Publications, Citations, and Impact Factors of Leading Investigators in Critical Care Medicine

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INTRODUCTION: Critical care medicine research is reported in major medical journals that can be accessed via computerized search engines such as PubMed (National Library of Medicine) or Web of Science (Thomson ISI [Institute for Scientific Information]). The crediting of report citations to specific journals or individuals is a rapidly developing and highly controversial evaluative process. METHODS: We conducted a citation analysis to measure the research and publication accomplishments of critical care medicine investigators, by tallying their numbers of published reports and numbers of citations to their reports. Major investigators were identified from the author indexes of major critical care medicine publications. From the Web of Science the number of publications and citations of their works were determined for 224 investigators for the period 1997 through August 2003. We calculated the individual researcher's "impact factor" by dividing the number of citations (made by other researchers to a given researcher's reports) by the number of articles that researcher had published. To estimate which countries are producing the most research on mechanical ventilation, we studied the abstract books from the 2001, 2002, and 2003 American Thoracic Society annual international conferences and tallied the numbers of posters (pertaining to mechanical ventilation) from the various countries. We then calculated a "country factor" as the number of posters per million population of the source country. RESULTS: We considered 44,576 citations in 3,755 publications. Using criteria selected to recognize original works, JL Vincent published the greatest number of reports (129). MA Matthay received the most citations (2,056). GU Meduri had the highest impact factor (25.32). There was a balance between the number of leading investigators from Europe and North America. Relative to its population size, Canada warrants leadership acknowledgment in critical care medicine, considering its number of leading investigators and poster presentations. CONCLUSIONS: From criteria selected to attribute original work to specific authors we identified 20 leading critical care medicine investigators, as measured by number of publications, citations, and impact factors. We also report a country factor based on posters (on mechanical ventilation) presented at the 2001–2003 international conferences of the American Thoracic Society. *Key words: citation, publication.* [Respir Care 2004;49(3):276–281.

Introduction

Investigators in critical care medicine are conducting research in all aspects of critically ill patient treatment, yet there is no established, accepted system for recognition and comparison of research accomplishments. Information on publications and citations of investigators is available via computerized search engines such as PubMed (National Library of Medicine)[1] and the Web of Science (Thomson ISI [Institute for Scientific Information])[2], among others. Publications may appear as original contributions, reviews, letters, editorials, text chapters, or conference abstracts.

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Evaluating and comparing the quality of research by individual investigators is difficult, considering the proliferation of journals, the diverse forms of publication, and the increasing number of authors per publication.[3–8] Assessment of the quality of the research is often anecdotal. Though science by its nature insists on measurements, there is no accepted measure of research quality.[4,5] Research measures based on a general model of research advancement have become available.[4] This model considers scientific progress as a structure built on a gradual accumulation of knowledge. Referring to supportive works in the reference/citation list is a recognition of past knowledge. As such, in a report, every citation to a previous report is a "vote" for that previous report. And every published report is a supervote by achieving publication status through the peer-review system.

Therefore, a tangible measure of scientific recognition could be the *number of publications* by that author. The number of times a report is referenced (*citations received*) by other publications (votes) is one measure of the importance of that work. An efficiency assessment of the average importance of a set of publications can be calculated by dividing the number of citations by the number of articles, to calculate an *impact factor* (IF). The counting of publications and citations and the calculation of journal IFs are conducted continually by a bibliometrics organization, the Institute for Scientific Information (Philadelphia, Pennsylvania): they monitor 5,700 publications with > 12 million citations per year.[4,5] The reports of Thomson ISI's work are available through library or Internet services and commercially available software.[2]

Journal IF, as determined by the Thomson ISI, has received considerable attention by promotion and tenure committees, governmental funding sources, libraries, and major journal editors.[3–5,7,9–11] Indeed, journal IF is widely (if only implicitly) used to determine academic appointment, promotion, or tenure decisions. In Europe, journal IFs are explicitly used to determine funding.[3,4,7,9] And journal IFs influence library subscription decisions. For these reasons, some journal editors have clearly declared the goal of raising their IF.[3,10–12] Advocates of IF claim that its use adds objectivity to what might otherwise be considered cronyism.[4–6] An opinion survey of 264 physicians who rated 9 medical journals found that IFs explained 82% of the variation in ratings.[13]

Yet the use of IF or citation analysis as a developing discipline is fraught with a number of serious potential problems.[7,14] The IF can be outright inaccurate when a critical or inaccurate citation is counted. Negative citation rates can be as high as 7%, but most citation errors are positive.[4,5] There is a systematic error in IF calculations when citations are made to letters, commentaries, and features in the journal. Journal IF is reported as an average citation rate for that journal, yet 46% of the articles published in medicine are never cited.[4,15] The database is biased toward the English language and American journals. And authors submit articles to specific journals for many reasons other than the journal's IF. Nevertheless, despite the many known problems, journal IF is an objective measure that is receiving attention.

Journal IF problems also apply to calculation of IFs for specific individuals, and numerous biases could be present in any system of calculating individual IF. Therefore there are no simple metrics for calculating individual IF, and individual IFs have not been routinely calculated or reported. The goal of the present report is to examine the publications, citations, and IFs of individual investigators in critical care medicine and determine the leading investigators. Impact factors for medical specialties other than critical care are typically higher (gastroenterology = 13.44, diabetes = 8.26, blood = 9.63, circulation = 10.89, and critical care medicine = 3.36), and a simple logic would lead to the conclusion that funding sources would support the disciplines with higher IFs.[3,16] For that reason alone it is important to recognize highly accomplished critical care investigators.

There is a precedent for systematically calculating an individual's IF. Impact factor analysis has been conducted for pre- and post-Nobel laureates.[17] Impact factors are often calculated for universities, specific university departments, and specific individuals.[5] Therefore, the goal of the present analysis is to determine, by an objective method with some precedent for its use, the leading investigators in critical care medicine.

In addition, though critical care medicine is practiced around the world, there is no measure of where critical care research is being conducted. The resources and opportunity to conduct research differ widely. The forums for reporting research results are international meetings such as that of the American Thoracic Society, where more than 5,000 posters are presented each year. Though critical care includes many aspects of health care and opportunities to present a report at an international symposium are limited by resources and meeting location, we conducted a relatively blunt assessment of the countries of origin of research on mechanical ventilation.

Methods

A list of leading investigators was compiled, primarily from the author index at the end of each volume of *Intensive Care Medicine*, *American Journal of Respiratory and Critical Care Medicine*, *Chest*, *Thorax*, *Respiratory Care*, and *Critical Care Medicine*. Volumes from the years 2000–2003 were taken into account. An investigator list was initially compiled by considering authors (listed in the author indexes) who had more than 3 publications. Consistent co-authors and authors from other key publications in critical care medicine between 1997 and August 2003 were also considered. Two-hundred twenty-four investigators were identified by this

method, and their publications were evaluated through searches at the Web of Science Web site.[2] Publications considered for analysis were original contributions or reviews published in refereed journals between 1997 and August 2003. We realized that including and excluding certain types of publications would recognize or neglect to recognize some important works. Nevertheless, we attempted to analyze only original and substantial contributions that could be attributed to specific investigators from a manageable data set. To limit the searches to refereed works and to avoid articles that were primarily expressions of opinion, we excluded letters, conference abstracts, and editorial material. Because many reports list numerous authors (as many as 300 authors) we decided to limit multiple-author publications. Though certain that some important works would be excluded from our analysis, publications with $>$ 10 authors were excluded from the analysis because we would not have been able to fairly attribute the work to specific authors. And, again, although the publication of position statements, practice guidelines, and consensus conferences represent important advancements in the compilation of accepted knowledge, such publications were excluded from the analysis because we could not attribute the publications to specific individuals. Throughout the analysis, articles, and authors were included that pertained to critical care medicine, as agreed upon by us, the 2 independent reviewers. Therefore, for each investigator considered, a determination was made for: (1) total number of publications, (2) total number of citations, and (3) individual IF (citations/publications) for the period 1997 through August 2003. All tallying and calculations were completed with standard spreadsheet software (Excel, Microsoft, Redmond, Washington).

An additional assessment was completed to compare the countries of origin of research on mechanical ventilation. We considered posters defended at the American Thoracic Society's international conference (the largest meeting of critical care practitioners) in 2001, 2002, and 2003 (approximately 5,000 posters/y), of which approximately 200 posters/y pertained to mechanical ventilation. We tallied the posters' countries of origin and indexed the number of posters from each country to that country's population (according to the 2003 estimate of the population reference bureau) to calculate the number of posters per 1,000,000 population in that country.

Results

Our analysis included 3,755 publications, which received 44,576 citations. Table 1 shows the 20 leading investigators by number of publications. The leading investigator with regard to number of publications was JL Vincent from Brussels, Belgium, who had 129 publications during the 6-year period. MA Matthay from San Francisco, California, had 122 publications. Eleven of the investigators are from Europe, 6 from the United States, and 3 from Canada.

Table 2 shows the 20 leading investigators by number of citations. Seven investigators received more than 900

Table 1. The 20 Leading Critical Care Medicine Investigators, As Measured by Number of Publications Between 1997 and August 2003*

Rank	Investigator	Location	Research Topics	Publications (No.)
1	Vincent JL	Brussels, Belgium	Septic shock	129
2	Matthay MA	San Francisco, California	ARDS pathology	122
3	Slutsky AS	Toronto, Ontario	Ventilation, ARDS pathology	75
4	Pinsky M	Pittsburgh, Pennsylvania	Cardiopulmonary interactions	70
5	Harf A	Paris, France	Mechanical ventilation	70
6	Reinhart K	Jena, Germany	Sepsis	66
7	Guyatt GH	Hamilton, Ontario	Meta-analyses	64
8	Light RW	Nashville, Tennessee	Chest wall disease	64
9	Brochard L	Paris, France	Mechanical ventilation	63
10	Parrillo JE	Camden, New Jersey	Sepsis, myocardial infarction	63
11	Evans TW	London, England	ARDS	61
12	Moxham J	London, England	Diaphragm function	58
13	Grimminger F	Giessen, Germany	Pulmonary hypertension	57
14	Cook DJ	Hamilton, Ontario	Meta-analyses	56
15	Roussos C	Athens, Greece	Ventilatory muscles	56
16	Lachmann B	Netherlands	Lung recruitment	55
17	Kollef MH	St Louis, Missouri	Ventilator-associated pneumonia	54
18	Marik PE	Pittsburg, Pennsylvania	Sepsis, ARDS	50
19	Brun-Buisson C	Paris, France	SIRS, ARDS	49
20	Bouros D	Crete, Greece	Pleural effusions	45

*As determined from a citation analysis of data from the Web of Science[2]
ARDS = acute respiratory distress syndrome
SIRS = systemic inflammatory response syndrome

Table 2. The 20 Leading Critical Care Medicine Investigators, as Measured by Numbers of Citations Received Between 1997 and August 2003*

Rank	Investigator	Location	Research Topics	Citations (No.)
1	Matthay MA	San Francisco, California	ARDS pathology	2,056
2	Slutsky AS	Toronto, Ontario	Ventilation, ARDS pathology	1,735
3	Vincent JL	Brussels, Belgium	Septic shock	1,643
4	Guyatt GH	Hamilton, Ontario	Meta-analyses	1,103
5	Cook DJ	Hamilton, Ontario	Meta-analyses	1,007
6	Kollef MH	St Louis, Missouri	Ventilator-associated pneumonia	999
7	Evans TW	London, England	ARDS	903
8	Brochard L	Paris, France	Mechanical ventilation	776
9	Brun-Buisson C	Paris, France	SIRS, ARDS	704
10	Niederman MS	Mineola, New York	Community-acquired pneumonia	688
11	Ely EW	Nashville, Tennessee	Ventilator weaning	673
12	Meduri GU	Memphis, Tennessee	Steroids in ARDS, NIV	633
13	Reinhart K	Jena, Germany	Sepsis	627
14	Pinsky M	Pittsburg, Pennsylvania	Cardiopulmonary interactions	626
15	Suter PM	Geneva, Switzerland	Sepsis, mechanical ventilation	612
16	Grimminger F	Giessen, Germany	Pulmonary hypertension	589
17	Hudson LD	Seattle, Washington	ARDS	536
18	Marini JJ	St Paul, Minnesota	Mechanical ventilation	530
19	Tobin MJ	Chicago, Illinois	Weaning criteria	520
20	Light RW	Nashville, Tennessee	Chest wall disease	511

*As determined from a citation analysis of data from the Web of Science[2]
ARDS = acute respiratory distress syndrome
SIRS = systemic inflammatory response syndrome
NIV = noninvasive ventilation

citations, with MA Matthay receiving the most: 2,056 citations. In this category there are 10 investigators from the United States, 7 from Europe, and 3 from Canada.

Table 3 shows the 20 leading investigators by individual IF. There were 74 investigators who had at least 20 publications considered in our IF analysis. GU Meduri led the group, with an IF of 25.32 citations/publication. Of the 20 IF leaders, 10 are from the United States, 5 from Canada, and 5 from Europe. The research topics attributed to the investigators in Tables 1–3 are merely a general overview, at best, of the investigator's overall work. Nevertheless, the research topics that had the most publications and citations include sepsis, acute respiratory distress syndrome, mechanical ventilation, and meta-analyses.

Table 4 shows the numbers of conference posters pertaining to mechanical ventilation that were defended at the annual international conferences of the American Thoracic Society in 2001, 2002, and 2003, by country. Canada, France, the United States, and Spain led in the number of posters per capita.

Discussion

The present report attempts to quantify publication accomplishments of major investigators in critical care medicine. Using a defined analysis criteria, we report the 20 leading critical care medicine investigators, as measured by number of publications, number of citations, and individual IF. A country rating based on poster presentations at American Thoracic Society meetings is also presented. Conclusions based on the data presented in this initial report would be speculative. The methods and criteria were selected to recognize the original, independent work that can be attributed to specific investigators from accessible information made available, primarily, through the Web of Science Web site.[2]

The measures chosen for this analysis were selected with certain intentions. The numbers of publications (Table 1) were tallied as a measure, albeit crude, of the total output of the investigator. The citation data (Table 2) were tallied to assess the importance of the investigator's publications, as measured by references to their reports by other investigators. As an index the IF is an efficiency rating of the authors' works; that is, the frequency with which each publication by that author is cited by others. Comparison of a journal IF and the individual IFs reported here is not valid, because the time-frame and criteria for the calculations are quite different. The country index was chosen as a snapshot of information from a large international forum, and is intended to reflect the relative contributions of individual countries (per capita) to research in mechanical ventilation.

Table 3. The 20 Leading Critical Care Medicine Investigators, as Measured by Individual Impact Factor* Between 1997 and August 2003†

Rank	Investigator	Location	Research Topics	Impact Factor
1	Meduri GU	Memphis, Tennessee	Steroids in ARDS, NIV	25.32
2	Hudson LD	Seattle, Washington	ARDS	24.36
3	Bernard GR	Nashville, Tennessee	Sepsis	23.80
4	Slutsky AS	Toronto, Ontario	Ventilation, ARDS pathology	23.13
5	Hunninghake GW	Iowa City, Iowa	Idiopathic pulmonary fibrosis	22.70
6	Keenan SP	New Westminster, British Columbia	Meta-analyses, NIV	22.09
7	Marini JJ	St Paul, Minnesota	Mechanical ventilation	22.08
8	Ely EW	Nashville, Tennessee	Weaning	19.23
9	Suter PM	Geneva, Switzerland	Sepsis, mechanical ventilation	19.13
10	Dreyfuss D	Paris, France	Ventilator-induced lung injury	18.76
11	Puybasset L	Paris, France	ARDS	18.67
12	Kollef MH	St Louis, Missouri	Ventilator-associated pneumonia	18.50
13	Cook DJ	Hamilton, Ontario	Meta-analyses	17.98
14	Guyatt GH	Hamilton, Ontario	Meta-analyses	17.23
15	Anzueto A	San Antonio, TX	Mechanical ventilation	17.15
16	Matthay MA	San Francisco, California	ARDS pathology	16.85
17	Niederman MS	Mineola, New York	Community-acquired pneumonia	16.78
18	Heyland DK	Kingston, Ontario	End-of-life decisions	16.43
19	Gattinoni L	Milan, Italy	Mechanical ventilation	15.62
20	Pelosi P	Milan, Italy	Mechanical ventilation	15.00

*A researcher's individual impact factor is calculated as the number of citations made to that researcher's published reports divided by the number of reports
†As determined from a citation analysis of data from the Web of Science[2]
ARDS = acute respiratory distress syndrome
NIV = noninvasive ventilation

Interpretation of this quantitative analysis by, for example, comparing or emphasizing the importance of certain numbers or values is likely to be highly speculative. Nevertheless, we make several general observations. Five investigators appear on each of the 3 listings: DJ Cook (Canada), AS Slutsky (Canada), MA Matthay (United States), MH Kollef (United States), and GH Guyatt (Canada). Overall there is a balance in the locations of leading investigators, between Europe and North America. Quite clearly, Canada has a prominent role in critical care research, particularly considering Canada's relatively small population. Since basic research findings often "feed" critical care knowledge, highly successful research groups are probably well-positioned on the basic-research/critical-care axis. The success of the research teams of MA Matthay and AS Slutsky could be explained by such positioning.

There are several reasons to limit interpretations of the present report. First of all, the years under review (1997–2003) were a small time frame in the careers of most investigators. Second, the selection criteria for including publications in the analysis are deficient, since important works have been excluded (publications with $>$ 10 authors, editorial material, posters, some major medical journals, guidelines, consensus reports). And, third, the overall methods employed and potential biases of the authors had effects on the data collected. Nevertheless, we imposed an exclusion criteria of reports with $>$ 10 authors, in an attempt to attribute work to individual investigators rather than attempt to fairly parse out credit among a large number of authors. Our IF analysis only included authors with $>$ 20 publications. A threshold was considered necessary ($>$ 20 publications included 74 authors) to exclude (perhaps unfairly) lower-output authors connected to a frequently cited publication, which could produce an inflated IF. Several potential sources of error were encountered and avoided, as possible, such as, defining (or excluding) a work as a critical care topic, sorting out the works of 2 authors with identical names, or finding all works of authors using 2 or more names.

Though crude, the tallying and IFs reported here are an acknowledgment of important research accomplishments by individual researchers and countries. None of the investigators were aware of this analysis, nor did we have specific goals in this analysis other than the accurate computation of publications and citations. Nevertheless, certain biases could easily have affected the precision of the results. First of all, the use of Web of Science for individual citation analyses has been criticized and Thomson ISI clearly acknowledges its limitations for this purpose.[4] We may have exhibited selection bias in identifying certain authors for analysis and in the selection of articles pertaining to critical care. For example, investigators with expertise in chest wall disease and interstitial pulmonary fibrosis have reports that overlap with critical care, yet

Table 4. Numbers of Conference Posters Pertaining to Mechanical Ventilation Defended at the Annual International Conference of the American Thoracic Society, 2001–2003, by Country

2001			2002			2003		
Rank	Country	Factor*	Rank	Country	Factor	Rank	Country	Factor
1	Switzerland	8.22	1	Canada	5.38	1	Canada	5.06
2	Canada	4.75	2	France	3.01	2	United States	3.09
3	France	4.68	3	United States	2.50	3	Spain	2.91
4	United States	2.57	4	Spain	2.18	4	Taiwan	2.61
5	Australia	2.51	5	Taiwan	1.85	5	France	2.17
6	Spain	2.18	6	Italy	1.05	6	Italy	1.75
7	Italy	2.10	7	United Kingdom	1.02	7	United Kingdom	0.85
8	Brazil	0.87	8	Brazil	0.81	8	Germany	0.72
9	Germany	0.60	9	Japan	0.63	9	Japan	0.71
10	Japan	0.39				10	Brazil	0.57

*The factor is calculated as total number of posters per million residents of the given country. Countries with fewer than 5 posters were not included. Canada, France, the United States, and Spain tended to lead in the number of posters defended at the American Thoracic Society conferences

they are not necessarily considered critical care researchers. In either case, we agreed to include, when in question, authors or articles relevant to critical care medicine.

Our posters-per-country analysis is a crude estimate of the research efforts of specific countries. Several factors influence whether a medical researcher can and wants to submit an abstract to an American Thoracic Society meeting, including his or her ability to travel to the United States, the existence of a national research funding structure, facility in speaking and writing English, the local use of mechanical ventilation, membership in the American Thoracic Society, and interest in and the drive to participate in critical care research. Over the 3-year period 2001–2003, Canada, France, and the United States appeared to be dominant in those factors.

As a scientific endeavor the present study is not precisely reproducible, because (1) the Web of Science is not static: articles and citations are continuously added, and (2) articles or authors selected for inclusion in the analysis would differ between reviewers. Though those facts may introduce subjectivity, articles are often clearly clinical (included) or clearly laboratory (excluded). In this analysis we did not find great differences between our 2 tallies, nor great differences when we repeated the tally later.

Conclusions

In summary, we compiled citation data from publications in critical care medicine between 1997 and August 2003 and reported a list of leading investigators in critical care medicine by a specified measurement method.

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The citation data was obtained, primarily, through the Institute for Scientific Information's Web of Science web site. Note that the Institute for Scientific Information makes no assurances about the methods and accuracy of our analysis.

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