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Association between chronic cerebrospinal venous insufficiency and multiple sclerosis: a systematic review and meta-analysis

Jun Yang ,[1] Na Zhang,[2] Cong Ding,[1] Xiuying He,[1] Meihua Li,[1] Wei Meng,[1] Taohui Ouyang[1]

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Department of Neurosurgery

JY, NZ and TO contributed equally.

JY and NZ are joint first authors.

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[1]Department of Neurosurgery, First Affiliated Hospital of Nanchang University, Nanchang, Jiangxi, China
[2]Department of Neurology, First Affiliated Hospital of Nanchang University, Nanchang, Jiangxi, China

Correspondence to
Dr Taohui Ouyang;
husttjouyang110@163.com

ABSTRACT

Objectives Numerous studies have indicated that chronic cerebrospinal venous insufficiency is a potential factor in causing multiple sclerosis in recent years, but this conclusion remains unconfirmed. This meta-analysis examined the correlation between multiple sclerosis and chronic cerebrospinal venous insufficiency.

Methods We searched Embase and Medline (Ovid) for publications published from 1 January 2006 to 1 May 2022. The meta-analysis was performed following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Results Eligible studies (n=20) included 3069 participants from seven countries. Pooled analysis indicated that chronic cerebrospinal venous insufficiency was more frequent in patients with multiple sclerosis than in healthy controls (OR 3.36; 95% CI 1.92 to 5.85; p<0.001) with remarkable heterogeneity among studies (I^2=79%). Results were more strongly correlated in subsequent sensitivity analyses, but heterogeneity was also more substantial. We removed studies that initially proposed a chronic cerebrospinal venous insufficiency team as well as studies by authors involved in or advocating endovascular therapies.

Conclusions Chronic cerebrospinal venous insufficiency is significantly associated with multiple sclerosis and it is more prevalent in patients with multiple sclerosis than in healthy individuals, but considerable heterogeneity of results is still observed.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A comprehensive analysis of the correlation between chronic cerebrospinal venous insufficiency and multiple sclerosis was performed.
⇒ The reasons for the close association between chronic cerebrospinal venous insufficiency and multiple sclerosis by means of sensitivity analysis and subgroup analysis were explored.
⇒ Further complements previous studies of this type to provide structured guidance for subsequent clinical trials.

INTRODUCTION

Multiple sclerosis (MS) is an inflammatory condition of the central nervous system of unknown cause, and most findings suggest that the reason is autoimmune pathology.[1] Chronic cerebrospinal venous insufficiency (CCSVI) is a syndrome characterised by multiple stenosis or obstruction of intracranial and extracranial veins, which results in inadequate cerebral venous drainage.[2] In 2008, Zamboni *et al* suggested that CCSVI could potentially cause MS.[3] This hypothesis assumed that multiple stenoses or obstructions of the veins, which in turn affect the extracranial outflow channels of the cerebral venous system (internal jugular and azygous veins), eventually lead to an increase in intracranial pressure, followed by blood–brain barrier rupture, local iron deposition and triggering of the inflammatory chain in MS.[4–7] This abnormal venous drainage can be diagnosed by Doppler ultrasound, MRI, cerebral perfusion studies and catheter venography. However, the so-called Zamboni criterion is the most widely used detection mode, and the operation is non-invasive. Zamboni *et al* defined five ultrasound criteria for diagnosing CCSVI by transcranial and extracranial echo colour Doppler in a study, which revealed that patients had CCSVI when two or more abnormal ultrasound parameters were observed.[4 5] These five ultrasound parameter criteria include (1) reflux in the internal jugular and/or vertebral veins in the supine and sitting positions; (2) reflux in the deep cerebral veins; (3) high-resolution B-mode evidence of internal jugular vein stenoses; (4) flow is not Doppler detectable in the internal jugular and/or vertebral veins; (5) reverted postural control of the main cerebral venous outflow route measured in internal jugular veins.

Since then, most investigators have used this criterion to diagnose patients with CCSVI, but

the evaluation results of the correlation between CCSVI and MS were inconsistent across studies. Coupled with the fact that despite the availability of neuroimaging techniques such as magnetic resonance venogram[8] or selective venography[9] to assess abnormal central system venous drainage, the pathogenic role of CCSVI in MS remains unproven. In addition, the possibility of CCSVI therapy has been a topic of conversation, including intravenous percutaneous transluminal angioplasty (termed 'liberation treatment') proposed by Zamboni *et al*.[10] This treatment has received widespread attention from patients with MS and scientific institutions worldwide.[11 12] Still, there are articles reporting its potential adverse consequences.[13] Although the follow-up clinical trials showed that venous angioplasty was relatively safe, it did not play an ideal therapeutic effect for patients with MS.[14–17] The lack of sufficient proof that CCSVI is connected to MS has called into question the idea of intravenous percutaneous transluminal angioplasty, especially given the various research results and associated negative side effects.

To evaluate whether CCSVI was connected with MS and whether its frequency varied between patients with MS and healthy controls, this study did a thorough meta-analysis by pooling studies on the connection of CCSVI with MS. Furthermore, sensitivity analyses were used to investigate potential explanations for heterogeneity.

MATERIALS AND METHODS

Literature search

This meta-analysis was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines.[18] The specific PROSPERO protocol process is placed in the online supplemental file 2. Two authors independently searched the Medline versus Embase databases using the Ovid portal, with search dates adjusted from 1 January 2006 to 1 May 2022. Disagreements between the two authors' searches were resolved by a third-party reviewer. The complete search strategy for this study can be found in the online supplemental appendix 1. Search terms included: "Multiple Sclerosis" and "Ultrasound". The search findings were restricted to English-language articles and human studies. Following that, we critically reviewed all publications that fit these parameters and conducted manual searches of their references and citations of relevant reviews to search for research outside the database. If data were missing or erroneous, the researchers contacted the author again.

Eligibility

The inclusion criteria were as follows: (1) English language, (2) use of Doppler ultrasound to detect CCSVI, (3) neurological testing criteria used to identify CCSVI, (4) inclusion of at least one control group and (5) blinding of study.

Exclusion criteria were: (1) no raw data or incomplete data, (2) overlapping data (the study with the complete data chosen for the series of the same author and pattern), (3) literature of too low quality or literature not available in full text, and (4) less than 10 cases or control subjects.

After deleting duplicates, two researchers independently read the titles and abstracts of all identified papers, read the full-text versions, compared the results and resolved discrepancies by a consensus.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data extraction

Two authors extracted data and entered them into a standardised collection form, independently reviewed and confirmed by a third author. The extracted data were as follows: first author, country, publication date, sample size, demographic characteristics of participants (age vs percentage female) and study characteristics of patients (disease duration, percentage treated and Expanded Disability Status Scale). For some of the missing data, the researchers were also active in obtaining them from the article's authors via email.

Quality assessment

All 20 studies used the Newcastle–Ottawa Quality Assessment Scale to assess the risk of bias.[19] The scale is based on case–control studies and consists of three domains: selection, comparability and exposure, with quality ratings ranging from 0 to 9. Four study items are in the selection domain, each given a maximum of one star. Three study items are in the exposure category, each given at least one star. For comparability, only one item is included, and a maximum of two stars is presented. We consider this high-quality literature with low bias if at least seven stars are awarded.

Statistical analyses

STATA V.17.0 (STATA, College Station, Texas, USA) was used to conduct the meta-analysis by the researchers. One investigator entered the detailed data into the software. Another investigator reviewed the data for accuracy, generating forest plots and OR to determine whether there was a statistical relevance between CCSVI and MS. We used either a random-effects or fixed-effects model for the meta-analysis. A random-effects model was selected if the results showed significant heterogeneity (I^2>50%). An OR greater than 1.0 in the results indicated that CCSVI could be a potential risk factor for MS. P values of <0.05 were considered statistically significant. The origins of heterogeneity in the included studies were examined using Cochran's Q and I^2 statistics. I^2 values of 50%–90% represent substantial heterogeneity, while at least 75% represent considerable heterogeneity.[20] By the Cochrane Review Manager version 5.4.1. for publication bias was assessed using Egger's test (p<0.05 indicates significant publication bias). If the results indicated the presence of publication bias, the fill-and-trim methods were used to detect publication bias. To determine the

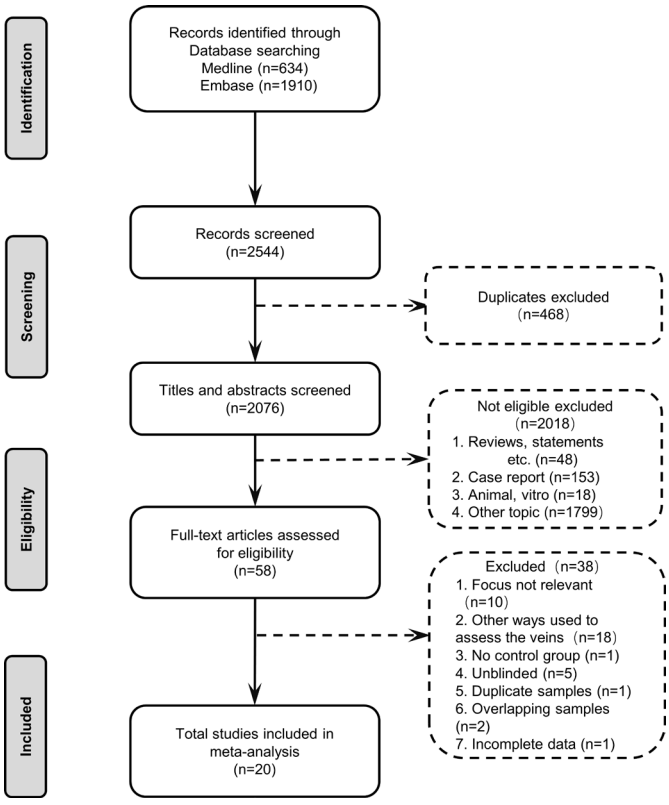

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of the literature search and study selection.

effect of individual studies in the article on the experimental results, the researchers used a sensitivity analysis by excluding individual studies. In addition, we used subgroup analysis to further look for sources of heterogeneity.

RESULTS

Included studies

The selection process of the study is shown in figure 1. During the initial search, 2544 studies were located, with 1910 records from the Embase database, 634 from the Medline database and no additional records. After removing 468 duplicate studies, 2076 publications were included in the title and abstract screening, and 58 were selected for full-text filtering. After full-text screening and checking, 38 of these articles were excluded: 10 examined irrelevant focus, 18 assessed veins in other ways, 1 without a control group, 5 did not use blinding, 1 used duplicate data, 2 used overlapping and 1 had incomplete experimental data. Ultimately, 20 studies[5 21–39] met the eligibility criteria (figure 1).

Study characteristics

Of the currently incorporated studies, 11 were conducted in Italy, 3 in the USA, 2 in Germany, 1 in Canada, 1 in Denmark, 1 in the Netherlands and 1 in Turkey (table 1). It is noteworthy that the included studies were conducted in Europe or North America. This study included healthy controls (table 1). All the studies used Doppler ultrasonography to detect CCSVI. Two studies[27 33] did not report an assessment of the five ultrasound parameters of the CCSVI, and three studies[29 32 34] reported only four estimates because the investigators were unable to perform the full five-item neurological protocol. Although eight papers covered ultrasound technology training, they did not describe in detail the procedures and quality of the training (table 1). Four ultrasound investigators[5 21 28 39] have participated in CCSVI endovascular treatment clinical trials or studies supporting liberation procedures.

In terms of blinding, 8 reports explained the blinding poorly but described the process more entirely in 12 studies, expressed it well in 2 of them and reported success with blinding (table 1). Five studies[21 24 28 30 35] described intraobserver variability. Nevertheless, only four studies[21 24 30 35] described good intraobserver and interobserver reliability in a run-in period. The experimental group in five studies was not age and gender matched to the control group (see online supplemental table 1). Eleven studies did not clearly describe how patients were identified for registration, and nine identified patients in a consecutive sample (table 1). In the study by Zamboni *et al*, there was also no separate discussion about the outcome in healthy individuals.[5]

Regarding the disease type of MS, relapsing-remitting MS was still dominant, with primary progressive MS and secondary progressive MS in second place (see online supplemental table 2). Six studies reported clinically isolated syndromes in patients, and all patients with MS had clinically isolated syndrome in the survey by Baracchini *et al*[38] (see online supplemental table 2). Furthermore, most patients received varying degrees of treatment, with acceptance rates ranging from 28% to 90% (see online supplemental table 2). Females were more prevalent in the experimental groups than in the control groups, with percentages ranging from 16.7% to 82.1% in the experimental groups and 36.4% to 75.0% in the control groups. Online supplemental table 2 summarises the data for patients with MS for age, the proportion of females, duration of disease and Expanded Disability Status Scale scores. These data are typical of patients with MS.

Risk of quality assessment

All 20 studies were included in the Newcastle–Ottawa Quality Assessment Scale, and all had a good quality rating result. Fifteen studies had a quality rating of greater than or equal to seven and were considered high-quality studies.[22 23 25 26 28–32 34–39] None of the incorporated studies were categorised as low quality with a high risk of bias assessment (see online supplemental table 3).

Pooling of studies

In further studies, figure 2 presents the meta-analysis results of the association of CCSVI with MS and the incidence of CCSVI in MS versus healthy controls. Twenty studies reported the incidence of CCSVI, with a significant difference in the incidence of CCSVI in MS

Table 1 The characteristics of meta-analysis study on the incidence of chronic cerebrospinal venous insufficiency in patients with multiple sclerosis (MS) and controls

Study	Country	MS cases (n)	Controls (n)	Blinding	Receive appropriate training in ultrasound operation	Involved in 'liberation procedure'	The way patients were identified for enrolment
Zivadinov *et al*[21]	USA	289	163	Describes the process of blinding, but does not demonstrate whether it was achieved	Yes	Yes	Convenience
Tromba *et al*[23]	Italy	112	67	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Consecutively
Leone *et al*[28]	Italy	68	68	The process of blinding is described and has been achieved	Yes	Yes	Consecutively
Cardaioli *et al*[34]	Italy	39	18	Described as blind only, but the process is not described or confirmed as blind	No	No	Consecutively
Imperiale *et al*[30]	Italy	80	41	The process of blinding is described and has been achieved	Yes	No	Consecutively
Mayer *et al*[25]	Germany	20	20	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Convenience
Baracchini *et al*[37]	Italy	60	60	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Consecutively
Costello *et al*[32]	Canada	120	60	Described as blind only, but the process is not described or confirmed as blind	No	No	Consecutively
Van den Berg *et al*[22]	Netherlands	90	41	Described as blind only, but the process is not described or confirmed as blind	Yes	No	Convenience
Patti *et al*[24]	Germany	148	172	Describes the process of blinding, but does not demonstrate whether it was achieved	Yes	No	Convenience
Baracchini *et al*[38]	Italy	50	110	Described as blind only, but the process is not described or confirmed as blind	No	No	Consecutively
Gandhi *et al*[31]	USA	90	38	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Consecutively
Centonze *et al*[33]	Italy	84	56	Describes the process of blinding, but does not demonstrate whether it was achieved	Yes	No	Convenience
Zamboni *et al*[5]	Italy	109	132	Described as blind only, but the process is not described or confirmed as blind	Yes	Yes	Convenience
Mancini *et al*[27]	Italy	103	42	Described as blind only, but the process is not described or confirmed as blind	No	No	Convenience
Marder *et al*[26]	USA	18	11	Described as blind only, but the process is not described or confirmed as blind	No	No	Convenience
Kantarci *et al*[29]	Turkey	62	54	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Convenience

Continued

Table 1 Continued

Study	Country	MS cases (n)	Controls (n)	Blinding	Receive appropriate training in ultrasound operation	Involved in 'liberation procedure'	The way patients were identified for enrolment
Blinkenberg *et al*[36]	Denmark	24	15	Described as blind only, but the process is not described or confirmed as blind	No	No	Convenience
Caprio *et al*[35]	Italy	78	28	Describes the process of blinding, but does not demonstrate whether it was achieved	Yes	No	Convenience
Amato *et al*[39]	Italy	15	16	Describes the process of blinding, but does not demonstrate whether it was achieved	No	No	Consecutively

n, number.

compared with healthy controls. In Zamboni *et al*'s study, three studies had an incidence of 0, reaching 100%.[25 26 36] There remained a wide variation in the strength of the association between CCSVI and MS. More specifically, the ORs ranged from 0.32 (95% CI: 0.01 to 8.26) in Mayer *et al*'s study to 58 035.00 (95% CI: 1142.20 to 2948755.78) in Zamboni *et al*'s research. According to the pooled analysis, CCSVI and MS were remarkably correlated (OR 3.36; 95% CI: 1.92 to 5.85; p<0.001). However, there was extensive heterogeneity among the studies (I^2=79%).

Publication bias

The Egger's test was employed to analyse publication bias, and its results showed no significant publication bias (t=1.22, p=0.241). Therefore, there is no need to use the fill-and-trim methods for further analysis.

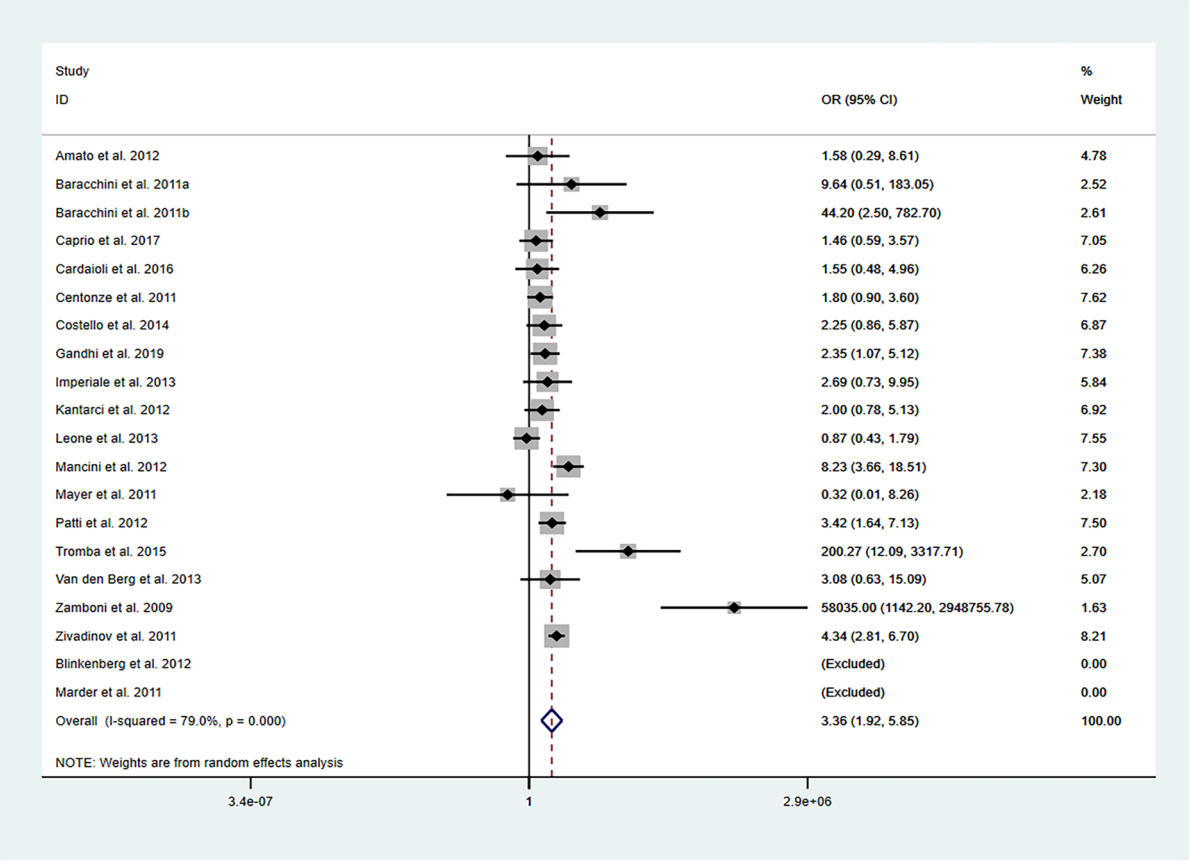

Figure 2 Meta-analysis of the probability of chronic cerebrospinal venous insufficiency in patients with multiple sclerosis versus healthy controls.

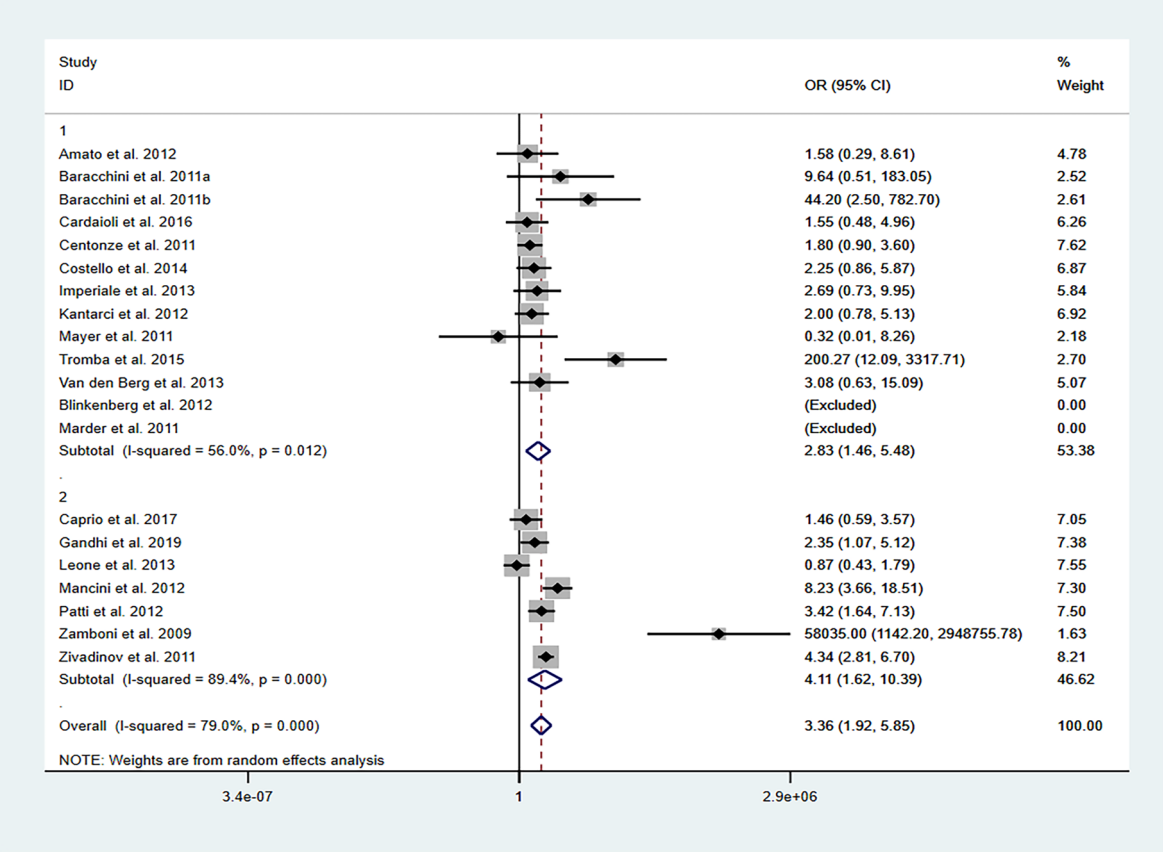

Figure 3 Subgroup analysis of the diagnosis of chronic cerebrospinal venous insufficiency in patients with multiple sclerosis versus healthy controls. Studies by the Zamboni group or group authors who have collaborated with Zamboni were removed (upper panel); studies by the Zamboni group or group authors who have collaborated with Zamboni (lower panel).

Sensitivity analyses

The sensitivity analysis results demonstrated that the combined effect sizes were not affected by the effects of any single study, suggesting good stability of the meta-analysis results (see online supplemental appendix 3).

Subgroup analysis

Since Zamboni *et al* were overly aggressive in their studies on CCSVI (n=11), additional subgroup analyses were performed by removing studies about Zamboni's team and those that had previously been conducted with that team (n=7). Although patients with MS had CCSVI at a higher rate than controls, the correlation between CCSVI and MS was diminished (OR 2.83; 95% CI: 1.46 to 5.48, p<0.05; figure 3) and remained strongly heterogeneous (I^2=56%). On the other hand, the correlation between the two was stronger (OR 4.11; 95% CI: 1.62 to 10.39, p<0.001; figure 3), and the heterogeneity was more pronounced in the seven excluded studies (I^2=89.4%).

In the following sensitivity analysis, considering the potential conflicts of interest between the studies, we deleted articles by authors involved in CCSVI endovascular treatment clinical trials or studies supporting liberation procedures (n=4). There was no substantial change in outcome, a diminished correlation (OR 2.87; 95% CI: 1.82 to 4.52; p<0.05; figure 4), and heterogeneity remained significant (I^2=54.4%). In contrast, a more significant correlation was obtained for those studies assessed in support of liberation therapy authors (OR 17.05; 95% CI: 1.27 to 229.53; p<0.0001; figure 4), along with more significant heterogeneity (I^2=96.1%).

DISCUSSION

This meta-analysis revealed a statistically significant relationship between CCSVI and MS and a wide range of heterogeneity. In a subsequent sensitivity analysis, the results showed that the combined effect size was not affected by any single study. We also performed subgroup analyses to seek sources of heterogeneity, but none of the results were satisfactory.

The meta-analysis also found that patients with MS had a higher prevalence of CCSVI than healthy groups, but it varied considerably across studies. On the other hand, however, we could not confirm what factors led to the significant differences in incidence between the studies. One of these possibilities is the ultrasound detection aspect. Many studies have shown that the quality level of Doppler ultrasound for diagnosing CCSVI depends on the operator and that trained operators perform better in reproducibility.[40 41] This imaging technique is more difficult when testing veins at low-pressure flow, and the dehydrated state of the subject[42] and head rotation[43] contribute to the poor quality of the results. Of all

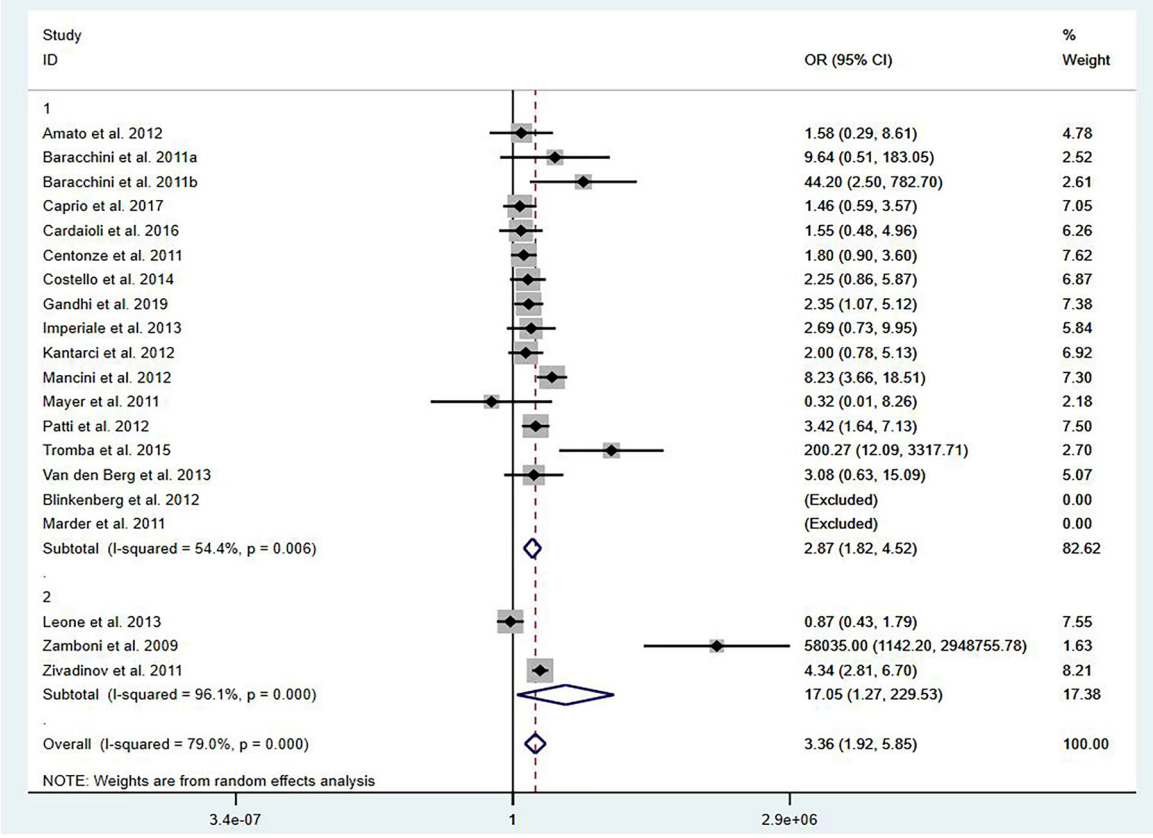

Figure 4 Subgroup analysis of the diagnosis of chronic cerebrospinal venous insufficiency in patients with multiple sclerosis versus healthy controls. Studies participating in or supporting emancipation therapy were removed (upper panel); studies participating in or supporting emancipation therapy (lower panel).

included studies, only eight articles had relevant operator training.[5 21 22 24 28 30 33 35] For consistency of operation, performance was equally poor, where only five included studies were evaluated[21 24 28 30 35] and four showed good agreement.[21 24 30 35] These data further suggest that the reproducibility of CCSVI diagnostics requires additional studies while emphasising the importance of relevant operator training in the skills.

Ultrasound detection of the intracranial cerebral venous system is the most challenging part. On the one hand, the cerebral vein detection procedure is complex and usually studied through a transcranial approach, taking either a temporal window or a transoccipital approach.[44 45] Although both provide better information on blood flow, detecting venous abnormalities is difficult. Due to the skull, the intracranial veins are not regulated by the respiratory pump as the extracranial veins usually are.[46] Furthermore, 17 of the surveyed studies conducted transcranial testing,[5 21–28 30 31 33 35–39] 8 employed a transtemporal window,[5 22 25 30 36–39] while the other 2 used a transtemporal and transoccipital approach[23 26] without detailing the modality used for the remaining. On the other hand, all included studies were performed in the context of a potential association between multiple sclerosis and CCSVI. However, when examined from an objective perspective, it seems more accurate to test the validity of a test versus a test using an established gold standard rather than focusing on the presence or absence of MS.[47] This suggests that the five neurological tests proposed by Zamboni *et al* are questionable, such as vascular stenosis, internal jugular vein cross-sectional area differences or reflux which are challenging to detect objectively by these criteria.[40] Therefore, the relationship between CCSVI and MS still needs more studies and uniform standards to be validated.

In addition, MRI, catheter venography and intravascular ultrasound are noteworthy in detecting the true prevalence of CCSVI, although the latter two are invasive procedures. The International Society for Neurovascular Disease has recommended a multimodality combination of invasive and non-invasive testing for extracranial venous anomalies to achieve optimal detection in patients of interest. Specifically, at least one invasive detection technique and at least one non-invasive detection technique should be used.[48]

Although CCSVI is thought to be associated with cerebral venous abnormalities, the aetiology of cerebral venous abnormalities and the possible pathophysiological link to MS and other neurological disorders remain unclear. Several studies have suggested that, in the setting of venous flow abnormalities, this potential association is related to the accumulation of leucocytes in the vasculature.[49 50]

Interestingly, this study contradicts a previous meta-analysis[51] that showed reduced heterogeneity after removing publications related to the liberation procedures (I^2=37.3%). In contrast, considerable heterogeneity was still observed after the same manipulation in this paper (I^2=54.4%), which may be due to inconsistent inclusion criteria for both studies. Although both included studies used neurological criteria, Tsivgoulis *et al*[51] included non-blinded studies as well as reports from experimental groups with fewer than 10 cases, leading to a final inclusion of demographics varying widely and inconsistent sensitivity analysis results. On the other hand, prior to the writing of this article, four meta-analyses had discussed the association between CCSVI and MS, but only one had reached a definitive conclusion. We need to be aware that the conclusions of previous meta-analyses influence the methodology and even the results of subsequent clinical trials, which then accumulate to trigger accumulation bias.[52] Overly optimistic initial studies or meta-analyses can inspire additional studies, while disappointing results can bring a series of studies to an end. Although we attempted to attenuate the effect of prior studies in our subgroup analysis (removing studies from the Zamboni-related teams), the final results were similar to the initial results. Attempts to eliminate such biases seem unrealistic because new research is continually inspired by previous research and may trigger more unnecessary research waste in the process of elimination. Although bias elimination is unavoidable, meaningful error control can be performed. One study has shown that the likelihood ratio is a valid test.[52] In future clinical trials or meta-analyses, researchers should be aware of the accumulation bias of previous studies.

LIMITATION

The current meta-analysis has some limitations that must be taken into account. First, we searched only two databases in this analysis; a lack of access to more databases and a lack of high-quality literature limited our further analysis. Second, some of the included studies had inferior descriptions of blinding and limited descriptions of ultrasonography, so we could not explore whether inconsistencies in blinding or differences in ultrasound protocols between studies contributed to the heterogeneity in the studies. Furthermore, six studies[5 21 24 30 38 39] also included groups without MS with other neurological disorders. In the current study, we included only healthy controls. We did not acquire the data of the individuals in the study, and there were considerable age and sex differences between the studies, coupled with the fact that five reports did not have controls of the same age and sex as the patients with MS, so it was impossible to determine whether demographic factors influenced the morbidity of CCSVI in controls and patients with MS. More critically, the topic of CCSVI versus MS remains controversial. Studies may be published regardless of the examination method or whether they are positively or negatively evaluated. Finally, the inconsistent diagnostic criteria for screening patients with MS across studies and the lack of reliable evidence in the text to determine the diagnosis of subjects made it impossible to judge the accuracy of the experimental versus control groups.

CONCLUSIONS

In summary, the present meta-analysis exhibited a strong correlation between CCSVI and MS, while CCSVI was more likely to occur in patients with MS than in healthy controls. CCSVI may be a potential risk factor for MS. Nevertheless, the heterogeneity was highly significant that we cannot draw clear conclusions. Future studies of higher quality, especially in terms of blinded quality and reproducibility of ultrasound diagnosis, are still needed to derive a deeper discussion of the association of CCSVI with MS.

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Contributors JY was the first author. NZ received funding. TO and JY designed the study. WM and ML collected the data. XH participated in data verification. CD analysed the data. JY drafted the manuscript. TO and NZ participated in the interpretation of the results and critical revision of important intellectual content of the manuscript and approved the final version of the manuscript. All authors have read and approved the final manuscript. WM and ML were the guarantors of the study.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval This study does not involve human participants; thus, ethical approval was not required.

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ORCID iD

Jun Yang http://orcid.org/0000-0001-5594-6133

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