High-performance information search filters for acute kidney injury content in PubMed, Ovid Medline and Embase

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ABSTRACT

Background. We frequently fail to identify articles relevant to the subject of acute kidney injury (AKI) when searching the large bibliographic databases such as PubMed, Ovid Medline or Embase. To address this issue, we used computer automation to create information search filters to better identify articles relevant to AKI in these databases.

Methods. We first manually reviewed a sample of 22 992 full-text articles and used prespecified criteria to determine whether each article contained AKI content or not. In the development phase (two-thirds of the sample), we developed and tested the performance of >1.3-million unique filters. Filters with high sensitivity and high specificity for the identification of AKI articles were then retested in the validation phase (remaining third of the sample).

Results. We succeeded in developing and validating high-performance AKI search filters for each bibliographic database with sensitivities and specificities in excess of 90%. Filters optimized for sensitivity reached at least 97.2% sensitivity, and filters optimized for specificity reached at least 99.5% specificity. The filters were complex; for example one PubMed filter included >140 terms used in combination, including ‘acute kidney injury’, ‘tubular necrosis’, ‘azotemia’ and ‘ischemic injury’. In proof-of-concept searches, physicians found more articles relevant to topics in AKI with the use of the filters.

Conclusions. PubMed, Ovid Medline and Embase can be filtered for articles relevant to AKI in a reliable manner. These high-performance information filters are now available online and can be used to better identify AKI content in large bibliographic databases.

Keywords: acute kidney injury, Embase, information retrieval, medical informatics, Medline

INTRODUCTION

Current, high-quality information is a prerequisite for evidence-based healthcare [1]. Although much of this information exists in bibliographic databases such as PubMed, searching these large databases to inform patient care often means sifting through several thousand non-relevant citations to uncover a select few articles of interest. Without sufficient time and skill, physicians and even those who perform systematic reviews may also miss articles relevant to their search [2, 3]. Better methods are needed for identifying literature in bibliographic databases for content areas in which new evidence is constantly emerging, and where point-of-care access to this information is imperative. Such is the case for the topic of acute kidney injury (AKI), a field that has undergone considerable changes in concept and nomenclature in recent years (and most recently redefined in international clinical practice guidelines) [4]. Routinely used search terms such as ‘acute renal failure’, ‘acute tubular necrosis’ and even ‘acute kidney injury’, when used alone, are poorly equipped to deal with these new definitions, lacking sensitivity for the retrieval of
AKI-relevant content in PubMed and other databases. A solution to the problem is to optimize bibliographic database searching for AKI content through the use of search filters.

Search filters are objectively derived using computer automation and use various search terms in combination to restrict a bibliographic database such as PubMed to a certain type of article [5, 6]. Methods-based filters, such as those incorporated into the PubMed interface in the ‘clinical queries’ section (which use up to eight terms in combination), have been highly successful in retrieving articles of diagnosis, etiology, therapy, prognosis and clinical prediction guides filtered for high methodological merit [7–10]. Topic-based search filters offer a unique opportunity to further focus the search in one content area. With relevant literature in nephrology now dispersed across over 400 journals, search filters such as those developed to retrieve articles relevant specifically to dialysis, kidney transplantation and glomerular disease are becoming increasingly important and have proven to maximize the retrieval of relevant articles, minimize non-relevant articles and increase the overall precision of each search [11–16]. These filters have used several terms in combination (sometimes up to 65 terms) and account for different ways the same concept can be expressed, British and American English spelling, and term-entering variability (such as a free text word, a medical subject heading or a truncated word).

A search filter for AKI would have the same functionality. For example, if users wanted to determine the evidence for the role of N-acetylcysteine in the prevention of contrast-induced nephropathy, they could simply type in the term ‘acetylcysteine’ and select the AKI filter to perform the search within a subset of articles in an online database that has been preselected as relevant to AKI. In this case, the filter acts as an optimized substitute for the many phrases commonly used to index and describe AKI, such as ‘acute renal failure’, ‘acute tubular necrosis’ and ‘contrast nephropathy’, which alone lack sufficient sensitivity to retrieve all relevant articles.

In this report, we describe how we used computer automation to develop high-performance information search filters to identify articles relevant to AKI in PubMed, Ovid Medline and Ovid Embase bibliographic databases. These high-performance AKI search filters proved valid when searching a separate set of articles, and we illustrate how searches were improved when the filter was used in some proof-of-concept physician searches.

**Materials and methods**

We used a diagnostic test assessment framework to develop and validate search filters for AKI. For the purpose of this study, AKI was defined as a sudden loss of kidney function as defined by the AKIN or RIFLE criteria or terms commonly used to describe this sudden loss of kidney function [17, 18].

**Sample of articles**

We first established the reference standard by manual review of a subset of full-text articles published in 39 journals between 2004 and 2008. To develop this collection of journals, we adopted a similar strategy for sampling as published in prior search filter studies. This approach has resulted in filters that generalize well over publication years and journal types [16, 19, 20]. We first compiled a list of 466 journals from a list of journals that had published at least one article relevant to renal care from 1961 to 2005 [11]. We then ranked these journals according to the number of articles with relevant information and selected the top 20 journals available to us electronically. In addition to this, we selected 19 more journals at random from the remaining 446 journals. We then randomly divided these 39 journals into development and validation sets at a ratio of 2 to 1, respectively.

**Article review**

For each journal in the development and validation set, we manually reviewed all full-text articles indexed in PubMed, Ovid Medline and Embase in 2006 and randomly selected an additional 500 full-text articles per year for the remaining years between 2004 and 2008 to review. These 22,992 articles included original investigations, reviews, letters and editorials. We derived a standardized checklist of qualifications and terms to classify articles as relevant to AKI from a review of nephrology textbooks and the medical subject heading (MeSH) thesaurus (Supplementary Appendix B). Three readers used this checklist to determine, whether the full. All reviewers were calibrated against a nephrologist in their application of checklist criteria using two test sets of 100 articles (agreement beyond chance, $\kappa = 0.91$).

**Filters**

Using computer automation, we developed unique filters for PubMed, Ovid Medline and Embase. We first identified the search terms used in filter development from the following sources: US National Library of Medicine (NLM) MeSH thesaurus using Medline MeSH browser [21], Medline permuted index [22], Emtree thesaurus [23], SNOMED clinical terms, nephrology textbooks [24], clinical practice guidelines [25, 26], systematic reviews [27–31], website glossaries and clinician and librarian opinions. Examples of these terms included ‘acute renal failure’, ‘acute dialysis’, ‘rapidly progressive glomerulonephritis’ and ‘rhabdomyolysis’. We selected MeSH terms with or without major focus and with or without additional subheadings or explosion capability. Major focus refers to records in which an index term has been tagged as the major topic of the article. Entering the exploded MeSH term ‘acute kidney injury’ means ‘acute tubular necrosis’ is also automatically included in the search. We considered free text words as full and truncated terms and accounted for both American and British English spelling. The inclusion of multiple endings was achieved through the use of the $\$ symbol (i.e. nephrotox$). Terms could appear anywhere in a citation but not solely in the journal name. We repeated the same process for Embase using Emtree index terms to replace the MeSH terms in PubMed and Ovid Medline.

We automated the process of combining and testing the filters by using a computer-implemented algorithm. The computer combined single-term filters into multiple-term filters by selectively using the Boolean operators ‘OR’, ‘AND’ and ‘NOT’ to maximize sensitivity and specificity. In the
development set, we then compared the retrieval performance of various filters (made up of individual and combinations of search terms) with the reference standard from manual review.

Statistical analysis
For each filter, we constructed a two-by-two contingency table and assessed filter performance by calculating sensitivity, specificity, precision and accuracy, similar to evaluation of a diagnostic test (Table 1). We then selected filters from the development phase that demonstrated high performance in either sensitivity or specificity without compromising precision and retested them in the validation set of articles.

Proof-of-concept searches
To illustrate the potential effectiveness of validated filters in PubMed, we selected five independent nephrologists from a directory of Canadian nephrologists provided by the Royal College of Physicians and Surgeons of Canada to provide a search query for a unique predetermined clinical question. We formulated five clinical questions, each which could be answered by a recent systematic review of 15 articles on prevention of contrast nephropathy.

Is acetylcysteine effective in preventing contrast-related nephropathy? was framed to match a systematic review of 15 articles on prevention of contrast nephropathy in adults by Nallamothu et al. [27]. Through means of an electronic survey, we asked each nephrologist to formulate a search strategy that they would use in PubMed for the given clinical question without knowledge of the search filter in use. We then applied these searches to the PubMed database with and without the filters validated as part of this study. Search dates were restricted to the date on which the review was updated. In each case, we noted the number of relevant articles identified in searches with and without the validated filters, compared with the reference standard, which in this case was the set of relevant articles as determined by each systematic review.

RESULTS

Sample of articles
We used 22 992 full-text articles from 39 journals (Supplementary Appendix A). In total, 21 300 articles contributed to the PubMed set, while 21 280 and 22 158 articles contributed to the Ovid Medline and Embase set, respectively. We assigned 14 619 articles to the development set and 8373 articles to the validation set. Of the 22 992 full-text articles included, a total of 386 (1.7%) contained AKI content, 286 of these articles were in the development set and the remaining 100 articles were in the validation set.

High-performance AKI search filters
Using computer automation in the development set of articles, we tested a total of 1 370 506 different multiple-term filters across all three databases. These filters included combinations of index terms specific to each database to help identify AKI content. The filters that operated best were complex; for example one PubMed filter included over 140 terms used in combination, including ‘acute kidney injury’, ‘tubular necrosis’, ‘azotemia’ and ‘ischemic injury’. Our best performing filters for PubMed, Ovid Medline and Embase are shown in Table 2, categorized by high sensitivity and high specificity. High-performance filters in the development set achieved 89.9–98.5% sensitivity, 94.3–99.5% specificity, 29.8–81.8% precision and 94.3–99.3% accuracy. Filters optimized for sensitivity achieved 97.2–98.5% sensitivity, and filters optimized for specificity achieved 99.5% specificity in the development set (Table 2).

The performance of these filters was consistent in the validation set. Filters in the validation set achieved 82.5–96.1% sensitivity, 94.7–99.2% specificity and 94.7–99.0% accuracy; however, precision dropped to 19.8–57.4%. Filters optimized for sensitivity achieved 94.6–96.1% sensitivity, and filters optimized for specificity achieved 99.1–99.2% specificity in the validation set (Table 2).

To put the performance of these multiple-term filters into context, we also compared these results to 261 255 simpler single-term filters. Single-term filters with the highest sensitivity achieved 87.4–94.9% sensitivity, 79.7–84.8% specificity and 80.1–84.9% accuracy; however, precision was low at 9.9–11.8% and terms appeared less relevant. For example the single-term filter with the highest sensitivity in PubMed was ‘nephropathy’. Single-term filters with the highest specificity achieved 99.6–99.9% specificity, 74.2–92.5% precision and 98.4–98.8% accuracy; however, sensitivity was low at 50.6–50.7% (when restricted to at least 50% sensitivity). In terms of achieving an optimal balance of sensitivity and specificity, our best performing multiple-term filters outperformed the single-term filters.

Proof-of-concept searches
We selected five systematic reviews to identify relevant articles for five AKI questions, each of which was posed to an independent nephrologist [27–31]. The number of included studies per systematic review ranged from 10 to 51. The search strategies for PubMed provided by the nephrologists to identify these articles included: ‘Acute Kidney Injury’ [MeSH] AND acetylcysteine’, ‘dopamine AND acute renal failure’, ‘fenoldopam AND acute kidney injury’, ‘biocompatible membranes AND survival AND ARF’ and ‘atrial natriuretic peptide AND acute kidney injury’.

Table 1. Two-by-two contingency table comparing filter to ‘reference standard’

<table>
<thead>
<tr>
<th>Filter (consisting of single or combined terms)</th>
<th>Manual review of each article</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Articles relevant to acute kidney injury</td>
<td>Articles not relevant to acute kidney injury</td>
</tr>
<tr>
<td>Article identified</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>Article not identified</td>
<td>c</td>
<td>d</td>
</tr>
</tbody>
</table>

Sensitivity = a/(a + c): proportion of all articles with information on AKI in the reference set that are retrieved by the filter (also called recall in information retrieval studies).

Specificity = d/(b + d): proportion of all articles without information on AKI in the reference set that are correctly not retrieved by the filter.

Precision = a/(a + b): proportion of all articles retrieved by the filter with information on AKI (also referred to as positive predictive value in diagnostic test terminology).

Accuracy = (a + d)/(a + b + c + d): proportion of all articles dealt with correctly by filter.
Table 2. AKI search filters for PubMed, Ovid Medline and Embase optimized for high sensitivity and high specificity

<table>
<thead>
<tr>
<th>PubMed filters*</th>
<th>Set</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Precision (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-sensitivity filter</td>
<td>Development Validation</td>
<td>97.2 (95.3–99.0)</td>
<td>94.8 (94.5–95.2)</td>
<td>31.5 (28.6–34.4)</td>
<td>94.9 (94.5–95.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>96.1 (92.4–99.8)</td>
<td>95.0 (94.6–95.5)</td>
<td>20.0 (16.5–23.6)</td>
<td>95.1 (94.6–95.5)</td>
</tr>
</tbody>
</table>

### High-sensitivity filter

| Postoperative* OR reperfusion* OR contrast medi* AND renal tubul* OR tubular* (tiab)
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Development</td>
</tr>
<tr>
<td>97.2 (95.3–99.0)</td>
</tr>
<tr>
<td>94.9 (94.5–95.4)</td>
</tr>
<tr>
<td>20.0 (16.5–23.6)</td>
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<tr>
<td>95.0 (94.6–95.3)</td>
</tr>
</tbody>
</table>

### High-specificity filter

<table>
<thead>
<tr>
<th>'Acute Kidney Injury' OR acute renal OR acute nephr* OR acute dialys* OR kidney ischemi* OR renal ischemi* OR renal ischaemi* OR induced kidney injury* OR acute renal injury* OR acute nephr* OR pre-renal OR perirenal OR 'Nephritis, Interstitial/chemically induced' OR 'Hemorrhagic Fever with Renal Syndrome' OR 'Acute Kidney Injury' OR acute kidney OR acute renal OR acute nephritis OR renal ischemia OR renal ischaemia OR renal injury OR renal ischaemia OR induced kidney injury OR allograft* OR glomerulosclerosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
</tr>
<tr>
<td>89.9 (86.5–94.0)</td>
</tr>
<tr>
<td>99.5 (99.4–99.6)</td>
</tr>
<tr>
<td>81.4 (77.3–85.5)</td>
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<tr>
<td>99.3 (99.1–99.4)</td>
</tr>
</tbody>
</table>

### Ovid Medline filters

<table>
<thead>
<tr>
<th>High-sensitivity filter</th>
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<tbody>
<tr>
<td>Development</td>
</tr>
<tr>
<td>97.2 (95.3–99.0)</td>
</tr>
<tr>
<td>94.9 (94.5–95.4)</td>
</tr>
<tr>
<td>20.0 (16.5–23.6)</td>
</tr>
<tr>
<td>95.0 (94.6–95.3)</td>
</tr>
</tbody>
</table>

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### Postoperative* OR reperfusion* OR contrast medi* AND renal tubul*

- Development: 89.9 (86.5–94.0)
- Validation: 82.5 (75.2–89.9)
- Specificity: 99.5 (99.4–99.6)
- Sensitivity: 81.4 (77.3–85.5)
- Positive Predictive Value: 99.3 (99.1–99.4)
- Negative Predictive Value: 99.0 (98.8–99.2)

### 'Acute Kidney Injury' OR acute renal OR acute nephritic OR acute dialys* OR kidney ischemia OR renal ischemia OR renal ischaemia OR induced kidney injury OR acute renal injury OR acute nephritic OR pre-renal OR perirenal OR 'Nephritis, Interstitial/chemically induced' OR 'Hemorrhagic Fever with Renal Syndrome' OR 'Acute Kidney Injury' OR acute kidney OR acute renal OR acute nephritis OR renal ischemia OR renal ischaemia OR renal injury OR renal ischaemia OR induced kidney injury OR renal failure OR allograft OR glomerulosclerosis

- Development: 89.9 (86.5–94.0)
- Validation: 82.5 (75.2–89.9)
- Specificity: 99.5 (99.4–99.6)
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- Negative Predictive Value: 99.0 (98.8–99.2)

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- Development: 89.9 (86.5–94.0)
- Validation: 82.5 (75.2–89.9)
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- Positive Predictive Value: 99.3 (99.1–99.4)
- Negative Predictive Value: 99.0 (98.8–99.2)
<table>
<thead>
<tr>
<th>Set</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Precision (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(95% Confidence Interval)</td>
<td>(95% Confidence Interval)</td>
<td>(95% Confidence Interval)</td>
<td>(95% Confidence Interval)</td>
</tr>
<tr>
<td>High-sensitivity filter</td>
<td>Development</td>
<td>89.9 (87.3–93.7)</td>
<td>99.5 (99.3–99.6)</td>
<td>80.9 (76.0–84.3)</td>
</tr>
<tr>
<td></td>
<td>Validation</td>
<td>82.5 (75.2–89.9)</td>
<td>99.2 (99.0–99.4)</td>
<td>57.1 (49.1–65.0)</td>
</tr>
<tr>
<td>Embase filters*</td>
<td>Development</td>
<td>98.5 (97.2–99.8)</td>
<td>94.3 (93.9–94.7)</td>
<td>29.8 (27.1–32.5)</td>
</tr>
<tr>
<td></td>
<td>Validation</td>
<td>94.6 (90.5–98.8)</td>
<td>94.7 (94.2–95.2)</td>
<td>19.8 (16.4–23.2)</td>
</tr>
</tbody>
</table>

**Shock.tw OR Blood Urea Nitrogen/ OR polyangiitis.mp OR wegener$ granulomatosis.mp) AND (kidney.mp OR renal.mp OR dialysis.mp OR ur?emis.tw OR dehydrat$s.mp OR creatinin$s.mp)) OR (nephropath$s AND ((contrast$ adj (medi$s OR induced OR agent$)) OR radiocontrast$s OR iodinated OR crystal$s OR cast)).mp. OR ((glomerulonephritis.mp OR nephritis.tw) AND (acute.tw OR crescentic.mp OR anca$s.tw OR rapidly progressive.tw)) OR ((Kidney Diseases/ OR (renal adj (insufficient$ or failure or function or impairment)).mp OR ischemia-reperfusion injury.tw OR glomerular filtration rate.tw) AND (exp *Cardiovascular Surgical Procedures/ OR Cardiovascular Diseases/ OR exp *Cardiovascular System/ su OR cardiac surg$s.mp OR cardiopulmonary.tw OR Ischemia/ OR exp *diagnostic imaging/ OR exp Neurologic Manifestations/ OR *Contrast Media/ OR preoperative$.tw OR pre-operative$.tw OR post-operative$.tw OR (exp Substance-Related Disorders/ OR microangiopath$s.tw OR cirrhosis.ti OR revers$s.tw OR ci.fs)) OR ((injury.mp or isch?emis.mp or reperfusion.mp or contrast medi$s.mp) AND (renal tubul$s.tw OR tubular.tw))) NOT (allograft$s OR glomerulosclerosis.ti)
<table>
<thead>
<tr>
<th>High-specificity filter</th>
<th>Development</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(((acut(e renal failure).mp OR (acute adj2 kidney or renal) OR neph$ OR glomer$ OR tubular)).ti OR *acute kidney failure/ OR (tarf or aki) and (renal or kidney)).mp OR (contrast$ adj (med$ or induced$ or agent$)) or iodinated or radiocontrast$).mp OR nephrotoxic$.ti OR *rapidly progressive glomerulonephritis/ OR ((crescent$ or progressive) adj glomerulonephritis$).ti OR *acute kidney tubule necrosis/ OR (induced adj (kidney injury or renal injury)).tw OR (acute nephr$).tw OR (pre-renal or prerenal).tw OR (((tubulointerstitial or interstitial or anti-glomerular or antiglomerular) and (glomerul$ or nephrit$)).ti OR *interstitial nephritis/) AND (acute or crescentic or atypical or drug-induced).mp OR (((crescent$ or progressive) adj glomerulonephritis$).mp AND (*glomerulonephritis/ OR (necrotizing or anca$ or vasculitis$).mp)) OR (exp kidney disease/ AND (*contrast medium/ OR *iodinated contrast medium/ OR *hantavirus/)) OR ((*kidney ischemia/ OR (renal inflammation).mp) AND (injury.ti OR *reperfusion injury/)) OR ((oligur$ OR (intensive care$).mp OR (emergency ward).mp OR (critical$ adj (care or ill$ or patient$)).mp OR (cardiac surg$).mp OR exp respiratory function disorder/)) AND ((renal failure$).tw OR (renal function).ti) OR (((thrombotic adj (thrombocytopenia$ or microangiopathy$)).tw OR (th$emolysis ur$emolysis$).ti OR *hemolytic uremic syndrome/ OR *thrombotic thrombocytopenic purpura/ OR *vasculitis/ OR *rhabdomyolysis/) AND (((kidney or renal) adj failure)).mp OR kidney biopsy/ OR acute disease/)) OR ((exp renal replacement therapy/ OR ((kidney or renal$) adj isch$emolysis$).mp OR apoptosis$.mp OR exp *heart surgery/ OR ((multi$ organ or multiorgan) adj (failure or dysfunction))).mp) AND ((acute adj2 (kidney or renal $)).mp OR ((kidney or renal) adj injury$).mp) OR (((acut(e kidney or renal$ OR glomer$ OR tubul$)).mp OR (renal AND (toxi$ OR tubul$)).ti) AND ((contrast$ OR med$).mp OR (induced adj2 (kidney or renal or nephr$))).tw OR *kidney failure/)) NOT allograft$ti)</td>
<td>90.8 (87.7–93.9)</td>
<td>99.5 (99.4–99.6)</td>
</tr>
<tr>
<td></td>
<td>84.0 (77.1–90.7)</td>
<td>99.1 (98.9–99.3)</td>
</tr>
</tbody>
</table>

*PubMed fields: *, truncation character; [tw], text word present in title, abstract, or MeSH term; [tiab], term present in title or abstract; [majr:noexp], not exploded and focused MeSH term; [mh:noexp], non-exploded MeSH term; [mh], exploded MeSH term; [majr], exploded and focused MeSH term; [ti], term present in title.

bOvid Medline fields: $, truncation character; mp, multiple posting (term appears in title, abstract, or MeSH); tw, text word present in title; /, MeSH character; adj, adjacent operator; *, focused MeSH term; adj2, defined adjacency operator; exp, exploded MeSH term; ?, optional wildcard; ti, term present in title.

Embase fields: exp, exploded Emtree term; /, Emtree character; adj, adjacent operator; $, truncation character; mp, multiple posting (term appears in title, abstract or Emtree); tw, term present in title or abstract; *, focused Emtree term; adj2, defined adjacency operator; ec, Embase section headings field; ti, term present in title.
In the five proof-of-concept searches, the increase in the number of relevant articles retrieved was between a 33 and 233% when a filter-aided search was performed compared with when the physician search was conducted alone (Table 3). The retrieval of non-relevant articles per each relevant article increased modestly with the filter-aided search compared with the physician search alone. As expected, high-performance filters designed to maximize sensitivity retrieved a greater number of non-relevant articles compared with the filters designed to maximize specificity. While the filters missed fewer relevant articles, there was still incomplete retrieval of relevant articles in four of five cases (between 40 and 93% of all relevant articles were retrieved with the filter-aided search).

**DISCUSSION**

Until recently, there has been no consensus on the clinical definition or diagnostic criteria for AKI. For example there are >35 different definitions in the literature that describe a sudden loss of kidney function and phrases such as 'acute renal failure' and 'acute tubular necrosis' are used loosely [4, 32]. In the same way that this lack of consensus has led to a wide variation in the reported incidence and clinical significance of an acute impairment of kidney function, it has also led to a high degree of variability in indexing of articles about AKI. Articles that may be of general AKI interest may be indexed with common phrases such as 'tubular necrosis' and 'prerenal azotemia', while others such as 'acute dialysis' may only imply AKI or make reference to more specific disease states such as with 'hepatorenal syndrome', 'rapidly progressive glomerulonephritis' or 'ischemia reperfusion injury'. Searches must be able to account for the historic and newer terminology used to describe AKI [17, 18]. Building on the same concepts, our group has used to create novel high-performance search filters for general nephrology, dialysis, renal transplantation and glomerular disease; using computer automation, we successfully developed search filters that address these challenges and allow users to capture articles relevant to AKI with a high degree of sensitivity, specificity and precision [12, 13, 15, 16].

All filters developed as part of this study achieved a balance of at least 90% sensitivity and specificity. Our best performing high-sensitivity filter was in Embase, which achieved 98.5% sensitivity and 94.3% specificity. The best performing high specificity filter was also in Embase, which reached 90.8% sensitivity and 99.5% specificity. As of September 2013, our high-sensitivity filter reduced the number of records retrieved in PubMed from >22 million citations to just <2,000,000 records; the high-specificity filter reduced this number to ~68,000 records. The effect of this on search results is similar to the increase in positive predictive value of a screening test when applied to a high-risk population: there is an increase in the precision of the search (greater proportion of relevant articles

<table>
<thead>
<tr>
<th>Clinical question</th>
<th>Number of relevant articles retrieved (n)</th>
<th>Number of non-relevant articles retrieved for each relevant article (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Physician search alone</td>
<td>Physician search with the high-sensitivity filter</td>
</tr>
<tr>
<td>Is acetylcysteine effective in preventing contrast-related nephropathy? (15 relevant articles)</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>What is the efficacy of low-dose dopamine (&lt;5 µg/kg of body weight per minute) compared with no therapy in patients with or at risk for acute renal failure? (51 relevant articles)</td>
<td>15</td>
<td>38</td>
</tr>
<tr>
<td>What is the impact of fenoldopam on acute kidney injury, patient mortality and length of hospital stay in critically ill patients? (12 relevant articles)</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Does the use of biocompatible membranes (BCM) confer an advantage in either survival or recovery of renal function over the use of bioincompatible membranes (BICM) in adult patients with acute renal failure (ARF) requiring intermittent hemodialysis? (10 relevant articles)</td>
<td>3</td>
<td>6</td>
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<tr>
<td>What are the benefits of atrial natriuretic peptide (ANP) in the prevention and treatment of acute kidney injury (AKI)? (10 relevant articles)</td>
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The search phrases provided by physicians by means of an electronic survey and applied to PubMed were ('Acute Kidney Injury'[MeSH] AND Acetylcysteine), (dopamine AND acute renal failure), (fenoldopam AND acute kidney injury), (biocompatible membranes AND survival AND ARF) and (atrial natriuretic peptide AND acute kidney injury).
High-performance search filters for acute kidney injury

This alone has merit to improve the user experience and article retrieval, though these filters serve many other purposes. These filters act as an optimized substitute for the variable terminology used to index articles relevant to AKI and allow users to simplify search strategies, targeting only the content of interest within the area of AKI and avoiding overly specific AKI terminology. In addition, these filters account for indexing inconsistencies that inexperienced users may not be prepared to deal with. For example many articles in the intensive care and surgical literature do not explicitly refer to a sudden loss of kidney function in the title, abstract or index terms and, only upon full-text examination, it is apparent that the article is relevant to AKI. Without a more sophisticated strategy that incorporates phrases such as ‘post-operative’, ‘critically-ill’ or ‘ischemia reperfusion’ in the search query, such articles may be overlooked [33].

While these filters are complex, combining >140 terms with Boolean operators, they are easy to apply and are ready for use (Supplementary Appendix C). At this time, these filters may be copied from Table 2 and pasted directly into the search query and saved for future use with user-generated search terms. In the future, these filters may also be incorporated into the PubMed and Ovid search engine interfaces to achieve more widespread access. In the meantime, we provide these filters online via the following link: http://hiru.mcmaster.ca/hiru/hiru_hedges_nephrology_filters.aspx. Users can select either the high-sensitivity (broad) filter or the high-sensitivity (narrow) filter according to the degree of article retrieval they deem manageable and the extent to which they place importance on retrieving all relevant articles. For busy clinicians at the point of care, we recommend use of the narrow high-sensitivity filter, while the high-sensitivity filter may be more appropriate for researchers who are interested in more comprehensive article retrieval. Although use of the high-sensitivity filter compromises precision to some extent, this may be offset by using these filters in combination with other methods based filters already incorporated into the PubMed interface to retrieve articles by study design, such as those optimized to retrieve high-quality studies about treatment (clinical queries ‘therapy’ filter) [34]. As we deliberately designed the filter to retrieve clinical and basic science content, this strategy may also be useful for users interested in only retrieving clinical AKI content.

AKI is a global problem, occurring in the community, hospital wards, emergency departments and intensive care units. Use of these filters can improve the quality and efficiency of article retrieval for a broad range of physicians managing AKI in these settings, which in turn may translate to more efficient and effective evidence-based decision-making, education and patient care. However, the effectiveness of these search filters is subject to some limitations. Most importantly, as with searches performed without a filter, results remain highly dependent on the quality of search terms entered by the user and the quality and consistency of indexing. This is evident from the incomplete retrieval of relevant articles in four of five proof-of-concept searches even with the high-sensitivity filter in use. Our filters cannot compensate for incorrect or incomplete indexing or terms and abbreviations entered by users that are overly specific, irrelevant, misspelled or inappropriately combined. Further, as knowledge of the pathogenesis of AKI grows and definitions change, these filters will need to be updated to incorporate new terminology used to index relevant articles. Although our filters retained high sensitivity and specificity in the validation phase, there was a drop in precision that was expected, as it was a smaller database by design with a lower proportion of relevant articles. Users can expect this to be more pronounced when applying the filter to the bibliographic database at large, as our collection of journals contributing to the validation set of articles was deliberately enriched with leading clinical nephrology journals. Finally, proof-of-concept searches were used to illustrate the functionality of our best performing filters with real physician searches. Based on these results, users can expect improved retrieval of relevant articles with a modest increase in the number of non-relevant articles, resulting in increased overall precision of the search. However, these results are limited by the methods used to define the reference standard (based on articles used in systematic reviews of variable quality) and should be viewed only as illustrative examples.

In conclusion, PubMed, Ovid Medline and Embase can be filtered for articles relevant to AKI in a reliable manner. Our filters are available online for use by clinicians and researchers. A future research agenda is to assess the uptake of these filters among physicians and measure the impact they have on information-seeking behavior, knowledge, decision-making and ultimately patient care.

Supplementary data are available online at http://ndt.oxfordjournals.org.

We thank Dr Christopher Lee for his help reviewing articles and Dr Ann McKibbon and Dr Salimah Shariff for their advice on this research. We also thank Mr Nicholas Hobson and Mr Chris Cotoi who performed the computer programming. This project was supported by an operating grant from the Canadian Institutes of Health Research (CIHR). A.M.H. was supported by the Clinical Investigator Program at Western University. A.X.G. was supported by a CIHR Clinician-Scientist Award.

We have no competing financial interests to declare. Results presented in this paper have not been published previously in whole or part, except in abstract format.
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Received for publication: 15.11.2013; Accepted in revised form: 18.12.2013