Recommendations for reporting of systematic reviews and meta-analyses of diagnostic test accuracy: a systematic review

Trevor A. McGrath 1, Mostafa Alabousi 2, Becky Skidmore 3, Daniël A. Korevaar 4, Patrick M. M. Bossuyt 4, David Moher 5, Brett Thombs 6 and Matthew D. F. McInnes 7*

Abstract

Background: This study is to perform a systematic review of existing guidance on quality of reporting and methodology for systematic reviews of diagnostic test accuracy (DTA) in order to compile a list of potential items that might be included in a reporting guideline for such reviews: Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy (PRISMA-DTA).

Methods: Study protocol published on EQUATOR website. Articles in full text or abstract form that reported on any aspect of reporting systematic reviews of diagnostic test accuracy were eligible for inclusion. We used the Ovid platform to search Ovid MEDLINE®, Ovid MEDLINE® In-Process & Other Non-Indexed Citations and Embase Classic+Embase through May 5, 2016. The Cochrane Methodology Register in the Cochrane Library (Wiley version) was also searched. Title and abstract screening followed by full-text screening of all search results was performed independently by two investigators. Guideline organization websites, published guidance statements, and the Cochrane Handbook for Diagnostic Test Accuracy were also searched. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Standards for Reporting Diagnostic Accuracy (STARD) were assessed independently by two investigators for relevant items.

Results: The literature searched yielded 6967 results; 386 were included after title and abstract screening and 203 after full-text screening. After reviewing the existing literature and guidance documents, a preliminary list of 64 items was compiled into the following categories: title (three items); introduction (two items); methods (35 items); results (13 items); discussion (nine items), and disclosure (two items).

Conclusion: Items on the methods and reporting of DTA systematic reviews in the present systematic review will provide a basis for generating a PRISMA extension for DTA systematic reviews.

Background

In their 2015 report titled “Improving Diagnosis in Healthcare”, the National Academy of Medicine identified a better understanding of the performance of diagnostic tests as an imminent priority for patient safety [1]. Systematic reviews, which incorporate findings from multiple primary studies, can increase confidence in our understanding of the accuracy of diagnostic tests in detecting medical conditions or diseases [2]. Systematic reviews and meta-analyses are cited more than any other study design and are prioritized in clinical practice guidelines [3–5]. Consistent with this, the number of systematic reviews, including those on diagnostic test accuracy (DTA), has grown extremely rapidly over the past decade [6, 7].

When systematic reviews and meta-analyses are poorly reported, readers are not able to assess the quality of the review and its underlying primary studies or to weigh the applicability of its conclusions. Thus, incomplete or inaccurate reports that do not transparently and completely convey review methods and results may mislead...
readers, rather than clarify the true value of a test. This contributes to waste of scarce medical research resources [8, 9] and hinders efforts to ensure the reproducibility of research. Previous studies have shown that many published DTA systematic reviews are not adequately reported [10, 11].

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement is a 27-item checklist and flow diagram that aims to provide guidance on complete and transparent reporting of systematic reviews [12]. Use of reporting guidelines, such as PRISMA, is associated with more informative reporting of medical research [10]. PRISMA was developed primarily for systematic reviews of medical interventions. While DTA systematic reviews share some common elements with intervention reviews, there are important differences. Thus, some items in the original PRISMA checklist may not apply to DTA reviews, and some essential items necessary for reporting DTA systematic reviews may be lacking [2, 6, 13, 14]. Existing guidance for reporting of DTA systematic reviews is limited to non-systematic “expert opinion” [2, 15, 16], guidance on specific methodologic items [6, 17], or work that is not yet complete [18].

The PRISMA-DTA group is developing an extension for DTA systematic reviews and meta-analyses. As the initial step, we performed a systematic review of existing guidance on reporting of DTA systematic reviews in order to compile a list of potential items that might be included in a reporting guideline for such reviews, the PRISMA extension for DTA (PRISMA-DTA).

Methods
The protocol for this review is available on the EQUATOR network’s website (http://www.equator-network.org/) in “guidelines under development” [19].

Database search
To identify published articles pertaining to reporting of DTA systematic reviews, an experienced medical information specialist (BS) developed a search strategy through an iterative process in consultation with the review team. The strategy was peer-reviewed prior to execution by another senior information specialist using the PRESS checklist [20]. Using the Ovid platform, we searched Ovid MEDLINE® and Ovid MEDLINE® In-Process & Other Non-Indexed Citations and Embase Classic+Embase on May 5, 2016. We also searched the Cochrane Methodology Register in the Cochrane Library, which contains records published July 2012 and earlier, (Wiley version) on the same date. Strategies used a combination of controlled vocabulary (e.g., “Diagnostic Tests, Routine,” “Review Literature as Topic,” “Publication Bias”) and keywords (e.g., “DTA,” “systematic review,” “reporting”). Vocabulary and syntax were adjusted across databases. There were no date or language restrictions on any of the searches. Specific details regarding search strategies appear in Appendix 1.

Inclusion/exclusion criteria, study selection, and data extraction
We included articles in full-text or abstract form that reported on any aspect of reporting DTA systematic reviews. Specifically, we included studies that evaluated the quality of reporting of any aspect of DTA systematic reviews and studies that provided guidance or suggestions as to how a DTA systematic review should be performed.

Titles and abstracts of all search results were screened independently for potential relevance by two investigators (MA, MDFM). For any citation deemed potentially relevant, full texts were retrieved and independently assessed in duplicate for inclusion with disagreements being resolved by consensus (TAM, MDFM). To facilitate the extraction process, studies were divided into several categories pertaining to the specific reporting topics: assessment of quality of reporting, general guidance on performing or reporting DTA systematic reviews, guidance on search methods for primary DTA studies, assessment of heterogeneity, pooling and meta-analysis methods, assessment of publication bias, risk of bias, and “other.” Reference list of included sources is provided in Appendix 2.

In addition to sources related to DTA systematic reviews, the following sources were reviewed: reporting guideline organizations’ websites (Enhancing the QUALity and Transparency of Health Research (EQUATOR) [21]), guidance for reporting systematic reviews and meta-analyses of other types of research (Meta-analysis of Observational Studies in Epidemiology (MOOSE) [22], PRISMA [12], PRISMA extensions [23–27]), guidance for reporting diagnostic test accuracy studies (STARD 2015 [28], STARD for abstracts), guidance for, or tools for assessing the methodologic quality of systematic reviews and meta-analyses (A Measurement Tool to Assess Systematic reviews (AMSTAR) [29], risk of bias in systematic reviews (ROBIS) [30], Methodological Expectations of Cochrane Intervention Reviews (MECIR) [31]), and The Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy (completed chapters) [18]. Post hoc assessment of the following items not included in the initial search was done: the Agency for Healthcare Research and Quality (AHRQ) Methods Guide for Comparative Effectiveness Research, the Institute of Medicine’s 2011 Standards for Systematic Reviews and the Centre for Reviews and Dissemination guidance [32–34]. No additional items were generated from these sources.

The PRISMA and STARD 2015 checklists were initially assessed independently and in duplicate in order to compile a list of potentially relevant items for the PRISMA-DTA
Results

Database search

The database search yielded 6967 results. After title and abstract screening, 386 results remained. This was further reduced to 203 results after full-text screening (Fig. 1).

Identification of potentially relevant items

After searching the existing literature and guidance documents, a preliminary list of 64 unique items was compiled and divided into the following categories mirroring the PRISMA statement: title (three items); introduction (two items); methods (35 items); results (13 items); discussion (nine items), and disclosure (two items). The methods section was further divided into eligibility criteria and search strategy (10 items), study selection and data extraction (seven items), primary study data items that should be provided (one item containing 10 sub-items.), risk of bias and heterogeneity (six items), and summary measures and statistics (11 items). The identified items along with citations for the sources from which they were taken are presented in Table 1; shaded items on the table indicate items specific to diagnostic accuracy systematic reviews, while unshaded items represent more general guidance for systematic reviews.

Items were taken from 19 unique sources with publication dates between 2007 and 2016, a combination of guidance documents and some of the 203 search results. The 19 sources included the PRISMA statement [12], the PRISMA Explanation and Elaboration document [35], STARD 2015 [28], MECIR [31], AMSTAR [36], QUADAS-2 [14], eight research articles [6, 17, 37–42], two reviews [2, 43], two DTA statistical methodology overviews [44, 45], and one conference abstract [46]. Many of the 203 included results contained redundant information; one source was cited per item.

Summary of rationale for relevant items

This section will highlight some of the items that are proposed that have particular relevance to DTA systematic reviews.

Title: The potential items listed in this section aim to clearly identify “big picture” components of study design; this not only allows immediate reader comprehension, but enhances indexing and searchability. Items 1 and 2 are drawn from PRISMA and STARD 2015 and require that the title indicate that the study is a systematic review (item 1) and is a study of diagnostic accuracy (item 2). Item 3 required reporting on whether the study design is comparative (one test vs. another) or non-comparative; comparative design is increasingly important, common, and associated with methodologic challenges [37].

Introduction: Item 4 requires framing the role of the index test in the existing clinical pathway; understanding the clinical role of a test is essential to generalizability of findings. For example, if a test evaluation focuses on a “triage” test (e.g., d-dimer for determination of pre-test probability prior to CT pulmonary angiogram), it may not be appropriate to generalize its use as a “replacement” test (e.g., d-dimer as a replacement for CT). The performance of diagnostic tests is variable depending on the specific clinical scenario [28, 47].

Methods—protocol, eligibility, and search: All items in this section are generalizable to all systematic reviews; none were deemed to be specific to DTA systematic reviews.

Methods—study selection and data collection: Multiple items in this section focus on specific details of the search strategy and are aimed at enhancing reproducibility. None of these is of particular specific relevance to DTA reviews; however, detail additional to that recommended by PRISMA has been listed since subsequent systematic review methodologic recommendations have suggested their inclusion [31].

Methods—primary study data items: Item 25 focuses on which characteristics from primary studies included in a review should be reported. Several aspects of this item are unique to DTA systematic reviews, such as...
| Item | Description | Ref |
|------|-------------|-----|
| 1    | Identify the report as a systematic review, meta-analysis or both | [12] |
| 2    | Identify the report as a study of diagnostic accuracy using at least one measure of accuracy | [28] |
| 3    | State whether the report is a comparative (one diagnostic test vs. another) or a non-comparative review | [37, 38] |
| 4    | State the scientific and clinical background, including the intended use and clinical role of the index test (e.g., triage test, add-on test, or replacement test) | [39] |
| 5    | List review objective using PICO format (participant characteristics, intervention, comparison, outcome) | [12] |
| 6    | Indicate if a review protocol exists, where it can be accessed and, if available, registration number | [12] |
| 7    | Report deviations from the original protocol | [31] |
| 8    | Report which outcomes are considered primary and secondary | [31] |
| 9    | Describe all information sources and the date of search | [12] |
| 10   | Report restrictions to search strategy (language, publication status, dates) | [31] |
| 11   | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated | [12] |
| 12   | Report whether hand searching of reference lists was done | [31] |
| 13   | Describe methods to ensure that overlapping patient populations were identified and accounted for | [31] |
| 14   | List any search of the gray literature including search of study registries | [31] |
| 15   | Specify criteria for eligibility | [12] |
| 16   | Report the process for selecting studies (i.e., screening, full-text eligibility) | [12] |
| 17   | Provide an appendix with studies excluded, with reasons for exclusion, during full-text screening | [12] |
| 18   | Describe method of data extraction from reports | [12] |
| 19   | Report which data items were extracted from included studies | [12] |
| 20   | Report how studies for which only a subgroup of participants is relevant to the review will be handled | [31] |
| 21   | Report how “indeterminate” or “missing” results for either the index test or reference standard were dealt with in the analysis | [40] |
| 22   | Report if and how any parameters beyond test accuracy will be evaluated (e.g., cost-effectiveness, mortality) | [46] |
| 23   | (a) Patient demographic information (age, gender) | [2, 12, 28] |
|      | (b) Target condition definition | |
|      | (c) Index test | |
|      | (d) Reference standard | |
|      | (e) Positivity thresholds | |
|      | (f) Blinding information | |
|      | (g) Clinical setting | |
|      | (h) Disease prevalence | |
|      | (i) Cross-tabulation of index test with reference standard (2 × 2 table) | |
|      | (j) Funding sources | |
| 24   | Report how included individual studies will be assessed for methodological quality (e.g., QUADAS-2) | [14] |
| 25   | Describe if and how “piloting” the risk of bias tool was done | [14] |
| 26   | List criteria used for risk of bias ratings applied during the review | [31] |
| 27   | Describe methods for study quality assessment | [12] |
| 28   | Provide measures of consistency (e.g., $\tau^2$) for each meta-analysis | [12] |
Table 1  Potential relevant items for PRISMA-DTA checklist. Items deemed by the authors to apply specifically to DTA reviews are in **Bold**

(Continued)

| Item | Ref |
|------|-----|
| 29. Describe test used to assess for publication bias | [12] |
| Methods: summary measures and statistics | |
| 30. State the principal summary measures of diagnostic accuracy to be assessed | [28] |
| 31. Report whether summary measures were calculated on a per-patient or per-lesion basis | [31] |
| 32. Report pre-defined criteria for minimally acceptable test performance | [42] |
| 33. State how multiple readers of an index test were accounted for | [17] |
| 34. Report the statistical method used for meta-analysis (e.g., hierarchical model) | [2] |
| 35. State which software package and macros was used for meta-analysis | [6] |
| 36. Report any programming deviations made from published software packages | [6] |
| 37. If comparative design, state the statistical methods used to compare test accuracy | [28] |
| 38. Describe methods of additional analyses (e.g., subgroup), indicating whether pre-specified | [12] |
| 39. Report how subgroup analyses were performed | [31] |
| 40. When performing meta-regression report the form of factors being explored (categorical vs. continuous) and the cut-off points used | [41] |

**Results**

| Item | Ref |
|------|-----|
| 41. Report studies from screen to inclusion, ideally with a flow diagram | [12] |
| 42. For each study, present characteristics for which data were extracted and provide the citations | [12] |
| 43. Present data on risk of bias of each study on a per-item or per-domain basis | [12, 14, 35] |
| 44. Present results of any assessment of publication bias | [12] |
| 45. Report any adverse events or harms from index test or reference standard | [31] |
| 46. For each study report 2 × 2 data (TP, FN, FP, TN) | [43, 45] |
| 47. For each study report summary estimates of accuracy and confidence intervals | [28] |
| 48. Report each meta-analysis including confidence intervals and measures of consistency (e.g., tau2) | [12] |
| 49. Graphically display results with an ROC curve or forest plots of sensitivity and specificity | [44] |
| 50. Report additional analyses (e.g., meta-regression) | [12] |
| 51. Report risk of bias in the synthesis (e.g., analyses stratified by risk of bias) | [31] |
| 52. Report summary of findings table with main outcomes and issues re: applicability of results | [31] |
| 53. Report "frequency" tables of 2 × 2 data demonstrating potential findings in a patient population based on the prevalence | [45] |

**Discussion**

| Item | Ref |
|------|-----|
| 54. Summarize findings including implications for practice | [12, 28] |
| 55. Provide a general interpretation of the results in the context of other evidence and implications for future research | [12] |
| 56. For comparative design, report whether conclusions were based on direct vs. indirect comparisons | [37] |
| 57. Discuss the implications of any missing data | [31] |
| 58. Discuss applicability concerns to different populations/settings | [14, 45] |
| 59. Discuss quality of included studies when forming conclusions | [36] |
| 60. Account for any statistical heterogeneity when interpreting the results | [31] |
| 61. Discuss the potential impact of reporting biases | [31] |
| 62. Discuss the five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness, and publication bias) | [31] |

**Disclosure**

| Item | Ref |
|------|-----|
| 63. Describe sources of funding for the review and role of funders | [12] |
| 64. Report potential relevant conflicts of interest for review investigators | [36] |

*Ref* = source reference(s) for the item
index test, reference standard, target condition definition, test positivity thresholds, and clinical setting. All this information is vital for readers to make an appropriate assessment of the review.

Methods—risk of bias and heterogeneity: Assessment of study quality and heterogeneity are not unique to DTA reviews. However, study quality assessment for diagnostic accuracy studies includes assessment of risk of bias and concerns regarding applicability, thus the quality assessment tool used in DTA reviews should capture and report these issues (item 24) [14]. Additionally, since sensitivity and specificity are correlated, univariate measures of heterogeneity, such as $I^2$, are typically not appropriate to report heterogeneity in diagnostic test accuracy reviews. Thus, heterogeneity may be reported either qualitatively or using measures that account for the correlation between sensitivity and specificity (item 28) [2].

Methods—summary statistics: Multiple readers may interpret an index test. How this is accounted for statistically may affect the results and, therefore, should be reported (item 33) [17]. An important difference in DTA meta-analysis from interventions is the correlation between sensitivity and specificity. Thus, it is very important to report the statistical model used for meta-analysis so readers can determine the impact of these methods on the results (item 34) [6].

Results: In order to facilitate reproduction of analyses and to make it clear to the readers which data was meta-analyzed, 2 x 2 data for each study included in meta-analyses should be made available (item 46) [43, 45].

Discussion and disclosure: All items in this section are generalizable to all systematic reviews; none was deemed to be specific to DTA systematic reviews.

Discussion
We consulted existing guidance on the reporting of systematic reviews and the published literature related to the conduct and reporting of DTA systematic reviews to identify 64 potential items for reporting DTA systematic reviews. The systematic, comprehensive search categorized by manuscript section builds on prior work, which has been based on non-systematic searches and expert opinion. The items identified will form the basis of a Delphi process. Wording of items as presented here may also be adjusted at the PRISMA-DTA consensus meeting. Therefore, it is advised to consult the final checklist after it has been published for use in guiding reporting systematic reviews of diagnostic test accuracy.

This evaluation improves on prior work, which has largely been based on non-systematic reviews, and expert opinion. The work is a small but essential step towards a clear reporting guideline for DTA systematic reviews. Future work should not only include creating the PRISMA-DTA checklist, but evaluating for “baseline” adherence to PRISMA-DTA in order to guide knowledge translation interventions aimed at targeted improvements for reporting of DTA systematic reviews.

Strengths and limitations
This systematic review benefits from a comprehensive, expert, peer-reviewed search, duplicate extraction, and categorization of potentially relevant items by manuscript section which mirrors the format of the PRISMA checklist. Limitations of our systematic review are that we did not formally assess the quality of sources for included items, we provide only a qualitative summary, and we may not have identified potentially relevant items from work yet to be published. We believe that many of these shortcomings will be addressed in the process for generation of the PRISMA-DTA checklist as outlined in our complete study protocol [48].

Conclusions
The reporting of DTA systematic reviews is often incomplete [10, 11, 49]. Incomplete reporting has been identified as a preventable source of waste in biomedical research [43]. Therefore, a reporting guideline specific to DTA systematic reviews is needed to reduce waste, increase utility, and facilitate reproducibility of these reviews. This systematic review is the first step towards gathering all relevant evidence pertinent to reporting of DTA systematic reviews. This step is critical in the EQUATOR network's established guidance for reporting guidelines development [50]. This information will serve as the substrate for a PRISMA-DTA extension to guide reporting of DTA systematic reviews and will complement the more than 300 reporting guidelines indexed by the EQUATOR Network [21].

Appendix 1
Search Strategy 2016 May 5 Ovid Multifile Database: Embase Classic+Embase <1947 to 2016 May 04>, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1946 to Present>

Search Strategy:

1 “Diagnostic Techniques and Procedures”/ (80885)
2 exp Diagnostic Imaging/ (2015520)
3 “Diagnostic Tests, Routine”/ (73316)
4 (diagnos* adj3 test*).tw,kw. (153714)
5 (diagnos* adj3 accura*).tw,kw. (155998)
6 (test* adj3 accura*).tw,kw. (29472)
7 (diagnos* adj3 compar*).tw,kw. (53752)
8 diagnostic stud$3.tw,kw. (12147)
| ID | Search Hits |
|----|-------------|
| #1 | [mh "Diagnostic Techniques and Procedures"] 116 |
| #2 | [mh “Diagnostic Imaging”] 35671 |
| #3 | [mh “Diagnostic Tests, Routine”] 328 |
| #4 | (diagnos* near/3 test*):ti,ab,kw 6315 |
| #5 | (diagnos* near/3accura*):ti,ab,kw 5863 |
| #6 | (test* near/3accura*):ti,ab,kw 3703 |
| #7 | (diagnos* near/3 compar*):ti,ab,kw 1936 |
| #8 | (diagnos next (study or studies)):ti,ab,kw 189 |
| #9 | DTA:ti,ab,kw 22 |
| #10 | (DTAR or DTARs):ti,ab,kw 2 |
| #11 | in Methods Studies 521 |

Methods – 521
Appendix 2

Table 2 List of 203 included studies

| 1. A. Hoyer, O. Kuss. Meta-analysis of diagnostic tests accounting for disease prevalence: a new model using trivariate copulas. Statistics in medicine. 2015///. 34:1912 |
| 2. A.D. Kester, F. Buntinx. Meta-analysis of ROC curves. Medical Decision Making. 2000///. 20:430 |
| 3. A.H. Zwinderman, P.M. Bossuyt. We should not pool diagnostic likelihood ratios in systematic reviews. Statistics in medicine. 2008///. 27:687 |
| 4. A.K. Nikoloulopoulos. A mixed effect model for bivariate meta-analysis of diagnostic test accuracy studies using a copula representation of the random effects distribution. Statistics in medicine. 2015///. 34:3842 |
| 5. A.N.A. Tosteson, C.B. Begg. A general regression methodology for ROC curve estimation. Medical Decision Making. 1988///. 8:204 |
| 6. A.S. Midgelet, T.A. Stukel, B. Littenberg. A meta-analytic method for summarizing diagnostic test performance: receiver-operating characteristic summary point estimates. Medical Decision Making. 1993///. 13:253 |
| 7. A.S. Rosman, M.A. Korsten. Application of summary receiver operating characteristic (sROC) analysis to diagnostic clinical testing. Advances in medical sciences. 2007///. 52:76 |
| 8. Alvaro Najib Atallah, Andrea Puchnick, Daniel Wu, David Carlos Shigueoka, Gianni Mara Silva dos Santos, Hernani Pinto de Jr. Lemos, Jose Eduardo Mourao, Wagner lared. Remarks about systematic reviews of diagnostic tests. Sao Paulo medical journal = Revista paulista de medicina. 2012///. 130:279 |
| 9. Athina Tatsioni, Deborah A. Zarin, Naomi Aranson, David J. Samson, Carole R. Flamm, Christopher Schmid, Joseph Lau. Challenges in meta-analyses of diagnostic test accuracy: a review of the literature. Annals of internal medicine. 2005///. 142:1048 |
| 10. B. Littenberg, L.E. Moses. Estimating diagnostic accuracy from multiple conflicting reports: a new meta-analytic method. Medical decision making: an international journal of the Society for Medical Decision Making. 1993///. 13:313 |
| 11. B. Opmeer, J. Reitsma, K. Broeze, B.W. Mol. The relation between heterogeneity in diagnostic accuracy, prevalence and patient characteristics: an illustration with individual patient data meta-analysis. Oral presentation at the 17th Cochrane Colloquium; 2009 Oct 11-14, Madrid, Spain [abstract]. #journal#. 2011///. Suppl1:9 |
| 12. B.D. Thombs, E. Arthurs, G. El-Baalbaki, A. Meijer, R.C. Ziegelstein, R.J. Steele. Risk of bias from inclusion of patients who already have diagnosis or are undergoing treatment for depression in diagnostic accuracy reviews of screening tools for depression: systematic review. BMJ (Online). 2011///. 343:no |
| 13. Behrouz Kassai, Sandrine Sonie, Nirav R. Shah, Jean Pierre Boissel. Literature search parameters marginally improved the pooled estimate accuracy for ultrasound in detecting deep venous thrombosis. Journal of clinical epidemiology. 2006///. 59:710 |
| 14. Ben A. Dwarmena. Evidence-based radiology: step 3—diagnostic systematic review and meta-analysis (critical appraisal). Seminars in roentgenology. 2009///. 44:170 |
| 15. Bhurke S. Parekh, C.S. Kwok, C. Pang, L. Hooper, Y.K. Loke, J.J. Ryder, A.J. Sutton, C.B. Hing, I. Harvey, F. Song. Uptake of methods to deal with publication bias in systematic reviews has increased over time, but there is still much scope for improvement. Journal of clinical epidemiology. 2011///. 64:349 |
| 16. Brian H. Willis, Christopher J. Hyde. Estimating a test’s accuracy using tailored meta-analysis-how setting-specific data may aid study selection. Journal of clinical epidemiology. 2014///. 67:538 |
| 17. Brian H. Willis, Christopher J. Hyde. What is the test’s accuracy in my practice population? Tailored meta-analysis provides a plausible estimate. Journal of clinical epidemiology. 2015///. 68:847 |

Table 2 List of 203 included studies (Continued)

| 18. Brian H. Willis, Muireann Quigley. The assessment of the quality of reporting of meta-analyses in diagnostic research: a systematic review. BMC medical research methodology. 2011///. 11:163 |
| 19. Brian H. Willis, Muireann Quigley. Uptake of newer methodological developments and the deployment of meta-analysis in diagnostic test research: a systematic review. BMC medical research methodology. 2011///. 11:27 |
| 20. Byron C. Wallace, Christopher H. Schmid, Joseph Lau, Thomas A. Trikalinos. Meta-analyst: software for meta-analysis of binary, continuous and diagnostic data. BMC medical research methodology. 2009///. 9:80 |
| 21. C. Davenport, C. Hyde. To what extent is the clinical context considered in diagnostic test accuracy reviews?: a methodological review. Oral presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22, Madrid, Spain [abstract]. #journal#. 2011///. Suppl9 |
| 22. C. Schmid, M. Chung, A. Tatsioni, L.L. Price, J. Lau. Evaluating heterogeneity in studies of diagnostic test accuracy [abstract]. #journal#. 2006///. #volume#:38 |
| 23. C. Schmid, M. Chung, P. Chew, J. Lau. Survey of diagnostic test meta-analyses [abstract]. #journal#. 2004///. #volumel#:50 |
| 24. C.B. Begg. Meta-analysis methods for diagnostic accuracy. Journal of clinical epidemiology. 2008///. 61:1081 |
| 25. C.M. Jones, T. Athanasiou. Diagnostic accuracy meta-analysis: review of an important tool in radiological research and decision making. The British journal of radiology. 2009///. 82:441 |
| 26. C.M. Rutter, C.A. Gatsonis. A hierarchical regression approach to meta-analysis of diagnostic test accuracy evaluations. Statistics in medicine. 2001///. 20:2865 |
| 27. Christiana A. Naaktgeboren, Wynanda A. van Enst, Eleanor A. Ochodo, Joris A.H. de Groot, Lotty Hooft, Mariska M. Leeflang, Patrick M. Bossuyt, Karel G.M. Moons, Johannes B. Reitsma. Systematic overview finds variation in approaches to investigating and reporting on sources of heterogeneity in systematic reviews of diagnostic studies. Journal of clinical epidemiology. 2014///. 67:1200 |
| 28. Collin B. Begg. Systematic reviews of diagnostic accuracy studies require study by study examination: first for heterogeneity, and then for sources of heterogeneity. Journal of clinical epidemiology. 2005///. 58:865 |
| 29. Constantine Gatsonis, Prashti Paliwal. Meta-analysis of diagnostic and screening test accuracy evaluations: methodologic primer. AJR american journal of roentgenology. 2006///. 187:271 |
| 30. D. Bohning, W. Bohning, H. Holling. Revisiting Youden’s index as a useful measure of the misclassification error in meta-analysis of diagnostic studies. Statistical methods in medical research. 2008///. 17:543 |
| 31. D. Stengel, K. Bauwens, J. Sehouli, A. Ekkernkamp, F. Porzolt. A likelihood ratio approach to meta-analysis of diagnostic studies. Journal of medical screening. 2003///. 10:497 |
| 32. D.L. Simel, P.M. Bossuyt. Differences between univariate and bivariate models for summarizing diagnostic accuracy may not be large. Journal of clinical epidemiology. 2009///. 62:1292 |
| 33. D.S. MacDonald-Jankowski, M.F. Dozier. Systematic review in diagnostic radiology. Dento maxillo facial radiology. 2001///. 30:78 |
| 34. Danielle B. Rice, Ian Shrier, Lorie A. Klaoda, Andrea Benedetti, Brett D. Thombs. Methodological quality of meta-analyses of the diagnostic accuracy of depression screening tools. Journal of psychosomatic research. 2016///. 94:84 |
| 35. Danlu Liu, Jin Xiaojin, Jinhui Tian, Kehu Yang. Quality assessment and factor analysis of systematic reviews and meta-analyses of endoscopic ultrasound diagnosis. PLoS one. 2015///. 10:e0120911 |
| 36. Deville, L.M. Bouter, P.D. Bezemer, N. Yzemans, van der-Windt DAWM. Heterogeneity in systematic reviews of diagnostic studies [abstract]. #journal#. 1999///. #volume#:38 |

Page 8 of 15
Table 2 List of 203 included studies (Continued)

37. E.C. Varmavakas. Meta-analyses of studies of the diagnostic accuracy of laboratory tests: a review of the concepts and methods. Archives of pathology & laboratory medicine. 1998///. 122:675

38. Eleanor A. Ochodo, Johannes B. Reitsma, Patrick M. Bossuyt, Mariska M.G. Leeffang. Survey revealed a lack of clarity about recommended methods for meta-analysis of diagnostic accuracy data. Journal of clinical epidemiology. 2013///. 66:1281

39. Eleanor A. Ochodo, Wynanda A. van Enst, Christiana A. Naaktgeboren, Joris A.H. de Groot, Lotty Hooft, Karel G.M. Moons, Johannes B. Reitsma, Patrick M. Bossuyt, Mariska M.G. Leeffang. Incorporating quality assessments of primary studies in the conclusions of diagnostic accuracy reviews: a cross-sectional study. BMC medical research methodology. 2014///. 14:33

40. Elodie Pambrou, Vincent Bouteloup, Rodolphe Thiebaut, Julien Asselineau, Victor de LEDinghen, Paul Perez, Steering Committee of the Transient Elastography Individual Patient Data meta-analysis Study (TE IPD Study). On the validity of meta-analyses: exhaustivity must be warranted, exclusion of duplicate patients too. Journal of clinical epidemiology. 2010///. 63:342

41. Erich P. Huang, Xiao Feng Wang, Kingskhu Roy Choudhury, Lisa M. McShane, Mithat Gonen, Jingjie Ye, Andrew J. Buckler, Paul E. Kinahan, Anthony P. Reeves, Edward F. Jackson, Alexander R. Guimaeraes, Gudrun Zahnmann, Meta-Analysis Working Group. Meta-analysis of the technical performance of an imaging procedure: guidelines and statistical methodology. Statistical methods in medical research. 2015///. 24:141

42. F. Grossenbacher, M. Battaglia, A. Duss, D. Pewsner, H. Bucher, M. Egger. Searching for diagnostic test evaluations: the importance of specialist journals and databases. #journal#. 2002///. #volume#:47

43. F.M. Chapple, G.M. Raab, J.M. Wardlaw. When are summary ROC curves appropriate for diagnostic meta-analyses? Statistics in medicine. 2009///. 28:2653

44. Francesco Sardanelli, Humayun Bashir, Dominik Berzacyz, Guglielmo Cannella, Ansagor Espeland, Nicola Flor, Thomas Helbich, Myriam Hunink, Dermot E. Malone, Ritse Mann, Claudia Muzzupappa, Lars J. Petersen, Katrine Riklund, Luca M. Sconfini, Zbigniew Serafin, Sandra Sprod, Jaap Stoker, Edwin J.R. van Beek, Dierk Vorwerk, Giovanni Di Leo. The role of imaging specialists as authors of systematic reviews on the technical performance of an imaging procedure: guidelines and its impact on scientific quality: report from the EuroEAM Evidence-based Radiology Working Group. Radiology. 2014///. 272:533

45. Fujian Song, Khalid S. Khan, Jacqueline Dinnes, Alex J. Sutton. Asymmetric funnel plots and publication bias in meta-analyses of diagnostic accuracy. International journal of epidemiology. 2002///. 31:88

46. G. Ritchie, J. Glanville, C. Lefebvre. Do published search filters to identify diagnostic test accuracy studies perform adequately? Health information and libraries journal. 2007///. 24:188

47. Gary H. Lyman, Benjamin Djulbegovic. The challenge of systematic reviews of diagnostic and staging studies in cancer. Cancer treatment reviews. 2005///. 31:628

48. Geert Jan Geersing, Walter Bouwmeester, Peter Zuilhof, Rene Spijker, Mariska Leeffang, Karel G.M. Moons, Karel Moons. Search filters for finding prognostic and diagnostic prediction studies in Medline to enhance systematic reviews. PLoS one. 2012///. 7.e32844

49. Georg M. Schuett, Peter Schlattmann, Marc Dewey. Use of 3 x 2 tables with an intention to diagnose approach to assess clinical performance of diagnostic tests: meta-analytical evaluation of coronary CT angiography studies. BMJ (Clinical research ed). 2012///. 345:e6717

50. Gerald W. Smetana, Craig A. Umscheid, Stephanie Chang, David B. Matchar. Methods guide for authors of systematic reviews of medical tests: a collaboration between the Agency for Healthcare Research and Quality (AHRQ) and the Journal of General Internal Medicine. Journal of general internal medicine. 2012///. 27 Suppl 1:51

Table 2 List of 203 included studies (Continued)

51. Gerta Rucker, Martin Schumacher. Summary ROC curve based on a weighted Youden index for selecting an optimal cutoff in meta-analysis of diagnostic accuracy. Statistics in medicine. 2010///. 29:3069

52. H. Chu, L. Nie, S.R. Cole, C. Poole. Meta-analysis of diagnostic accuracy studies accounting for disease prevalence: alternative parameterizations and model selection. Statistics in medicine. 2009///. 28:2384

53. H. Chu, S.R. Cole. Bivariate meta-analysis of sensitivity and specificity with sparse data: a generalized linear mixed model approach. Journal of clinical epidemiology. 2006///. 59:1331

54. H. Putter, M. Fiocco, T. Stijnen. Meta-analysis of diagnostic test accuracy studies with multiple thresholds using survival methods. Biometrical journal. Biometrische Zeitschrift. 2010///. 52:95

55. H.C. de Vet, T. van der Weijden, J.W. Muris, J. Heyrman, F. Buntinx, J.A. Knottnerus. Systematic reviews of diagnostic research. Considerations about assessment and incorporation of methodological quality. European journal of epidemiology. 2001///. 17:301

56. H.C. de Vet, T. Weijden, J.W. Muris, J. Heyrman, F. Buntinx, J.A. Knottnerus. Systematic reviews of diagnostic research considerations about assessment and incorporation of methodological quality. European journal of epidemiology. 2001///. 17:301

57. Hailtuo Chu, Hongfei Guo, Yiie Zhou. Bivariate random effects meta-analysis of diagnostic studies using generalized linear mixed models. Medical decision making: an international journal of the Society for Medical Decision Making. 2010///. 30:499

58. Hailtuo Chu, Hongfei Guo. A unification of models for meta-analysis of diagnostic accuracy studies. Biostatistics (Oxford, England). 2009///. 10:201

59. Honest Honest, Khalid S. Khan. Reporting of measures of accuracy in systematic reviews of diagnostic accuracy. BMC health services research. 2002///. 24

60. I. Nicolau, D. Ling, L. Tian, C. Lienhardt, M. Pai. Quality and reporting of measures of accuracy in systematic reviews of diagnostic accuracy. Journal of clinical epidemiology. 2011///. 173:3317

61. Issa J. Dahabreh, Mei Chung, Georgios D. Kitsios, Teruhiko Terasawa, Gowni Raman, Athina Tatsioni, Arnette Tobor, Joseph Lau, Thomas A. Trikalinos, Christopher H. Schmid. Survey of the methods and reporting practices in published meta-analyses of test performance: 1987 to 2009. Research synthesis methods. 2013///. 4:242

62. J. Boissel, M. Cucherat. The meta-analysis of diagnostic test studies. European radiology. 1998///. 8:484

63. J. Burch, M. Westwood, Weiser K. Soares. Should data from case-controlled studies be included in systematic reviews alongside diagnostic cohort studies? [abstract]. #journal#. 2006///. #volume#:86

64. J. Crossen, B.W. Mol, J. Post, Riet G. Ter. Is it necessary to perform full text papers selection by two independent reviewers in systematic reviews on diagnostic accuracy? [abstract]. #journal#. 2004///. #volume#:117

65. J. Deeks, A. Rutjes, J. Reitsma, M. Leeffang, P. Bossuyt. Statistical methods for investigating heterogeneity related to methodological quality in meta-analyses of studies of diagnostic accuracy [abstract]. #journal#. 2005///. #volume#:47

66. J. Deeks, P. Macaskill, L. Irwig. By how much does publication bias affect the results of systematic reviews of diagnostic test accuracy? [abstract]. #journal#. 2004///. #volume#:48

67. J. Deeks, P. Macaskill, L. Irwig. Detecting publication bias in systematic reviews of diagnostic test accuracy [abstract]. #journal#. 2004///. #volume#:47

68. J. Dinnes, J. Deeks, J. Kirby, P. Roderick. A methodological review of how heterogeneity has been examined in systematic reviews of diagnostic test accuracy. Health technology assessment (Winchester, England). 2005///. 9:1
Table 2 List of 203 included studies (Continued)

87. Johannes B. Reitsma, Karel G.M. Moons, Patrick M.M. Bossuyt, Kristian Linnet. Systematic reviews of studies quantifying the accuracy of diagnostic tests and markers. Clinical chemistry. 2012///. 58:1534

88. Jonathan J. Deeks, Petra Macaskill, Les Irwig. The performance of tests of publication bias and other sample size effects in systematic reviews of diagnostic test accuracy was assessed. Journal of clinical epidemiology. 2005///. 58:882

89. Joris Menten, Emmanuel Lesaffre. A general framework for comparative Bayesian meta-analysis of diagnostic studies. BMC medical research methodology. 2015///. 15:70

90. Juneyoung Lee, Kyung Won Kim, Sang Hyun Choi, Jimi Huh, Seong Ho Park. Systematic review and meta-analysis of studies Evaluating diagnostic test accuracy: a practical review for clinical researchers-part II. Statistical Methods of Meta-Analysis. Korean journal of radiology. 2015///. 16:1188

91. K. Bawens, A. Ekkernkamp, D. Stengel. QUADAS: early experience with a new methodological scoring tool for diagnostic meta-analyses [abstract]. #journal#. 2005///. #volume#:#4

92. K. Russell, N. Hooton, S. Blitz, C. Spooner, J. Beach, B. Rowe. Should sensitivities derived from 2 × 1 tables be included in diagnostic systematic reviews? A review of systematic reviews [abstract]. #journal#. 2005///. #volume#:#125

93. K.E. Hartmann, D.B. Matchar, S. Chang. Chapter 6: Assessing applicability of medical test studies in systematic reviews. Journal of general internal medicine. 2012///. 27:539

94. K.S. Khan, J. Dinnes, J. Kleijnen. Systematic reviews to evaluate diagnostic tests. European Journal of Obstetrics Gynecology and Reproductive Biology. 2001///. 95:6

95. K.S. Khan, L.M. Bachmann, Riet G. Ter. Systematic reviews with individual patient data meta-analysis to evaluate diagnostic tests. European Journal of Obstetrics Gynecology and Reproductive Biology. 2003///. 108:121

96. Khalid S. Khan. Systematic reviews of diagnostic tests: a guide to methods and application. Best practice & research. Clinical obstetrics & gynecology. 2005///. 19:37

97. L. Chong, R. Sun. Methodological developments and statistic software used in diagnostic systematic reviews in China. Poster presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. Suppl:144

98. L. Irwig, A.N. Tosteson, C. Gatsonis, J. Lau, G. Colditz, T.C. Chalmers, F. Mosteller. Guidelines for meta-analyses evaluating diagnostic tests. Annals of internal medicine. 1994///. 120:667

99. L. Irwig, P. Macaskill, P. Glasziou, M. Fahey. Meta-analytic methods for diagnostic test accuracy. Journal of clinical epidemiology. 1995///. 48:119

100. L. Manchikanti, R. Derby, L. Wolfer, V. Singh, S. Datta, J.A. Hirsch. Evidence-based medicine, systematic reviews, and guidelines in interventional pain management: part 7: systematic reviews and meta-analyses of diagnostic accuracy studies. Pain physician. 2009///. 12:929

101. L.E. Moses, D. Shapiro, B. Littenberg. Combining independent studies of a diagnostic test into a summary ROC curve: data-analytic approaches and some additional considerations. Statistics in medicine. 1993///. 12:1293

102. L.M. Bachmann, P. Estermann, C. Kronenberg, Riet G. Ter. Identifying diagnostic accuracy studies in EMBASE. #journal#. 2003///. 91:341

103. L.M. Bachmann, R. Coray, P. Estermann, Riet G. Ter. Identifying diagnostic studies in MEDLINE: reducing the number needed to read. #journal#. 2002///. 9:653

104. Long Ge, Jian Cheng Wang, Jin Long Li, Li Liang, Ni An, Xin Tong Shi, Yin Chun Liu, Jin Hui Tian. The assessment of the quality of reporting of systematic reviews/meta-analyses in diagnostic tests published by authors in China. PloS one. 2014///. 9:e85908
Table 2: List of 203 included studies (Continued)

- M. Hellmich, K.R. Abrams, A.J. Sutton, Bayesian approaches to meta-analysis of ROC curves. Medical Decision Making. 1999///. 19:252

- M. Kastner, N.L. Wilczynski, A.K. McKibbon, A.X. Garg, R.B. Haynes. Diagnostic test systematic reviews: bibliographic search filters ("Clinical Queries") for diagnostic accuracy studies perform well. Journal of clinical epidemiology. 2009///. 62:974

- M. Lassere. Pooled metaanalysis of radiographic progression: comparison of Sharp and Larsen methods. The Journal of rheumatology. 2000///. 27:269

- M. Leeflang, P.M. Bossuyt, L. Invig. Sensitivity and specificity do vary with disease prevalence: implications for systematic reviews of diagnostic test accuracy [abstract]. #journal#. 2006///. volume#85

- M. Leeflang, R. Scholten, H. Reitsma, J. Rutjes, J. Deeks, P. Bossuyt. Incorporating methodological quality in meta-analyses of diagnostic accuracy studies [abstract]. #journal#. 2005///. volume#81

- M. Lassere. Pooled metaanalysis of radiographic progression: comparison of Sharp and Larsen methods. The Journal of rheumatology. 2000///. 27:269

- M. Leeflang, P.M. Bossuyt, L. Invig. Sensitivity and specificity do vary with disease prevalence: implications for systematic reviews of diagnostic test accuracy [abstract]. #journal#. 2006///. volume#85

- M. Leeflang, R. Scholten, H. Reitsma, J. Rutjes, J. Deeks, P. Bossuyt. Incorporating methodological quality in meta-analyses of diagnostic accuracy studies [abstract]. #journal#. 2005///. volume#81

- M. Leeflang, R. Scholten, R. Reitsma, H. Rutjes, P. Bossuyt. Should diagnostic search filters be used in systematic reviews? [abstract]. #journal#. 2004///. volume#74

- M. Pai, L. Flores, A. Hubbard, L. Riley, J. Colford. Quality assessment in meta-analyses of diagnostic studies: what difference does email contact with authors make? [abstract]. #journal#. 2003///. volume#36

- M. Pai, M. McCulloch, W. Eanoria, Jr. Colford. Systematic reviews of diagnostic test evaluations: what's behind the scenes?. Evidence-based medicine. 2004///. 9:101

- M. Pennant, S. Wisniewski, C. Hyde, C. Davenport, J. Deeks. A tool to improve efficiency and quality in the production of protocols for Cochrane Reviews of Diagnostic Test Accuracy. Poster presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. Suppl65

- M. Wei, M. Liu. The current status of systematic reviews on diagnostic tests published in Chinese [abstract]. #journal#. 2007///. volume#170

- M. Westwood, P. Whiting, J. Cooper, J. Kleijnen. Using the QUADAS tool in the conduct of systematic reviews of diagnostic tests [abstract]. #journal#. 2003///. volume#15

- M. Westwood, P. Whiting. Should systematic reviews of diagnostic tests go beyond test accuracy? Poster presentation at the 16th...
Table 2 List of 203 included studies (Continued)

141. P. Whiting, A. Rutjes, M. Westwood, S. Mallett, J. Deeks, J. Reitsma, M. Leeflang, J. Sterne, P. Bossuyt. QUADAS-2: an updated quality assessment tool for diagnostic accuracy studies. Oral presentation at the 19th Cochrane Colloquium: scientific evidence for healthcare quality and patient safety; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. Suppl:14

142. P. Whiting, M. Westwood, J. Deeks, R. Harbord, L. Bachmann, M. Egger, J. Sterne. Graphical presentation of diagnostic information: a methodological review [abstract]. #journal#. 2005///. #volume#:109

143. P. Whiting, M. Westwood, M. Burke, J. Sterne, J. Glanville. Is it necessary to search a wide range of databases to identify diagnostic test accuracy studies? [abstract]. #journal#. 2006///. #volume#:89

144. P. Whiting, R. Gupta, J. Burch, J. Kleijnen, A. Marson, C. Forbes. What to do with non 2 x 2 data from a diagnostic systematic review? An example from a review on identifying the seizure focus in patients with epilepsy [abstract]. #journal#. 2004///. #volume#:203

145. P.E. Verde. Meta-analysis of diagnostic test data: a bivariate Bayesian modeling approach. Statistics in medicine. 2010///. 29:3088

146. P.F. Whiting, J.A. Sterne, M.E. Westwood, L.M. Bachmann, R. Harbord, M. Egger, J.J. Deeks. Graphical presentation of diagnostic information. BMC medical research methodology. 2008///. 8:20

147. P.F. Whiting, M.E. Westwood, M. Burke, J.A.C. Sterne, J. Glanville. Can diagnostic filters offer similar sensitivity and a reduced number needed to read compared to searches based on index test and target condition? Oral presentation at the 16th Cochrane Colloquium: Evidence in the era of globalization; 2008 Oct 3-7; Freiburg, Germany [abstract]. Zeitschrift für Evidenz, Fortbildung und Qualitat im Gesundheitswesen. 2008///. 102:10

148. P.Lina Santaguida, Crystal M. Riley, David B. Matchar. Chapter 5: assessing risk of bias as a domain of quality in medical test studies. Journal of general internal medicine. 2012///. 27 Suppl:153

149. P.M.M. Bossuyt. Informative reporting of systematic reviews in radiology. Radiology. 2013///. 269:313

150. Paul Christian Burkner, Philipp Doebler. Testing for publication bias in diagnostic meta-analysis: a simulation study. Statistics in medicine. 2014///. 33:3061

151. Paul Cronin, James V. Rawson. Review of research reporting guidelines for radiology researchers. Academic radiology. 2016///. 23:537

152. Penny F. Whiting, Anne W.S. Rutjes, Marie E. Westwood, Susan Mallett, Jonathan J. Deeks, Johannes B. Reitsma, Bettina Reitsma, Mariska M.G. Leeflang, Jonathan A.C. Sterne, Patrick M.M. Bossuyt, QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Annals of internal medicine. 2011///. 155:529

153. Penny F. Whiting, Marie E. Westwood, Anne W.S. Rutjes, Johannes B. Reitsma, Patrick M.M. Bossuyt, Jos Kleijnen. Evaluation of QUADAS, a tool for the quality assessment of diagnostic accuracy studies. BMC medical research methodology. 2006///. 6:9

154. Penny Whiting, Anne W.S. Rutjes, Jacqueline Dinnes, Johannes B. Reitsma, Patrick M.M. Bossuyt, Jos Kleijnen. A systematic review finds that diagnostic reviews fail to incorporate quality despite available tools. Journal of clinical epidemiology. 2005///. 58:1

155. Penny Whiting, Anne W.S. Rutjes, Johannes B. Reitsma, Patrick M.M. Bossuyt, Jos Kleijnen. The development of QUADAS: a tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. BMC medical research methodology. 2005///. 3:25

156. Penny Whiting, Marie Westwood, Margaret Burke, Jonathan Sterne, Julie Glanville. Systematic reviews of test accuracy should search a range of databases to identify primary studies. Journal of clinical epidemiology. 2008///. 61:357

157. Penny Whiting, Marie Westwood, Rebecca Beynon, Margaret Burke, Jonathan Ac Sterne, Julie Glanville. Inclusion of methodological filters in searches for diagnostic test accuracy studies misses relevant studies. Journal of clinical epidemiology. 2011///. 64:602

Table 2 List of 203 included studies (Continued)

158. Penny Whiting, Roger Harbord, Jos Kleijnen. No role for quality scores in systematic reviews of diagnostic accuracy studies. BMC medical research methodology. 2005///. 5:19

159. Peter Schlattmann, Maryna Verba, Marc Dewey, Mario Walther. Mixture models in diagnostic meta-analyses—clustering summary receiver operating characteristic curves accounted for heterogeneity and correlation. Journal of clinical epidemiology. 2015///. 68:61

160. R. Beynon, M. Leeflang, A. Eisinga, S. McDonald, R. Mitchell. A systematic review of studies that develop or evaluate search filters for the retrieval of diagnostic studies in MEDLINE. Oral presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. Suppl:20

161. R. Harbord, L. Bachmann, A. Shang, P. Whiting, J. Deeks, M. Egger, J. Sterne. An empirical comparison of methods for meta-analysis of studies of diagnostic accuracy [abstract]. #journal#. 2005///. #volume#:46

162. R. Harbord, L. Bachmann, J. Deeks, P. Whiting, M. Egger, J. Sterne. Meta-analysis of studies of diagnostic accuracy: a unified approach [abstract]. #journal#. 2005///. #volume#:45

163. R.D. Riley, S.R. Dodd, J.V. Craig, J.R. Thompson, P.R. Williamson. Meta-analysis of diagnostic test studies using individual patient data and aggregate data. Statistics in medicine. 2008///. 27:6111

164. Richard D. Riley, Ikhlaaq Ahmed, Joie Ensor, Yemisi Takwoingi, Amanda Kirkham, R.Katie Morris, J.Pieter Noordzij, Jonathan J. Deeks. Meta-analysis of test accuracy studies: an exploratory method for investigating the impact of missing thresholds. Systematic reviews. 2015///. 4:12

165. R.D. Riley, S.R. Dodd, J.V. Craig, P.R. Williamson. Meta-analysis of diagnostic test studies using individual patient data and aggregate data. Oral presentation at the 16th Cochrane Colloquium: evidence in the era of globalization; 2008 Oct 3-7; Freiburg, Germany [abstract]. Zeitschrift für Evidenz, Fortbildung und Qualitat im Gesundheitswesen. 2008///. 102:28

166. R.M. Harbord, J.J. Deeks, M. Egger, P. Whiting, J.A. Sterne. A unification of models for meta-analysis of diagnostic accuracy studies. Biostatistics (Oxford, England). 2007///. 8:239

167. Rachel Mann, Simon M. Gilbody. Should methodological filters for diagnostic test accuracy studies be used in systematic reviews of psychometric instruments? A case study investigating screening for postnatal depression. Systematic reviews. 2012///. 1:9

168. Rebecca Beynon, Mariska M.G. Leeflang, Steve McDonald, Anne Eisinga, Ruth L. Mitchell, Penny Whiting, Julie M. Glanville. Search strategies to identify diagnostic accuracy studies in MEDLINE and EMBASE. The Cochrane database of systematic reviews. 2013///. 9:MR000022

169. Richard D. Riley, Ikhlaaq Ahmed, Thomas P.A. Debray, Brian H. Willis, J.Pieter Noordzij, Julian P.T. Higgins, Jonathan J. Deeks. Summarising and validating test accuracy results across multiple studies for use in clinical practice. Statistics in medicine. 2015///. 34:2081

170. Roger M. Harbord, Penny Whiting, Jonathan A.C. Sterne, Matthias Egger, Jonathan J. Deeks, Aijing Shang, Lucas M. Bachmann. An empirical comparison of methods for meta-analysis of diagnostic accuracy showed hierarchical models are necessary. Journal of clinical epidemiology. 2008///. 61:1095

171. S. Halligan. Systematic reviews and meta-analysis of diagnostic tests. Clinical radiology. 2005///. 60:977

172. S. Mallett, J. Deeks, D. Altman. Treatment of heterogeneity in systematic reviews of diagnostic tests in cancer [abstract]. #journal#. 2004///. #volume#:159

173. S. Mallett, N. Summerton, J. Deeks, S. Halligan, D. Altman. Systematic reviews of diagnostic tests in cancer: assessment of methodology and reporting quality [abstract]. #journal#. 2003///. #volume#:15

174. S. Sandberg. Systematic reviews of diagnostic tests—a new challenge for laboratory medicine. Scandinavian Journal of Clinical and Laboratory Investigation. 1997///. 57:369
study variability. Binomial distribution of meta-analysis was preferred to model within-

Biometrics. Research synthesis methods. Multiple tests.

Terrin, Christopher H. Schmid. Methods for the joint meta-analysis of
diagnostic tests in cancer: review of methods and reporting. BMJ Clinical research
ed. 2008///. 28:639

V. Hasselblad, L.V. Hedges. Meta-analysis of screening and diagnos-
tic studies [abstract]. #journal#. 1997///. #volume#:8

T.H. Hamza, H.C. Houwelingen, M.H. Heijenbrok-Kal, T. Stijnen. As-
sociating explanatory variables with summary receiver operating charac-
teristic curves in diagnostic meta-analysis. Journal of clinical epidemiology. 2009///. 62:1284

T.H. Hamza, J.B. Reitsma, T. Stijnen. Meta-analysis of diagnostic studies: a comparison of random intercept, normal-normal, and
binomial-normal bivariate summary ROC approaches. Medical Decision Making. 2008///. 28:639

T.H. Hamza, L.R. Arends, H.C. Houwelingen, T. Stijnen. Multivariate random effects meta-analysis of diagnostic tests with multiple thresh-
olds. BMC medical research methodology. 2009///. 9:73

Taye H. Hamza, Hans C. van Houwelingen, Theo Stijnen. The binomial distribution of meta-analysis was preferred to model within-
study variability. Journal of clinical epidemiology. 2008///. 61:41

Thomas A. Trikalinos, David C. Hoaglin, Kevin M. Small, Norma Terrin, Christopher H. Schmid. Methods for the joint meta-analysis of
multiple tests. Research synthesis methods. 2014///. 5:294

V. Dukic, C. Gatsonis. Meta-analysis of diagnostic test accuracy assess-
ment studies with varying number of thresholds. Biometrics. 2003///. 59:936

V. Hasselblad, L.V. Hedges. Meta-analysis of screening and diagnos-
tic tests. Psychological bulletin. 1995///. 117:167

V. Veljanovitch. Meta-analysis for combining Bayesian probabilities. #journal#. 1991///. 35:192

W. Devill. Meta-analysis of diagnostic research: does an optimal weight factor exists? #journal#. 2000///. #volume#:34

W. Devill, N. Zeremans, L.M. Boutier, P.D. Bezemert, D.A.W. Windt. Heterogeneity in systematic reviews of diagnostic studies [abstract]. #journal#. 1999///. #volume#:3 #pages# 19

W. Ern, R.P.M. Scholten, L. Hooff. Could a search for a diagnostic test accuracy review be restricted to MEDLINE? Oral presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. #volume#:Suppl#19

W.Annefloer van Enst, Eleanor Ochodo, Rob J.P.M. Scholten, Lotty Hooff, Mariska M. Leeflang. Investigation of publication bias in meta-
analyses of diagnostic test accuracy: a meta-epidemiological study. BMC medical research methodology. 2014///. 14:70

W.L. Devill. Pooling diagnostic publications: watch for outliers! [abstract]. #journal#. 1997///. #volume#:280

W.L. Devill, F. Buntinx. Guidelines for conducting systematic reviews of studies evaluating the accuracy of diagnostic tests. #journal#. 2002///. #volume#:145

W.P. Oosterhuis, R.W. Niessen, P.M. Bossuyt. The science of systematic reviewing studies of diagnostic tests. Clinical chemistry and
laboratory medicine. 2008///. 38:577

Walter L. Devill, Frank Buntinx, Lex M. Bouter, Victor M. Montori, Henrica C.W. de Vet, Danielle A.W.M. van der Windt, P.Dick Bezemert. Conducting systematic reviews of diagnostic studies: didactic guidelines. BMC medical research methodology. 2002///. 2:9

William Hollingsworth, L.Santiago Medina, Robert E. Lenkinski, Dean K. Shibata, Byron Bernal, David Zurakowski, Bryan Comstock, Jeffrey G. Jarvik. Interrater reliability in assessing quality of diagnostic accuracy studies using the QUADAS tool. A preliminary assessment. Academic radiology. 2006///. 13:803

Wynanda Annefloer van Enst, Christiana A. Naaktgeboren, Eleanor A. Ochodo, Joris A.H. de Groot, Mariska M. Leeflang, Johannes B. Reitsma, Rob J.P.M. Scholten, Karel G.M. Moons, Aeilko H. Zwinderman, Patrick M.M. Bossuyt, Lotty Hooff. Small-study effects and time trends in diagnostic test accuracy meta-analyses: a meta-epidemiological study. Systematic reviews. 2015///. #volume#:4 #issue#:6

Yemisi Takwoingi, Mariska M.G. Leeflang, Jonathan J. Deeks. Empirical evidence of the importance of comparative studies of diagnostic test accuracy. Annals of internal medicine. 2013///. 158:544

Yemisi Takwoingi, Richard D. Riley, Jonathan J. Deeks. Meta-
analysis of diagnostic accuracy studies in mental health. Evidence-based mental health. 2015///. 18:103

Z. Zhelev, R. Garside, C. Hyde. Investigating and improving the understanding of Cochrane diagnostic test accuracy reviews. Oral presentation at the 19th Cochrane Colloquium; 2011 Oct 19-22; Madrid, Spain [abstract]. #journal#. 2011///. Suppl#8

Zhiivo Zhelev, Ruth Garside, Christopher Hyde. A qualitative study into the difficulties experienced by healthcare decision makers when reading a Cochrane diagnostic test accuracy review. Systematic reviews. 2013///. #volume#:2 #issue#:3 #pages# 232

Abbreviations
AHRQ: Agency for Healthcare Research and Quality; AMSTAR: A Measurement Tool to Assess Systematic reviews; DTA: Diagnostic test accuracy;
EQUATOR: Enhancing the QUALity and Transparency Of health Research;
MECIR: Methodological Expectations of Cochrane Intervention Reviews;
MOOSE: Meta-analysis of Observational Studies in Epidemiology; PRESS: Peer Review of Electronic Search Strategies; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PRISMA-DTA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy; QUADAS: QUAliity Assessment of Diagnostic Accuracy Studies; ROBIS: Risk of Bias in Systematic Reviews; STARD: Standards for Reporting Diagnostic Accuracy

Acknowledgements
Not Applicable.

Availability of data and materials
Data not provided in this manuscript or related appendices is available from the authors on request.

Authors’ contributions
TAM, MA, BS, and MDFM contributed to the data collection. TAM and MDFM contributed to the data analysis. MDFM is the guarantor of the entire study. All authors have substantial contributions to study protocol design and approval, manuscript revision, and approval of final version of the manuscript.
Funding
Canadian Institute for Health Research (Grant Number 375751).
Canadian Agency for Drugs and Technologies in Health (CADTH).
STAndards for Reporting of Diagnostic accuracy studies group (STARD).
University of Ottawa Department of Radiology Research Stipend Program.

Ethics approval and consent to participate
Ethical approval is not required for this type of study at the authors’ institutions.

Consent for publication
All authors provide consent for publication.

Competing interests
David Moher is Editor-in-Chief of Systematic Reviews. No other relevant competing interests.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
1Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada. 2Department of Radiology, McMaster University, Hamilton, ON, Canada. 3Ottawa Hospital Research Institute, Ottawa, ON, Canada. 4Department of Clinical Epidemiology, Biostatistics and Bioinformatics, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands. 5Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON, Canada. 6Lady Davis Institute of the Jewish General Hospital and Department of Psychiatry, McGill University, Montreal, Quebec, Canada. 7University of Ottawa Department of Radiology, Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON, K1Y 4E9, Canada.

Received: 4 July 2017 Accepted: 28 September 2017
Published online: 10 October 2017

References
1. Singh H, Graber ML. Improving diagnosis in health care—the next imperative for patient safety. N Engl J Med. 2015;373:2493–5.
2. Mclnnes MD, Bossuyt PM. Pitfalls of systematic reviews and meta-analyses in imaging research. Radiology. 2015;277:23–21.
3. Patsopoulos NA, Analatos AA, Ioannidis JP. Relative citation impact of various study designs in the health sciences. JAMA. 2005;292:2362–6.
4. Harbour R, Miller J. A new system for grading recommendations in evidence based guidelines. BMJ. 2001;323:334–6.
5. Institute of Medicine (US) Committee on Standards for Developing Trustworthy Clinical Practice Guidelines. Clinical Practice Guidelines We Can Trust. National Academies Press (US). 2011. https://www.ncbi.nlm.nih.gov/books/NBK209539/.
6. McGrath TA, Mclnnes MD, Korevaar DA, Bossuyt PM. Meta-analyses of diagnostic accuracy in imaging journals: analysis of pooling techniques and their effect on summary estimates of diagnostic accuracy. Radiology. 2016;281:78–85.
7. Bastian H, Glasziou P, Chalmers I. Seventy-five trials and eleven systematic reviews a day: how will we ever keep up? PLoS Med. 2010;7:e1000326.
8. Chalmers I, Glasziou P. Avoidable waste in the production and reporting of meta-analyses of health care interventions: checklist and explanations. Ann Intern Med. 2015;162:777–84.
9. Shamsie R, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA, Group P-P. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 2015, 349:g7647.
10. Stewart LA, Clarke M, Rovers M, Riley RD, Simmonds M, Stewart G, Tierney JF, Group P-ID. Preferred Reporting Items for Systematic Review and Meta-Analyses of individual participant data: the PRISMA-IPD Statement. JAMA. 2015;313:1657–65.
11. Welch V, Petticrew M, Tugwell P, Moher D, O'Neill J, Waters E, White H. Group P-EB. PRISMA-Equity 2012 extension: reporting guidelines for systematic reviews with a focus on health equity. PLoS Med. 2012;9:e1001333.
12. Beller EM, Glaziou PP, Altman DG, Hopewell S, Bastian H, Chalmers I, Gatzke PC, Lasserson T, Tovey D, Group PIA. PRISMA for abstracts: reporting systematic reviews in journal and conference abstracts. PLoS Med. 2013;10:e1001419.
13. Bossuyt PM, Reitsma JB, Rovers M, Glasziou CA, Glaziou PP, Irwig L, Iljner JG, Moher D, Rennie D, de Vet HC, et al. STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. Radiology. 2015;277:826–32.
14. Shea BJ, Bouter LM, Peterson J, Boers M, Andersson N, Ormio Z, Ramsay T, Bai A, Shukla VK, Grimshaw JM. External validation of a measurement tool to assess systematic reviews (AriASTAR). PLoS One. 2007;2:e1350.
15. Whiting PF, Savovć J, Higgins JP, Caldwell DM, Reeves BC, Shea B, Davies P, Kleijnen J, Churchill R, group R. ROBIS: a new tool to assess risk of bias in systematic reviews was developed. J Clin Epidemiol. 2016;69:225–34.
16. Chandler J, Churchill R, Higgins J, Lasserson T, Tovey D. Methodological standards for the conduct of new Cochrane Intervention Reviews (MECIR). The Cochrane Collaboration; 2013. http://methods.cochrane.org/meicr.
17. Quality AFHRa: Methods Guide for Evaluation and Effective Reporting Effective Reviews. 2008.
18. Research IoMUcoF5RcoCE: Finding What Works in Health Care: standards for systematic reviews. National Academies Press; 2011. https://www.nap.edu/read/13059/chapter/1.
19. Dissemination CFRa: Systematic Reviews: CRD’s guidance for undertaking reviews in health care. York University, 2009. https://www.york.ac.uk/media/crd/Systematic_Reviews.pdf.
20. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gatche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting system...
systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol. 2009;62:e1–34.

36. Shea BJ, Grimshaw JM, Wells GA, Boers M, Andersson N, Hamel C, Porter AC, Tugwell P, Moher D, Bouter LM. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol. 2007;7:10.

37. Takwoingi Y, Leeflang MM, Deeks JJ. Empirical evidence of the importance of comparative studies of diagnostic test accuracy. Ann Intern Med. 2013;158:544–54.

38. Menten J, Lesaffre E. A general framework for comparative Bayesian meta-analysis of diagnostic studies. BMC Med Res Methodol. 2015;15:70.

39. Leeflang MM, Rutjes AW, Reitsma JB, Hooft L, Bossuyt PM. Variation of a test’s sensitivity and specificity with disease prevalence. CMAJ. 2013;185:ES37–44.

40. Staub LP, Dyer S, Lord SJ, Simes RJ. Linking the evidence: intermediate outcomes in medical test assessments. Int J Technol Assess Health Care. 2012;28:52–8.

41. Naaktgeboren CA, van Enst WA, Ochodo EA, de Groot JA, Hooft L, Leeflang MM, Bossuyt PM, Moons KG, Reitsma JB. Systematic overview finds variation in approaches to investigating and reporting on sources of heterogeneity in systematic reviews of diagnostic studies. J Clin Epidemiol. 2014;67:1200–9.

42. McGrath T, McInnes MDF, van Es N, Leeflang MMG, Korevaar DA, Bossuyt PMM. Overinterpretation of research findings: evidence of “spin” in systematic reviews of diagnostic accuracy studies. Clin Chem. 2017;63:770–7.

43. Glasziou P, Altman DG, Bossuyt PM, Bouter LM, Clarke M, Jülliers S, Michie S, Moher D, Wager E. Reducing waste from incomplete or unusable reports of biomedical research. Lancet. 2014;383:267–76.

44. Takwoingi Y, Riley RD, Deeks JJ. Meta-analysis of diagnostic accuracy studies in mental health. Evid Based Ment Health. 2015;18:103–9.

45. Riley RD, Ahmed I, Debray TP, Willis BH, Noodzij JP, Higgins JP, Deeks JJ. Summarising and validating test accuracy results across multiple studies for use in clinical practice. Stat Med. 2015;34:2081–103.

46. Westwood M, Whiting P. Should systematic reviews of diagnostic tests go beyond test accuracy? In 16th Cochrane Colloquium: evidence in the era of globalisation; Freiburg, Germany. 2008. https://www.york.ac.uk/inst//crd/Posters/Shoul%20Systematic%20Review%20%20Diagnostic%20%20Test%20%20Accuracy.pdf.

47. Cohen JF, Korevaar DA, Altman DG, Bruns DE, Gatsonis CA, Hooft L, Irwig L, Levine D, Reitsma JB, de Vet HC, Bossuyt PM. STARD 2015 guidelines for reporting diagnostic accuracy studies: explanation and elaboration. BMJ Open. 2016;6:e012799.

48. McInnes M, Altman DG, Bossuyt P. Development and implementation of a reporting guideline for systematic reviews and meta-analyses of diagnostic accuracy studies. The PRISMA-DTA initiative. 2016.

49. Willis BH, Quigley M. Uptake of newer methodological developments and the deployment of meta-analysis in diagnostic test research: a systematic review. BMC Med Res Methodol. 2011;11:27.

50. Moher D, Schulz KF, Simera I, Altman DG. Guidance for developers of health research reporting guidelines. PLoS Med. 2010;7:e1000217.