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ORIGINAL PAPER

# Adjunctive Nonconvulsive Electrotherapy for Patients with Depression: a Systematic Review

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## Abstract

The efficacy and safety of adjunctive nonconvulsive electrotherapy (NET) for patients with depression are undetermined. This systematic review was conducted to examine the efficacy and safety of adjunctive NET for patients with depression. Chinese (WanFang and Chinese Journal Net) and English (PubMed, EMBASE, PsycINFO and the Cochrane Library) databases were systematically searched from their inception until Jan 27, 2021 by three independent investigators. One randomized controlled trial (RCT) with 3 treatment arms (n = 108) and two observational studies (single-group, before-after design, n = 31) were included. In the RCT, the antidepressant efficacy of NET on depression was similar to that of electroconvulsive therapy (ECT) ($P > 0.05$) but with significantly fewer neurocognitive impairments as measured by the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) ($P < 0.05$). In two observational studies, the 17-item Hamilton Depression Rating Scale (HAMD-17) scores decreased significantly from baseline to post-NET (all $Ps < 0.05$), without adverse neurocognitive effects. In the RCT, adverse drug reactions (ADRs) were not separately reported among the 3 treatment arms but a similar rate of discontinuation was reported. The currently available limited evidence from 3 studies suggests that NET as an adjunctive treatment may be a safe, well-tolerated, effective therapy for depression without serious neurocognitive impairments.

**Keywords** Nonconvulsive electrotherapy · Depression · Systematic review

## Introduction

Depression, a common mental disorder, is a leading cause of disability worldwide and can substantially impair the quality of life and social function of both patients and caregivers [1, 2]. Antidepressants (ADs) are the current mainstay pharmacological

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therapy for depression, but their therapeutic effect and side effects are disappointing [3, 4]. Consequently, augmentation strategies of ADs with nonpharmacological therapy [5, 6], such as adjunctive electroconvulsive therapy (ECT) [7, 8], transcranial magnetic stimulation (TMS) including repeated TMS (rTMS) and deep TMS (dTMS) [9, 10], and nonconvulsive electrotherapy (NET) [11], have been used to enhance and hasten the efficacy of ADs.

ECT has been considered the most effective therapy for treatment-refractory depression (TRD) in clinical practice and has been used for more than 80 years for various mental diseases [8, 12]; however, some patients suffering from depression refuse to receive ECT treatment over concern about ECT-related adverse neurocognitive effects [13, 14]. Two recent single-arm open-label studies consistently reported that NET with 1/8 of the standard ECT at below the seizure threshold can induce rapid and robust antidepressant effects on subjects suffering from TRD but with fewer neurocognitive dysfunctions than ECT [11, 15].

NET was conducted by electrical brain stimulation administered using the standard ECT technique but below the seizure threshold [11, 15]. Unlike ECT, NET electric stimulation has insufficient strength to evoke convulsions and does not induce neurocognitive dysfunction [15]. An animal trial reported that the antidepressant-like effects of subconvulsive electrical stimulation were similar to those of ECT but without neurocognitive dysfunctions induced by convulsive treatment [16]. Importantly, a recent randomized controlled trial (RCT) found that NET with 1/2 of the standard ECT below the seizure threshold had a rapid antidepressant effect comparable to ECT with the standard dose but with fewer neurocognitive dysfunctions than ECT [17].

To date, no systematic review on NET as an adjunctive treatment for depression has been published. Thus, the aim of this systematic review was to examine the antidepressant effect, safety and tolerability of NET as an adjunctive treatment for depression.

## Methods

### Search Strategy

Three investigators (DBC, LMG, and MH) independently searched Chinese (WanFang and Chinese Journal Net) and English (PubMed, EMBASE, PsycINFO, and the Cochrane Library) databases from their inception until Jan 27, 2021 for studies examining NET as an adjunctive treatment for patients with depression using the following search terms: ("depression"[Mesh] OR depression OR depressive OR depressed OR melancholia) AND (nonconvulsive electr* OR low-charge OR low-dose OR subthreshold) AND ("electroconvulsive therapy"[Mesh] OR ECT OR MECT OR electroconvulsive therapy). We also manually searched the reference lists of the included studies for additional studies [11, 15, 17].

### Study Selection and Outcome Measures

Only RCTs and observational studies investigating the therapeutic effect, safety and tolerability of NET as an adjunctive treatment for depression were eligible for

inclusion, which were decided by three independent investigators (DBC, LMG, and MH). The electrical stimulation dose was not convulsion-evoking in the included studies. Thus, some studies at low stimulus doses but with convulsive seizures were excluded [18, 19]. Case reports/series, retrospective studies, meta-analyses and reviews were excluded.

The primary outcome was antidepressant efficacy as measured by standardized rating scales, such as the Hamilton Depression Rating Scale (HAMD). Key secondary outcomes included (1) neurocognitive function, (2) adverse events reported by patients, and (3) discontinuation due to any reason.

### Data Extraction and Study Quality

Three investigators (DBC, LMG, and MH) independently extracted and checked the data. Inconsistencies were resolved by consensus involving a senior author (WZ). First and/or corresponding authors were contacted by email for missing data if necessary. For RCTs, the Cochrane risk of bias [20] was used to assess the study quality.

## Results

### Literature Search

As shown in Fig. 1, a total of 652 hits were identified based on the above search strategy (n = 651) and manual search (n = 1). Finally, one RCT [17] and 2 observational studies [11, 15] fulfilled the inclusion criteria.

### Characteristics of Each Included Study

Table 1 summarizes the characteristics of the studies, including one RCT [17] (n = 108) and two observational studies (n = 31) [11, 15]. Two studies (66.7%, 2/3) were published in the last two years, suggesting that adjunctive NET for depression is a new clinically important topic. In Regenold et al.'s study, seizure-free data were obtained and analysed from 11 of 13 subjects [11]; however, 5 of 36 participants in one NET group with 40% age electrical dosage had a seizure, which was included and analysed in the RCT [17].

### Quality Assessment

As depicted in Fig. 2, the RCT was rated as low risk with regard to random sequence generation, attrition bias and selective reporting using the Cochrane risk of bias tool [17]. The two observational studies were a single group with a before-after design [11, 15].

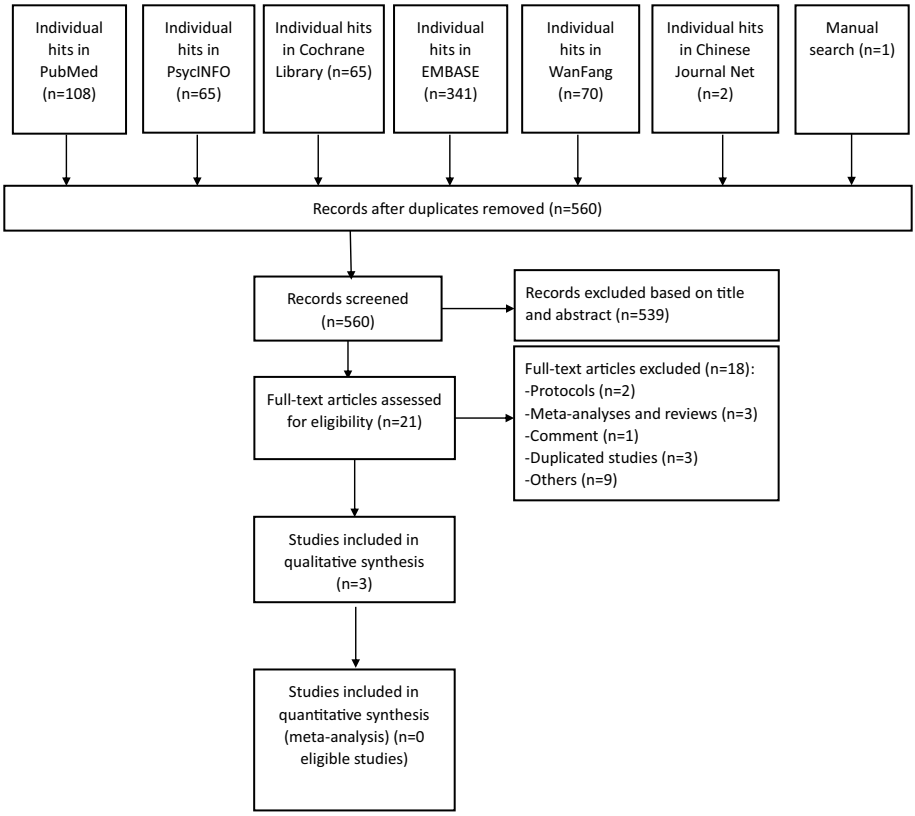


**Fig. 1** PRISMA flow diagram

## Antidepressant Efficacy and Neurocognitive Function

In the RCT [17], the antidepressant efficacy of NET on depression was similar to that of ECT ($P > 0.05$) but with significantly fewer neurocognitive impairments as measured by the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) ($P < 0.05$) (Table 2).

In the two observational studies, the HAMD-17 scores decreased significantly from baseline to post-NET (all $Ps < 0.05$, Table 2) [11, 15]. Zheng et al. reported a significant improvement in neurocognitive performance as measured by the Wisconsin Card Sorting Test (WCST) after NET ($P < 0.05$, Table 2) [15]. Another observational study found that Mini-Mental State Exam (MMSE) scores increased insignificantly after post-NET ($P > 0.05$) [11].

## ADRs and Discontinuation Rate

Table 3 summarizes the rate of ADRs and discontinuation. In the RCT, the specific ADRs were not separately reported among the 3 treatment groups but similar rates of discontinuation were reported among the groups (all $Ps < 0.05$) [17]. Regenold et al. reported that 2 of 13 participants were lost due to seizures at their initial treatment [11].

**Table 1** Summary of each included study

| Study (country) | N (♂/♀) | Diagnosis | -Design -Intervention (dosing, sample size) | Study duration (wks) | Age[a]: yrs (range) | Anaesthesia (mg/kg) | ECT or NET treatment duration (n/wks) |
|---|---|---|---|---|---|---|---|
| Li et al. [17] (China) | 108 (44/64) | MDD | -RCT -NET (age*80%*1/4, n = 36) versus NET (age*80%*1/2, n = 36) versus ECT (age*80%, n = 36) | 2 | 37.9 (18–65) | Propofol (1–2) | 8 (5 times during the first week and every other day during the second week) |
| Regenold et al. [11] (USA) | 11 (5/6)[b] | TRD (5 unipolar, 6 bipolar) | -Observational study -NET alone (age*50%*1/8, n = 11) | 2–4 | 39.8 (≥ 18) | Methohexital (1)[c] | 6–12 (3/wks) |
| Zheng et al. [15] (China) | 20 (11/9) | TRD (20 unipolar) | -Observational study -NET alone (age*50%*1/8, n = 20) | 2 | 29.2 (18–50) | Propofol (1) | 6 (3/wks) |

*ECT* electroconvulsive therapy, *MDD* major depressive disorder, *N* number of patients, *NET* nonconvulsive electrotherapy, *RCT* randomized controlled study, *TRD* treatment-refractory depression, *wks* weeks, *yrs* years

[a]Available data were extracted based on the mean baseline value of each included trial

[b]Seizure-free data was obtained from 11 of 13 subjects

[c]The dose was administered initially at approximately 1 mg/kg, which was adjusted depending on the initial treatment effects

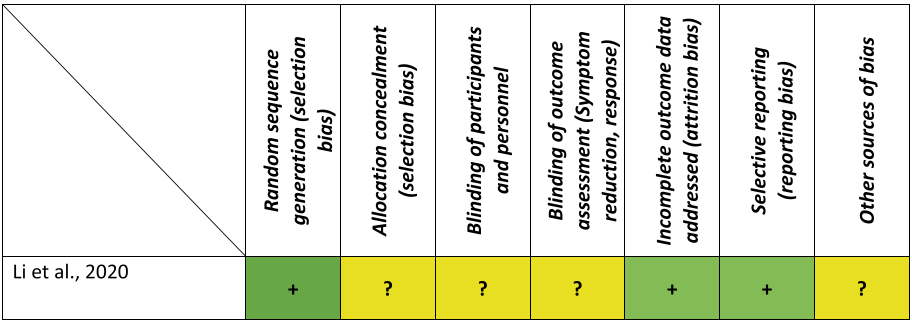


**Fig. 2** The Cochrane risk of bias

## Discussion

To the best of our knowledge, this systematic review is the first to examine the efficacy and safety of adjunctive NET for subjects suffering from depression. In this comprehensive systematic review, three studies with a total of 139 depressed patients were included and analysed [11, 15, 17]. The results of this systematic review demonstrate that NET may have similar antidepressant efficacy to ECT with less neurocognitive impairment, suggesting that NET may be a safe, well-tolerated, and effective nonpharmacological therapeutic intervention for the treatment of depression. Although NET appears to be an interesting and potentially important additional therapy, further studies are warranted to confirm and extend these findings.

As reported in Regenold et al.'s study [11], the mechanism of the antidepressant effects of NET may be related the location of the stimulus [21–23]. Previous studies have shown that bifrontal ECT can produce increases in cerebral blood flow (CBF) and activation in the prefrontal and anterior cingulate regions while preserving the temporal lobes, which may result in comparable antidepressant effects and fewer adverse neurocognitive effects than bitemporal ECT [24, 25]. Recently, a meta-analysis also indicated that the antidepressant efficacy of bifrontal ECT was comparable to that of bitemporal ECT, with fewer adverse effects [26]. Hence, bifrontal NET, as a bifrontal ECT variant, appears to have antidepressant efficacy. The stimulation does not act directly on the temporal lobe and was associated with less neurocognitive impairment than ECT.

Interestingly, rTMS was proven to be an effective technique via electrodes placed on the scalp for depression regardless of low-frequency rTMS (LF-rTMS) or high-frequency rTMS (HF-rTMS) [27–29]. Of note, LF-rTMS was found to have better tolerability and efficacy than HF-rTMS in subjects with a high risk of seizures or when the patient did not respond to HF-rTMS because LF TMS does not induce seizures [10, 30]. Hence, the antidepressant response to rTMS further suggests that a seizure may not be necessary to achieve an antidepressant response to ECT. Several meta-analyses focusing on the efficacy and acceptability of ECT versus rTMS for depression have consistently found that the antidepressant effect of rTMS is inferior to that of ECT [28, 31, 32]. However, to date, no head-to-head studies have been conducted to directly compare the treatment outcomes of TMS and NET in depression.

**Table 2** Antidepressant efficacy and neurocognitive function

| Study | NET dosing | Clinical outcomes | Post-NET (mean ± SD) | Post-ECT (mean ± SD) | Findings |
|---|---|---|---|---|---|
| RCT (n = 108) | | | | | |
| Li et al. [17] | (Age*80%)*1/4 | HAMD-17 | 24.4 ± 4.9 | 21.7 ± 5.1 | NS |
| | | RBANS | 65.2 ± 12.2 | 55.2 ± 11.2 | ***P* < 0.05** |
| | | SIOSS | 13.3 ± 3.8 | 10.7 ± 3.0 | ***P* < 0.05** |
| | (Age*80%)*1/2 | HAMD-17 | 21.2 ± 6.1 | 21.7 ± 5.1 | NS |
| | | RBANS | 63.9 ± 11.5 | 55.2 ± 11.2 | ***P* < 0.05** |
| | | SIOSS | 10.9 ± 2.8 | 10.7 ± 3.0 | NS |
| Observational study (n = 31) | | | | | |
| | | | **Pre-NET (mean ± SD)** | **Post-NET (mean ± SD)** | |
| Regenold et al. [11] | (Age*50%)*1/8 | HAMD-17 | 20.3 ± 2.7 | 6.7 ± 2.0 | ***P* < 0.05** |
| | | MMSE | 28.2 ± 2.0 | 29.1 ± 1.6 | NS |
| | | AMI-SF | NR | NR[a] | NS |
| Zheng et al. [15] | (Age*50%)*1/8 | HAMD-17 | 26.2 ± 2.4 | 10.4 ± 2.0 | ***P* < 0.05** |
| | | WCST: | | | |
| | | Completing classification number | 5.5 ± 1.1 | 6.5 ± 0.9 | ***P* < 0.05** |
| | | Total error number | 8.9 ± 2.9 | 6.2 ± 2.5 | ***P* < 0.05** |
| | | Persistent error number | 1.9 ± 1.8 | 0.9 ± 1.0 | ***P* < 0.05** |
| | | Random error number | 7.0 ± 2.5 | 5.4 ± 2.0 | ***P* < 0.05** |

*AMI-SF* Autobiographical Memory Inventory-Short Form, *ECT* electroconvulsive therapy, *HAMD-17* 17-item Hamilton Depression Rating Scale, *MMSE* Mini-Mental State Examination, *NET* nonconvulsive electrotherapy, *NR* not reported, *NS* no significant, *RBANS* Repeatable Battery for the Assessment of Neuropsychological Status, *SIOSS* Self-Rating Idea of Suicide Scale, *WCST* Wisconsin Card Sorting Test

[a]Mean AMI-SF post-treatment scores were 97% of the baseline scores. Bolded values are $P < 0.05$

**Table 3** ADRs and discontinuation rates

| Study | ADRs | | | | Discontinuation due to any reason (%) | | |
|---|---|---|---|---|---|---|---|
| | Events | Total (%) | NET (%) | ECT (%) | Total (%) | NET (%) | ECT (%) |
| Li et al. [17] | Constipation | 15 (13.9) | NR | NR | 16 (14.8) | 11 (15.3) | 5 (13.9) |
| | Dizziness | 6 (5.6) | NR | NR | | | |
| | Headache | 4 (3.7) | NR | NR | | | |
| | Myalgia | 4 (3.7) | NR | NR | | | |
| | Arrhythmia | 4 (3.7) | NR | NR | | | |
| | Hypertension | 4 (3.7) | NR | NR | | | |
| | Have a cold | 4 (3.7) | NR | NR | | | |
| | Loosening of teeth | 2 (1.9) | NR | NR | | | |
| | Delirium | 1 (0.9) | NR | NR | | | |
| | hypotension | 1 (0.9) | NR | NR | | | |
| | Anaesthetic allergy | 1 (0.9) | NR | NR | | | |
| Regenold et al. [11] | Induced seizure | 3 (23.1) | | - | 2 (15.4) | | - |
| | Headache | 5 (38.5) | | | | | |
| | Fatigue | 6 (46.2) | | | | | |
| | Jaw pain | 2 (15.4) | | | | | |
| | Cardiac arrhythmia | 1 (7.7) | | | | | |
| | Anxiety dream | 2 (15.4) | | | | | |
| | Dizziness | 1 (7.7) | | | | | |
| | Sore throat | 1 (7.7) | | | | | |
| Zheng et al. [15] | NR | NR | | - | 0 | | - |

*ADRs* adverse drug reactions, *ECT* electroconvulsive therapy, *NET* nonconvulsive electrotherapy, *NR* not reported

This study has several limitations. First, meta-analysis could not be performed due to the heterogeneity of the included studies, such as differences in their study design and methodology. Second, only 3 studies [11, 15, 17] with relatively small sample sizes (n = 139) fulfilled the inclusion criteria and were used in the qualitative analysis. Among the 3 studies [11, 15, 17], only one RCT [17] was available, and the other 2 studies were observational trials [11, 15]. Third, the MMSE and WCST, used separately in two observational studies [11, 15], appeared to not be suitable instruments to measure the neurocognitive functions of depression. Specific neurocognitive batteries, such as the MATRICS Consensus Cognitive Battery (MCCB), should be used and are recommended.

## Conclusion

The currently available limited evidence from 3 studies suggests that NET as an adjunctive treatment may be a safe, well-tolerated, effective therapy for patients with depression without serious neurocognitive impairments. Further RCTs with larger samples and rigorous methodology are needed to confirm these findings.

**Abbreviations** ADs: Antidepressants; ADRs: Adverse drug reactions; CBF: Cerebral blood flow; dTMS: Deep transcranial magnetic stimulation; ECT: Electroconvulsive therapy; HAMD-17: 17-Item Hamilton Depression Rating Scale; HF-rTMS: High-frequency repeated transcranial magnetic stimulation; LF-rTMS: Low-frequency repeated transcranial magnetic stimulation; MCCB: MATRICS Consensus Cognitive Battery; MMSE: Mini-Mental State Exam; NET: Nonconvulsive electrotherapy; RBANS: Repeatable Battery for the Assessment of Neuropsychological Status; RCT: Randomized controlled trial; rTMS: Repeated transcranial magnetic stimulation; TMS: Transcranial magnetic stimulation; TRD: Treatment-refractory depression; WCST: Wisconsin Card Sorting Test

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**Availability of Data and Material** The data of this article are included within the article.

## Declarations

**Conflicts of Interest** The authors declare no conflicts of interest in conducting this study or preparing the manuscript.

## References

1. Huang R, Wang K, Hu J. Effect of probiotics on depression: a systematic review and meta-analysis of randomized controlled trials. Nutrients. 2016;8(8):483.
2. Murray CJ, Barber RM, Foreman KJ, Abbasoglu Ozgoren A, Abd-Allah F, Abera SF, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. Lancet. 2015;386(10009):2145–91.
3. Kikuchi T, Suzuki T, Uchida H, Watanabe K, Mimura M. Association between antidepressant side effects and functional impairment in patients with major depressive disorders. Psychiatry Res. 2013;210(1):127–33.
4. Trivedi MH, Rush AJ, Wisniewski SR, Nierenberg AA, Warden D, Ritz L, et al. Evaluation of outcomes with citalopram for depression using measurement-based care in STAR*D: implications for clinical practice. Am J Psychiatry. 2006;163(1):28–40.
5. Voineskos D, Daskalakis ZJ, Blumberger DM. Management of treatment-resistant depression: challenges and strategies. Neuropsychiatr Dis Treat. 2020;16:221–34.
6. Borrione L, Bellini H, Razza LB, Avila AG, Baeken C, Brem AK, et al. Precision non-implantable neuromodulation therapies: a perspective for the depressed brain. Revista brasileira de psiquiatria (Sao Paulo, Brazil : 1999). Braz J Psychiatry. 2020;42(4):403–19.
7. Dominiak M, Antosik-Wójcińska AZ, Goetz Z, Sikorska O, Stefanowski B, Gorostiza D, et al. Efficacy, safety and tolerability of formula-based unilateral vs bilateral electroconvulsive therapy in the treatment of major depression: a randomized open label controlled trial. J Psychiatr Res. 2021;133:52–9.
8. UK Ect Review Group. Efficacy and safety of electroconvulsive therapy in depressive disorders: a systematic review and meta-analysis. Lancet. 2003;361(9360):799–808.
9. Thompson L. Treating major depression and comorbid disorders with transcranial magnetic stimulation. J Affect Disord. 2020;276:453–60.

10. McClintock SM, Reti IM, Carpenter LL, McDonald WM, Dubin M, Taylor SF, et al. Consensus recommendations for the clinical application of repetitive transcranial magnetic stimulation (rTMS) in the treatment of depression. J Clin Psychiatry. 2018;79(1):16cs10905.
11. RegenoldWT, Noorani RJ, Piez D, Patel P. Nonconvulsive electrotherapy for treatment resist-antunipolar and bipolar major depressive disorder: a proof-of-concept trial. BrainStimul. 2015;8(5):855-61.
12. Weiner RD. The practice of electroconvulsive therapy: recommendations for treatment, training, and privileging: a task force report of the American Psychiatric Association. American Psychiatric Pub. 2018.
13. Squire LR. ECT and memory loss. Am J Psychiatry. 1977;134(9):997–1001.
14. Wang G, Zheng W, Li XB, Wang SB, Cai DB, Yang XH, et al. ECT augmentation of clozapine for clozapine-resistant schizophrenia: a meta-analysis of randomized controlled trials. J Psychiatr Res. 2018;105:23–32.
15. Zheng W, Jiang ML, He HB, Li RP, Li QL, Zhang CP, et al. A preliminary study of adjunctive non-convulsive electrotherapy for treatment-refractory depression. Psychiatr Q. 2020;92(1):311–20.
16. Gersner R, Toth E, Isserles M, Zangen A. Site-specific antidepressant effects of repeated subconvulsive electrical stimulation: potential role of brain-derived neurotrophic factor. Biol Psychiatry. 2010;67(2):125–32.
17. Li W, Ji CJ, Yang KB, Cai HP, Wang X, Wei YJ, et al. Evaluation of efficacy and safety about subthreshold modified electroconvulsive therapy for depression. Chin J Psychiatry. 2020;53(01):42–8.
18. Lapidus KA, Shin JS, Pasculli RM, Briggs MC, Popeo DM, Kellner CH. Low-dose right unilateral electroconvulsive therapy (ECT): effectiveness of the first treatment. J ECT. 2013;29(2):83–5.
19. Sackeim HA, Decina P, Kanzler M, Kerr B, Malitz S. Effects of electrode placement on the efficacy of titrated, low-dose ECT. Am J Psychiatry. 1987;144(11):1449–55.
20. Higgins J, Higgins J. Cochrane handbook for systematic reviews of interventions. 2008:Ltd: Chichester: Wiley.
21. Kang HJ, Voleti B, Hajszan T, Rajkowska G, Stockmeier CA, Licznerski P, et al. Decreased expression of synapse-related genes and loss of synapses in major depressive disorder. Nat Med. 2012;18(9):1413–7.
22. Padmanabhan JL, Cooke D, Joutsa J, Siddiqi SH, Ferguson M, Darby RR, et al. A human depression circuit derived from focal brain lesions. Biol Psychiatry. 2019;86(10):749–58.
23. WangXQ, Zhang L, Xia ZY, Chen JY, Fang Y, Ding YQ. PTEN in prefrontal cortex isessential in regulating depression-like behaviors in mice. Transl Psychiatry. 2021;11(1):185.
24. Blumenfeld H, McNally KA, Ostroff RB, Zubal IG. Targeted prefrontal cortical activation with bifrontal ECT. Psychiatry Res. 2003;123(3):165–70.
25. Bailine SH, Rifkin A, Kayne E, Selzer JA, Vital-Herne J, Blieka M, et al. Comparison of bifrontal and bitemporal ECT for major depression. Am J Psychiatry. 2000;157(1):121–3.
26. Dunne RA, McLoughlin DM. Systematic review and meta-analysis of bifrontal electroconvulsive therapy versus bilateral and unilateral electroconvulsive therapy in depression. World J Biol Psychiatry. 2012;13(4):248–58.
27. Berlim MT, Van den Eynde F, Jeff DZ. Clinically meaningful efficacy and acceptability of low-frequency repetitive transcranial magnetic stimulation (rTMS) for treating primary major depression: a meta-analysis of randomized, double-blind and sham-controlled trials. Neuropsychopharmacology. 2013;38(4):543–51.
28. Brunoni AR, Chaimani A, Moffa AH, Razza LB, Gattaz WF, Daskalakis ZJ, et al. Repetitive transcranial magnetic stimulation for the acute treatment of major depressive episodes: a systematic review with network meta-analysis. JAMA Psychiat. 2017;74(2):143–52.
29. Berlim MT, Van den Eynde F, Daskalakis ZJ. High-frequency repetitive transcranial magnetic stimulation accelerates and enhances the clinical response to antidepressants in major depression: a meta-analysis of randomized, double-blind, and sham-controlled trials. J Clin Psychiatry. 2013;74(2):e122–9.
30. Lefaucheur JP, André-Obadia N, Antal A, Ayache SS, Baeken C, Benninger DH, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS). Clin Neurophysiol. 2014;125(11):2150–206.
31. Chen JJ, Zhao LB, Liu YY, Fan SH, Xie P. Comparative efficacy and acceptability of electroconvulsive therapy versus repetitive transcranial magnetic stimulation for major depression: a systematic review and multiple-treatments meta-analysis. Behav Brain Res. 2017;320:30–6.
32. Mutz J, Vipulananthan V, Carter B, Hurlemann R, Fu CHY, Young AH. Comparative efficacy and acceptability of non-surgical brain stimulation for the acute treatment of major depressive

episodes in adults: systematic review and network meta-analysis. BMJ (Clinical research ed). 2019;364:l1079.

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