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Diagnostic validity of magnetic resonance parkinsonism index in differentiating patients with progressive supranuclear palsy from patients with Parkinson's disease

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ABSTRACT

Background: Progressive supranuclear palsy is a neuropathologically defined disease, and many studies worked on detecting the diagnostic use of Magnetic resonance imaging. This article purposed to detect the diagnostic performance of Magnetic resonance parkinsonism index (MRPI).

Methods: We systematically searched electronic database PubMed for articles published since 1996 using the National Institute of Neurological Disorders and Stroke and Society for PSP (NINDS-SPSP) criteria as the diagnostic standard. Methodological quality was assessed by Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) and software Review Manager 5.3, software STATA 14.0 and meta-disc were applied in statistics analysis.

Results: Totally 14 articles were included in this article. MRPI is proved to have pooled sensitivity of 0.98, pooled specificity of 0.99 in differentiating patients with Progressive supranuclear palsy (PSP) from patients with Parkinson's disease (PD) and the area under the Receiver operating characteristic curve value was 1.00.

Conclusion: MRPI shows excellent performance in differentiating patients with PSP from patients with PD, the clinical usage of MRPI in auxiliary diagnosis of PSP is recommended.

1. Introduction

Progressive supranuclear palsy (PSP) is a neurodegenerative disorder characterized by supranuclear vertical gaze abnormalities, postural instability and falls. Although clinical signs as vertical gaze palsy are specific for PSP [1], it is difficult to distinguish PSP from Parkinson's disease (PD), especially in the early stages of disease [2,3]. Management and prognosis of PSP differs significantly from PD, which makes it essential to make an early distinction between PSP and PD. The most widely accepted and validated method for differentiating between PSP and PD is the clinical criteria proposed by the National Institute of Neurological Disorders and Stroke and Society for PSP (NINDS-SPSP) [4]. "Probable" PSP is described as demonstration of a vertical supranuclear gaze palsy, postural instability and falls within the first year of symptom onset. "Possible" PSP is described as presence of either supranuclear gaze palsy or a combination of slow vertical saccades and postural instability with falls within the first year.

Many researches on detecting usage of Magnetic resonance imaging in diagnosis of PSP. Structural differences on conventional MRI (hummingbird sign, midbrain area, midbrain rostral tegmentum diameter, divergence of red nuclei and MR Imaging Index) Volume changes, Signal abnormalities, Diffusion-weighted imaging and diffusion tensor imaging perform well [5]. And, MR Imaging Index especially magnetic resonance parkinsonism index (MRPI) have been proved to be accurate in discriminating patients affected by PSP from patients affected by PD. The pons area-midbrain area ratio (P/M) is calculated as dividing pons area by midbrain area, MCP width-SCP width ratio (MCP/SCP) is calculated as dividing the mean value of bilateral middle cerebellar peduncles (MCPs) width by the mean value of bilateral superior cerebellar peduncles (SCPs), MRPI is calculated as [(P/M)•(MCP/SCP)] [6]. However diagnostic validity of MRPI are inconsistent in different articles. For example, Longoni G et al. [7] revealed sensitive of 100% and specificity of 92%. Möller L et al. [8] revealed sensitive of 68.9% and specificity of 67.7%.

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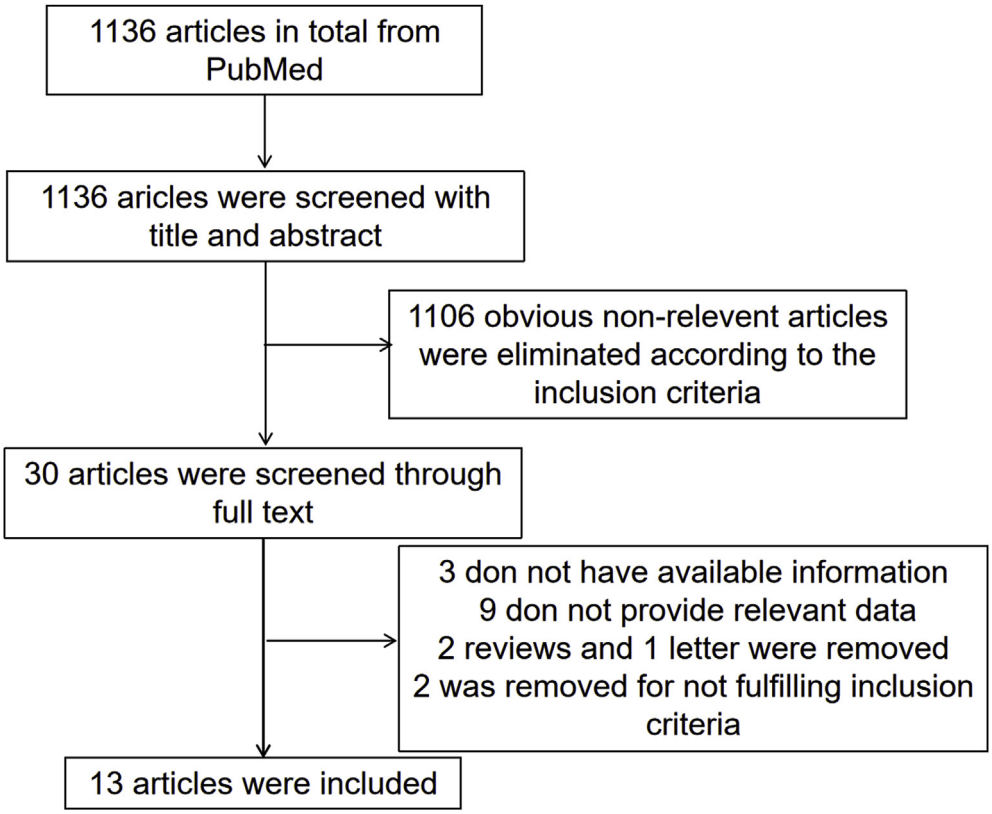

Fig. 1. Flow chart of selection process to enroll eligible studies.

This article is designed to detect diagnostic accuracy of MRPI to differentiate between patients with PSP and patients with PD. And, this is the first article presenting a systematic review and meta-analysis of diagnostic value of MRPI.

2. Materials and methods

2.1. Search strategy

A systematic search of literature was performed by two investigators (ZHANG KJ and LIANG ZZ) in February 2019. Electronic database PubMed was systematically searched by two combination of terms as "magnetic resonance imaging" + "progressive supranuclear palsy" and "magnetic resonance parkinsonism index" + "parkinson disease" or "progressive supranuclear palsy" with time limit from 1 January 1996 to 12 February 2019. Various alterations in spelling were searched due to the pronounced heterogeneity. The detailed search strategies were shown in Supplementary Table 1.

2.2. Selection criteria

We included all studies regardless of study design according to the following inclusion criteria: (1) Original studies; (2) Papers were published in English and focused on human beings (3) Proving diagnostic values of MRPI; (4) Patients included in the study were diagnosed with PSP; (5) PD patients or healthy controls were involved as control groups; (6) Clinical diagnosis of PSP and PD was based on proposed clinical criteria [3].

We excluded studies according to the following exclusion criteria: (1) Studies without control groups; (2) Studies from conference abstracts, letters, editorials or reviews (3) Information are insufficient for building 2*2 tables for calculating sensitivity and specificity.

2.3. Data extraction and quality assessment

Data about the following variables were extracted independently by two reviewers from each study: author, design of the study, year of publication, country of origin, number of patients, sex composition, age at examination, age at onset, control type, testing method and cut-off value. Two reviewers independently used Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) [9] tools for assessing the quality of each included study. The QUADAS-2 is composed of four parts, which are index detection, reference norm, flow and timing. Each is marked as "YES", "UNCLEAR" and "NO" according to the level of bias and risk. Software Review Manager 5.3 was used to assess QUADAS-2.

2.4. Data analysis

The threshold effect was measured by *P*-value of Spearman correlation coefficient, and it was conducted by software meta-disc. If *P*-value > 0.05, it meant that there was no threshold effect. Heterogeneity was evaluated by *P*-value of Cochran-Q test and I-square statistic. If *P*-value > 0.05 and I^2 < 50%, studies were thought to be free of significant heterogeneity, a fixed effects model should then be performed. If *P*-value < 0.05 and I^2 > 50%, studies were thought to be of heterogeneity, a random effects model should then be performed. Publication bias was assessed by Deek's funnel plot asymmetry test, If Deek's Funnel plot graphics was symmetrical and *P* > 0.05, it suggested no significant publication bias. Software STATA 12.0 was applied in evaluation of heterogeneity and Publication bias. Then, Sensitivity, Specificity, Positive likelihood ratio (PLR), negative likelihood ratio (NLR) and diagnostic odds ratio (DOR) with the 95% confidence interval (CI) were calculated using STATA 12.0. And, Forest plots that indicates sensitivity, specificity and their confidence interval of each study, Receiver operating characteristic curve (ROC) that shows superior diagnostic accuracy, area under the ROC curve (AUC) was also conducted.

Studies were divided into subgroups depending on specific MRPI cut-off value. We grouped studies according to three different MRPI ranges: < 13.0, 13.0–13.5, > 13.5. Then, we further analysis data on diagnostic validity on the midbrain area-pons area ratio (M/P) to compare with MRPI. Sensitivity, Specificity, PLR, NLR, DOR of groups above were calculated using software meta-disc. MRPI values of PSP patients are significantly higher than patients with PD or healthy patients.

3. Results

Following the systematic search of literature, a total of 1136 studies were obtained. Majority of studies were excluded based on carefully review of title and abstract and only 30 studies were necessarily retrieved in full text. And through full-text scan, only 13 papers were finally included with eligibility. The selection of the studies has been summarized in Fig. 1.

3.1. Study characteristic

Among 13 included articles, 11 articles [6–8,10–17] used PD as control group and 10 [6–8,10–12,16–19] articles used healthy control as control group. Both “Probable” PSP and “Possible” PSP according to the NINDS-SPSP criteria were included, and PSP-Parkinsonism (PSP-P) was not included for not satisfying NINDS-SPSP criteria. To avoid involving duplicated data, we anatomized articles written by the same author of same country. Two articles were written by Nigro S, we extracted data from 1.5T scanner from one article [11] and extracted data from 3T scanner from another article [12]. Two articles written by Constantinides VC used different control groups, data from these two articles were involved in two independent analysis [15,19]. One article written by Quattrone A included patients from June 2002 to May 2006 [6], another article included patients between 2009 and 2017 [17]. Data from these two articles were both included. And nine studies involved using M/P or P/M ratio in differentiating patients with PSP and PD [6–8,10,12–16]. Seven studies involved using M/P or P/M ratio in differentiating patients with PSP and healthy control [6,7,10,12,16,18,19]. Major characteristics of enrolled studies is shown in Table 1.

3.2. Quality assessment

The results of QUADAS-2 showed that the risk of bias was low and overall qualities of included studies were high. And outcomes of QUADAS-2 were shown in suppplementary Fig. 1 and Supplementary Fig. 2.

3.3. Data analysis

For results of *P*-value of Cochran-Q test and *I*-square statistic, *P*-value < 0.05 and I^2 > 50%, studies were thought to be of heterogeneity and a random effects model was performed.

Meta-analytic results show that when using MRPI in differentiating PSP from PD, pooled sensitivity is 0.98 (95% CI 0.93; 1.00), pooled specificity is 0.99 (95% CI 0.97; 1.00), ROC-Area is 1.00 (95% CI 0.99; 1.00), PLR is 138.5 (95% CI 27.7; 691.5), NLR is 0.02 (95% CI 0.00; 0.07), DOR is 7357 (95% CI 520; 104145), The Deek's Funnel plot graphics were symmetrical and P > 0.05, suggesting no significant publication bias and no threshold effect. The Deek's Funnel plot graphics is shown in Fig. 2. And the Forest plots is shown in Fig. 3, SROC curve is shown in Fig. 4. When using MRPI in differentiating PSP from healthy controls, pooled sensitivity is 0.941 (95% CI 0.912; 0.96), pooled specificity is 0.943 (95% CI 0.919; 0.961), PLR is 28.237 (95% CI 7.831; 101.818), NLR is 0.047 (95% CI 0.016; 0.135), DOR is 738.62 (95% CI 104.77; 5207.4).

When using a MRPI cut-off of < 13.0 with control group of PD patients, pooled sensitivity is 0.782 (95% CI 0.714; 0.840), pooled specificity is 0.751 (95% CI 0.696; 0.801), PLR is 9.603 (95% CI 1.595; 57.813), NLR is 0.173 (95% CI 0.059; 0.507), DOR is 71.937 (95% CI 5.173; 1000.4). When using a MRPI cut-off of 13.0–13.5, pooled sensitivity is 0.959 (95% CI 0.899; 0.989), pooled specificity is 0.993 (95% CI 0.975; 0.999), PLR is 76.913 (95% CI 27.129; 218.053), NLR is 0.053 (95% CI 0.013; 0.209), DOR is 2378.1 (95% CI 365.81; 15459.5). When using a MRPI cut-off of > 13.5, pooled sensitivity is 1.000 (95% CI 0.981; 1.000), pooled specificity is 0.994 (95% CI 0.985; 0.998), PLR is 75.279 (95% CI 20.711; 273.617), NLR is 0.018 (95% CI 0.006; 0.056), DOR is 4371.6 (95% CI 1021.0; 18718.7). results of subgroup analysis is shown in Table 2.

For analysis of M/P ratio, when PD patients were regarded as

Table 1
Major characteristics of enrolled studies.

author	design	year	nation	number	age(MA, SD)	onset age(MA,SD)	diagnosis	MRPI(MV, SD)	control	MRPI(mean value, SD)	cut-off value
Sankhla CS	CSS	2016	India	26	(66.15, 7.43)	(63.58, 6.76)	PSP	(23.48, 9.6)	PD	(9.07, 2.23)	> 12.4
							PSP	(23.38, 9.6)	HC	(9.45, 1.87)	> 12.4
Nigro S	CSS	2017	Italy	44	(64.70, 5.85)	(68.80, 5.24)	"probable" PSP	(19.01, 5.42)	PD	(10.28, 1.94)	> 13.42
							"probable" PSP	(19.01, 5.42)	HC	(10.41, 2.15)	> 13.19
Nigro S	CSS	2017	Italy	15	(70.07, 3.15)	(67.27, 3.39)	"probable" PSP	(27.03, 5.78)	PD	(9.77, 1.78)	> 15.64
							"probable" PSP	(27.03, 5.78)	HC	(9.3, 1.45)	> 13.2
				20	(68, 5.69)	(65.84, 5.72)	"possible" PSP	(17.71, 2.88)	PD	(9.77, 1.78)	> 13.38
							"possible" PSP	(17.71, 2.88)	HC	(9.3, 1.45)	> 13.2
Zanigni S	CSS	2016	Italy	23	(72.8, 7.1)	–	PSP	(17.89, 7.28)	PD	(8.73, 1.97)	> 10.67
Nizamani WM	CSS	2017	Pakistan	34	(66.76, 6.27)	–	PSP	(21, -)	PD	(9.5, -)	> 13.5
Constantinides VC	CSS	2018	Greece	24	(63.2, 6.8)	–	PSP	–	PD	–	> 12.7
Silsby M	CSS	2017	Australia	16	(71.1, 5.1)	–	PSP	(17.55, 4.127)	HC	(10.294, 2.049)	> 13.1
Möller L	CSS	2017	Germany	106	(69, 0.6)	(66.1, 0.6)	PSP	–	PD	–	> 8.98
							PSP	–	HC	–	> 8.35
Constantinides VC	CSS	2018	Greece	24	(63.2, 6.8)	–	PSP	(16.2, 3.3)	HC	(8.6, 1.7)	> 12.6
Morelli M	CSS	2011	Italy	42	(70.25, 6)	(66.69, 6.9)	PSP	(21.4, 7.4)	PD	(9.8, 1.64)	> 13.6
							PSP	(21.4, 7.4)	HC	(9.9, 1.73)	> 13.27
Quattrone A	CSS	2018	Italy	46	(70.4, 5.2)	(66.4, 5.3)	PSP	(20.41, 4.7)	PD	(9.58, 1.6)	> 13.88
							PSP	(20.41, 4.7)	HC	(9.05, 1.3)	> 13.88
Longoni G	CSS	2011	Italy	10	–		PSP	(14.9, 5.3)	PD	(10.7, 2.4)	> 13.57
							PSP	(14.9, 5.3)	HC	(10.5, 2.4)	> 13.44
Quattrone A	CSS	2008	Italy	33	(69.3, 6.1)	(66.3, 6.7)	PSP	(19.42,-)	PD	(9.4,-)	> 13.55
							PSP	(19.42,-)	HC	(9.21,-)	> 13.58

MRPI, Magnetic resonance parkinsonism index, CCS, Case-control study, CS, Cohort study, MA, Mean age, MV, Mean value, SD, Standard deviation, PSP, Progressive supranuclear palsy, PD, Parkinson's disease, HC, Healthy control.

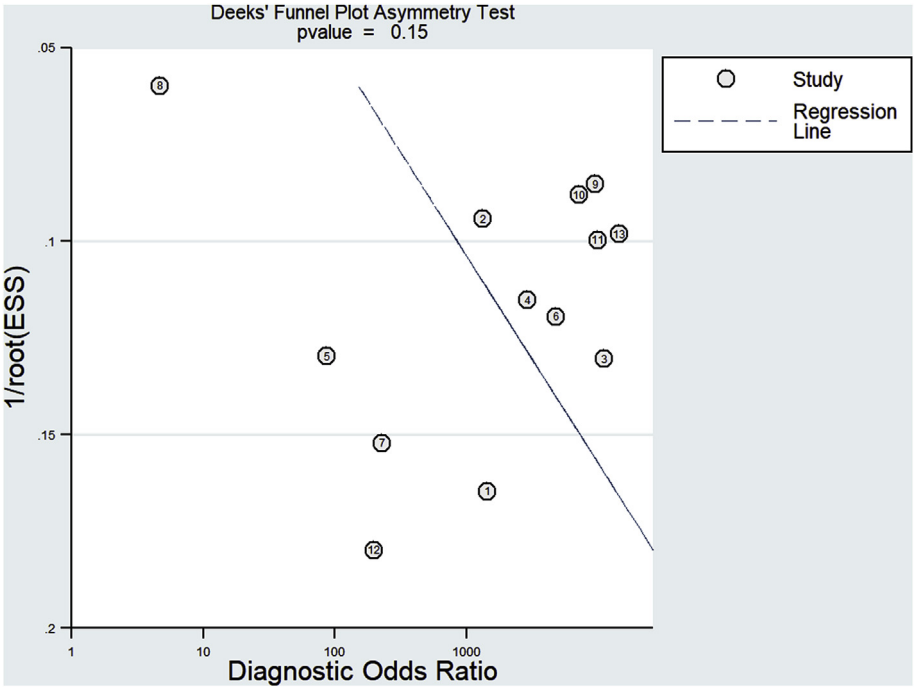

Fig. 2. The Deek's Funnel plot graphics.

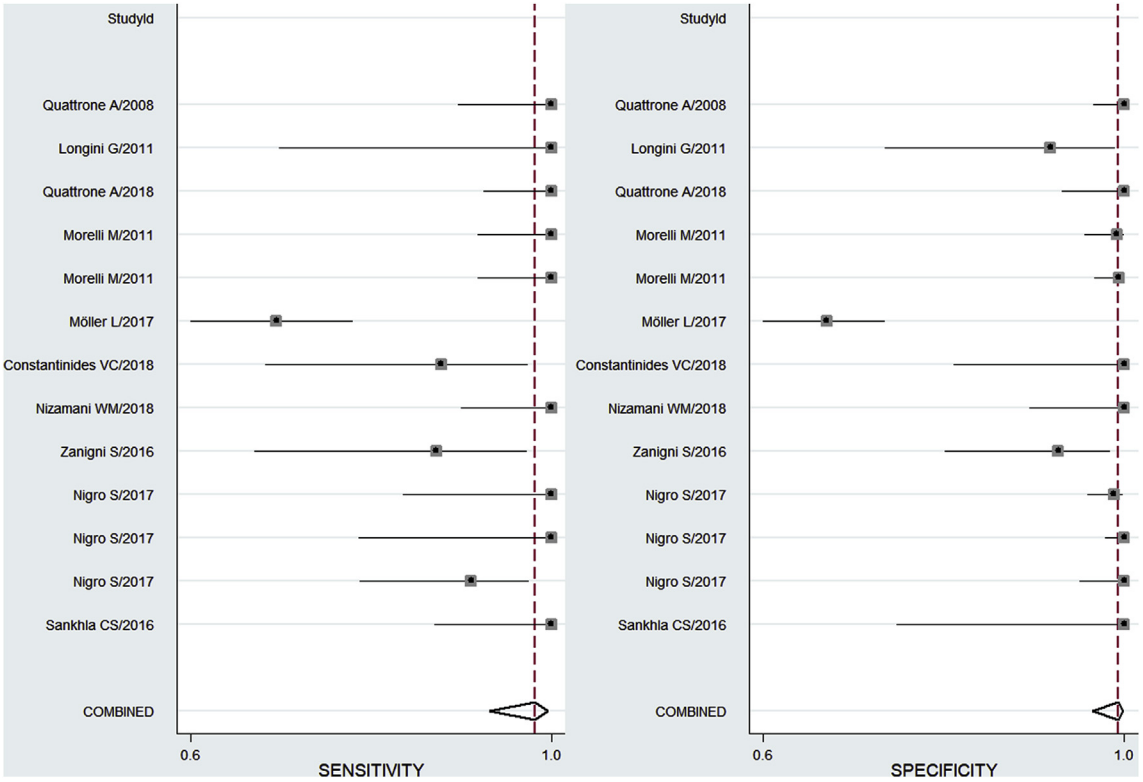

Fig. 3. Forest plots of pooled sensitivity and pooled specificity of using MRPI in differentiating PSP from PD.

control groups, pooled sensitivity is 0.92 (95% CI 0.84; 0.96), pooled specificity is 0.94 (95% CI 0.88; 0.97), PLR is 15.14 (95% CI 7.32; 31.31), NLR is 0.09 (95% CI 0.04; 0.18), DOR is 171.46 (95% CI 47.82; 614.80). When healthy controls were regarded as control groups, pooled sensitivity is 0.890 (95% CI 0.846; 0.924), pooled specificity is 0.937 (95% CI 0.909; 0.958), PLR is 12.224 (95% CI 6.794; 21.995), NLR is 0.070 (95% CI 0.024; 0.202), DOR is 252.68 (95% CI 56.205; 1136.0).

4. Discussion

PSP is a neurodegenerative disorder. Because levodopa responsiveness is poor and fast deteriorate in PSP, it is important to distinguish between PSP and PD [20]. However, it is difficult to make a clinical distinction between PSP and PD for similar clinical features present, especially in the early stages of disease. Our study suggested that MRPI is useful in differentiating PSP from PD with pooled sensitivity of 0.98,

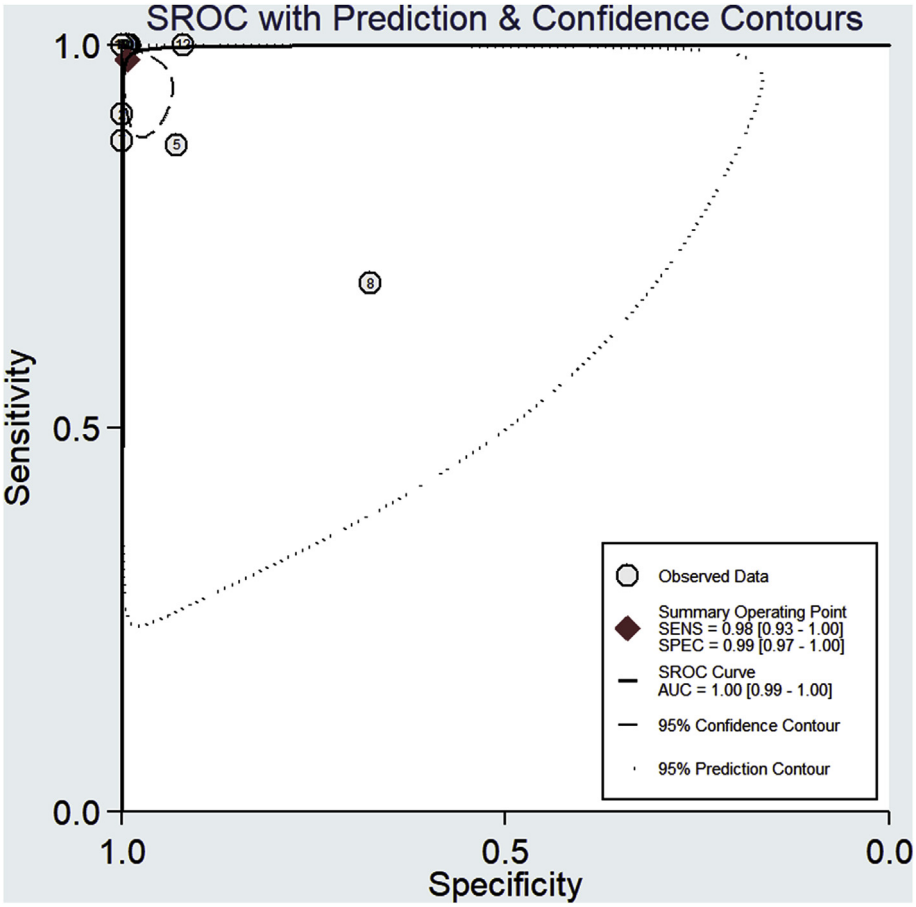

Fig. 4. SROC curve of using MRPI in differentiating PSP from PD.

pooled specificity of 0.99.

Midbrain atrophy is a pathological feature of PSP, Various MR measurements studies confirm that midbrain area is smaller in PSP patients than in PD patients or healthy controls [6,10–12,18]. MR indexes as P/M ratio, MCP/SCP ratio, MRPI et al. are generated based on width and area changes of brain structures. Among those indexes MRPI and P/M ratio are proved to have better performances than others. Zanigni S et al. [13] reveled that P/M ratio has higher sensitivity (0.96) than MRPI (0.87), while MRPI has higher specificity (0.93) than P/M ratio (0.90). When comparing patients with PSP with healthy control, Silsby M et al. [18] revealed that both M/P and MRPI showed equal sensitivity (87.5%) but M/P ratio has a higher specificity (100%) than MRPI (86.4%). Morelli M [16] revealed that MRPI had better performance in patients with “Probable” PSP or “Possible” PSP. Our results show that when using PD patients as control groups, MRPI has pooled sensitivity of 0.98 and pooled specificity of 0.99, M/P ratio has pooled sensitivity of 0.92 and pooled specificity of 0.94. When using healthy controls as control groups, MRPI has pooled sensitivity of 0.941 and pooled specificity of 0.943, M/P has pooled sensitivity of 0.890 and pooled specificity of 0.937. MRPI has better performance than M/P ratio in either differentiating patients between PSP and PD or differentiating patients between PSP and healthy controls. And it is reported that MRPI is a conservative imaging measurement for not influenced by aging or PD-related changes in brainstem structures [21]. We recommend usage of MRPI in MR measurement for differentiating patients with PSP from patients with PD or healthy controls.

We set groups according to ranges of MRPI cut-off value: < 13.0, 13.0–13.5, > 13.5. When cut-off value is set as < 13.0, MRPI has limited validity in differentiating patients with PSP from PD, pooled sensitivity is 0.782 and pooled specificity is 0.751. When cut-off value is set as 13.0–13.5, MRPI has better performance with pooled sensitivity of 0.959 and pooled specificity of 0.993. When cut-off value is set as > 13.0, MRPI has the best performance in differentiating patients with PSP from PD, the pooled sensitivity is 1.000 and pooled specificity is 0.994. In MR measurement, patients with PSP have higher MRPI values than patients with PD or healthy controls, and patients with “Probable” PSP have higher MRPI value than patients with “Possible” PSP [10]. We attribute the different diagnostic performance of different cut-off values ranges to patients of different countries included, measurement errors and inclusion of patients with “Possible” PSP. And

Table 2
Results of groups set according to different MRPI ranges.

MRPI value	sensitivity(95% CI)	specificity(95% CI)	PLR(95% CI)	NLR(95% CI)	DOR(95% CI)
8.98–15.64	0.98(0.93; 1.00)	0.99(0.97; 1.00)	138.5(27.7; 691.5)	0.02(0.00; 0.07)	7357(520; 104145)
< 13.0	0.782(0.714; 0.840)	0.751(0.696; 0.801)	9.603(1.595; 57.813)	0.173(0.059; 0.507)	71.937(5.173; 1000.4)
13.0–13.5	0.959(0.899; 0.989)	0.993(0.975; 0.999)	76.913(27.129; 218.053)	0.053(0.013; 0.209)	2378.1(365.81; 15459.5)
> 13.5	1(0.981; 1.000)	0.994(0.985; 0.998)	75.279(20.711; 273.617)	0.018(0.006; 0.056)	4371.6(1021.0; 18718.7)

PLR, Positive likelihood ratio, NLR, Negative likelihood ratio, DOR, Diagnostic odds ratio, 95% CI, 95% confidence interval.

setting a higher cut-off value may promote diagnostic accuracy of MRPI.

In this study, we do not include patients with PSP-Parkinsonism (PSP-P) or other atypical variants of PSP for not fulfilling the NINDS-SPSP criteria. And NINDS-SPSP criteria is reported to be limited in diagnosing patients with atypical variants. A new criteria developed based on NINDS-SPSP criteria is proved to have higher accuracy in diagnosis of atypical variants of PSP [22]. The author suggested that NINDS-SPSP "Possible" and "Probable" cases should be classified as probable Richardson' s syndrome (PSP-RS). While MRPI is reported to be more powerful than clinical features in predicting evaluation of unclassified parkinsonism in PSP phenotypes [23]. Longoni G et al. [7] suggested that MRPI had pooled sensitivity of 0.70, pooled specificity of 0.68 in differentiating patients with PSP-P and PD. Quattrone A et al. [17] suggested that MRPI had pooled sensitivity of 0.735, pooled specificity of 0.981 in differentiating patients with PSP-P and PD. Quattrone A [17] also promoted a new version of MRPI 2.0 with higher diagnostic performance than MRPI in differentiating patients with PSP-P from patients with PD. Diagnostic usage of MRPI in PSP-P or other atypical variants of PSP remains to be inspected. We look forward to the establishment of uniformly accepted clinical diagnostic criteria available for atypical variants of PSP and more studies including patients with PSP-P and other variants of PSP.

There are some limitations to the current study. First, cases included were not pathologically confirmed even if the clinical evaluations has been performed according to the international established criteria and expert guidelines, and sensitivity and specificity of clinical diagnostic criteria for PSP are well documented. Second, PSP-P or other atypical variants of PSP are not included. Third, not all studies included providing Mean value and Standard deviation of index test. We looked forward on more original studies involving larger sample size of both patients and healthy controls, and studies providing thorough information on patients characteristics and confidence interval. Fourth, cut-off values of studies included are not pre-specified and Data driven cut-off values are different among different studies, which may lead to overestimation of test performance. We recommended unification of cut-off value and application of unified pre-specified cut-off value for reduction of bias. While, the robust SROC showed excellent performance of MRPI, which may prove the validity of MRPI and reduce bias [24]. Fifth, studies with positive results are more likely to be pubulished or acquired, but those with negative results not. We designed the search strategy in detail and screened literature thoroughly for reduction of bias.

Above all, this is the first article presenting a systematic review and meta-analysis of diagnostic value of MRPI. MRPI is proved to be validity in differentiating patients with PSP from patients with PD. And MRPI is proved to perform better than M/P ratio in distinguishing patients with PSP from patients with PD. And we recommended clinical usage of MRPI in auxiliary diagnosis of PSP.

Source of funding

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Conflicts of interest

The authors declare no potential conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.parkreldis.2019.08.007.

References

[1] D.R. Williams, A.J. Lees, et al., What features improve the accuracy of the clinical diagnosis of progressive supranuclear palsy-parkinsonism (PSP-P)? Mov. Disord. 25 (2010) 357–362.
[2] A.J. Hughes, S.E. Daniel, Y. Ben-Shlomo, The accuracy of diagnosis of parkinsonian syndromes in a specialist movement disorder service, Brain 125 (2002) 861–870.
[3] Y. Osaki, Y. Ben-Shlomo, A.J. Lees, et al., Accuracy of clinical diagnosis of progressive supranuclear palsy, Mov. Disord. 19 (2004) 181–189.
[4] I. Litvan, Y. Agid, D. Calne, et al., Clinical research criteria for the diagnosis of progressive supranuclear palsy (Steele-Richardson-Olszewski syndrome): report of the NINDS-SPSP international workshop, Neurology 47 (1996) 1–9.
[5] S. Bacchi, I. Chim, S. Patel, Specificity and sensitivity of magnetic resonance imaging findings in the diagnosis of progressive supranuclear palsy, J Med Imaging Radiat Oncol 62 (2018) 21–31.
[6] A. Quattrone, G. Nicoletti, D. Messina, et al., MR imaging index for differentiation of progressive supranuclear palsy from Parkinson disease and the Parkinson variant of multiple system atrophy, Radiology 246 (2008) 214–221.
[7] G. Longoni, F. Agosta, V.S. Kostić, et al., MRI measurements of brainstem structures in patients with Richardson's syndrome, progressive supranuclear palsy-parkinsonism, and Parkinson's disease, Mov. Disord. 26 (2011) 247–255.
[8] L. Möller, J. Kassubek, M. Südmeyer, et al., Manual MRI morphometry in Parkinsonian syndromes, Mov. Disord. 32 (2017) 778–782.
[9] P.F. Whiting, A.W. Rutjes, M.E. Westwood, et al., QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies, Ann. Intern. Med. 155 (2011) 529–536.
[10] C.S. Sankhla, K.B. Patil, N. Sawant, S. Gupta, Diagnostic accuracy of Magnetic Resonance Parkinsonism Index in differentiating progressive supranuclear palsy from Parkinson's disease and controls in Indian patients, Neurol. India 64 (2016) 239–245.
[11] S. Nigro, G. Arabia, A. Antonini, et al., Magnetic Resonance Parkinsonism Index: diagnostic accuracy of a fully automated algorithm in comparison with the manual measurement in a large Italian multicentre study in patients with progressive supranuclear palsy, Eur. Radiol. 27 (2017) 2665–2675.
[12] S. Nigro, M. Morelli, G. Arabia, et al., Magnetic Resonance Parkinsonism Index and midbrain to pons ratio: which index better distinguishes Progressive Supranuclear Palsy patients with a low degree of diagnostic certainty from patients with Parkinson Disease? Park. Relat. Disord. 41 (2017) 31–36.
[13] S. Zanigni, G. Calandra-Buonaura, D.N. Manners, et al., Accuracy of MR markers for differentiating progressive supranuclear palsy from Parkinson's disease, Neuroimage Clin 30 (2016) 736–742.
[14] W.M. Nizamani, F. Mubarak, M.D. Barakzai, M.S. Ahmed, Role of magnetic resonance planimetry and magnetic resonance parkinsonism index in discriminating Parkinson's disease and progressive supranuclear palsy: a retrospective study based on 1.5 and 3 T MRI, Int. J. Gen. Med. 31 (2017) 375–384.
[15] V.C. Constantinides, G.P. Paraskevas, G. Velonakis, et al., MRI planimetry and magnetic resonance parkinsonism index in the differential diagnosis of patients with parkinsonism, AJNR Am J Neuroradiol 39 (2018) 1047–1051.
[16] M. Morelli, G. Arabia, M. Salsone, et al., Accuracy of magnetic resonance parkinsonism index for differentiation of progressive supranuclear palsy from probable or possible Parkinson disease, Mov. Disord. 26 (2011) 527–533.
[17] A. Quattrone, M. Morelli, S. Nigro, et al., A new MR imaging index for differentiation of progressive supranuclear palsy-parkinsonism from Parkinson's disease, Park. Relat. Disord. 54 (2018) 3–8.
[18] M. Silsby, R.Y. Tweedie-Cullen, C.R. Murray, et al., The midbrain-to-pons ratio distinguishes progressive supranuclear palsy from non-fluent primary progressive aphasias, Eur. J. Neurol. 24 (2017) 956–965.
[19] V.C. Constantinides, G.P. Paraskevas, E. Stamboulis, E. Kapaki, Simple linear brainstem MRI measurements in the differential diagnosis of progressive supranuclear palsy from the parkinsonian variant of multiple system atrophy, Neurol. Now. 39 (2018) 359–364.
[20] A.J. Hughes, S.E. Daniel, L. Kilford, A.J. Lees, Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinico-pathological study of 100 cases, J. Neurol. Neurosurg. Psychiatry 55 (1992) 181–184.
[21] M. Morelli, G. Arabia, D. Messina, et al., Effect of aging on magnetic resonance measures differentiating progressive supranuclear palsy from Parkinson's disease, Mov. Disord. 29 (2014) 488–495.
[22] G.U. Höglinger, G. Respondek, M. Stamelou, et al., Clinical diagnosis of progressive supranuclear palsy: the movement disorder society criteria, Mov. Disord. 32 (2017) 853–864.
[23] M. Morelli, G. Arabia, F. Novellino, et al., MRI measurements predict PSP in unclassifiable parkinsonisms: a cohort study, Neurology 77 (2011) 1042–1047.
[24] M.M. Leeflang, K.G. Moons, J.B. Reitsma, et al., Bias in sensitivity and specificity caused by data-driven selection of optimal cutoff values: mechanisms, magnitude, and solutions, Clin. Chem. 54 (2008) 729–737.