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ORIGINAL ARTICLE

The methodological quality of robotic surgical meta-analyses needed to be improved: a cross-sectional study

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Abstract

Objectives: The aims of the article were to assess the methodological quality of robotic surgical meta-analyses (MAs) using A MeaSurement Tool to Assess systematic Reviews (AMSTAR-2) and to explore the factors of methodological quality.

Study Design and Setting: Robotic surgical MAs published between 2015 and 2018 were identified through a systematical search in PubMed, EMBASE, Cochrane library, and Web of Science databases. The methodological quality of eligible MAs was evaluated by AMSTAR-2. Data extraction and the methodological quality of MAs assessment were double checked by four trained reviewers. The intraclass correlation coefficient (ICC) was used to assess the consistency of quantitative measurements, and the ICC for overall score and score of critical domains were 0.952 and 0.912, respectively. Multivariate regression analysis was used to identify potential factors affecting methodological quality.

Results: A total of 123 MAs focused on 18 surgical locations were included. The findings showed that, regarding quality, only two (1.6%) of 123 MAs were high, two (1.6%) were moderate, two (1.6%) were low, and the remainder 117 (95.1%) were critical low. Multiple linear regression analysis revealed that publishing year and journal rank independently associated with methodological quality of MAs; origin region ($P > 0.05$), Preferred Reporting Items for Systematic Reviews and Meta-Analyses ($P = 0.421$), randomized controlled trial enrollment ($P = 0.304$), and funding support ($P = 0.958$) did not influence the quality of the MAs. Registration (item 2) and funding reported for individual studies (item 10) showed the poorest adherence in the MAs.

Conclusion: Our study showed that the previously published robotic surgical MAs lack good scientific quality, especially in those published in Q2- to Q4-rated journals. Potential solutions to improve the quality of future robotic surgical MAs include preregistration and funding reported for individual studies.

Keywords: AMSTAR-2; Methodological quality; Robotic surgical; Meta-analyses; Cross-sectional study

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What is new?

Key findings

- Previously published robotic surgical meta-analyses (MAs) lack sufficient scientific quality although the methodological quality of MAs showed a tendency to improve.
- Publishing year and journal rank independently associated with the methodological quality of MAs, whereas origin region, Preferred Reporting Items for Systematic Reviews and Meta-Analyses, and funding support did not influence the methodological quality of MAs.

What this adds to what was known?

- This is the first study to assess the methodological quality of robotic surgical MAs by A MeaSurement Tool to Assess systematic Reviews.

What is the implication and what should change now?

- The methodological quality of published MAs in the field of robotic surgery was suboptimal, especially of those published in Q2- to Q4-rated journals. Strategies for improving the quality of MAs should be explored.
- Funding reported for individual studies and preregistration is a potential solution to improve the quality of future robotic surgical MAs.

1. Introduction

Since being approved by the Food and Drug Administration (FDA) in 2000, robotic surgery (RS) has been widely applied in various surgical fields due to the improved comfort for surgeons and dexterity of movement, minimized hand tremor, and wide range of movements allowing for increased precision [1,2]. Numerous observational studies [3,4] and limited randomized controlled trials (RCTs) [5−7] were performed to explore the advantages of RS compared with laparoscopic surgery (LS), video-assisted surgery (VS), or open surgery (OS) regarding application purposes, whereas the results were controversial [8,9]. In addition, high-quality meta-analyses (MAs) have been increasingly regarded as one of the key tools for achieving evidence [10,11]. Therefore, the number of published MAs of comparative studies in RS increase rapidly.

There are risks in uncritically accepting the results of MAs, especially for those MAs with serious heterogeneity or methodological dilemmas [12,13]. Heterogeneity is inherent in MAs, and not a problem to be solved, whereas methodological dilemmas involve puzzles that are potentially solvable. Therefore, it is important for users to identify high-quality MAs. Although several instruments have been designed to assess the methodological quality of systematic reviews, not all instruments have been systematically developed or empirically validated [14−17]. For example, A MeaSurement Tool to Assess systematic Reviews (AMSTAR) represented a validated instrument to evaluate systematic reviews of RCTs [15,18] and has been widely used in many countries to assess the methodological quality of MAs in various fields [19−22]. However, robotic surgical MAs often include a large proportion of non-RCTs [23,24].

AMSTAR-2, the updated version of AMSTAR, could be used to assess systematic reviews based on non-RCTs [12]. When compared with risk of bias in systematic reviews (ROBIS) [25], a tool to evaluate risk of bias of systematic review, AMSTAR-2 considered more aspects related to methodological quality, for example, registration and conflict of interest were only included in AMSTAR-2 scale but were related to the quality of systematic review. In addition, AMSTAR-2 provided more specific methods about how to analyze and interpret data than ROBIS.

In this study, we aimed to (1) assess the methodological quality of robotic surgical MAs using AMSTAR-2 and (2) explore potential risk factors associated with the methodological quality of robotic surgical MAs.

2. Methods

2.1. Search strategy

We performed a comprehensive literature search in PubMed, EMBASE, Cochrane Library, and Web of Science databases from their inception dates to November 21, 2017. Search terms included the following text words: “meta*analysis*,” “systematic*,” “robotic*,” “Computer* Surgery,” “remote surgery,” “telerobot*,” and MeSH words: “Robotic Surgical Procedures,” “computer assisted surgery,” and “Meta-analysis as Topic.” No limitation was used. The full search strategies are presented in Appendix S1. An additional search was performed to identify recently published robotic surgical MAs (from November 1, 2017, to September 21, 2018).

2.2. Inclusion and exclusion criteria

The inclusion criteria were (1) populations: patients undergoing surgery; (2) interventions: RS; (3) comparisons: LS/VS, RS, or OS; and (4) study designs: meta-analysis. Studies including the following were excluded: (1) letters, editorials and expert opinions, case reports, abstracts only, and conference proceedings; (2) unable to provide extractable available data; (3) articles published in non-English or non-Chinese language; and (4) articles published before 2015 (because SRs or MAs should be updated within 2 or 3 years according to the Cochrane Handbook for Systematic Reviews of Interventions [version 5.1.0] [26]).

Moreover, if the same author and/or institution was reported in more than one study, only the most recent study or largest population was included.

2.3. Data collection

Data collection consisted of three aspects: general characteristics, methodological quality of MAs, and detailed characters of MAs. Four reviewers (P.J.Y., H.J.L., Y.Q.X., and M.X.L) were trained according to the AMSTAR-2 comprehensive user guide, and previously, a standard form was designed to record the data. Reviewers were divided into two groups and independently screened articles and extracted information. Any discrepancy between reviewers was resolved by discussion or by resorting to a third reviewer (L.Y.) if consensus could not be reached.

General characteristics included (1) first author and year of publication, (2) region and country in which the study was performed, (3) journal, (4) impact factor (IF; these were obtained from the In Cites Journal Citation Reports dataset updated September 9, 2017); and (5) the journal's ranking based on SJR Best Quartile, which was obtained from the latest data (2017) from the SCImago Journal & Country Rank indicator [27]. Journals were classified into Q1−Q4 referring to their SJR Best Quartile.

Detailed characteristics included (1) respective surgical locations, (2) the number of subjects undergoing surgery, (3) the control group (LS, VS, RS, or OS), (4) the design of primary studies (RCTs, quasi-randomized, observational, or mixed), (5) the number of primary studies included in the review, (6) the number of primary studies included in each MA, (7) presence or absence of funding source, (8) presence or absence of preregistration, which referred to an international registry of systematic-review protocols (PROSPERO) database, the Cochrane Collaboration or other platforms for preregistrations [28], (9) the fact that if the study followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; "yes" would involve (a) published journals demanded authors to follow PRISMA and (b) the full text of MAs reported followed PRISMA).

2.4. Assessment of methodological quality

The methodological quality of eligible MAs was independently evaluated by trained reviewers using the latest version of AMSTAR [12]. AMSTAR is a popular instrument for critically appraising systematic reviews of RCTs [25,29]. As an updated version of AMSTAR, AMSTAR-2 will assist in identification of high-quality systematic reviews [12] and appraise systematic reviews that included randomized and/or nonrandomized studies of health care interventions.

AMSTAR-2 contains 16 items, among which seven are critical domains. AMSTAR-2 items may not only be able to give an overall score [30,31] but also an overall rating

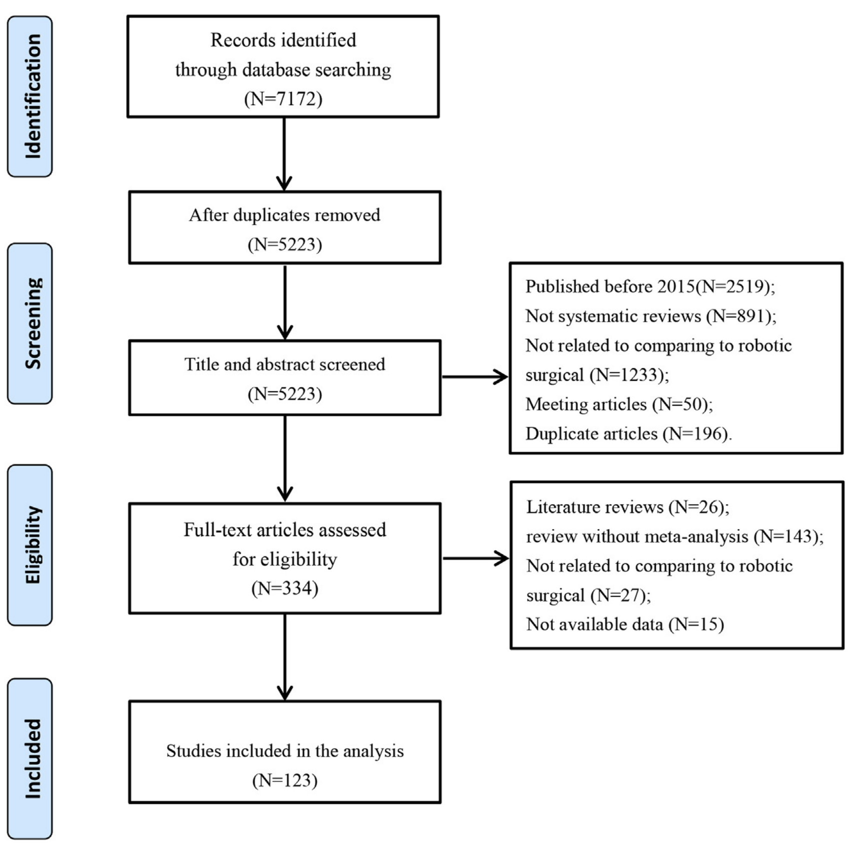

Fig. 1. PRISMA diagram. Selection process of robotic surgical MAs. MA, meta-analyses; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

based on weaknesses in critical domains. Moreover, AMSTAR-2 classifies the overall confidence of the results of the review into four levels: high, moderate, low, and critically low [12]. Discrepancies between reviewers were resolved by discussion or by a third reviewer in cases when a consensus was not reached.

2.5. Assessment of reviewer agreement

To assess the consistency of quantitative measurements in the pre-experiment, the intraclass correlation coefficient (ICC) was used. In brief, four reviewers independently extracted information and assessed the quality of eligible MAs. The ICC values for overall score and score of critical domains were 0.952 and 0.912, respectively.

2.6. Analysis of variables

In this study, we explored the differences of methodological quality of robotic surgical MAs according to (1) publication year, (2) study region, (3) journal rank, (4) following PRISMA, (5) preregistration, (6) RCT enrollment, and (7) funding support. In a previous study, it was shown that the publication year of MAs associated with an increase in AMSTAR score [29]. In addition, previous studies showed that the origin region of MAs development, ranking of journals, whether MAs followed PRISMA, presence or absence of any RCT enrollment, preregistration, and funding source associated with methodological quality in various fields [7,20,29,31−34]. Therefore, the influence of these variables on methodological quality of robotic surgical MAs was included in this study.

2.7. Data analysis

For analysis, data were entered into a spreadsheet program (Microsoft Excel 2013, Microsoft, WA, USA). For accuracy, double entry verification was performed. Statistical analyses and preparation of figures were performed using Stata, version 13 (Stata Corp., College Station, TX, USA). For continuous variables, data were reported either as the mean ± standard deviation or as the median with interquartile range according to normality tests (Kolmogorov−Smirnov and Shapiro−Wilk).

Categorical variables were expressed as frequencies and percentages. Kruskal−Wallis rank test and two-sample Kolmogorov−Smirnov test were used to compare the methodological quality among multifactor variables because the methodological quality was ordered categorical data. RS and LS/VS involved minimally invasive surgeries, and when compared with OS, LS/VS may be associated with less pain, a shorter duration of hospitalization, and a quicker return to function [35]. Therefore, to increase comparability, we compared the methodological quality among multifactor variables in different comparisons of MAs.

Multivariate regression was used to explore the potential factors affecting the methodological quality of robotic surgical MAs, whereas variance inflation factors (VIFs) were used to test the multicollinearity among the explanatory factors in the regression. Data from these analyses were reported as coefficients with 95% confidence intervals (CIs). Statistical comparisons or interactions with $P < 0.05$ were considered statistically significant. For all statistical tests, a two-tailed α level of 0.05 was used.

3. Results

3.1. Selection of studies

Through searches of electronic databases, 7,172 records were obtained. After removing duplicate records, 5,223 records were screened, and after review of titles and abstracts, a total of 4,889 records were excluded. Of the remaining 334 records, the full-text was reviewed, and of these, 123 MAs were included in this work. No additional studies were identified through reference review. The study selection flow is detailed by a PRISMA flow diagram and shown in Figure 1.

3.2. General characteristics

The 123 robotic surgical MAs were published in 74 journals and contained 1,878 primary studies. The number of MAs increased over time except for 2018, as the search date was limited to September 21, 2018. A total of 19 MAs were related to both OS and LS/VS. One MA reported two surgical locations. In addition, 1 MA related to LS/VS reported two surgical locations, and 1 MA related to LS/VS reported 11 surgical locations. Therefore, a total of 155 research objects were collected, among which 51 of the 155 objects were related to OS, and the remaining 104 were related to LS/VS. Detailed characteristics of the 123 robotic surgical MAs are presented in Table 1.

Most MAs originated in Asia (64.2%, $n = 79$), followed by Europe (24.4% $n = 30$). The ranking of MAs by journal impact was as follows: Q1 (50.4%, $n = 62$), Q2 (36.6%, $n = 45$), Q3 (9.8%, $n = 12$), and Q4 (3.3%, $n = 4$). Nearly half (48.8%, $n = 60$) of the MAs followed the PRISMA, and more than one-third (38.2%, $n = 47$) of the MAs enrolled at least one RCT. In addition, less than one-third (29.3%, $n = 36$) of the MAs were supported by at least one funding source, and only eight (6.5%) MAs were preregistered on platforms (six on the PROSPERO database, one on the Cochrane Collaboration, and the other at http://www.researchregistry.com).

3.3. Methodological quality of robotic surgical MAs

Only two (1.6%) MAs were of high-quality, two (1.6%) were of moderate quality, two (1.6%) were of low-quality,

Table 1. Characteristics and methodologic quality for the robotic surgical MAs

Characteristics	*N* (%) (*N* = 123)	Total (*N* = 123)				*P* value
		H (*N* = 2)	M (*N* = 2)	L (*N* = 2)	CL (*N* = 117)	
Publish year						0.619
2015	24 (19.5)	0 (0.0)	0 (0.0)	0 (0.0)	24 (100.0)	
2016	35 (28.5)	0 (0.0)	0 (0.0)	2 (5.7)	33 (94.3)	
2017	42 (34.2)	2 (4.8)	1 (2.4)	0 (0.0)	39 (92.9)	
2018	22 (17.9)	0 (0.0)	1 (4.6)	0 (0.0)	21 (95.5)	
Origin region						<0.001
Asia	79 (64.2)	0 (0.0)	0 (0.0)	1 (1.3)	78 (98.7)	
Europe	30 (24.4)	1 (3.3)	1 (3.3)	0 (0.0)	28 (93.3)	
North America	10 (8.1)	0 (0.0)	0 (0.0)	0 (0.0)	10 (100.0)	
Oceania	4 (3.3)	1 (25.0)	1 (25.0)	1 (25.0)	1 (25.0)	
Journal rank						0.404
Q1	62 (50.4)	2 (3.2)	2 (3.2)	1 (1.6)	57 (91.9)	
Q2	45 (36.6)	0 (0.0)	0 (0.0)	1 (2.2)	44 (97.8)	
Q3	12 (9.8)	0 (0.0)	0 (0.0)	0 (0.0)	12 (100.0)	
Q4	4 (3.3)	0 (0.0)	0 (0.0)	0 (0.0)	4 (100.0)	
PRISMA						0.342
No	63 (51.2)	0 (0.0)	2 (3.2)	61 (96.8)	24 (100.0)	
Yes	60 (48.8)	2 (3.3)	2 (3.3)	0 (0.0)	56 (93.3)	
Preregistration						<0.001
No	115 (93.5)	0 (0.0)	0 (0.0)	2 (1.7)	113 (98.3)	
Yes	8 (6.5)	2 (25.0)	2 (25.0)	0 (0.0)	4 (50.0)	
RCT enrollment						0.019
No	76 (61.8)	0 (0.0)	0 (0.0)	1 (1.3)	75 (98.7)	
Yes	47 (38.2)	2 (4.3)	2 (4.3)	1 (2.1)	42 (89.4)	
Funding support						0.108
No	87 (70.7)	2 (2.3)	2 (2.3)	2 (2.3)	81 (93.1)	
Yes	36 (29.3)	0 (0.0)	0 (0.0)	0 (0.0)	36 (100.0)	

and the remaining 117 MAs (95.1%) were of critical low quality (Table 1).

3.3.1. *Methodological quality of robotic surgical MAs in different control groups*

The number of robotic surgical MAs focused on the RS vs. LS/VS (n = 104) was higher than MAs focused on RS vs. OS (n = 51). Regarding methodological quality, MAs that focused on RS vs. LS/VS were inferior to those MAs focused on RS vs. OS; however, significant difference was not observed (P = 0.28). In the 51 MAs that focused on RS vs. OS, two (3.9%) were of high quality, two (3.9%) were of moderate quality, and the remaining 47 (92.2%) were of critically low quality. Furthermore, of the 104 MAs that focused on RS vs. LS/VS, three (2.9%) were of moderate quality, two (1.9%) were of low quality, and the remaining 99 (95.2%) were of critically low quality (Table 1).

3.3.2. *Methodological quality at different surgical locations*

Figure 2 displays the methodological quality of robotic surgical MAs at different surgical locations. The included MAs focused on 23 surgical locations, among which the top five surgical locations included prostate (11.0%, n = 17), rectum (10.3%, n = 16), bladder (10.3%, n = 16), stomach (8.4%, n = 13), and pancreas (7.1%, n = 11). The quality of MAs in the bladder and prostate was better than at other locations.

The 51 MAs that focused on RS vs. OS related to 18 surgical locations. The five most common locations included bladder, prostate, pancreas, kidney, and thyroid, and MAs in the bladder and prostate were of superior quality, among which two were of high-quality MAs, and two were of moderate quality.

The 104 MAs that focused on RS vs. LS/VS were related to 19 surgical locations. The five most common locations included rectum, stomach, prostate, colon, and lung.

RS vs. OS (N = 51)				RS vs. LS/VS (N = 104)			
H (N = 2)	M (N = 2)	CL (N = 47)	P value	M (N = 3)	L (N = 2)	CL (N = 99)	P value
			0.051				0.731
0 (0.0)	0 (0.0)	11 (100.0)		0 (0.0)	0 (0.0)	17 (100.0)	
0 (0.0)	0 (0.0)	9 (100.0)		0 (0.0)	2 (6.5)	29 (93.6)	
2 (11.1)	2 (11.1)	14 (77.8)		2 (6.7)	0 (0.0)	28 (93.3)	
0 (0.0)	0 (0.0)	13 (100.0)		1 (3.9)	0 (0.0)	25 (96.2)	
			<0.001				<0.001
0 (0.0)	0 (0.0)	32 (100.0)		0 (0.0)	1 (1.5)	65 (98.5)	
1 (9.1)	0 (0.0)	10 (90.9)		1 (4.0)	0 (0.0)	24 (96.0)	
0 (0.0)	0 (0.0)	5 (100.0)		0 (0.0)	0 (0.0)	9 (100.0)	
1 (33.3)	2 (66.7)	0 (0.0)		2 (50.0)	1 (25.0)	1 (25.0)	
			0.283				0.644
2 (6.3)	2 (6.3)	28 (87.5)		3 (5.4)	1 (1.8)	52 (92.9)	
0 (0.0)	0 (0.0)	15 (100.0)		0 (0.0)	1 (2.9)	33 (97.1)	
0 (0.0)	0 (0.0)	4 (100.0)		0 (0.0)	0 (0.0)	10 (100.0)	
—	—	—		0 (0.0)	0 (0.0)	4 (100.0)	
			0.043				0.839
0 (0.0)	0 (0.0)	25 (100.0)		0 (0.0)	2 (4.4)	43 (95.6)	
2 (7.7)	2 (7.7)	22 (84.6)		3 (5.1)	0 (0.0)	56 (94.9)	
			<0.001				<0.001
0 (0.0)	0 (0.0)	45 (100.0)		0 (0.0)	2 (2.1)	95 (97.9)	
2 (33.3)	2 (33.3)	2 (33.3)		3 (42.9)	0 (0.0)	4 (57.1)	
			0.023				0.077
0 (0.0)	0 (0.0)	28 (100.0)		0 (0.0)	1 (1.7)	59 (98.3)	
2 (8.7)	2 (8.7)	19 (82.6)		3 (6.8)	1 (2.3)	40 (90.9)	
			0.163				0.129
2 (5.7)	2 (5.7)	31 (88.6)		3 (4.2)	2 (2.8)	67 (93.1)	
0 (0.0)	0 (0.0)	16 (100.0)		0 (0.0)	0 (0.0)	32 (100.0)	

Abbreviations: CL, critically low; H, high; L, low; LS, laparoscopic surgery; M, moderate; OS, open surgery; PRISMA, preferred reporting items for systematic reviews and meta-analyses; RCT, randomized controlled trials; RS, robotic surgery; VS, video-assisted surgery.

None of these was of high quality, one was of moderate quality; two were of low quality; and the remainders were of critically low quality.

3.3.3. Subgroup analysis by other variables

The methodological quality of MAs was significantly different in origin regions (total: $P < 0.001$; OS was the control group: $P < 0.001$; LS/VS was the control groups: $P < 0.001$) and preregistration (total: $P < 0.001$; OS was the control group: $P < 0.001$; LS/VS was the control groups: $P < 0.001$). In addition, PRISMA was significantly different in the RS vs. OS group ($P = 0.043$). RCT enrollment was significantly different between the total ($P = 0.019$) and RS vs. OS ($P = 0.023$) group. As for other variables, no significant differences were observed (Table 1).

3.4. Multivariate analysis

Considering the stability of the model and the influence of multicollinearity, we used a multiple linear regression model to test variables including publishing year, origin region, journal rank, PRISMA, RCT enrollment, and funding support. The results showed that the publishing year and

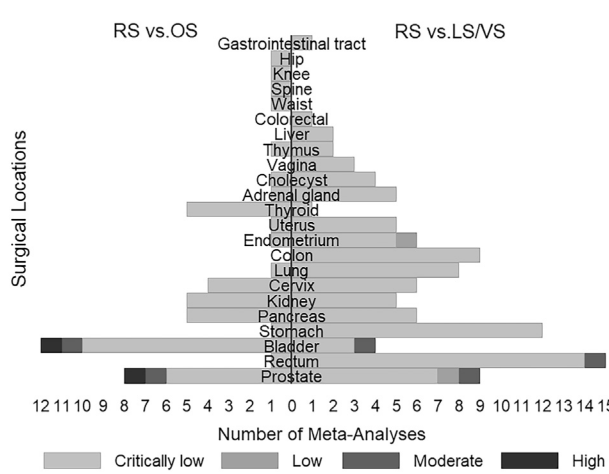

Fig. 2. Methodologic quality for the robotic surgical MAs in different surgical locations. LS, laparoscopic surgery; MAs, meta-analyses; OS, open surgery; RS, robotic surgery; VS, video-assisted surgery.

Table 2. Multiple linear regression analysis of potential factors affecting methodologic quality of robotic surgical MAs (N = 123)

Characteristics	Coefficients	95% CI	*P* value
Publish year (2015)			
2016	1.96	0.85, 3.07	0.001
2017	2.09	0.97, 3.21	<0.001
2018	2.45	1.13, 3.78	<0.001
Origin region (Asia)			
Europe	−0.61	−1.58, 0.35	0.211
North America	−0.77	−2.28, 0.73	0.311
Oceania	1.87	−0.43, 4.17	0.110
Journal rank (Q2)			
Q1	0.92	0.08, 1.77	0.032
Q3	−1.26	−2.67, 0.14	0.077
Q4	−0.83	−3.03, 1.37	0.458
PRISMA (no)			
Yes	0.36	−0.52, 1.24	0.421
RCT enrollment (no)			
Yes	0.43	−0.40, 1.26	0.304
Funding support (no)			
Yes	0.02	−0.86, 0.91	0.958

Abbreviations: CI, confidence interval; MAs, meta-analyses; PRISMA, preferred reporting items for systematic reviews and meta-analyses; RCT, randomized controlled trials.

journal rank were independently associated with methodological quality of the published MAs, whereas origin region ($P > 0.05$), PRISMA ($P = 0.421$), RCT enrollment ($P = 0.304$), and funding support ($P = 0.958$) did not influence the methodological quality of the published MAs (Table 2).

The methodological quality of MAs published in 2018 (coefficient, 2.45; 95% CI, 1.13−3.78; $P < 0.001$), 2017 (coefficient, 2.09; 95% CI, 0.97−3.21; $P < 0.001$), and 2016 (coefficient, 1.96; 95% CI, 0.85−3.07; $P = 0.001$) were superior to MAs published in 2015, and the quality increased over time. No significant differences were observed in methodological quality of MAs that originated in Asia vs. Europe (coefficient, −0.61; 95% CI, −1.58 to 0.35; $P = 0.211$), North America (coefficient, −0.77; 95% CI, −2.28 to 0.73; $P = 0.311$), or Oceania (coefficient, 1.87; 95% CI, −0.43 to 4.17; $P = 0.110$). MAs published in Q2-rated journals had a significantly inferior methodological quality when compared with MAs in Q1-rated journals (coefficient, 0.92; 95% CI, 0.08−1.77; $P = 0.032$) but was similar to those published in Q3-rated journals (coefficient, −1.26; 95% CI, −2.67 to 0.14; $P = 0.077$) and Q4-rated journals (coefficient, −0.83; 95% CI, −3.03 to 1.37; $P = 0.458$; Table 2).

3.5. Adherence of individual items of AMSTAR-2

Figure 3 illustrates the adherence of individual item of AMSTAR-2. Item 1 (PICO: populations, interventions, comparisons, and outcomes, 100%) has the best adherence in two types of MAs, followed by item 16 (conflict of interest), 88.2% in MAs of RS vs. OS and 87.5% in MAs of RS vs. LS/VS. Item 2 (registration) and item 10 (funding reported for individual studies) were found to have the poorest adherence. Details are shown in Appendix S2.

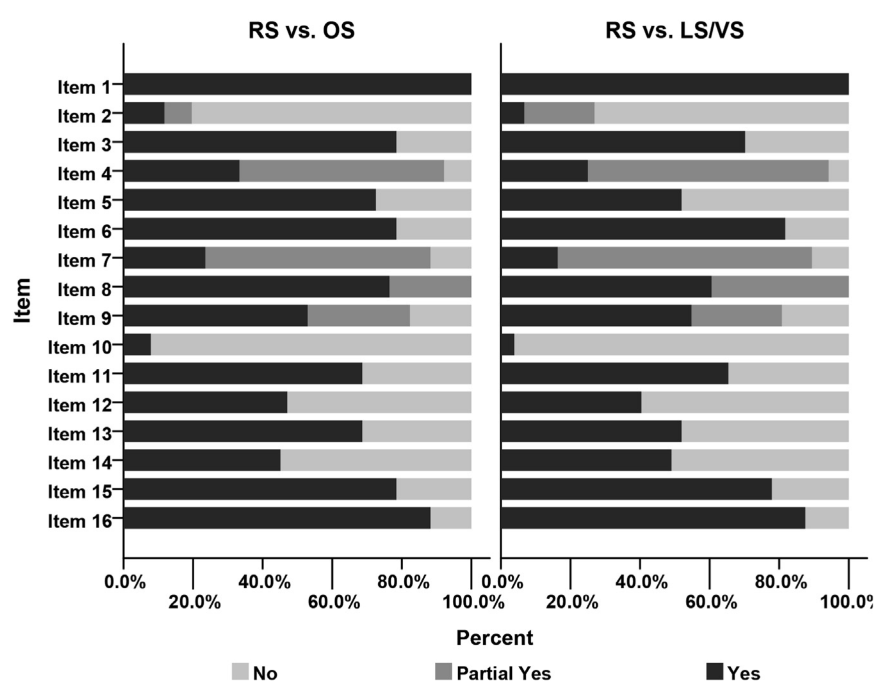

Fig. 3. Adherence of 16 items of AMSTAR-2. LS, laparoscopic surgery; OS, open surgery; RS, robotic surgery; VS, video-assisted surgery.

4. Discussion

4.1. Summary of findings

In this study of robotic surgical MAs published from 2015 to 2018, specific trends in methodological quality were identified, with an increasing improvement over time. However, only two (1.6%) MAs were of high quality, two (1.6%) were of moderate quality, two (1.6%) were of low quality, and the rest 117 (95.1%) were of critical low quality. This indicated suboptimal methodological quality of previously published MAs in the field of RS. The suboptimal quality may be associated with the rank of publishing journals of the MAs. Furthermore, item 2 (registration) and item 10 (funding reported for individual studies) were found to have the poorest adherence.

4.2. Establishment of regression model

Multivariate analysis was performed for the total 123 MAs, but not for the RS vs. OS group, as it only has 51 MAs and is unable to provide sufficient statistical power to establish a regression model. AMSTAR-2 was able to classify the methodological quality of the review results into four levels, which was considered categorical data; therefore, ordinal regression was chosen to evaluate the potential factors of the methodological quality. However, 117 (95.1%) MAs were of critically low level, and the estimated probability for this level will always be one; therefore, there is no need to fit the ordinal regression model. Thus, we selected the overall score as the dependent variable and used multiple linear regression instead.

4.3. Methodological quality of the published RS MAs

In this study, we found that the methodological quality of previously published MAs in the field of RS was prone to be inferior. These findings were consistent with those of a previous study, which specifically focused on appraising the quality of published surgical MAs [32]. Various reasons may explain the inferior methodological quality: (1) the number of RCT in surgery is relatively small, and many surgical MAs only included retrospective or prospective observational studies; (2) RCTs in the surgical field are particularly susceptible to methodological flaws [36], especially in terms of allocation concealment and double-blind, and may significantly influence the quality; (3) the reporting quality of MAs was directly related to the methodological quality [37], and the reporting quality of current surgical MAs remained suboptimal [32].

Although MAs were considered the highest level of evidence as they can increase statistical power and precision of estimates of effects and exposure risks [10], it is essential that the documents are of high quality in both design and methodology. The variation of methodological quality of MAs might lead to different conclusions to the same question [38]. On the other hand, MAs cannot overcome the limitations from heterogeneity and methodological dilemmas. Thus, guideline panels, health professionals, and other stakeholders should be critical and look carefully to the methodological quality of available MAs [12].

4.4. Factors affecting the quality of robotic surgical MAs

In this study, we found that the methodological quality was associated with the publishing journals rank of MAs. Multivariate analyses demonstrated that the quality of MAs published in Q2-rated journals was inferior compared with that of Q1-rated journals but was similar to MAs in Q3-rated and Q4-rated journals. In a previous study, it demonstrated that MAs published in high-ranking journals were of higher methodological quality, which was consistent with our results [32]. In another study on orthodontics, it found that a higher AMSTAR score was associated with both the journal's *h*-index and IF [29]. These findings showed a possible preference of submitting high-quality MAs to journals that are cited more frequently (higher citation rates and IFs) and read by a broader audience [39]. In addition, when compared with low-ranking journals, high-ranking journals tend to have more article submissions, a higher profession of peer reviewers, scrutinized more carefully by editors and outside peer reviewers, and decided more prudent by the editorial boards [32].

In addition, we found that the quality of robotic surgical MAs was not related with the region of origin. Multivariate regression analysis showed that the quality of MAs originated in Europe, North America, and Oceania was similar to those originated in Asia. Two previous studies also showed the methodological quality of MAs originated in Europe seemed to be in concordance with those originated in Asia [29,34]. Furthermore, another study found that the overall methodological and reporting quality of SRs from China and the United States were similar [40]. These findings were in line with data obtained in our study. What should be noticed is that another study divided the region of origin into Asia and non-Asian regions [32], which revealed that the quality of MAs originated in Asia (predominantly China) were somewhat inferior when compared with those in non-Asian regions. The inconformity may be associated with various classifications of region of origin.

A lower rate of protocol usage and reporting of funding source for individual studies were found in robotic surgical MAs, which contributed to the suboptimal quality of MAs. The influence of financial conflicts of interest on research results focused on clinical trials [41–43]. In addition, systematic reviews documented that sponsorship by the pharmaceutical industry was associated with findings that were favorable to the sponsor's product [44,45]. This point was later proven in a Cochrane review [46]. Such influences may not be determined as flaws in design or methods [12] and cannot be explained by standard ''Risk of bias'' assessments [46].

A registry of protocols of MAs should help to optimize the use of finite resources to avoid unnecessary duplication and encourage collaboration [28] and to reduce the selective outcome-reporting bias [12,47]. In addition, in previous studies, it was suggested that MAs that were based on a protocol for guidance had a higher methodological quality compared with others [29,32,48]. Platforms for preregistrations have been provided by several organizations, such as the Cochrane and Campbell Collaborations [49,50], the Joanna Briggs Institute, and PROSPERO [28]. However, in this study, we found that only 6.5% (n = 8) of the 123 MAs were preregistered. Certainly, registry of protocols of MAs is a promising measure worth researchers' attention, which might lead to a significant improvement of quality. Hence, we recommend preregistration to be a mandatory checkpoint for future publishing of MAs.

4.5. Comparison with other studies

To our knowledge, Zhang et al. published a similar article in Journal of Clinical Epidemiology in 2016 [32], which focused on the methodological quality of surgical MAs published in the year 2013 using AMSTAR. However, our study provided more valuable information to readers and users. Firstly, our study yielded the findings based on AMSTAR-2, which is especially applicable to evaluate surgical MAs, as most surgical MAs were based on nonrandomized studies [12]. Secondly, our study could be more comparable and representative for the included MAs pertinent to RS in this study. Moreover, MAs published in 2013 might be outdated according to Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) [26].

4.6. Strengths and limitations

To our knowledge, this is the first study to assess the methodological quality of robotic surgical MAs and investigate the potential factors of the quality of MAs. Moreover, we select AMSTAR-2, a new and more appropriate instrument, to assess the methodological quality of robotic surgical MAs.

However, this study has several limitations. First, only articles written in English or Chinese were enrolled for analysis. This may impair the accuracy of the quality comparison especially when studies from different regions were compared. Second, in the present study, we only addressed the methodological quality of MAs. Reporting quality has a significant impact on the quality of MAs, but we put the PRISMA into the multivariate analysis to control for this effect. Third, the MAs published before 2015 were not included in our study, which might influence the distribution of overall quality. Fourth, although we used the VIFs to test the multicollinearity among factors in the multiple linear regression, and no multicollinearity was found; there may still be potential correlations between several factors. Finally, our study was based on published information, which is a limitation common to the MAs.

5. Conclusion

Although the number and methodological quality of robotic surgical MAs showed a tendency to improve, the previously published MAs lack good scientific quality, especially those published in Q2- to Q4-rated journals. Reporting of funding sources of individual studies and preregistration may be a potential solution to improve the quality of future MAs. Efforts should be made to improve the methodological quality of MAs in the RS field.

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclinepi.2018.12.013.

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