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Clinical Efficacy of SEEG Guided Radiofrequency Thermocoagulation in Drug refractory Epilepsy
-- An Updated Systematic Review and Meta analysis

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Abstract: **Objective:** At present, stereotactic electroencephalography(SEEG) guided radiofrequency thermocoagulation(RFTC) has been widely used in the clinical treatment of epilepsy, but there is no unified understanding of the clinical effectiveness of this technique. The purpose of this paper is to summarize the efficacy of the method and the differences of its efficacy in different etiologies by analyzing the published literature, so as to provide reference for clinical practice.

Methods: We searched within Web of Science, PubMed, EmbaseandCochraneusing a predetermined search string to identify and evaluate relevant studies. The primary outcome was seizure-free rate after SEEG guided RFTC treatment of epilepsy. The secondary outcome was the rate of complications. All the publications until 5 February 2021 were searched.

Results: Thirty-three studies, with a total number of 808 patients, were identified. The seizure-free rate of patients with drug-refractory epilepsy after radiofrequency thermocoagulation was 44.40% (95%CI 34.50%-54.80%), and statistical heterogeneity was high. Subgroup analysis showed that heterogeneity originated from etiology. The pooled complication rate was 17.60% (95 % CI 11.70%–25.50%) with high heterogeneity (I^2 = 72.93 %). Subgroup analysis showed that heterogeneity of complication rate originated from etiology. The complication rate of HS group, HH group, “others”, PNH group were 43.50%, 33.70%, 24.00% and 4.80%, respectively.

Significance: SEEG guided radiofrequency thermocoagulation is effective in the treatment of drug-resistant epilepsy. Etiology has a significant effect on the seizure-free rate and the complication rate after radiofrequency thermocoagulation. PNH, FCD and HH have a relatively significant effect, PNH has the best effect.

Keywords: Stereotactic electroencephalography; Radiofrequency thermocoagulation; Epilepsy; Clinical effect; Meta-analysis

1. Introduction

Epilepsy is one of the most common neurological disorders, second only to stroke, affecting an estimated 65 million people worldwide(Moshe et al., 2015).[1] In approximately 30% of people with epilepsy, the condition is intractable to anti- epileptic drugs, so further therapeutic procedures should be considered(Kwan et al., 2011).[2] In 1965, the application of radiofrequency thermocoagulation (RFTC) in the clinical treatment of epilepsy was reported for the first time. Subsequently, RFTC had been widely used in clinic as a treatment for epilepsy (Mempel et al., 1980; Parrent et al., 1999; Fukuda et al., 1999).[3-5] Stereotactic electroencephalograph-guided RFTC appeared in 2004, compared with the traditional RFTC, the epileptic network was identified and destroyed precisely with the help of SEEG technology (Guenot et al., 2004).[6] SEEG guided RFTC has fewer complications than traditional surgery. In particular, there were no reports of changes in language or visuospatial memory(Moles et al).[7] These advantages gradually make RFTC an important surgical treatment for focal epilepsy, especially for patients with focal lesions that are not suitable for surgical resection.

Previous studies have shown that the clinical efficacy of SEEG guided RFTC in patients with drug-refractory epilepsy varies greatly. The prognosis of RFTC in the treatment of epilepsy may be closely related to the etiology. Some studies have shown that RFTC has a good effect on patients with periventricular nodular heterotopia (PNH)(Mirandola et al., 2017)[8] and hippocampus sclerosis (HS) (Fan et al., 2019).[9] Other studies have shown that there is a great difference in the seizure-free rate after RFTC treatment of patients with focal cortical dysplasia (FCD)(Cossu et al., 2015; Wellmer et al., 2018; Jie Deng et al., 2020).[10-12] In conclusion, the efficacy of SEEG guided RFTC in treating epilepsy caused by different etiologies is also quite different. However, there are some problems in previous relevant meta studies, such as small sample size and less comprehensive subgrouping of etiology(Bourdillon et al., 2018).[13] Moreover, only articles published in English were included in meta-analysis. Due to China's large population, there are about 9 million epilepsy patients in China, and there are nearly 40 thousand newly increased patients every year. It is regrettable that Chinese articles are not included in the meta-analysis. Therefore, this paper systematically searched correlative literatures on SEEG guided RFTC in the treatment of epilepsy, and conducted a meta-analysis, so as to explore the clinical efficacy of SEEG guided RFTC in the treatment of epilepsy and analyze the differences in efficacy under different etiologies.

2. Methods and analysis

2.1 Search strategy

To investigate the clinical efficacy of SEEG guided RFTC and its influencing factors, we systematically searched multiple databases. First of all, the following English databases was searched: Web of Science, PubMed, Embase, andCochrane, the search string was as follows: [Stereoelectroencephalography OR SEEG] AND [Thermocoagulation OR Radiofrequency OR Radiofrequency-Thermocoagulation] AND [Epilepsy OR Seizure OR Seizure]. In the Chinese database (China National Knowledge Infrastructure database, Wanfang database and Chongqing VIP Database), the literatures with the subject terms of [stereotopic electroencephalography] AND [radiofrequency thermocoagulation] AND [epilepsy] were searched. All the publications until 5 February 2021 were searched without any restriction of countries or article type.

2.2 Selection criteria

The criteria of enrolled studies included: (1) The studies reported seizure free rates of patients with medication-refractory epilepsy treated with SEEG guided RFTC; (2) Sample size ≥5 cases. The Exclusion criteria were as follows: (1) case reports or conference summaris; (2) Patients with an average follow-up time of less than 6 months; (3) Patients who underwent epilepsy resection after thermocoagulation; (4) Overlapping cases.

2.3 Quality assessment

Two review authors independently appraised the methodological quality (risk of bias) within each included study according to cross section quality evaluation of research - the AHRQ (agency for healthcare research and quality). AHRQ included 11 evaluation criteria to evaluate the quality of the included literatures. Any disagreements that arose between the reviewers were resolved through discussions, or by further discussion with a third reviewer.

2.4 Extraction and Data Management

Two authors independently extracted data. Any disagreement was resolved by discussion until consensus was reached. The following data were extracted: author, year of publication, average age of patients, etiology, sample size, gender, follow-up time, number of cases seizure-free, and number of complications.

2.5 Statistical analysis

The software Comprehensive Meta-Analysis Version 3.0 was used for Meta-analysis. The primary outcome was seizure-free rate after SEEG guided RFTC treatment of epilepsy. In this study, publication bias was assessed by funnel plots and Egger's test. Heterogeneity was assessed by observing the characteristics of participants and radiofrequency thermocoagulation. Also, Q test and I^2were used to choose between fixed effects and random effects meta-analysis. If the result of Q test is significant or the value of $I^2$is higher than 75%, the random effect model is more suitable, otherwise, the fixed effect model is more suitable (Higgins et al., 2003).[14] In addition, previous studies suggest that the etiology of epilepsy may affect the efficacy of RFTC in patients with drug-refractory epilepsy, thus the etiology of epilepsy was be used for subgroup analyses.

3. Results

3.1 Results of the study search

A total of 397 publications were searched from relevant databases through the above search strategies. First, 249 studies were obtained after eliminating duplicate publication. Subsequently, 112 researches including case reports, reviews and conference abstracts were excluded. Then 94 articles with obviously inconsistent abstract and title were excluded. Finally, 10studies were excluded according to the inclusion criteria for missing information.

In the end, 33 articles were selected. The selection strategy is shown in a flow diagram (Fig. 1).

3.2 Population characteristics

The total of 808 cases were included in this study. The demographics and characteristics are shown in Table 1.

3.3 Quality assessment

The risk of bias scores ranged from 8 to 10 out of a possible total of 11. The results of quality evaluation are shown in Table 1.

3.4 Risk of publication bias

First, the publication bias test for this meta-analysis was conducted through funnel plot, and the results were shown in Figure 2. The ef-

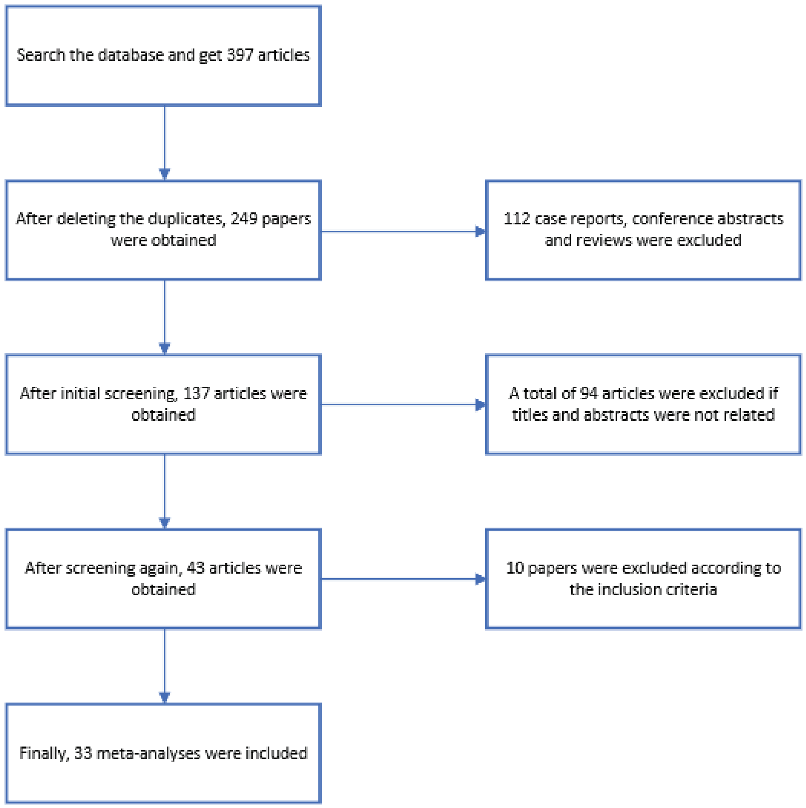

Fig. 1 Diagram of systematic search.

Table 1. Included studies

First author	Year published	Sample size (male)	Mean age (range) (y)	Type of epilepsy	Mean follow-up (range) (m)	Number of Seizure-free	Number of complications	Quality score
Jie Deng 12	2020	69 (44)	1.4-17.4 (median 7)	FCD, HS, PNH, Malaciaetc	6-30	45	25	9
Xuguang Zhong 44	2020	38 (26)	19-38 (23.5±11.27)	FCD Ⅰ , FCD Ⅱ etc	12-60	3	6	10
Chenwei Xu 34	2018	12 (8)	22.2±7.8	HS, FCD Ⅰ betc	2-11	1	0	10
Zhong Zheng 36	2018	7 (4)	5-46 (19.7±14)	HH	6-37	5	3	9
Gang Hua 38	2018	9 (4)	3-23 (median 13)	HH	2-54	7	5	9
Gang Hua 43	2020	13 (6)	5.5-35 (median 18)	HH, PNH etc	3-21	10	7	9
Fuyong Chen 41	2019	9 (6)	26-55 (32.22±9.07)	HH, HS, PNH etc	2-9	6	2	9
Chang Liu 32	2018	5(4)	12-34 (median 20)	PNH	1-24	5	0	8
Yuguang Guan 28	2017	33(19)	-	others	6-15	4	0	9
Li Yuan 27	2014	48(26)	58-73 (63.1±4.0)	HS	6-24	25	20	9
Chaohui Wu 26	2013	7 (3)	16-45 (29.6±11.1)	Viral encephalitis, HS	24-52	3	0	9
Weifeng Lu 24	2012	32	18-75 (median 36)	MTLE	24	13	-	10
Tonggang Su 25	2012	36(21)	21-54 (median 31.7)	others	12-42	21	2	10
Chao Lu 33	2018	24(12)	2-18 (10.8± 5.8)	HH, PNH, HS, others	3-36	14	0	8
Tie Fang 37	2018	13 (7)	2-15 (median 6.3)	FCD etc	6-12	10	-	8
Huaqiang Zhang 35	2018	48 (28)	2-53 (19.1 ±12.5)	HH, PNH, Tuberous sclerosis	5-35	23	8	9
Dimova 16	2017	23 (13)	6-53 (median 30)	FCD, PNH etc	32	1	3	9
Cossu 10	2015	89(49)	2-49 (median 26.7)	HS, FCD, PNH, others	12	16	2	9
Wang 42	2020	6 (3)	1.4-12 (5.08±4.73)	HH	11-27	4	-	9
Mullatti 17	2019	19(11)	7-44 (27.5±11.6)	FCD, negative MRI	>12	10	8	10

First author	Year published	Sample size (male)	Mean age (range) (y)	Type of epilepsy	Mean follow-up (range) (m)	Number of Seizure-free	Number of complications	Quality score
Chipaux 40	2019	46	18m-18y	FCD, HS	8-24	6	5	9
Moles 7	2018	21 (9)	12-49	HS, FCD	12	0	0	9
Bai 39	2019	56(30)	2-43 (16.5±10.6)	FCD etc	>12	7	23	9
Mirandola 8	2017	17(10)	-	PNH	50	13	0	10
Zhao 30	2017	12(11)	14-43 (29.17±8.41)	Trauma, Measles, Fever etc	12-62	5	-	9
Wei 31	2017	9 (5)	14.9±8.5	HH	5-29	5	1	10
Fan 9	2019	21(12)	2-16 (26.1±5.8)	HS	12	16	10	9
Pizzo 29	2017	10 (2)	15-42 (28.5±10.8)	PNH	>18	1	-	9
Homma 22	2007	5 (4)	50.6±30.5	HH	26-102	3	-	9
Wellmer 11	2018	7	-	FCD	16-57	5	-	9
Kameyama23	2009	18(15)	2-36 (median 14.8)	HH	>6	15	0	9
Guenot 6	2004	20(16)	31	others	8-31	3	0	9
Lee 21	2019	7 (3)	30-59 (median 42.7)	others	>6	4	0	10

Abbreviations: *HH (Hypothalamic hamartoma); MTLE (Medial temporal lobe epilepsy); GMH (Gray matter heterotopic)*

fect values are concentrated at the top of the graph and distributed on both sides of the total effect, indicating that there may be publication bias in the study. Egger's linear regression was further used to test again, and the result showed that the intercept was -0.06 (P > 0.05), indicating that there was no publication bias in this study.

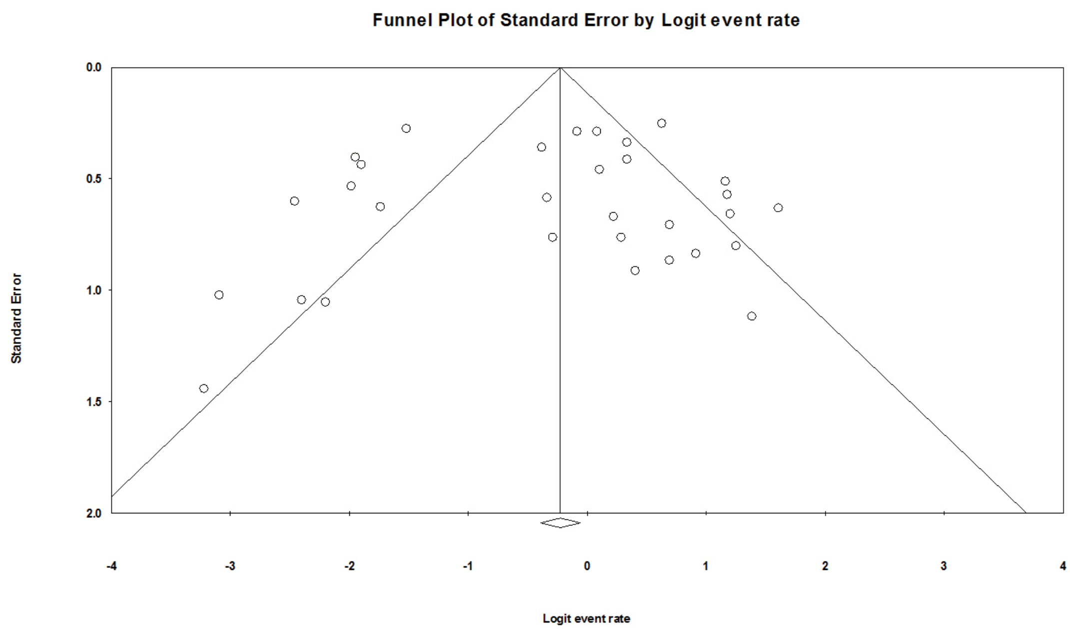

Fig. 2 Funnel Plot

3.5 Efficacy outcomes

3.5.1 Seizure freedom

The random-effects model was used to estimate the seizure-free rate after radiofrequency thermocoagulation, and the results showed that the combined seizure-free rate was 44.40% (95% CI 34.50%-54.8%; Fig. 3). The heterogeneity test results showed that Q value was 169.52(P < 0.001), I^2 value was 81.13%. This indicated that the results were high heterogeneous.

3.5.2 Complications

Twenty-seven studies provided information about postoperative complication rates. The pooled complication rate was 17.60% (95 % CI 11.70%–25.50%) with high heterogeneity (I^2 = 72.93%) in all patients (see Fig. 5). Most of the complications are temporary, such as fever, headache and limb dyskinesia. Individual patients will have permanent neurological impairment, such as hemiplegia.

Meta Analysis

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Total
deng（2020）	0.652	0.533	0.755	2.487	0.013	45 / 69
zhong（2020）	0.079	0.026	0.218	-4.084	0.000	3 / 38
xu(2018)	0.083	0.012	0.413	-2.296	0.022	1 / 12
Lee（2019）	0.571	0.230	0.856	0.377	0.706	4 / 7
guan（2017）	0.121	0.046	0.282	-3.714	0.000	4 / 33
yuan（2014）	0.521	0.382	0.657	0.289	0.773	25 / 48
wu（2013）	0.429	0.144	0.770	-0.377	0.706	3 / 7
lu（2012）	0.406	0.253	0.581	-1.054	0.292	13 / 32
su（2012）	0.583	0.419	0.731	0.995	0.320	21 / 36
Dimova (2017)	0.043	0.006	0.252	-3.023	0.003	1 / 23
Cossu（2015）	0.180	0.113	0.274	-5.499	0.000	16 / 89
Min Wang（2020）	0.667	0.268	0.916	0.800	0.423	4 / 6
Mullatti（2019）	0.526	0.311	0.732	0.229	0.819	10 / 19
zhang（2018）	0.479	0.343	0.618	-0.289	0.773	23 / 48
zheng（2018）	0.714	0.327	0.928	1.095	0.273	5 / 7
hua（2018）	0.778	0.421	0.944	1.562	0.118	7 / 9
hua（2020）	0.769	0.478	0.924	1.829	0.067	10 / 13
chen（2019）	0.667	0.333	0.889	0.980	0.327	6 / 9
liu（2018）	0.800	0.309	0.973	1.240	0.215	4 / 5
Chipaux（2019）	0.130	0.060	0.261	-4.333	0.000	6 / 46
Moles（2018）	0.023	0.001	0.277	-2.629	0.009	0 / 21
Bai（2019）	0.125	0.061	0.240	-4.816	0.000	7 / 56
Mirandola（2017）	0.765	0.514	0.909	2.061	0.039	13 / 17
lu（2018）	0.583	0.383	0.759	0.813	0.416	14 / 24
fang（2018）	0.769	0.478	0.924	1.829	0.067	10 / 13
Zhao（2017）	0.417	0.185	0.692	-0.575	0.566	5 / 12
Wei(2017)	0.556	0.251	0.823	0.333	0.739	5 / 9
Fan（2019）	0.762	0.540	0.897	2.270	0.023	16 / 21
Pizzo (2017)	0.100	0.014	0.467	-2.084	0.037	1 / 10
Homma（2007）	0.600	0.200	0.900	0.444	0.657	3 / 5
Wellmer（2018）	0.714	0.327	0.928	1.095	0.273	5 / 7
Shigeki（2009）	0.833	0.591	0.945	2.545	0.011	15 / 18
Guenot（2004）	0.150	0.049	0.376	-2.770	0.006	3 / 20
	0.444	0.345	0.548	-1.052	0.293	

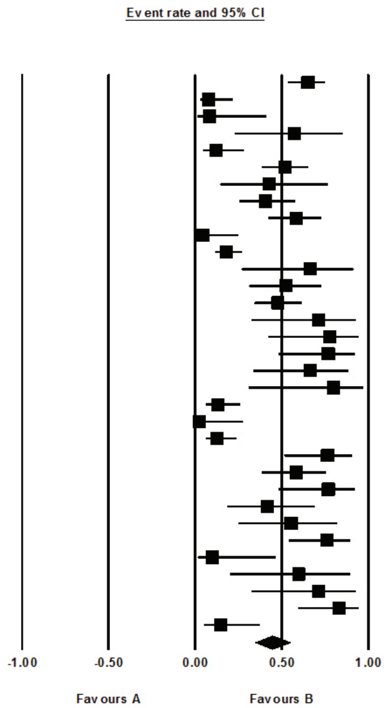

Fig. 3 Forest Plot

Meta Analysis

Group by type	Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Total
Cerebral malacia	deng（2020）6	0.200	0.027	0.691	-1.240	0.215	1 / 5
Cerebral malacia		0.200	0.027	0.691	-1.240	0.215	
FCD	deng（2020）1	0.800	0.600	0.914	2.773	0.006	20 / 25
FCD	Cossu（2015）3	0.042	0.003	0.425	-2.170	0.030	0 / 11
FCD	Wellmer（2018）	0.714	0.327	0.928	1.095	0.273	5 / 7
FCD		0.712	0.525	0.847	2.202	0.028	
HH	Min Wang（2020）	0.667	0.268	0.916	0.800	0.423	4 / 6
HH	zheng（2018）	0.714	0.327	0.928	1.095	0.273	5 / 7
HH	hua（2018）	0.778	0.421	0.944	1.562	0.118	7 / 9
HH	Wei(2017)	0.556	0.251	0.823	0.333	0.739	5 / 9
HH	Homma（2007）	0.600	0.200	0.900	0.444	0.657	3 / 5
HH	Shigeki（2009）	0.833	0.591	0.945	2.545	0.011	15 / 18
HH		0.710	0.571	0.819	2.871	0.004	
HS	deng（2020）3	0.625	0.285	0.875	0.699	0.484	5 / 8
HS	yuan（2014）	0.521	0.382	0.657	0.289	0.773	25 / 48
HS	Cossu（2015）1	0.500	0.168	0.832	0.000	1.000	3 / 6
HS	Fan（2019）	0.762	0.540	0.897	2.270	0.023	16 / 21
HS		0.583	0.471	0.686	1.459	0.145	
negative MRI	deng（2020）2	0.563	0.324	0.775	0.499	0.618	9 / 16
negative MRI		0.563	0.324	0.775	0.499	0.618	
others	deng（2020）5	0.625	0.285	0.875	0.699	0.484	5 / 8
others	deng（2020）7	0.600	0.200	0.900	0.444	0.657	3 / 5
others	zhong（2020）	0.079	0.026	0.218	-4.084	0.000	3 / 38
others	xu(2018)	0.083	0.012	0.413	-2.296	0.022	1 / 12
others	Lee（2019）	0.571	0.230	0.856	0.377	0.706	4 / 7
others	guan（2017）	0.121	0.046	0.282	-3.714	0.000	4 / 33
others	wu（2013）	0.429	0.144	0.770	-0.377	0.706	3 / 7
others	lu（2012）	0.406	0.253	0.581	-1.054	0.292	13 / 32
others	su（2012）	0.583	0.419	0.731	0.995	0.320	21 / 36
others	Dimova (2017)	0.043	0.006	0.252	-3.023	0.003	1 / 23
others	Cossu（2015）4	0.083	0.035	0.185	-5.134	0.000	5 / 60
others	Mullatti（2019）	0.526	0.311	0.732	0.229	0.819	10 / 19
others	zhang（2018）	0.479	0.343	0.618	-0.289	0.773	23 / 48
others	hua（2020）	0.769	0.478	0.924	1.829	0.067	10 / 13
others	chen（2019）	0.667	0.333	0.889	0.980	0.327	6 / 9
others	Chipaux（2019）	0.130	0.060	0.261	-4.333	0.000	6 / 46
others	Moles（2018）	0.023	0.001	0.277	-2.629	0.009	0 / 21
others	Bai（2019）	0.125	0.061	0.240	-4.816	0.000	7 / 56
others	lu（2018）	0.583	0.383	0.759	0.813	0.416	14 / 24
others	fang（2018）	0.769	0.478	0.924	1.829	0.067	10 / 13
others	Zhao（2017）	0.417	0.185	0.692	-0.575	0.566	5 / 12
others	Guenot（2004）	0.150	0.049	0.376	-2.770	0.006	3 / 20
others		0.355	0.307	0.406	-5.416	0.000	
PNH	deng（2020）4	0.833	0.194	0.990	1.039	0.299	2 / 2
PNH	Cossu（2015）2	0.667	0.376	0.869	1.132	0.258	8 / 12
PNH	liu（2018）	0.800	0.309	0.973	1.240	0.215	4 / 5
PNH	Mirandola（2017）	0.765	0.514	0.909	2.061	0.039	13 / 17
PNH		0.739	0.574	0.856	2.745	0.006	
Overall		0.459	0.417	0.502	-1.852	0.064	

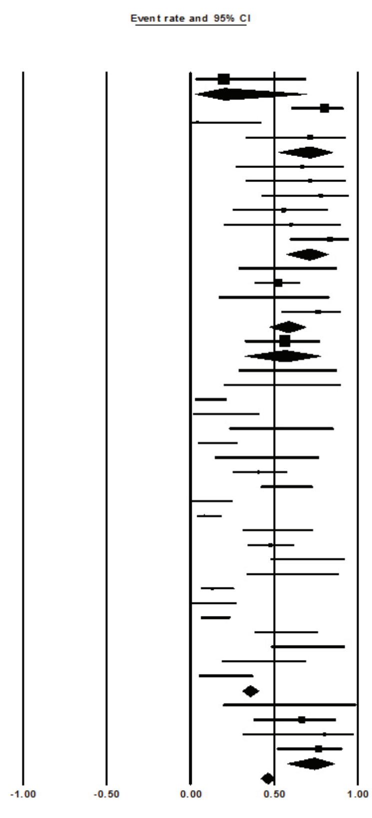

Fig. 4 Subgroup analysis Result of Seizure-free Rate

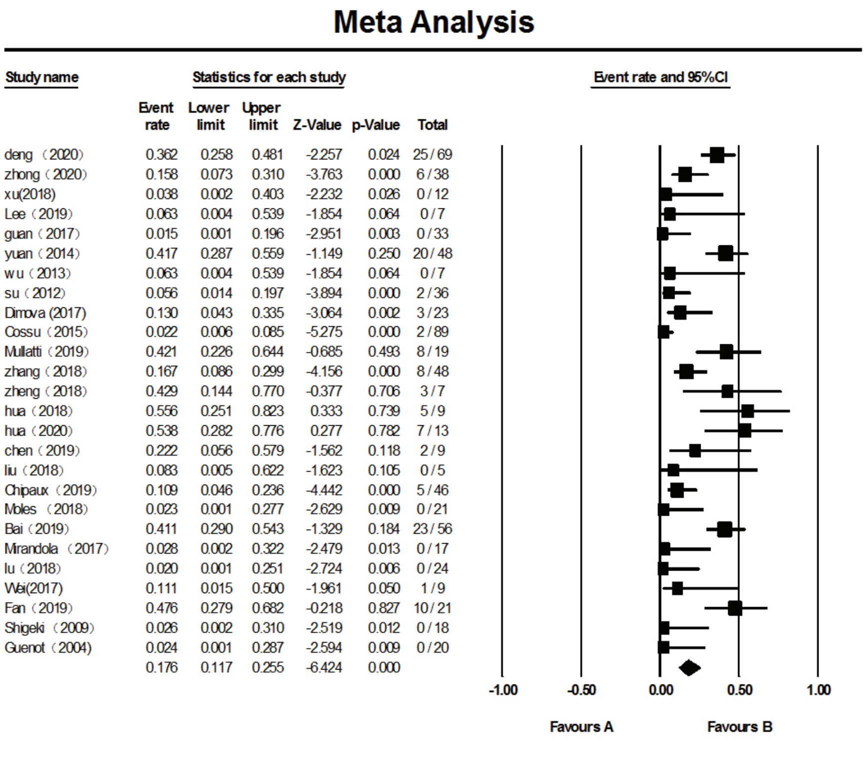

Fig. 5 Forest Plot

3.5.3 Subgroup analysis

To further investigate the reasons for the high heterogeneity of seizure-free rates, we performed a subgroup analysis. The results are shown in Figure 4 and table 2. Considering that the efficacy of SEEG guided RFTC may be affected by the etiology of epilepsy, patients were divided into 7 groups according to the etiology: FCD (n = 43, 3studies), HH (n = 54, 6 Studies), HS (n =83, 4 studies), PNH (n = 36, 4 studies), encephalomalacia (n =5, 1 study), MRI negativity (n = 16, 1 study) and others (n =542, 22 studies). Some articles did not report seizure-free rates based on different etiology, so they were classified into "others" groups by subgroup analysis. Subgroup analysis showed that the

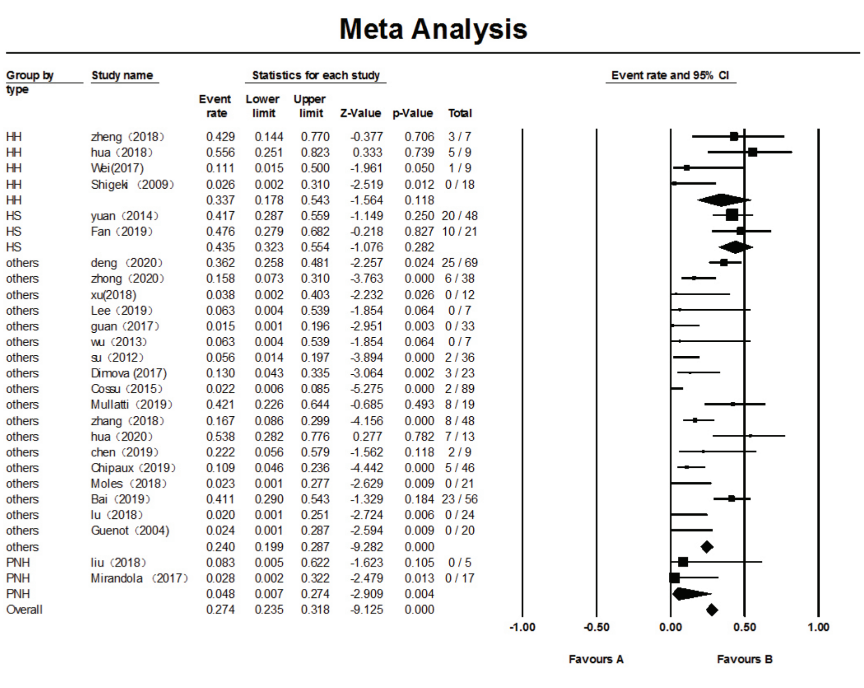

Fig. 6 Subgroup analysis Result of Complication Rate

Q value (between groups) was 50.44, P < 0.001. In addition, the I^2 of FCD group and "others" group were 77.14% and 80.96% respectively, which were high heterogeneity. The heterogeneity of the remaining etiology groups was very low, so the etiology had a significant impact on seizure-free rates. The seizure-free rates of PNH group, FCD group, HH group, HS group, MRI negative group, "others" group and encephalomalacia group were 73.90%, 71.20%, 71.00%, 58.30%, 56.30%, 35.50% and 20.00%, respectively.

To further investigate the high heterogeneity observed for the complication rate, a subgroup analysis was performed. Subgroup analysis showed that the Q value (between groups) was 14.95, P= 0.002. The heterogeneity of PNH group and HS group was very low (0.00%), indicating that etiology contributed to the high heterogeneity of complication rate. The complication rate of HS group, HH group, "others", PNH group were 43.50%, 33.70%, 24.00% and 4.80%, respectively.

Table 2 Subgroup analysis Result

Group	K	95%CI			Heterogeneity			
		Point estimate	Lower limit	Upper limit	Q-value	df	P-value	I-squared
FCD	3	0.712	0.525	0.847	8.749	2	0.013	77.141
HH	6	0.710	0.571	0.819	2.821	5	0.728	0.000
HS	4	0.583	0.471	0.686	3.597	3	0.308	16.606
negative MRI	1	0.563	0.324	0.775	0.000	0	1.000	0.000
PNH	4	0.739	0.574	0.856	0.611	3	0.894	0.000
malacia	1	0.299	0.071	0.704	0.591	1	0.442	0.000
Others	22	0.355	0.307	0.406	110.313	21	0.000	80.963
Totol between	-	-	-	-	50.44	6	0.000	-

4. Discussions

More and more studies have reported the prognosis of patients with drug-resistant epilepsy treated by SEEG guided RFTC. Previous studies have conducted a meta-analysis on the efficacy of RFTC in the treatment of epilepsy (Bourdillon et al., 2018; Wang, Y et al., 2020), [13, 15] however, there are few literatures included in the analysis of the two studies, and the subgroup analysis based on etiology is different. Although both of them found high heterogeneity in seizure-free rates, the source of heterogeneity was not clear through subgroup analysis, and the authors suggest that heterogeneity is not only related to the underlying etiology of epilepsy. In our study, two independent searchers conducted a more rigorous and detailed literature search and formulated strict inclusion and exclusion criteria. Finally, 33 literatures meeting the criteria were included in the study, and the number of included literatures was far more than that of the previous meta-analysis. Although in Bourdillon's study, treatment outcomes included seizure-free rate and responder rate, the reporting standards of responder rate in different literatures were inconsistent, thus we chose seizure-free rate to evaluate the efficacy. When selecting the original data from the study, we found that the follow-up time varied greatly in different literature studies (Dimova et al., 2017; Mullatti et al., 2019).[16, 17] To reduce the risk of publication bias, we excluded samples with an average follow-up of less than 6 months. Studies have shown that there is still a certain difference between SEEG guided RFTC and resection in the treatment of epilepsy (Moles et al., 2018),[7] so cases with resection after RFTC are excluded.

The results showed that the overall seizure-free rate was 44.40%. The heterogeneity of seizure results in different studies was very high, with I2 value of 81.13%. It is necessary to determine the factors related to seizure. Seven studies were included in the meta-analysis of SEEG guided RFTC for epilepsy by A. Negida. The results of meta regression analysis showed that the efficacy did not depend on the age of the study population, the percentage of female participants or the number of thermocoagulation (P > 0.05) (Negida et al., 2019).[18] In our study, Egger's linear regression showed that there was no publication bias, but the funnel plot was not completely symmetrical, so the interpretation of the results should be cautious. According to the etiology of epilepsy (FCD, HH, HS, MRI negative, PNH, softening focus), we conducted subgroup analysis. The results showed that Q value (between groups) was 50.44, P < 0.001. Except for FCD group and “other” group, I^2 was 77.14% and 80.96% respectively, which was high heterogeneity. The heterogeneity of the remaining etiology groups was very low. This indicated that the main source of high heterogeneity was etiology, and the efficacy of RFTC is mainly affected by etiology, which was different from the results of previous meta-analysis (Bourdillon et al., 2018; Wang, Y et al., 2020).[13, 15] The heterogeneity of FCD was as high as 77.14%, which may be due to the influence of FCD classification. Clinical practice showed that the efficacy of FCD Ⅱ b was better because of clear and focal lesions (Tassi et al., 2012),[19] but the efficacy of other types was still poor. In addition, the heterogeneity of "others" group was as high as 80.96%, which may be due to which studies included in this group did not report results based on etiology, resulting in high heterogeneity. The seizure-free rates of PNH group, FCD group, HH group and HS group were 73.90%, 71.20%, 71.00% and 58.30% respectively, which indicated that their curative effect was good. The reason may be that the lesions were clear and focal (Wang, D et al., 2020),[20] which were positive on MRI images. The seizure-free rate of PNH was as high as 73.90%, the subgroup analysis of complication rate showed that the complication rate was affected by the etiology, and the complication rate of PNH was the lowest (4.80%). RFTC may be an ideal treatment for patients with PNH related drug-resistant epilepsy. For patients who do not meet the conditions of epilepsy surgery, this is a feasible intervention option.

The risk of complications after SEEG guided RFTC is low. The main complications include high fever, mild limb dyskinesia, headache, nausea, drowsiness and so on, most of them are transient and can be recovered at discharge. In future, SEEG-RFTC will be more likely to be used in patients with small lesions in the deep brain in those with multiple etiologies or with multiple epileptogenic focus, who were not ideal candidates for resective surgery. In addition, patients treated with RFTC have shorter hospital stay, lower cost of the whole process, less injury, and no need for severe postoperative care. Therefore, SEEG guided RFTC has a unique value for patients (Lee et al., 2019).[21]

This study analyzed the efficacy of RFTC to provide a possible reference for clinical efficacy evaluation. In addition, by analyzing the influence of epilepsy etiology on the curative effect of thermocoagulation, it shows that the curative effect of thermocoagulation is mainly affected by the etiology, which provides guidance for clinicians to choose RFTC treatment for different epilepsy patients. It is helpful to further improve the development of RFTC technology and help patients with epilepsy to relieve symptoms and obtain better curative effect. The advantages of this study include that more meta-analysis literatures are included; In order to reduce the influence of other factors on the efficacy of RFTC, follow-up time and history of resection should be taken into account; The subgroup analysis of etiology added more etiologies, and the study found that there were differences in the efficacy of etiology groups, which can be used to guide clinical practice. The limitations of this study include the low level of evidence, lack of control group, and retrospective study, this direction needs further study.

5. Conclusions

SEEG guided RFTC is an effective stereotactic invasive surgical technique for the treatment of drug-resistant epilepsy, which can be considered when conventional resection is not feasible. PNH patients showed the best effect, and encephalomalacia had the worst effect. The clinical application value of SEEG guided RFTC is worthy of further exploration.

6. Disclosure

None of the authors have any conflicts of interest to disclose. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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