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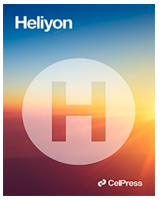

Systematic review and meta-analysis

Baroreflex activation therapy for heart failure with reduced ejection fraction: A comprehensive systematic review and meta-analysis

Ruijie Shi [a,b,c], Tong Sun [a,b,c], Mengxi Wang [a,b,c], Qian Xiang [a,b,c], Yuhan Ding [a,b,c], Siyuan Yin [a,b,c], Yan Chen [a,b], Le Shen [a,b], Peng Yu [a,b], Xiaohu Chen [a,b,*]

[a] Department of Cardiology, Affiliated Hospital of Nanjing University of Chinese Medicine, Nanjing, China
[b] Department of Cardiology, Jiangsu Province Hospital of Chinese Medicine, Nanjing, China
[c] First Clinical Medical College, Nanjing University of Chinese Medicine, Nanjing, China

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ABSTRACT

Background: In recent years, baroreflex activation therapy (BAT) has been utilized to treat heart failure with reduced ejection fraction (HFrEF). However, the supporting literature on its efficacy and safety is still limited. This investigation elucidates the effects of BAT in HFrEF patients to provide a reference for future clinical applications.
Methods: This investigation follows Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines. Relevant investigations on the use of BAT in HFrEF patients were searched and selected from 5 databases, including Web of Science, MEDLINE, PubMed, Embase, and Cochrane Library, from inception to December 2022. The methodological quality of eligible articles was assessed via the Cochrane risk of bias tool, and for meta-analysis, RevMan (5.3) was used.
Results: Randomized controlled trials comprising 343 participants were selected for the meta-analysis, which revealed that in HFrEF patients, BAT enhanced the levels of LVEF (MD: 2.97, 95 % CI: 0.53 to 5.41), MLHFQ (MD: −14.81, 95 % CI: −19.57 to −10.06) and 6MWT (MD: 68.18, 95 % CI: 51.62 to 84.74), whereas reduced the levels of LVEDV (MD: −15.79, 95 % CI: −32.96 to 1.37) and DBP (MD: −2.43, 95 % CI: −4.18 to −0.68).
Conclusion: It was concluded that BAT is an efficient treatment option for HFrEF patients. However, to validate this investigation, further randomized clinical trials with multiple centers and large sample sizes are needed.

1. Introduction

Globally, one of the major and most frequent causes of enhanced mortality and morbidity is heart failure (HF), accounting for an average of 33 % and one-third of all deaths worldwide [1]. Of these, HF with reduced ejection fraction (HFrEF) is more frequent and seriously affects the quality of life. Because of multiple structural and functional dysregulations in ventricular filling or blood ejection, alleviated exercise tolerance in HFrEF patients directly impacts their prognosis [2]. Guideline-directed medical therapy (GDMT)

* Corresponding author. Department of Cardiology, Affiliated Hospital of Nanjing University of Chinese Medicine, Nanjing, China.
E-mail address: chenxhdoctor@126.com (X. Chen).

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Abbreviations

BAT	Baroreflex Activation Therapy
CBM	China Biology Medicine
CI	Confidence Intervals
CNKI	China National Knowledge Infrastructure
DBP	Diastolic Blood Pressure
eGFR	estimated Glomerular Filtration Rate
GDMT	Guideline-Directed Medical Therapy
HF	Heart Failure
HFrEF	Heart Failure with Reduced Ejection Fraction
LVEDV	Left Ventricular End-Diastolic Volume
LVEF	Left Ventricular Ejection Fraction
MLHFQ	Minnesota Living with Heart Failure Questionnaire
NYHA	New York Heart Association
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RCT	Randomized Controlled Trials
SBP	Systolic Blood Pressure
6MWT	Six-Minute Walk Test
VIP	China Science and Technology Journal Database
OD	Odd ratio
MD	Mean Difference
CI	Confidence Intervals

recommends diuretics, β-blockers, ACEI/ARB, MRA, ARNI, etc.; however, there are problems of individual variability of medications and adverse effects with prolonged use [3]. Cardiac resynchronization therapy is an advanced technique discovered recently that can effectively maintain the heart's pumping function; however, the associated economic and social burden also cannot be ignored [4].

The literature suggests that baroreflex control abnormalities cause sympathetic imbalance, which is linked with the stimulation of the renin-angiotensin-aldosterone system and can exacerbate HF [5]. Restoring baroreflex function may improve autonomic balance, which is beneficial for the patients. Therefore, BAT has received immense attention for treating HF, especially in HFrEF. During BAT, electrodes linked with a subcutaneous pulse generator for appropriate amplitude, frequency, and duration stimulation are placed in the carotid sinus. With encouraging preclinical results, randomized controlled trials (RCTs) were conducted to test the safety and efficacy of BAT, revealing a new option for the treatment of HFrEF [6,7]. Unfortunately, the available literature supporting BAT is insufficient, limiting its promotion. This investigation was designed to elucidate the effects of BAT in HFrEF patients to furnish references for future clinical management.

2. Methods

2.1. Search strategy

This investigation followed PRISMA [8]. Relevant articles in all the languages were systematically searched in 5 databases, including Web of Science, MEDLINE, PubMed, Embase, and Cochrane Library, from inception to December 2022. The search terms were baroreflex activation therapy (BAT), HF, and RCTs. For example, search terms for relevant articles in PubMed were:

(baroreflex activation therapy **OR** baroreceptor reflex **OR** baroreceptor) AND (myocardial failure **OR** heart failure **OR** congestive heart failure **OR** cardiac failure) AND (randomized controlled trials **OR** RCTs **OR** clinical trial)

2.2. Study selection

All searched records were screened for relevance, and two reviewers read all abstracts independently (TS and MXW). The full texts were read of studies that evaluated the effects of BAT in HF patients. A third reviewer (QX and YHD) was approached in case of disagreements between the first two reviewers. After removing irrelevant articles, those that met the diagnostic criteria for HF were selected. Articles were excluded if they used BAT as an adjunctive treatment. Reviews, case reports, studies on mechanisms, trials with inappropriate participants, and studies with an irrelevant intervention or ineligible outcome measures were also removed.

2.3. Participants

Inclusion criteria: (1) resting heart rate between 60 and 100 beats/minute, (2) 6-min walk test (6MWT) between 150 and 450 m, (3) left ventricular ejection fraction < 40 %, (4) New York Heart Association (NYHA) class-III HF, (5) ready to undergo surgical treatment, (6) provides informed consent, (7) Period of observation: 3–6 months.

Exclusion criteria: (1) life expectancy of < 1 year, (2) NYHA class-IV HF, (3) current angina or heart attack, (4) involved in parallel participation in other clinical trials in the short term.

2.4. Intervention and comparison

Four trials, including the experimental and control cohorts, were added to this review. The intervention in the control cohort was GDMT, while the experimental cohort was supplemented with BAT.

2.5. Outcomes

The primary outcome variables were the Left Ventricular Ejection Fraction (LVEF), the Minnesota Living with Heart Failure Questionnaire (MLHFQ), The 6-min walking test (6MWT), and left ventricular end-diastolic volume (LVEDV). The secondary outcome measures were estimated glomerular filtration rate (eGFR), diastolic blood pressure (DBP), and systolic blood pressure (SBP).

2.6. Data extraction

The researchers (SYY and YC) independently collected the data from the selected papers using a standardized data table. The extracted information included the year of publication, sample size, first author, intervention, treatment course, and outcome.

2.7. Quality assessment

The Cochrane Evaluation Manual tool assessed the quality and risk of bias. The tool includes randomization questions, departures from intended interventions, outcome completeness, selection of reported outcomes, and other biases. Each item was rated for a low, high, or unclear risk of bias.

2.8. Statistical measurements

Cochrane Collaboration Review Manager 5.3 software was utilized for all statistical assessments. Binary variable data were measured by odds ratio (OR), and continuous normally distributed data were expressed as mean difference (MD). All effect sizes were pooled with 95 % confidence intervals (CI). The features of the research interventions were documented and compared with the planned groups for each synthesis. In cases where data was unavailable, efforts were made to contact the authors for clarification. The

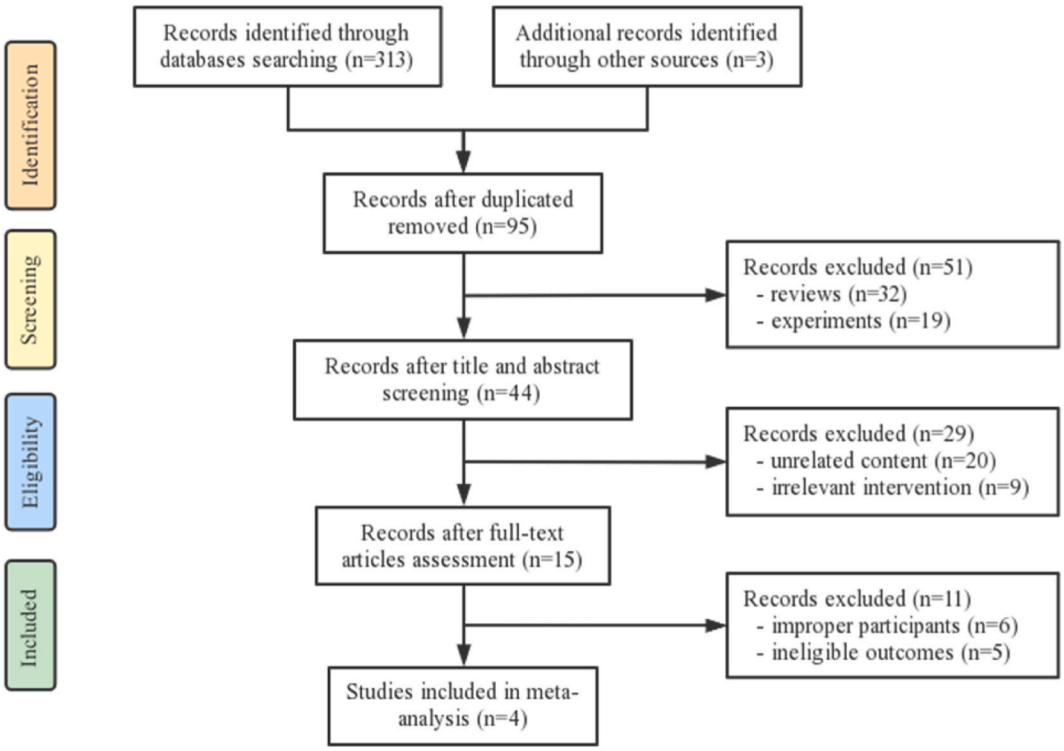

Fig. 1. Flowchart depicting articles selection for Meta-analysis.

utilization of Microsoft software was employed to present the outcomes of individual research investigations as well as the amalgamation of several studies. To quantify the heterogeneity between studies, I^2 statistic was carried out, where low heterogeneity means $I^2 < 50$ % and substantial heterogeneity means $I^2 > 50$ %. A fixed-effects model was used for low heterogeneity data and a random-effects model for high. A sensitivity analysis was performed to evaluate the robustness of the synthesis findings, while a subgroup analysis was conducted in cases where heterogeneity could not be identified (Supplementary Materials).

3. Results

3.1. Studies identification

A total of 316 relevant articles were identified. Of these, 221 were duplicates, and 51 were excluded after screening the abstracts. 40 clinical trials were excluded after revision for various reasons, like unrelated content, irrelevant intervention, improper participants, and ineligible outcomes (Fig. 1). The final meta-analysis included a total of 4 research studies, encompassing a sample size of 200 experimental subjects and 205 control subjects.

3.2. Characteristics of the included investigations

Table 1 summarizes the characteristics of the included articles. All the articles were in the English language. The study encompassed a total of 405 patients, with sample sizes varying from 18 to 245 [9–12].

3.3. Quality assessment

Fig. 2 summarizes the risk of bias based on the Cochrane criteria. All included trials were RCTs, of which one described an adequate randomization process. Concealment of allocation was not reported in 3 studies. All 4 studies had a double-blind design, and the low risk of bias was due to a selective reporting bias because of missing results (Fig. 3).

4. Meta-analysis

4.1. Primary outcomes

4.1.1. Left ventricular ejection fraction

Two studies [10,11] compared LVEF in HFrEF patients. The fixed-effect model meta-analysis was carried out, which indicated that the LVEF was superior in the experimental cohort than the control cohort; however, no statistical difference was observed (OR: 2.97, 95 % CI: 0.53 to 5.41, $p = 0.02$, I^2: 0 %; Fig. 4).

4.1.2. Minnesota Living with heart failure Questionnaire(MLHFQ)

Four studies [9–12] conducted an evaluation of the MLHFQ in patients with HFrEF. The study observed a significant level of heterogeneity among the participants. The sensitivity analysis suggested that the potential origin of this discrepancy could be attributed to Abraham's research, which focused on evaluating the deviation from the initial state to the final observed outcome, rather

Table 1
Basic characteristics of the included studies.

Study ID	Sample Size (E/C)	Gender(M/F)	Age	Intervention		Course	Outcome assessment
				Experimental Group	Control Group		
Abraham et al. (2015)	64/54	T:55/9 C:43/11	T:64.0 ± 11.0 C:66.0 ± 12.0	BAT + GDMT	GDMT	6 months	6MWT, MLHFQ
Dell'Oro et al. (2017)	7/17	T:6/1 C:13/4	T:66.5 ± 3.0 C:68.4 ± 2.9	BAT + GDMT	GDMT	6 months	6MWT, LVEF, LVEDV, MLHFQ, SBP, DBP, eGFR
Gronda et al. (2016)	9/9	T:8/1 C:8/1	T:66.1 ± 8.2 C:68.4 ± 10.0	BAT + GDMT	GDMT	3 months	6MWT, LVEF, LVEDV, MLHFQ, SBP, DBP, eGFR
Zile et al. (2020)	120/125	T:102/18 C:103/22	T:62.0 ± 11.0 C:63.0 ± 10.0	BAT + GDMT	GDMT	6 months	6MWT, MLHFQ, SBP, DBP

GDMT: guideline-directed medical therapy.

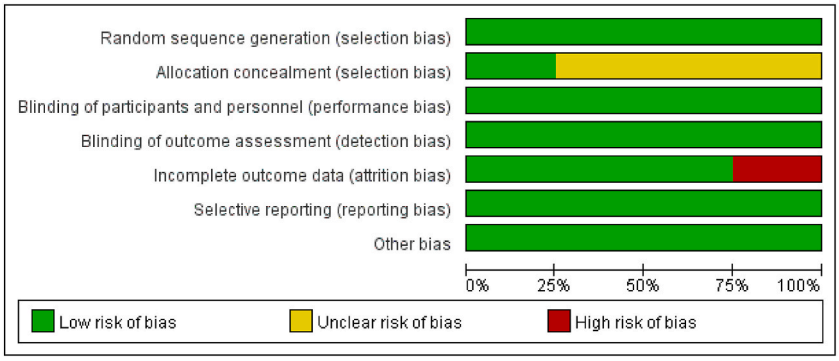

Fig. 2. Quality assessment for methodologies.

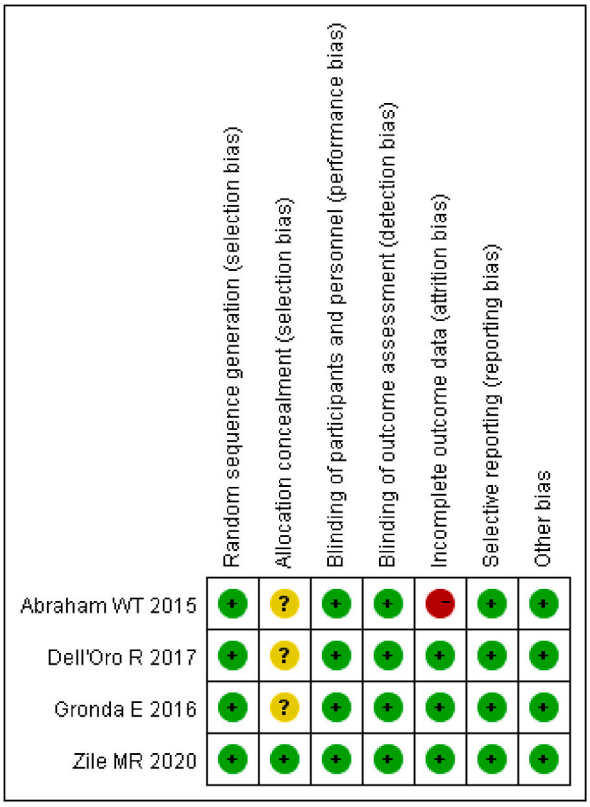

Fig. 3. Risk of bias.

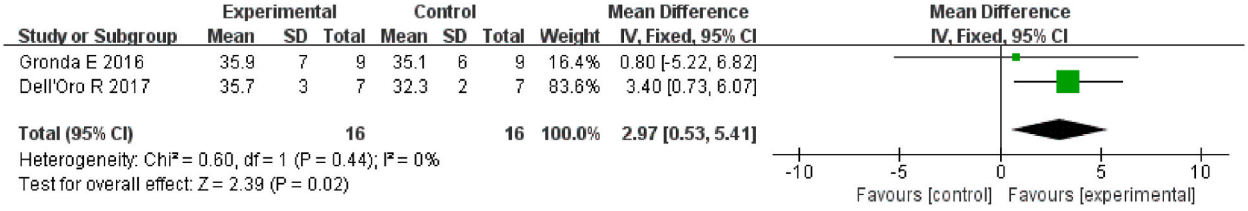

Fig. 4. Forest plot of Left ventricular ejection fraction (LVEF).

than directly examining the immediate findings as conducted by other studies. This observation was further supported by the absence of heterogeneity in the remaining three trials following subgroup analysis, wherein no statistically significant heterogeneity was found in the other three investigations. Based on the random-effects model, it was shown that the experimental cohort had a greater improvement in MLHFQ compared to the control cohort (MD: −14.81, 95 % CI: −19.57 to −10.06, $p < 0.00001$, I^2: 97 %; Fig. 5).

4.1.3. Six-minute walk test

The 6MWT was evaluated in individuals with HFrEF across many studies [9–12]. Similar to the MLHFQ mentioned before, we examined the factors contributing to variability and conducted a subgroup analysis. The level of heterogeneity seen was decreased as anticipated. In our analysis, a random-effects model was employed to examine the entire dataset. The results revealed a significant difference in the duration of the 6MWT between the experimental and control cohorts, with the former exhibiting a longer duration (MD: 68.18, 95 % CI: 51.62 to 84.74, $p < 0.00001$, I^2: 94 %; Fig. 6).

4.1.4. Left ventricular end-diastolic volume

Two studies [10,11] evaluated LVEDV in HFrEF patients. Using a fixed-effect model, effect sizes were pooled for meta-analysis, which revealed that compared with the control cohort, LVEDV was reduced in people in the experimental group (MD: −15.79, 95 % CI: −32.96 to 1.37, $p = 0.07$, I^2: 0 %; Fig. 7).

4.2. Secondary outcomes

4.2.1. Systolic blood pressure

The SBP was reported by 3 investigations [10–12]. After fixed-effect modeling, the results indicated that alleviated SBP in the experimental cohort than in the control cohort but not statistically different (MD: −1.92, 95 % CI: −4.63 to 0.79, $p = 0.16$, I^2: 0 %; Fig. 8).

4.2.2. Diastolic blood pressure

Three studies [10–12] indicated DBP in HFrEF patients. For the meta-analysis, the effect size was combined using a fixed-effect model, and it suggested alleviated DBP in the experimental cohort, which differed significantly from the control cohort (MD: −2.43, 95 % CI: −4.18 to −0.68, $p = 0.007$, I^2: 0 %; Fig. 9).

4.2.3. Estimated glomerular filtration rate

Three studies [10–12] reported eGFR, and via fixed-effect model, it was indicated that eGFR was enhanced in the experimental cohort than in the control cohort; however, the statistical difference was insignificant (MD: 1.42, 95 % CI: −8.55 to 11.39, $p = 0.78$, I^2: 0 %; Fig. 10).

4.2.4. Adverse events

During the trial, it was observed that two patients encountered a surgical hematoma [9]. Additionally, four patients experienced procedure-related emergency situation, such as acute decompensated heart failure and stroke [12]. The remaining investigations revealed no adverse events.

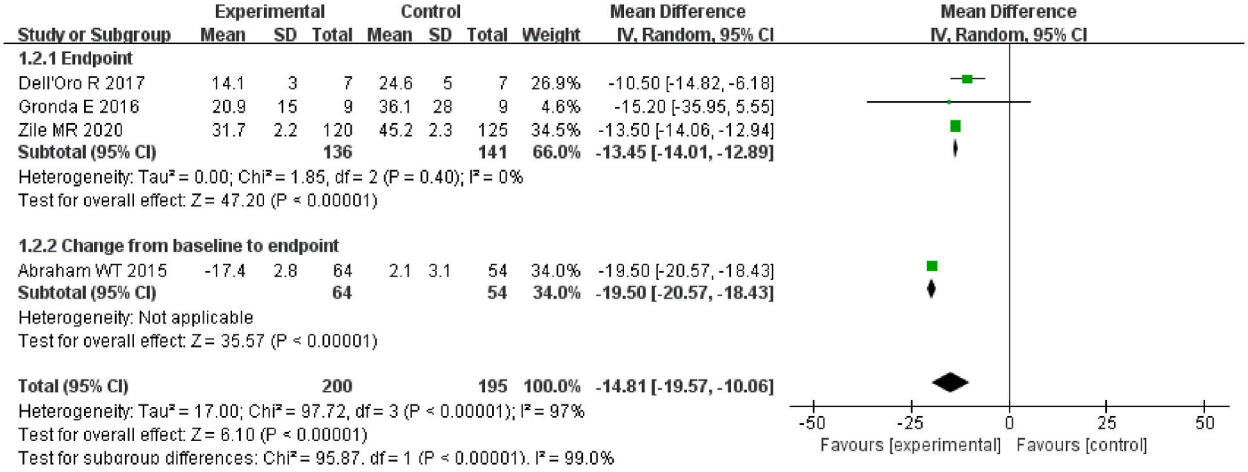

Fig. 5. Forest plot of Minnesota living with heart failure questionnaire (MLHFQ).

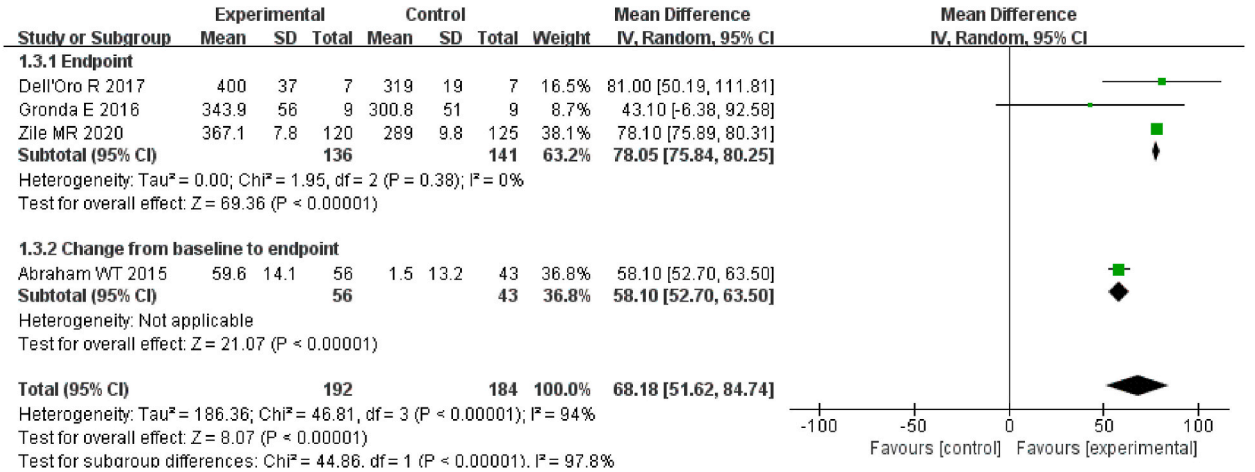

Fig. 6. Forest plot of The 6 Minute Walk Test (6WMT).

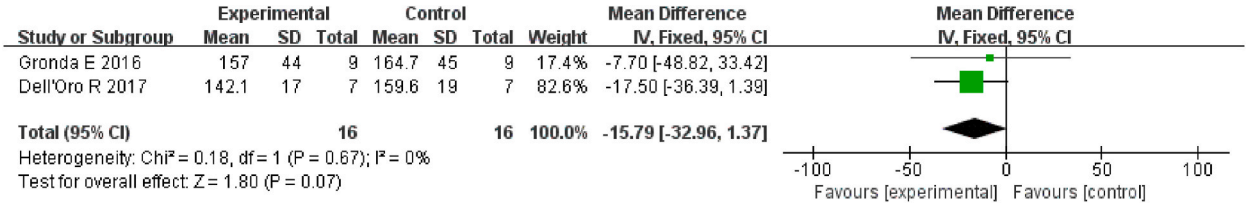

Fig. 7. Forest plot of Left ventricular end-diastolic volume (LVEDV).

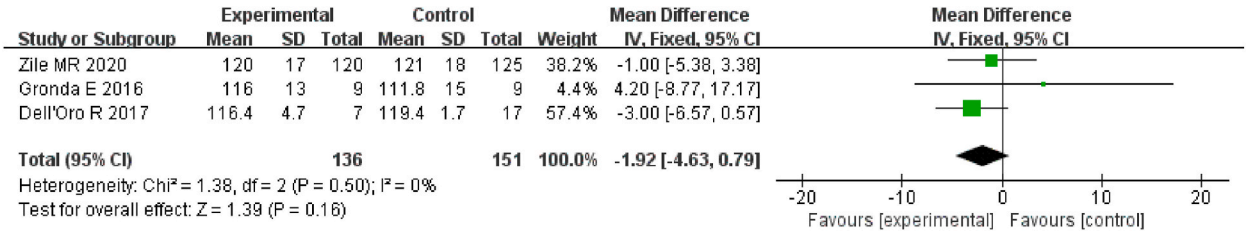

Fig. 8. Forest plot of SBP.

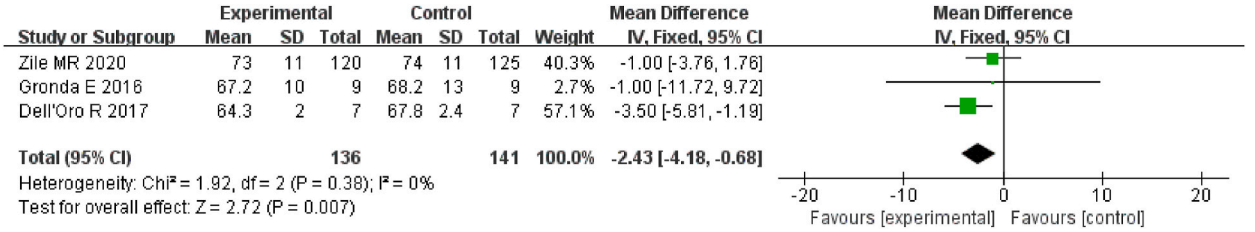

Fig. 9. Forest plot of DBP.

5. Discussion

With the increasing incidence of HF, various non-drug treatments have gradually gained clinical attention. The literature essentially associates the autonomic nervous system with the onset and development of HF; its imbalance exacerbates myocardial remodeling and peripheral vasoconstriction, increasing hospitalization risk. Over the past decade, neuromodulation via BAT has emerged as an innovative therapeutic strategy for HF [13]. Stimulation of carotid baroreceptors decreased central-mediated sympathetic outflow and increased parasympathetic activity, enhancing arterial and venous compliance and reducing peripheral

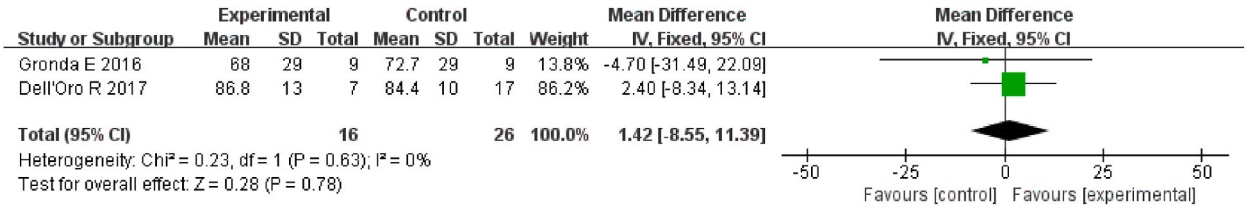

Fig. 10. Forest plot of eGFR.

resistance [14]. Baroreflex amplification has been used to reduce treatment-resistant hypertension, and subsequent data suggest that the benefits of this intervention may extend to HF [15,16]. Baroreflex stimulation in dogs with HF has been shown to reverse ventricular remodeling and improve survival [17,18]. It has also revealed positive results in humans [19]. Chronic carotid baroreceptor stimulation consistently reduces sympathetic activation in HFrEF patients, favoring clinical implementation and having strong prognostic value [20]. Improved oxygen uptake indicates better cardiopulmonary function and exercise capacity [21].

This meta-analysis presents empirical support for the utilization of BAT in patients with HFrEF. Four studies [9–12] were selected, which included a total of 200 patients in the experimental cohort and 205 subjects in the control cohort. The objective of these studies was to assess the effectiveness and safety of BAT. The parameter stability of BAT is derived from muscle sympathetic nerve activity measurements. 6MWT, LVEF, LVEDV, MLHFQ, SBP, DBP, and eGFR were compared between the two cohorts. Finally, it was found that BAT could increase 6MWT, reduce LVEDV, and ameliorate MLHFQ, indicating improved cardiac function. Several studies even showed a reduction in DBP in the experimental group and a reduced hospitalization burden in HF patients [9]. Meanwhile, the decline in readmission rates signaled a change in the clinical status of HF and strongly predicted the endpoint [10]. However, BAT did not appear to alter arterial stiffness in the cohort, illustrating no typical alterations in the vascular status of severe HF patients in the short term [11].

Interestingly, some studies reported a statistically non-significant decrease in SBP, indicating that baroreceptor-dependent vasodilation was accompanied by increased output to counteract the decrease in SBP. There was no significant LVEF, possibly because cardiac output did not increase as quickly as LVEDV decreased. Fluid retention is the most common symptom in HF patients, causing a load on renal function; this meta-analysis indicated that the presence or absence of BAT had a minimal relationship with eGFR; however, the above conclusion did not have a statistically substantial difference significant, therefore, caution should be taken in extrapolating.

Since advanced HF patients consider multiple implantation devices, this issue was also investigated. A separately published analysis of 12 patients showed that patients with implantable cardioverter defibrillators were also able to adapt to pressure-reflex activation therapy, and no interaction between the devices was found, suggesting a direction for future research [22].

Recently, BAT has become an available technique for restoring sympathetic nerve function in severecongestive HF. This investigation has laid the foundation for the clinical use of BAT, providing new insights into treating patients with HFrEF. However, the result should be further validated due to possible confounding factors in the existing literature.

6. Limitations

1) The included studies' sample size was limited, potentially impacting the clinical heterogeneity. 2) Most studies did not report allocation concealment, which may influence the investigator's preference for the outcome. 3) Only HFrEF was focused, which may have reduced the meta-analysis's reliability. The question of whether and how BAT can be utilized for other types of HF ought to be elucidated in the future.

7. Conclusion

It is concluded that BAT is an effective technique for treating HFrEF. Further multi-center RCTs with large sample sizes are required to validate the conclusion of this investigation and provide a more theoretical basis for the HF treatment.

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Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding authors.

CRediT authorship contribution statement

Ruijie Shi: Writing – original draft. **Tong Sun:** Data curation. **Mengxi Wang:** Data curation. **Qian Xiang:** Investigation. **Yuhan Ding:** Investigation. **Siyuan Yin:** Investigation. **Yan Chen:** Investigation. **Le Shen:** Methodology. **Peng Yu:** Methodology. **Xiaohu Chen:** Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24177.

References

[1] S. Emmons-Bell, C. Johnson, G. Roth, Prevalence, incidence and survival of heart failure: a systematic review, Heart 108 (17) (2022 Aug 11) 1351–1360.
[2] P.A. Heidenreich, B. Bozkurt, D. Aguilar, L.A. Allen, J.J. Byun, M.M. Colvin, A. Deswal, M.H. Drazner, S.M. Dunlay, L.R. Evers, J.C. Fang, S.E. Fedson, G. C. Fonarow, S.S. Hayek, A.F. Hernandez, P. Khazanie, M.M. Kittleson, C.S. Lee, M.S. Link, C.A. Milano, L.C. Nnacheta, A.T. Sandhu, L.W. Stevenson, O. Vardeny, A.R. Vest, C.W. Yancy, AHA/ACC/HFSA guideline for the management of heart failure: executive summary: a report of the American college of cardiology/ American heart association joint committee on clinical practice guidelines, Circulation 145 (18) (2022) e876–e894, 2022 May 3.
[3] T.A. McDonagh, M. Metra, M. Adamo, R.S. Gardner, A. Baumbach, M. Böhm, H. Burri, J. Butler, J. Čelutkienė, O. Chioncel, J.G.F. Cleland, A.J.S. Coats, M. G. Crespo-Leiro, D. Farmakis, M. Gilard, S. Heymans, A.W. Hoes, T. Jaarsma, E.A. Jankowska, M. Lainscak, C.S.P. Lam, A.R. Lyon, J.J.V. McMurray, A. Mebazaa, R. Mindham, C. Muneretto, M.F. Piepoli, S. Price, G.M.C. Rosano, F. Ruschitzka, A.K. Skibelund, ESC Scientific Document Group, ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) with the special contribution of the Heart Failure Association (HFA) of the ESC, Rev. Esp. Cardiol. 75 (6) (2021) 523, 2022 Jun.
[4] F. Gentile, C. Passino, M. Emdin, A. Giannoni, Baroreflex activation therapy in heart failure: targeting the right patient, Eur. J. Heart Fail. 24 (9) (2022 Sep) 1674–1676.
[5] J.S. Floras, P. Ponikowski, The sympathetic/parasympathetic imbalance in heart failure with reduced ejection fraction, Eur. Heart J. 36 (30) (2015 Aug 7) 1974, 82b.
[6] F.A. Weaver, W.T. Abraham, W.C. Little, C. Butter, A. Ducharme, M. Halbach, D. Klug, E.G. Lovett, N. Madershahian, J. Müller-Ehmsen, J.E. Schafer, M. Senni, V. Swarup, R. Wachter, M.R. Zile, Surgical experience and long-term results of baroreflex activation therapy for heart failure with reduced ejection fraction, Semin. Thorac. Cardiovasc. Surg. 28 (2) (2016 Summer) 320–328.
[7] M.R. Zile, W.T. Abraham, J. Lindenfeld, F.A. Weaver, F. Zannad, T. Graves, T. Rogers, E.G. Galle, First granted example of novel FDA trial design under Expedited Access Pathway for premarket approval: BeAT-HF, Am. Heart J. 204 (2018 Oct) 139–150.
[8] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, PRISMA Group, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (7) (2009 Jul 21) e1000097.
[9] W.T. Abraham, M.R. Zile, F.A. Weaver, C. Butter, A. Ducharme, M. Halbach, D. Klug, E.G. Lovett, J. Müller-Ehmsen, J.E. Schafer, M. Senni, V. Swarup, R. Wachter, W.C. Little, Baroreflex activation therapy for the treatment of heart failure with a reduced ejection fraction, JACC Heart Fail 3 (6) (2015 Jun) 487–496.
[10] R. Dell'Oro, E. Gronda, G. Seravalle, G. Costantino, L. Alberti, B. Baronio, T. Staine, E. Vanoli, G. Mancia, G. Grassi, Restoration of normal sympathetic neural function in heart failure following baroreflex activation therapy: final 43-month study report, J. Hypertens. 35 (12) (2017 Dec) 2532–2536.
[11] E. Gronda, G. Brambilla, G. Seravalle, A. Maloberti, M. Cairo, G. Costantino, E. Lovett, E. Vanoli, G. Mancia, G. Grassi, Effects of chronic carotid baroreceptor activation on arterial stiffness in severe heart failure, Clin. Res. Cardiol. 105 (10) (2016 Oct) 838–846.
[12] M.R. Zile, J. Lindenfeld, F.A. Weaver, F. Zannad, E. Galle, T. Rogers, W.T. Abraham, Baroreflex activation therapy in patients with heart failure with reduced ejection fraction, J. Am. Coll. Cardiol. 76 (1) (2020 Jul 7) 1–13.
[13] N. Babar, D. Giedrimiene, Updates on baroreflex activation therapy and vagus nerve stimulation for treatment of heart failure with reduced ejection fraction, Cardiol Res 13 (1) (2022 Feb) 11–17.
[14] M.R. Zile, W.T. Abraham, F.A. Weaver, C. Butter, A. Ducharme, M. Halbach, D. Klug, E.G. Lovett, J. Müller-Ehmsen, J.E. Schafer, M. Senni, V. Swarup, R. Wachter, W.C. Little, Baroreflex activation therapy for the treatment of heart failure with a reduced ejection fraction: safety and efficacy in patients with and without cardiac resynchronization therapy, Eur. J. Heart Fail. 17 (10) (2015 Oct) 1066–1074.
[15] M.E.A.M. van Kleef, C.M. Devireddy, J. van der Heyden, M.C. Bates, G.L. Bakris, G.W. Stone, B. Williams, W. Spiering, C.A.L.M.-F.I.M. Investigators, Treatment of resistant hypertension with endovascular baroreflex amplification: 3-year results from the CALM-FIM study, JACC Cardiovasc. Interv. 15 (3) (2022 Feb 14) 321–332.
[16] I.M.G. Freitas, L.B. de Almeida, N.P. Pereira, P.A.C. Mira, R.B. de Paula, D.G. Martinez, E. Toschi-Dias, M.C. Laterza, Baroreflex gain and vasomotor sympathetic modulation in resistant hypertension, Clin. Auton. Res. 27 (3) (2017 Jun) 175–184.
[17] I.H. Zucker, J.F. Hackley, K.G. Cornish, B.A. Hiser, N.R. Anderson, R. Kieval, E.D. Irwin, D.J. Serdar, J.D. Peuler, M.A. Rossing, Chronic baroreceptor activation enhances survival in dogs with pacing-induced heart failure, Hypertension 50 (5) (2007 Nov) 904–910.
[18] J. Wang, Q. Yu, M. Dai, Y. Zhang, Q. Cao, Q. Luo, T. Tan, Y. Zhou, L. Shu, M. Bao, Carotid baroreceptor stimulation improves cardiac performance and reverses ventricular remodelling in canines with pacing-induced heart failure, Life Sci. 222 (2019 Apr 1) 13–21.
[19] A.J.S. Coats, W.T. Abraham, M.R. Zile, J.A. Lindenfeld, F.A. Weaver, M. Fudim, J. Bauersachs, S. Duval, E. Galle, F. Zannad, Baroreflex activation therapy with the Barostim™ device in patients with heart failure with reduced ejection fraction: a patient level meta-analysis of randomized controlled trials, Eur. J. Heart Fail. 24 (9) (2022 Sep) 1665–1673.
[20] A. Giannoni, F. Gentile, F. Buoncristiani, C. Borrelli, P. Sciarrone, J. Spiesshoefer, F. Bramanti, G. Iudice, S. Javaheri, M. Emdin, C. Passino, Chemoreflex and baroreflex sensitivity hold a strong prognostic value in chronic heart failure, JACC Heart Fail 10 (9) (2022 Sep) 662–676.
[21] P.I. Nottebohm, D. Dumitrescu, S. Hamacher, C. Hohmann, N. Madershahian, S. Baldus, H. Reuter, M. Halbach, Cardiopulmonary function during exercise in heart failure with reduced ejection fraction following baroreflex activation therapy, Ther Adv Cardiovasc Dis 16 (2022 Jan-Dec) 17539447221131203.
[22] N. Madershahian, M. Scherner, J. Müller-Ehmsen, M. Halbach, T. Hickethier, R. Velden, Y.H. Choi, J. Wippermann, T. Wahlers, Baroreflex activation therapy in patients with pre-existing implantable cardioverter-defibrillator: compatible, complementary therapies, Europace 16 (6) (2014 Jun) 861–865.