Optimal search strategies for retrieving scientifically strong studies of diagnosis from Medline: analytical survey

R Brian Haynes, Nancy L Wilczynski for the Hedges Team

Abstract

Objective To develop optimal search strategies in Medline for retrieving sound clinical studies on the diagnosis of health disorders.

Design Analytical survey.


Participants 170 journals for 2000 of which 161 were indexed in Medline.

Main outcome measures The sensitivity, specificity, precision ("positive predictive value"), and accuracy of 4862 unique terms in 17 287 combinations were determined by comparison with a hand search of all articles (the "gold standard") in 161 journals published during 2000 (49 028 articles).

Results Only 147 (18.9%) of 778 articles about diagnostic tests met basic criteria for scientific merit. Combinations of search terms reached peak sensitivities of 98.6% at a specificity of 74.3%. Compared with best single terms, best multiple terms increased sensitivity for sound studies by 6.8% (absolute increase), while also increasing specificity (absolute increase 6.0%) when sensitivity was maximised. When terms were combined to maximise specificity, the single term, specificity, was 98.4%, outperformed combinations of terms. The strategies newly reported in this paper outperformed other validated search strategies except for one strategy that had slightly higher sensitivity (99.3% vs 98.6%) but lower specificity (54.7% vs 74.3%).

Conclusion New empirical search strategies in Medline can optimise retrieval of articles reporting high quality clinical studies of diagnosis.

Introduction

Accurate diagnosis is the cornerstone of decision making for clinical intervention and is increasingly important as the number of validated treatments for specific conditions increases. Clinical research, usually widely accessible first in the biomedical journal literature, provides quantitative information about the sensitivity, specificity, and predictive value of many clinical and diagnostic tests, but this information is buried in a much larger biomedical literature. A recent survey showed that clinicians are highly interested in using evidence based information and frequently use Medline. Information pertaining to diagnosis is second most commonly sought by clinicians after treatment.

Finding the current best evidence in Medline for a diagnostic process is daunting, given that Medline has over 11 million articles from over 4500 journals, covering all aspects of biomedical and health research. A recent qualitative study found that two of the six obstacles to answering clinical questions with evidence were the time required to find information and the difficulty in selecting an optimal search strategy. Even clinicians who in principle support the use of evidence for patient care often do not have time to find and apply it in practice. When they do try, searches are not performed effectively.

Search filters ("hedges") can improve the retrieval of clinically relevant and scientifically sound studies from Medline and similar databases. For instance, when we searched Medline for studies on the diagnosis of arthritis from 1996 to the present using the term "arthritis", 7083 articles alone were retrieved; using "arthritis and diagnosis" yielded 3451 articles. Although this filtered out over half the articles, there were still many articles to sort through, with no guarantee that the most rigorous studies would be retrieved. More sophisticated search filters can be created by combining disease content terms with medical subject headings, explosions, publication types, subheadings, and textwords (see box). These detect design features indicating methodological rigour for applied healthcare research using such terms as "gold standard" as a filter, seeking studies in which a test of uncertain value is compared with one of known high accuracy.

In the early 1990s our group at McMaster University developed search filters on a small subset of 10 journals and for four types of article (therapy, diagnosis, prognosis, and causation (aetiology)). These strategies have been adapted for use in the Clinical Queries interface of Medline (www.ncbi.nlm.nih.gov/entrez/query/static/clinical.html). This research is being updated and expanded with data from 161 journals indexed in Medline from 2000. The robustness of empirical search strategies developed in 1991 for detecting clinical content in Medline in 2000 has already been reported. We report on the information retrieval properties of single terms and combinations of terms in Medline for identifying methodologically sound studies on the diagnosis of health disorders.

Methods

We developed search strategies by using methodological search terms and phrases in a subset of Medline records matched with a handsearch of the contents of 161 journal titles for 2000. The search strategies were treated as diagnostic tests for sound studies, and the manual review of the literature was treated as the gold standard. It is potentially confusing to use the terminology of diagnostic testing for assessing strategies for retrieving articles about diagnostic tests, especially when some of the search terms are the same. Nevertheless, the principles for retrieval are the
same as those for diagnosis. Thus we determined the sensitivity, specificity, accuracy, and precision (a library science term equivalent to the diagnostic test term "positive predictive value") of single term and multiple term Medline search strategies (table 1 and box). Sensitivity and specificity are not affected by the proportion of high quality articles in the database; precision depends on this proportion, and so does accuracy, but to a lesser extent.

After extensive attempts only 2% (n = 968) of the handsearch items did not match citations in Medline. Unmatched citations that were detected by a search strategy were included in cell b of the analysis table (table 1), leading to slight underestimates of the precision, specificity, and accuracy of the search strategy. Similarly, unmatched citations that were not detected by a search strategy were included in cell d of the table, leading to slight overestimates of specificity and accuracy.

Manual review
Six research assistants reviewed all issues of 170 journals for 2000 of which 161 were indexed in Medline. The journal titles were regularly reviewed for content for four evidence based journals prepared by our group, Evidence-Based Medicine, Evidence-Based Nursing, Evidence-Based Mental Health, and ACP journal Club, according to an explicit process that assesses the scientific merit and clinical relevance of original and review articles. These journals (examples bracketed) include content on critical appraisal of the healthcare literature, and the second to fourth criteria have been empirically validated.16 17 The research assistants were rigorously calibrated and periodically checked for application of criteria to determine if each article was methodologically sound for any of six categories of purpose (diagnosis and screening, treatment and prevention, prognosis, aetiology and harm, clinical prediction guides, and economics).18 Inter-rater agreement for identifying the purpose of articles was 81% beyond chance (κ 0.81, 95% confidence interval 0.79 to 0.84). Inter-rater agreement for which articles met all scientific criteria was 89% beyond chance (κ 0.89, 0.78 to 0.99).19 Articles that seemed to pass the criteria were reviewed by at least the lead author (RBH).

Collecting search terms
To construct a comprehensive set of possible search terms, we listed MeSH terms and textwords related to study criteria and then sought input from clinicians and librarians through interviews, requests by email and at meetings and conferences, review of published and unpublished searching strategies from other groups, and requests to Medline experts. Individuals were asked what terms or phrases they used when searching for each category. Terms could be subject headings, publication types, check tags, and subheadings, or could be single words or phrases as textwords, denoting their presence in titles and abstracts of articles. Various truncations were also applied to the textwords, as textwords, denoting their presence in titles and abstracts of articles. Various truncations were also applied to the textwords, phrases, and MeSH terms. We compiled a list of 5395 terms of which 4862 were unique. All terms were tested in all purpose categories using the Ovid Technologies searching system. Optimised strategies for aetiology and studies of clinical prediction guides have been published elsewhere.19 20

Data collection
Data collection forms were used to record handsearched data for each article found in each issue of the 161 journal titles. These data were scanned using Teleform software (Cardiff Software; Vista, CA). After verification of the data online, the handsearch data were written to an Access database (Microsoft). Each journal title was searched in Medline for 2000, and the full Medline records were captured for all articles in the journals. Medline data were then linked with the handsearch data.

Testing strategies
We calculated the sensitivity, specificity, precision, and accuracy for each term for each category of article. For some categories of articles, such as therapy, we were able to split the database into 60% and 40% components to provide a development and validation database. For diagnosis, however, this was not possible as there were an insufficient number of diagnosis articles that were considered methodologically rigorous. Individual search terms with a sensitivity of more than 25% and a specificity of more than 75% for the diagnosis category were incorporated into the development of search strategies that included a combi-
nation of two or more terms. All combinations of terms used the Boolean OR—for example, “sensitivity OR specificity”.

For the development of multiple term search strategies to optimise either sensitivity or specificity, we tested the combination of individual terms with all two term search strategies with sensitivity at least 75% and specificity at least 50%. For optimising accuracy, two term search strategies with accuracy of more than 75% were considered for multiple term development. Overall, we tested 17 287 multiple term search strategies. Search strategies were also developed that optimised combined sensitivity and specificity (equivalent to the optimal point on a receiver operating characteristic curve, minimising the total number of errors).

Results

Overall, 49 028 articles were included in the analysis. Of these, 778 (1.6% of original studies and review articles, case reports, or general interest papers) were classified as original studies evaluating a diagnosis question, of which 147 (18.9%) met the methodological criteria.

Table 2 shows the operating characteristics for the single terms with the highest sensitivity and specificity. The best accuracy when keeping sensitivity to 50% or more was seen with the term “specificity.tw.” (tw. is Ovid search system’s syntax for searching all words in the title and abstract of an article).

Tables 3 and 4 show the strategies yielding the highest sensitivity and specificity based on testing of all strategies for combinations up to three terms. Some one term and two term strategies outperformed multiple term strategies (table 4). Because of the low prevalence of diagnosis articles, the accuracy of search terms is driven by their specificity, and thus the three search strategies yielding the highest accuracy are the same as those yielding the highest specificity (table 4). Table 5 shows the three search strategies best optimising the trade-off between sensitivity and specificity.

Logistic regression modelling did not lead to the development of search strategies that outperformed those already developed using the Boolean approach.

We used our data to test 10 published strategies and one previously unpublished strategy for retrieving diagnostic test studies from Medline. Two strategies were modified slightly to eliminate the content words in the search strategies. When we used our handsearch data, the published and unpublished strategies containing only methodological terms had a sensitivity range of 85.0% to 99.3%. One strategy had slightly higher sensitivity (99.3%) than our most sensitive strategy (98.6%), but it came with a large trade-off for specificity (54.7%), compared with

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### Table 2: Best single terms for high sensitivity searches, high specificity searches, and searches that optimise the balance between sensitivity and specificity for retrieving studies of diagnosis. Values are percentages (95% confidence intervals)

<table>
<thead>
<tr>
<th>Search strategy in Ovid format</th>
<th>Sensitivity (n=147)</th>
<th>Specificity (n=48 881)</th>
<th>Precision*</th>
<th>Accuracy (n=49 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High sensitivity‡: di.xs.</td>
<td>91.8 (87.4 to 96.3)</td>
<td>68.3 (67.9 to 68.7)</td>
<td>0.9 (0.7 to 1.0)</td>
<td>63.4 (68.0 to 68.8)</td>
</tr>
<tr>
<td>High specificity‡: specificity.tw.</td>
<td>64.6 (56.9 to 72.4)</td>
<td>98.4 (98.2 to 98.5)</td>
<td>10.6 (8.6 to 12.6)</td>
<td>98.3 (98.1 to 98.4)</td>
</tr>
<tr>
<td>Optimising sensitivity and specificity§: exp “diagnostic techniques and procedures”</td>
<td>66.7 (59.1 to 74.3)</td>
<td>74.6 (74.2 to 75.0)</td>
<td>0.8 (0.6 to 0.9)</td>
<td>74.5 (74.2 to 74.9)</td>
</tr>
</tbody>
</table>

See box for description of terms.  
*Denominator varies by row; see table 1 for calculation.  
‡Keeping sensitivity ≥ 75%.  
§Keeping specificity ≥ 50%.  
§§Keeping (abs(sensitivity–specificity)) to a minimum.

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### Table 3: Top three search strategies yielding highest sensitivity (keeping specificity ≥ 50%) with combinations of terms. Values are percentages (95% confidence intervals)

<table>
<thead>
<tr>
<th>Search strategy in Ovid format</th>
<th>Sensitivity (n=147)</th>
<th>Specificity (n=48 881)</th>
<th>Precision*</th>
<th>Accuracy (n=49 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitiv:.mp. OR diagnos:.mp. OR di.fs.</td>
<td>98.6 (96.8 to 100.0)</td>
<td>74.3 (73.9 to 74.7)</td>
<td>1.1 (1.0 to 1.3)</td>
<td>74.3 (74.0 to 74.7)</td>
</tr>
<tr>
<td>sensitiv:.mp. OR diagnos:.mp. OR accuracy.tw.</td>
<td>98.0 (95.7 to 100.0)</td>
<td>82.7 (82.4 to 83.1)</td>
<td>1.7 (1.4 to 2.0)</td>
<td>82.8 (82.5 to 83.1)</td>
</tr>
<tr>
<td>sensitiv:.mp. OR diagnos:.mp. OR test:.tw.</td>
<td>98.0 (95.7 to 100.0)</td>
<td>75.1 (74.8 to 75.5)</td>
<td>1.2 (1.0 to 1.4)</td>
<td>75.2 (74.8 to 75.6)</td>
</tr>
</tbody>
</table>

See box for description of terms.  
*Denominator varies by row; see table 1 for calculation.

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### Table 4: Top three search strategies yielding highest specificity (and highest accuracy) (keeping sensitivity ≥ 50%) with combinations of terms. Values are percentages (95% confidence intervals)

<table>
<thead>
<tr>
<th>Search strategy in Ovid format</th>
<th>Sensitivity (n=147)</th>
<th>Specificity (n=48 881)</th>
<th>Precision*</th>
<th>Accuracy (n=49 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>specificit.tw.</td>
<td>64.6 (56.9 to 72.4)</td>
<td>98.4 (98.2 to 98.5)</td>
<td>10.6 (8.6 to 12.6)</td>
<td>98.3 (98.1 to 98.4)</td>
</tr>
<tr>
<td>specificiti.tw. OR predictive value:.tw.</td>
<td>72.8 (65.6 to 80.5)</td>
<td>97.9 (97.8 to 98.1)</td>
<td>9.6 (7.9 to 11.3)</td>
<td>97.9 (97.7 to 98.0)</td>
</tr>
<tr>
<td>accurac:.tw. OR predictive value:.tw.</td>
<td>52.4 (44.3 to 60.5)</td>
<td>97.9 (97.8 to 98.1)</td>
<td>7.1 (5.8 to 8.6)</td>
<td>97.8 (97.7 to 97.9)</td>
</tr>
</tbody>
</table>

See box for description of terms.  
*Denominator varies by row; see table 1 for calculation.

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### Table 5: Top three search strategies for optimising sensitivity and specificity (based on minimising absolute difference between sensitivity and specificity). Values are percentages (95% confidence intervals)

<table>
<thead>
<tr>
<th>Search strategy using Ovid format</th>
<th>Sensitivity (n=147)</th>
<th>Specificity (n=48 881)</th>
<th>Precision*</th>
<th>Accuracy (n=49 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitiv:.mp. OR predictive value:.mp. OR accurac:.tw.</td>
<td>92.5 (88.3 to 96.8)</td>
<td>92.1 (91.8 to 92.3)</td>
<td>3.4 (2.8 to 3.9)</td>
<td>92.1 (91.8 to 92.3)</td>
</tr>
<tr>
<td>sensitiv:.mp. OR predictive value:.mp. OR accuracy.tw.</td>
<td>92.5 (88.3 to 96.8)</td>
<td>92.1 (91.8 to 92.3)</td>
<td>3.4 (2.8 to 3.9)</td>
<td>92.1 (91.8 to 92.3)</td>
</tr>
<tr>
<td>sensitiv:.mp. OR diagnostic.mp. OR predictive value:.tw.</td>
<td>92.5 (88.3 to 96.8)</td>
<td>91.8 (91.6 to 92.1)</td>
<td>3.3 (2.8 to 3.8)</td>
<td>91.8 (91.6 to 92.1)</td>
</tr>
</tbody>
</table>

See box for description of search terms.  
*Denominator varies by row; see table 1 for calculation.
specificity, accuracy, and balance of sensitivity and specificity for
This study documents search terms with best sensitivity, 

Discussion
Our study documents search terms with best sensitivity, 

Table 6 Comparison of performance of strategies from 1991 and 2000, compiled using 2000 dataset. Values are percentages

<table>
<thead>
<tr>
<th>Approach and year</th>
<th>Strategy in Ovid format</th>
<th>Sensitivity (n=147)</th>
<th>Specificity (n=48 881)</th>
<th>Precision*</th>
<th>Accuracy (n=49 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximize sensitivity:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>exp sensitivity and specificity <strong>OR sensitivity.tw. OR di.xs. OR du.fs. OR specificity.tw.</strong></td>
<td>96.6</td>
<td>65.0</td>
<td>0.8</td>
<td>65.7</td>
</tr>
<tr>
<td>2000</td>
<td>sensitiv:.mp. OR diagnos:.mp. OR dr.ts.</td>
<td>98.6</td>
<td>74.3</td>
<td>1.1</td>
<td>74.3</td>
</tr>
<tr>
<td>Maximize specificity:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>exp sensitivity and specificity <strong>OR predictive value:tw.</strong></td>
<td>79.6</td>
<td>94.9</td>
<td>4.5</td>
<td>94.8</td>
</tr>
<tr>
<td>2000</td>
<td>specificity.tw.</td>
<td>79.6</td>
<td>98.4</td>
<td>10.6</td>
<td>98.3</td>
</tr>
</tbody>
</table>

See box for description of terms.

*Denominator varies by row; see table 1 for calculation.

our strategy’s specificity of 74.3%; see table 3). The specificities 
clinical queries in PubMed or as stored searches that can be 
invoked at the user’s request. The US National Library of Medi-
cine has updated their Clinical Queries site for searching 
Medline for studies of diagnostic tests and other clinical topics, 
and they are available free (web.nch.nlm.nih.gov/entrez/query/
static/clinical.shtml). Further, the new strategies have been 
incorporated into Ovid’s main search engine for Medline 
(www.ovid.com), with the high specificity strategies being 
incorporated into Skolar (www.skolar.com).

Our search strategies were designed to retrieve diagnostic 
tests that meet criteria for validity, just 18.9% of all diagnos-
sis studies in our database. We did not test the performance of 
these strategies for all diagnosis studies, but in a similar project 
for studies of health services research, we found that the highest 
sensitivity strategies for the better designed studies had 5-10% 
lower sensitivity for all articles on the same topic, with no impor-
tant differences in specificity (unpublished data).

Other investigators have attempted to find strategies that 
outperform those we previously published, with some success.*

Our new strategies have set the bar higher, but there is still 
significant room for improvement, particularly for the 
precision of searches.

The Hedges Team includes Angela Eady, Brian Haynes, Susan Marks, Ann McKeown, Doug Morgan, Cindy Walker-Dilks, Stephen Walter, Stephen Werre, Nancy Wilczynski, and Sharon Wong, all at McMaster University Faculty of Health Sciences.

Contributors: RBH planned the study, designed the protocol, and interpreted the data; he will act as guarantor. NLM supervised the research staff, and collected, analysed, and interpreted the data. The Hedges Team conducted the study: AE, SM, AM, CW-D, S Werre, and S Wong collected the data. DM programmed the data set and analysed the data. S Walter and S Werre provided statistical advice, and S Werre did supplementary analyses. The manuscript was prepared by NLM and RBH.

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Ethical approval: Not required.


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Health Information Research Unit, Department of Clinical Epidemiology and Biostatistics, McMaster University Faculty of Health Sciences, 1200 Main Street West, Hamilton, ON, L8N 3Z5, Canada

R Brian Haynes professor

Nancy I. Wilczynski research associate

Correspondence to: R B Haynes bhaynes@mcmaster.ca