A View of the Literature

The most influential articles in critical care medicine☆
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Keywords:
Critical care; ICU; Citation classics; Landmark articles

Abstract

Purpose: The study aimed to examine query strategies that would provide an exhaustive search method to retrieve the most referenced articles within specific categories of critical care.

Material and Methods: A comprehensive list of the most cited critical care medicine articles was generated by searching the Science Citation Index Expanded data set using general critical care terms such as “critical care,” critical care journal titles, and keywords for subsubjects of critical care.

Results: The final database included 1187 articles published between 1905 and 2006. The most cited article was referenced 4909 times. The most productive search term was “intensive care.” However, this term only retrieved 25% of the top 100 articles. Furthermore, 662 of the top 1000 articles could not be found using any of the basic critical care search terms. Sepsis, acute lung injury, and mechanical ventilation were the most common areas of focus for the articles retrieved.

Conclusion: Retrieving frequently cited, influential articles in critical care requires using multiple search terms and manuscript sources. Periodic compilations of most cited articles may be useful for critical care practitioners and researchers to keep abreast of important information.

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1. Introduction

Modern methods to search for important medical literature have recently flourished with the dissemination and near ubiquity of Internet-based search engines (e.g., PubMed, MEDLINE, OVID). Articles that have been cited most often, referred to as “citation classics,” are frequently important sources of both detailed information that has changed clinical/research practices as well as of useful connectors to other relevant literature that cites these articles. Finding landmarks or classic articles still requires an understanding of the literature and how articles are referenced. Different databases may categorize disciplines and journals from the same clinical areas under different terms and yield different results when using the same search term.

These referencing differences as well as other conceptual arguments have led to some debate regarding attributing the number of times an article is cited to its quality [1-4]. However, there is general agreement that the number of times an article is cited does reflect the “impact of that article on the scientific market” [5].

Garfield [6] first published citation classics of the Journal of the American Medical Association in 1987. Similar studies (citation classic or impact factors) have been published with respect to various clinical specialties [7-15]. In 2004, Baltussen and Kindler [16] published citation classics of the critical care literature and enumerated the 71 top-cited articles in critical care journals and the 45 top-cited critical care articles in non-critical care journals. This article was somewhat limited by the number of citations referenced as

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well as the absence of specific critical care topic citations groups. The first and primary aim of this study was to expand on Baltussen’s earlier work and provide an updated and more comprehensive catalogue of the most influential articles pertaining to critical care medicine and within specific categories of critical care, something not done in previous studies of this type. We also examined the methods used to retrieve articles to provide an exhaustive search method that future researchers may use in modern electronic databases to find frequently cited critical care articles.

2. Methods

2.1. Creation of master comprehensive list

To develop the most comprehensive master list of most often cited critical care medicine–related articles, we first focused on querying the ISI Web of Knowledge (2008 Thompson Corporation) using the Science Citation Index Expanded (SCI Expanded) data set. The SCI Expanded is a database that provides bibliographic information, abstracts, references, and citations counts for more than 6650 scholarly science and technology journals. The SCI Expanded search was limited to articles published from 1900 to December 31, 2007. To find any article among the broadest selection of scientific journals related to critical care, we searched for any article that contained the keywords “critical-case,” “intensive-case,” “ICU,” or “critically-ill OR critical-illness” and that had been cited more than 100 times. A total of 472 articles were retrieved with this technique after duplicates were removed (see Fig. 1A).

Because many critical care articles found in the SCI Expanded were not tagged by the general keywords noted above, we also searched within critical care journals. To do this, we used the Journal Citation Report (JCR) 2006 to identify journals specializing in critical care medicine from more than 7500 scholarly journals. We first reduced the target list to 16 English-language journals of 18 critical care journals identified by the JCR. We reviewed any article that had been cited more than 100 times and saved articles pertaining to critical care medicine (Fig. 1B). This search resulted in 470 hits; however, we removed 159 duplicate articles that were already found by keyword searches to bring the total database to 783 articles (Fig. 1).

2.2. Creation of disease/condition-specific lists

A representative list of most cited articles for each of the specific critical care topics was created from the existing database and by searching each topic individually using the terms in Table 1. Using these search terms, articles pertinent to
critical care and referenced more than 100 times were added to the database. These searches by specific disease or conditions added 404 articles to the master database as 194 articles were already in the database from either the initial search or from the journal search. From this master database of 1187 articles, we then generated a list of all articles cited more than 150 times (Table 2). We organized this table by topics particularly relevant to critical care. Within each category we listed both the most cited articles within that topic as well as that article’s ranking within the top 200 most cited articles. Finally, we also listed the absolute number of citations for each article.

3. Results

The final database included 1187 articles (Fig. 1). The articles collated in this study came from almost 100 different journals with publication years ranging from 1905 (#149) to 2006 (average publication year = 1991). Surprisingly, of the top 1000 most cited critical care articles, 662 were not found using any of the basic critical care search terms—critical care, intensive care, ICU, or critically ill/critical illness. These articles were discovered only after searching within a specific critical care journal (n = 227) or by specific critical care topics (Table 1) (n = 373). In fact, only 4 of the top 100 articles could be found using any 1 of the 4 basic critical care terms listed above. Of these search terms, the most productive was “intensive care” (25 of top 100 articles), then “critically ill” or “critical illness” (19/100), “ICU” (11/100), and finally “critical care” (5/100). Sepsis/systemic inflammatory response syndrome was the most common topic (193 articles), followed by acute lung injury and mechanical ventilation (177 articles). Overall, 41% of the most cited articles came from critical care journals as designated by the JCR. The most articles were from Critical Care Medicine (23%) followed by American Journal of Respiratory and Critical Care (7%), Journal of Trauma (5%), Intensive Care Medicine (4%), and Shock (1%). Among the non—critical care journals, the New England Journal of Medicine (11%) followed by JAMA (9%) provided the most articles.

<table>
<thead>
<tr>
<th>Table 1 Specific critical care subjects</th>
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<tbody>
<tr>
<td>Subject area</td>
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<tr>
<td>Sepsis and infectious disease</td>
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<tr>
<td>Mechanical ventilation and lung injury</td>
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<tr>
<td>Mental status</td>
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<tr>
<td>Physiologic predictors</td>
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<td>Organ dysfunction</td>
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<tr>
<td>Resource utilization</td>
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<tr>
<td>Resuscitation</td>
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<tr>
<td>Shock (excluding infectious causes)</td>
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</table>

*Denotes any form of the word preceding the symbol, i.e., septic shock, septic.

4. Discussion

One method to quickly retrieve scholarly articles related to critical care medicine is by using readily available, Internet-based, bibliographic database search tools supported by most medical libraries. We have found, however, that commonly used basic search terms retrieve under only 50% of the most cited and therefore arguably most influential articles in critical care. Therefore, although searches may have become much faster and easier, they may not be sufficient to retrieve a comprehensive list of articles.

We found that there is no single term that exhaustively retrieves all critical care medicine articles. The best generic search term, “intensive care,” only retrieved 25% of what one would consider the 100 of the most influential articles in critical care. Furthermore, the search term “critical care” was linked to only 5 of the top 100 articles, although it is a common keyword used by many search engines. Not to mention the fact that it is in the title of 8 of the 18 “critical care” journals.

One goal of this study was to determine the most efficient search terms for future literature searches. The capriciousness of how efficient a search term is perhaps no better illustrated than with our experience retrieving articles on ICU mortality prediction models. That not one of the basic critical care search terms in the Science Citation Index was tagged to these most influential articles highlights some of the difficulties in finding the most cited studies in critical care. It is clear that even for other types of articles, the best yield of
Table 2  Most cited articles in critical care medicine by subject (no. of times cited)

A. Sepsis/systemic inflammatory response syndrome


Table 2  (continued)  Most cited articles in critical care medicine by subject (no. of times cited)

A. Sepsis/systemic inflammatory response syndrome


Table 2 (continued)

Overall Citation Rank

A. Sepsis/systemic inflammatory response syndrome (no. of times cited)

49. (#178) Szabo, C. The pathophysiological role of peroxynitrite in shock, inflammation, and ischemia-reperfusion injury. Shock 1996. (350)
56. (#190) Fourrier, F et al. Septic shock, multiple organ failure, and disseminated intravascular coagulation—compared

Table 2 (continued)

Overall Citation Rank

B. Outcome/benchmarking/prediction model articles (no. of times cited)

5. (#21) Knaus, WA et al. A controlled trial to improve care for seriously ill hospitalized-patients—the study to understand prognoses and preferences for outcomes and risks of treatments (support). JAMA 1995. (1056)
9. (#38) Vincent, JL et al. The SOFA (sepsis-related organ failure assessment) score to describe organ dysfunction/failure. Intens Care Med 1996. (735)

(continued on next page)
Table 2 (continued)

B. Outcome/benchmarking/prediction model articles (no. of times cited)

22. (#150) Champion, HR et al. The major trauma outcome study—establishing national norms for trauma care. J Trauma 1996. (386)
29. Ware, JE et al. Comparison of methods for the scoring and statistical-analysis of SF-36 health profile and summary measures—summary of results from the medical outcomes study. Med Care 1995. (259)

C. Mechanical and positive pressure ventilation/airway articles (no. of times cited)


Table 2 (continued)

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The most influential articles in critical care medicine

Table 2 (continued)

C. Mechanical and positive pressure ventilation/airway articles (no. of times cited)


D. Acute lung injury/adult respiratory distress syndrome articles (no. of times cited)

14. (#100) Bell, RC et al. Multiple organ system failure and infection in adult respiratory-distress syndrome. Ann Intern Med 1983. (495)

Table 2 (continued)

D. Acute lung injury/adult respiratory distress syndrome articles (no. of times cited)


E. Infection disease articles (nonsepsis) (no. of times cited)


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18. (#130) Goldmann, DA et al. Strategies to prevent and control the emergence and spread of antimicrobial-resistant microorganisms in hospitals—a challenge to hospital leadership. JAMA 1996. (412)


Table 2 (continued)

E. Infection disease articles (nonsepsis) (no. of times cited)


F. Hemodynamic monitoring/oxygen delivery articles (no. of times cited)


### Table 2 (continued)

| 3. | (#29) Connors, AF et al. The effectiveness of right heart catheterization in the initial care of critically ill patients. *JAMA* 1996. (890) |

### Table 2 (continued)


### G. Neurologic and sedation articles (no. of times cited)


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Table 2 (continued)

H. ICU management/resource utilization articles (no. of times cited)

12. Angus, DC et al. Current and projected workforce requirements for care of the critically ill and patients with pulmonary disease—can we meet the requirements of an aging population? JAMA 2000. (209)
20. Carson, SS et al. Effects of organizational change in the medical intensive care unit of a teaching hospital—a comparison of “open” and “closed” formats. JAMA 1996. (134)

I. Acute kidney injury articles (no. of times cited)

Table 2 (continued)

1. Acute kidney injury articles (no. of times cited)


Table 2 (continued)

J. Resuscitation and cardiac arrest articles (no. of times cited)


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### Table 2 (continued)

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<th>Reference</th>
<th>Citation</th>
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### Table 2 (continued)

**L. Transfusion medicine/hematology/bleeding articles (no. of times cited)**

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<tr>
<th>Reference</th>
<th>Citation</th>
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</table>
Table 2 (continued)

L. Transfusion medicine/hematology/bleeding articles (no. of times cited)

<table>
<thead>
<tr>
<th>Article</th>
<th>No. of Times Cited</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. Corwin, HL et al. RBC transfusion in the ICU—is there a reason. Chest 1995.</td>
<td>118</td>
</tr>
<tr>
<td>23. Fitzgerald, RD et al. Transfusing red blood cells stored in citrate phosphate dextrose adenine-1 for 28 days fails to improve tissue oxygenation in rats. Crit Care Med 1997.</td>
<td>100</td>
</tr>
</tbody>
</table>

Article’s rankings listed by subgroup then by its position within the overall top 200 citations.

This study, like previous ones focusing on citations, has several limitations. Perhaps the most relevant is the debate as to what constitutes the most influential articles within a professional discipline [1,4,18]. Citation data found in all bibliographic databases rely not only on correctly acquiring cited references but also on the assumption that a primary study cites other references that are most relevant to the published article. It is likely that this study captured many of the classic articles in critical care as each article in our list of the top 200 articles was cited at least 300 times. Considering that 46% of articles published in medicine are never even cited, this is a remarkable observation [19]. Certainly, these articles deserve attention and must have made an indelible impact. However, this is not always the case. Authors may preferentially cite their or their colleagues’ previous works both because of familiarity or to increase the citation of that article. Recent scholarship on social networks, especially in the age of accelerated knowledge transmission, suggests that there may be an enhanced level of “connectedness” related to these networks [20,21]. It is not known whether, or how, this connectedness may be influencing the dissemination and therefore the pattern of references within the critical care community or among specific critical care topics. However, it is possible that the pattern of some citations may reflect the influence of an individual, as some have referred to as the “ceremonial citation,” rather than the specific findings within an article [16,22,23]. In addition, authors are more likely to cite articles of their own language [8,24] or articles that come from a highly cited journal. Not surprisingly, Baltussen found that among the most cited 45 articles, most of them came from non-critical care-focused journals [16]. Nevertheless, using citations as a proxy for influence and importance has both face validity and is supported by empiric data demonstrating that citation analyses correlate with articles with the highest quality hierarchies of evidence and research design [25].

Most importantly, the use of citations is also confounded by the effect of time from the year of publication [26] with peak of citations differing for different journals and areas of research. Once citations do peak, they eventually become part of common knowledge and are no longer cited. Previous studies suggest that articles peak 7 to 10 years after publication [15,26]. It has been suggested that “classic” articles are relevant to only a few decades and many important articles are lost to the passage of time [15]. These findings may be supported by the fact that among the top 200 articles in this study, 158 were published during or after 2000. It is probably too early to tell how electronic databases

only 25% indicates the need for a comprehensive search strategy such as the one used in this study.

Although this is a problem for those looking for research articles, it can also be an issue for the way published research becomes cited by others. For example, articles without abstracts or very brief abstracts were often found only after using exact topic words found in the article’s title or by starting a search from within a specific critical care journal itself. Our experience has been previously demonstrated where the choice of keywords and abstract construction significantly impacts the likelihood that an article will be found using modern electronic searches [17].

This study does highlight the importance of sepsis and infectious disease as well as respiratory physiology in critical care with more than half the articles falling into 1 of these 2 broad categories. On the other hand, the most cited article was related to physiologic predictors of morbidity and mortality and the next 3 articles were related to mental status.

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will change the epidemiology of citation classics because it is easier to retrieve and perhaps cite influential articles than before the age of the Internet.

In conclusion, although Web-based search engines can produce lists of references within seconds to minutes, the utility of these searches can be quite limited as a complete end effective literature search remains an art. Periodic reviews of the literature may prove helpful to trainees mastering the most influential literature of our field as well as more established professionals searching for starting points for new investigations.

References