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Systematic Review

Efficacy of Deep Brain Stimulation for Camptocormia in Parkinson's Disease: A Systematic Review and Meta-Analysis

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Abstract

Background: Camptocormia is one of the most common postural disorders of Parkinson's disease (PD) which has limited treatment options. In this review, we summarize the efficacy of deep brain stimulation (DBS) for camptocormia in PD. **Methods**: The PubMed (https://pubmed.ncbi.nlm.nih.gov/) and EMBASE databases (https://www.embase.com/) were searched for the terms "Parkinson Disease" and "camptocormia" in combination with "deep brain stimulation". We then explored the efficacy of DBS for camptocormia by statistical analysis of the bending angle, the Unified Parkinson's Disease Rating Scale III (UPDRS-III) and L-dopa equivalent daily dose (LEDD), and by evaluating the prognosis after DBS. **Results**: Twenty articles that reported results for 152 patients were included in this review. These comprised 136 patients from 16 studies who underwent subthalamic nucleus deep brain stimulation (STN-DBS), and 13 patients from 3 studies who underwent globus pallidus internus deep brain stimulation (GPi-DBS). One study used both STN-DBS (2 patients) and GPi-DBS (one patient). After 3–21 months of follow-up, the mean bending angle during the Off-period was significantly reduced compared to pre-DBS (31.5 ± 21.4 vs. 53.6 ± 22.7, respectively; $p < 0.0001$). For the STN-DBS trials, the mean post-operative bending angles during both Off- and On-periods were significantly reduced compared to pre-operative (32.1 ± 22.7 vs. 55.4 ± 24.1, $p = 0.0003$; and 33.1 ± 21.5 vs. 43.7 ± 20.6, $p = 0.0003$, respectively). For GPi-DBS, the mean bending angle post-DBS during the Off-period was considerably lower than pre-DBS (28.5 ± 10.7 vs. 42.9 ± 9.9, $p < 0.001$). The decrease in bending angle after DBS was negatively correlated with the duration of camptocormia ($R = -0.433$, $p = 0.013$), whereas positively associated with the pre-bending angle ($R = 0.352$, $p = 0.03$). **Conclusions**: DBS is an effective treatment for camptocormia in PD. Patients in the early stage of camptocormia with more significant bending angle may benefit more from DBS.

Keywords: camptocormia; Parkinson's disease; deep brain stimulation

1. Introduction

Camptocormia is a common postural deformity in Parkinson's disease (PD), with a prevalence estimated to range from 3% to 18% [1]. It is described as forward flexion of the thoracolumbar spine, which aggravates in the standing position and disappears in the supine position. In addition to PD, other potential etiologies for camptocormia include axial myopathy, joint degenerative diseases, and atypical PD such as multiple system atrophy and progressive supranuclear palsy. However, the prevalence of camptocormia in PD (22.5%) is much higher than in other diseases [2]. Camptocormia may aggravate rapidly with the progression of PD and will be accompanied by dyskinesias, falls, severe back pain, difficulty in eating, and even respiratory failure, all of which significantly impact the quality of life and increase motor disability and care burden.

Camptocormia can be classified into lower camptocormia (total camptocormia angle $\geq 30°$) and upper camptocormia (upper camptocormia angle $\geq 45°$). The total camptocormia (TCC) angle is defined as the angle between the line from the lateral malleolus to the L5 spinous process, and the line between the C7 spinous process and the L5 spinous process. The upper camptocormia (UCC) angle is defined as the angle between the line from the vertebral fulcrum to the C7 spinous process and the L5 spinous process [3,4].

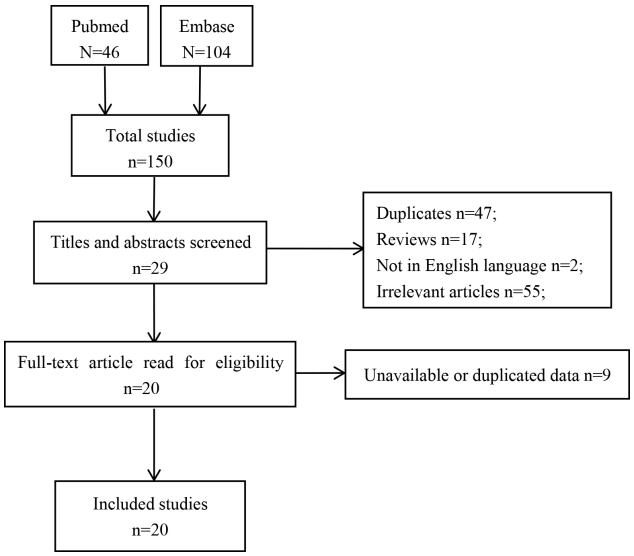

Fig. 1. Flowchart of study selection.

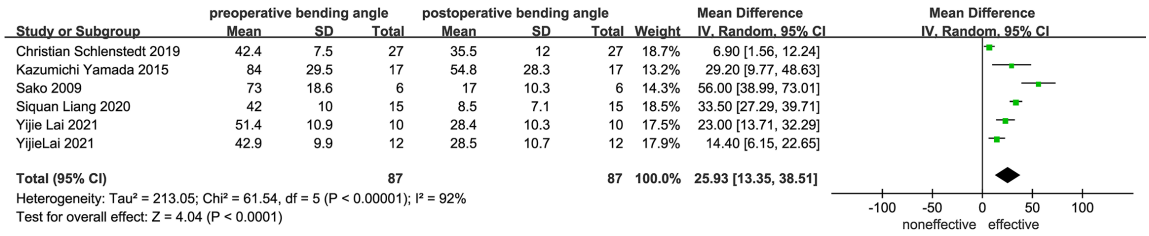

Fig. 2. Comparison bending angle between pre- and post-DBS (Off-period). DBS, deep brain stimulation.

The pathogenesis of camptocormia is unclear, with several potential contributing factors including dystonia, myopathy, proprioceptive disintegration, medication effects and soft tissue changes. Paraspinal dystonia is often observed in the early stage of camptocormia, followed gradually combined with focal myopathy and soft tissue changes [5].

Camptocormia usually appears in the advanced stage of PD, and has generally proved refractory to pharmacological treatment. Some studies have reported that dopaminergic drugs may even induce or aggravate camptocormia, especially high-dose and long-term use of levodopa and dopamine receptor agonists [6,7]. The effectiveness of other therapeutic options such as lidocaine injection, botulinum toxin injection and rehabilitation training remains controversial. Complications from spinal surgery are common [5]. In recent years, deep brain stimulation (DBS) has been used to treat camptocormia in PD. Given the inconsistent results reported so far, we conducted this meta-analysis to assess the efficacy of DBS for camptocormia in PD patients.

2. Materials and Methods

Selection of Studies for Analysis

We examined 46 articles from PubMed and 104 articles from EMBASE. The inclusion criteria were: (1) definitive diagnosis of PD and camptocormia, with the camptocormia related to PD; (2) Intervention with DBS; (3) English language study. The exclusion criteria were: (1) Review article; (2) Articles with missing or non-extractable data; (3) Duplicate articles or those with repeat clinical data. Twenty studies containing a total of 152 patients [3,8–26] met all of the criteria and were included in the analysis. Three studies used globus pallidus internus deep brain stimulation (GPi-DBS), 16 used subthalamic nucleus deep brain stimulation (STN-DBS), and one study used both (Fig. 1). And the CRD number of the systematic review on the PROSPERO is 353766.

3. Data Extraction

Information extracted from the selected papers included authors, year of publication, type of research, number of participants, age, gender, PD duration, camptocormia duration, bending angles (in both On and Off periods), the Unified Parkinson's Disease Rating Scale III (UPDRS-III) score (in both On and Off periods), mean follow-up time, and the L-dopa equivalent daily dose (LEDD) assessed both pre- and post-DBS (Tables 1,2, Ref. [3,8–26]).

3.1 Risk of Bias

The quality of articles was evaluated according to the following criteria: (I) Randomized controlled trial; (II) Prospective observational or case-controlled study; (III) Retrospective study; (IV) Case report or series (<10 patients) [27].

3.2 Statistical Analysis

Review Manager software (version 5.3, The Nordic Cochrane Centre, Copenhagen, Denmark) and SPSS Statistics (version 17.0, IBM SPSS Inc, Chicago, IL, USA) were used for statistical analysis. Mean differences and 95% confidence intervals for the variables are presented as forest plots, with the Chi-squared and I^2 tests used to quantitatively evaluate the heterogeneity between studies. The fixed-effects model was adopted when $I^2 \leq 50\%$, while the random-effects model was used when $I^2 > 50\%$. For a more appropriate statistical analysis, all STN-DBS and GPi-DBS studies containing less than 5 patients were incorporated into new groups named case reports. The difference in bending angle change between STN-DBS and GPi-DBS was studied by using the *t*-test. Pearson correlation analysis was employed to evaluate associations between the reduced bending angle of camptocormia after surgery and various clinical features including age, duration of PD and camptocormia, LEDD, pre-bending angle and UPDRS-III. A p value of <0.05 was considered statistically significant.

4. Results

Details of the 20 studies and 152 participants included in this meta-analysis are listed in Tables 1,2. The patients were comprised of 55 males, 45 females and 52 with unknown gender. STN-DBS was employed as the intervention in 16 studies (136 patients) and GPi-DBS (13 patients) in three studies. One study used both STN-DBS (2 patients) and GPi-DBS (one patient). Comparisons of the clinical data between pre- and post-DBS periods are shown in Figs. 2,3. After an average of 3–21 months follow-up post DBS, the mean bending angle assessed during the Off-period was markedly lower than during the pre-operative

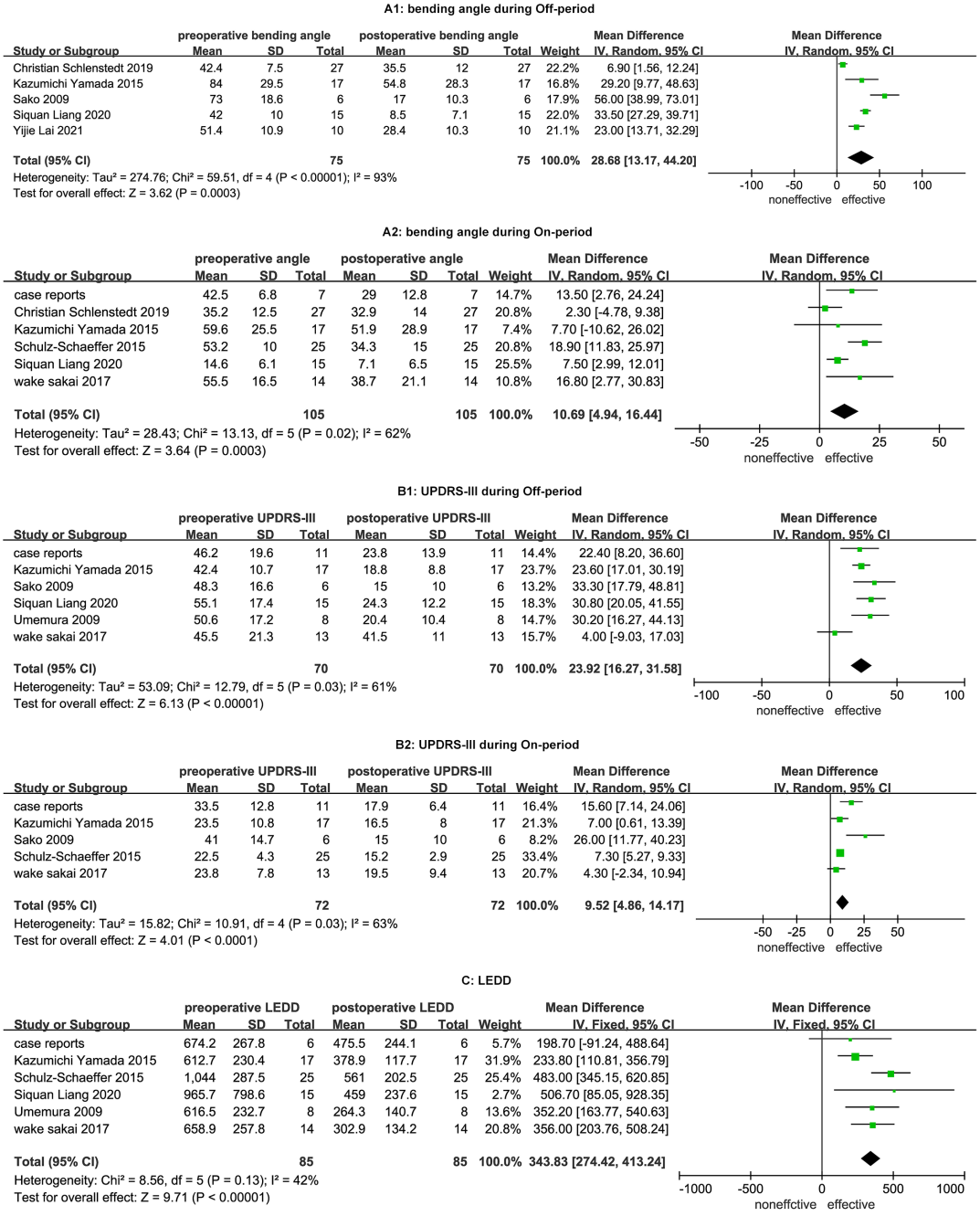

Fig. 3. Comparisons of clinical data between pre- and post-STN-DBS. A1: comparison bending angle between pre- and post-STN-DBS during Off-period; A2: comparison bending angle between pre- and post-STN-DBS during On-period; B1: comparison UPDRS-III between pre- and post-STN-DBS during Off-period; B2: comparison UPDRS-III between pre- and post-STN-DBS during On-period; C: comparison LEDD between pre- and post-STN-DBS. DBS, deep brain stimulation; STN, subthalamic nucleus; UPDRS-III, the Unified Parkinson's Disease Rating Scale III; LEDD, L-dopa equivalent daily dose.

Table 1. Clinical characteristics of the studies and participants included in this meta-analysis.

Authors	Years	Study Type	Method	Participants	Mean age (Years)	Gender (M/F)	Duration of PD (Years)	Duration of Camptocormia (Months)	Evidence Level	Follow-up (Months)
Lai *et al.* [3]	2021	Retrosp obs cohort	STN	10	N	N	N	N	III	6.0 ± 2.2
Lai *et al.* [8]	2021	Retrosp obs cohort	GPi	11	N	N	N	N	III	7.3 ± 3.3
Liang *et al.* [9]	2020	Prosp trail	STN	15	62.5 ± 8.1	7/8	10.5 ± 4.5	25.2 ± 10.8	II	6
Schlenstedt *et al.* [26]	2019	Retrosp obs cohort	STN	27	N	N	N	N	III	6–12
Sakai *et al.* [10]	2017	Retrosp obs cohort	STN	14	51.9 ± 9.7	8/6	13.1 ± 4.9	40.8 ± 22.8	III	6
Yamada *et al.* [11]	2016	Prosp trail	STN	17	66.4 ± 6.8	7/10	12.9 ± 6.0	48.2 ± 34.6	II	≥3
Schulz-Schaeffer *et al.* [12]	2015	Retrosp obs cohort	STN	25	67.1 ± 4.8	21/4	15.4 ± 4 .0	62.4 ± N	III	6–12
Umemura *et al.* [13]	2010	Case series	STN	8	65.1 ± 6.3	2/6	15.5 ± 4.8	N	IV	12
Sako *et al.* [14]	2009	Case series	STN	6	51.2 ± 5.9	2/4	9.0 ± 2.3	N	IV	N
Soares *et al.* [15]	2019	Case series	STN	2	65.5 ± 6.4	1/1	10.5 ± 2.1	5.3 ± 5.3	IV	8–12
Roediger *et al.* [16]	2019	Retrosp obs cohort	STN	3	N	N	N	N	III	15.4 ± 11.0
Pandey *et al.* [17]	2016	Case report	STN	1	58	1/0	7	60	IV	3
Ekmekci *et al.* [18]	2016	Case report	STN	1	51	0/1	10	N	IV	6
Lyons *et al.* [19]	2012	Case report	STN	1	63	0/1	19	228	IV	3
Asahi *et al.* [20]	2011	Case series	STN	4	62.8 ± 4.2	2/2	11.5 ± 1.7	62.4 ± 27.8	IV	25.8 ± 9.8
Capelle *et al.* [21]	2011	Case series	STN	2	69.0 ± 5.7	2/0	13.5 ± 2.1	N	IV	21
Yamada *et al.* [22]	2006	Case report	STN	1	71	0/1	11	N	IV	3
Hellmann *et al.* [23]	2006	Case report	STN	1	53	N	25	228	IV	10
Capelle *et al.* [21]	2011	Case report	GPi	1	64	1/0	10	N	IV	21
Thani *et al.* [24]	2011	Case report	GPi	1	57	0/1	13	24	IV	14
Micheli *et al.* [25]	2005	Case report	GPi	1	62	1/0	9	2	IV	3

Obs, observational; Prosp, prospective; Retrosp, retrospective; PD, Parkinson's disease; STN, subthalamic nucleus; GPi, globus pallidus internus; F, female; M, male; N, not available.

Table 2. Clinical data of participants assessed pre- and post-DBS.

Authors	Method	Bending angle (Off)		Bending angle (On)		UPDRS-III (Off)		UPDRS-III (On)		LEDD	
		Pre-DBS	Post-DBS	Pre-DBS	Post-DBS	Pre-DBS	Post-DBS	Pre-DBS	Post-DBS	Pre-DBS	Post-DBS
Yamada *et al.* [11]	STN	84.0 ± 29.5	54.8 ± 28.3	59.6 ± 25.5	51.9 ± 28.9	42.4 ± 10.7	18.8 ± 8.8	23.5 ± 10.8	16.5 ± 8.0	612.7 ± 230.4	378.9 ± 117.7
Sakai *et al.* [10]	STN	N	N	55.5 ± 16.5	38.7 ± 21.1	45.5 ± 21.3	41.5 ± 11.0	23.8 ± 7.8	19.5 ± 9.4	658.9 ± 257.8	302.9 ± 134.2
Schlenstedt *et al.* [26]	STN	42.2 ± 7.5	35.5 ± 12.0	35.2 ± 12.5	32.9 ± 14	N	N	N	N	N	N
Liang *et al.* [9]	STN	42.0 ± 10.0	8.5 ± 7.1	14.6 ± 6.1	7.1 ± 6.5	55.1 ± 17.4	24.3 ± 12.2	N	N	965.7 ± 798.6	459.0 ± 237.6
Lai *et al.* [3]	STN	51.4 ± 10.9	28.4 ± 10.3	N	N	N	N	N	N	N	N
Lai *et al.* [8]	GPi	42.9 ± 9.9	28.5 ± 10.7	N	N	N	N	62.9 ± 19.5	N	N	N
Schulz-Schaeffer *et al.* [12]	STN	N	N	53.2 ± 10.0	34.3 ± 15.0	N	N	22.5 ± 4.3	15.2 ± 2.9	1044.0 ± 287.5	561.0 ± 202.5
Umemura *et al.* [13]	STN	N	N	N	N	50.6 ± 17.2	20.4 ± 10.4	28.6 ± 11.6	N	616.5 ± 232.7	264.3 ± 140.7
Sako *et al.* [14]	STN	73 ± 18.6	17.0 ± 10.3	N	N	48.3 ± 16.6	15.0 ± 10.0	41.0 ± 14.7	15.0 ± 10.0	N	N
Case reports. [15–23]	STN	N	N	42.5 ± 6.8	29.0 ± 12.8	46.2 ± 19.6	23.8 ± 13.9	33.5 ± 12.8	17.9 ± 6.4	674.2 ± 267.8	475.5 ± 244.1
Case reports. [21,24,25]	GPi	N	N	N	N	41.3 ± 14.4	25.0 ± 11.5	N	N	708.3 ± 518.6	675.0 ± 330.7

DBS, deep brain stimulation; STN, subthalamic nucleus; GPi, globus pallidus internus; LEDD, L-dopa equivalent daily dose; UPDRS-III, the Unified Parkinson's Disease Rating Scale III; N, not available.

Table 3. Correlation analysis between clinical data and decreased angle of camptocormia after DBS.

	Decreased angle after DBS in On-period		Decreased angle after DBS in Off-period	
	Pearson Correlation	*p*-value	Pearson Correlation	*p*-value
Age	–0.241	0.107	–0.275	0.095
Duration of PD	0.128	0.398	–0.269	0.102
Duration of CC	–0.104	0.493	–0.433*	0.013*
LEDD	–0.062	0.748	–0.404	0.136
Pre-bending angle (On)	0.157	0.298	–0.241	0.184
Pre-bending angle (Off)	0.036	0.845	0.352*	0.030*
Pre-UPDRS-III (On)	–0.023	0.939	–0.070	0.895
Pre-UPDRS-III (Off)	0.036	0.852	0.081	0.728

DBS, deep brain stimulation; PD, Parkinson's disease; CC, Camptocormia; LEDD, L-dopa equivalent daily dose.

period (31.5 ± 21.4 vs. 53.6 ± 22.7, respectively; $p < 0.0001$, Fig. 2). A similar improvement in the mean bending angle was observed between STN-DBS and GPi-DBS (23.3 ± 33.1 vs. 14.4 ± 14.6, respectively; $t = 0.91$, $p = 0.36$).

Subgroup analysis was performed to explore the effectiveness of STN and GPi-DBS. For the STN-DBS trials, the mean post-operative bending angles during both the Off- and On-periods were significantly reduced compared to the pre-operative period (32.1 ± 22.7 vs. 55.4 ± 24.1, $p = 0.0003$; and 33.1 ± 21.5 vs. 43.7 ± 20.6, $p = 0.0003$, respectively; Fig. 3A1,A2). The average post-operative UPDRS-III scores evaluated during the Off- and On-periods (24.9 ± 13.6 vs. 47.2 ± 17.3, $p < 0.00001$; and 16.7 ± 6.9 vs. 26.2 ± 10.7, $p < 0.0001$, respectively, Fig. 3B1,B2), as well as the mean LEDD (430.1 ± 207.3 mg/day vs. 814.2 ± 443.0 mg/day, $p < 0.00001$, respectively, Fig. 3C), were also significantly lower than during the pre-operative period. For GPi-DBS, the average bending angle post-DBS during the Off-period showed more improvement than pre-DBS (28.5 ± 10.7 vs. 42.9 ± 9.9, respectively, $p < 0.001$). However, there was few GPi-DBS study reported the changes of clinical variables during the On-period after surgery.

The correlation analysis between clinical data and decreased angle of camptocormia after DBS were listed in Table 3. Pearson correlation analysis showed that the decease in bending angle after DBS was negatively correlated with the duration of camptocormia (R = –0.433, $p = 0.013$, Table 3), whereas positively associated with the pre-bending angle (R = 0.352, $p = 0.03$, Table 3).

5. Discussion

Camptocormia is a common postural disorder that generally occurs during the advanced stage of PD. DBS is an effective treatment that can alleviate many motor and non-motor symptoms of PD patients in clinical practice. This meta-analysis found that the average post-operative UPDRS-III scores and mean LEDD were lower than during the pre-operative period, thus supporting the efficacy of DBS for the treatment of motor symptoms.

The mean post-operative bending angles following both STN-DBS and GPi-DBS were also found to be significantly lower than in the pre-operative period, indicating that DBS can markedly improve camptocormia in PD patients. The underlying pathogenesis of camptocormia is still unclear, although the central pathophysiological mechanism is thought to play an important role in the occurrence and progression of this condition [28,29]. DBS may send high-frequency stimulation to reduce the firing frequency on GPi/STN, thereby inducing disinhibition of motor thalamic nuclei and ultimately exciting the motor cortex [30]. Therefore, we speculate the improvement of camptocormia following DBS occurs mainly through above mentioned central pathophysiological mechanism that alleviates dysregulation of the basal ganglia and dystonia [29].

We found that the decreased bending angle after DBS was negatively correlated with the duration of camptocormia, whereas positively associated with the pre-bending angle. This concurs with previous studies that found camptocormia duration of $\leq$1.5 or 2 years was associated with a greater decrease in the bending angle after DBS, whereas camptocormia of >40 months was unlikely to show improvement [12,27]. Together, these results support the theory that patients with longer duration of camptocormia experience less benefit from DBS. Peripheral mechanisms such as hyperactivity, fatty infiltration and edema of the paraspinal muscles may play more important roles in the later stage of camptocormia in PD [28]. However, DBS alleviates camptocormia mainly through central mechanisms. This may explain why patients with longer duration of camptocormia benefit less from DBS.

In this meta-analysis, STN-DBS was observed to show a similar decrease in the mean bending angle as GPi-DBS. Previous studies have also reported similar improvement of motor symptoms in PD patients [31,32]. However, GPi and STN each have advantages and disadvantages. For example, STN-DBS may be associated with a greater reduction of dopaminergic medication and alleviation of non-motor symptoms than GPi-DBS, but also with a higher risk of cognitive deterioration over time. On the other hand, patients with more severe dyskinesia or gait disorders may

benefit more from GPi-DBS [31,32]. Some authors have also suggested superiority of GPi-DBS for PD [33]. Therefore, the choice of whether to use GPi or STN for PD patients with camptocormia may depend on other motor and non-motor symptoms, such as tremor, dyskinesia, gait, cognition and mood.

This meta-analysis has several limitations. Firstly, the sample size was relatively small. Secondly, only English language studies were included, which might give rise to some bias. Thirdly, the included studies may have heterogeneity in camptocormia, PD characteristics and follow-up time.

6. Conclusions

DBS can improve camptocormia in PD patients. Patients in the early stage of camptocormia and with a greater bending angle may benefit more from DBS.

Abbreviations

PD, Parkinson's disease; DBS, deep brain stimulation; LEDD, L-dopa equivalent daily dose; STN-DBS, subthalamic nucleus deep brain stimulation; GPi-DBS, globus pallidus internus deep brain stimulation; TCC, total camptocormia; UCC, upper camptocormia.

Author Contributions

FW and XG participated in design, literature selection, data extraction, statistical analysis, and drafting the manuscript. LH and HZ performed study selection and statistical analysis. All authors also participated in analyzing results, revising the manuscript, and approving the final version of this manuscript.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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