)	11 (50)	11 (100)	11 (50)	17 (77.3)	22 (100)	–	0 (0)	24.2
34	10 (76.9)	3 (23.1)	10 (76.9)	No data	No data	No data	No data	No data	No data	No data	No data	6
35	No data	12 (42.9)	16 (57.1)	12 (42.9)	28 (100)	–	0 (0)	12 (42.9)	28 (100)	–	0 (0)	73.4
36	22 (71)	2 (6.5)	29 (93.5)	1 (5)	20 (65.5)	1 (9.1)	11 (35.5)	0 (0)	8 (25.8)	2 (8.7)	23 (74.2)	18
37	17 (71)	11 (46)	13 (54)	11 (46)	24	–	0 (0)	No data	No data	No data	No data	19
38	35 (87.5)	25 (62.5)	15 (37.5)	No data	35 (87.5)	No data	5 (12.5)	No data	No data	No data	No data	44.6
39	9 (90)	8 (80)	2 (20)	8 (80)	10 (100)	–	0 (0)	–	0 (0)	8 (80)	10 (100)	41.7
40	6 (60)	2 (20)	8 (80)	2 (25)	8 (80)	0 (0)	2 (20)	0 (0)	1 (10)	2 (22.2)	9 (90)	12
41	26 (68.4)	5 (13.2)	33 (86.8)	No data	No data	No data	No data	3 (18.8)	16 (42.1)	2 (9.1)	22 (57.9)	22

Note: I — current; *U* — voltage; *t* — temperature; W — power.