

ORIGINAL ARTICLE

Gender Differences in Authorship of Critical Care Literature

Kelly C. Vranas^{1,2,3*}, David Ouyang^{4*}, Amber L. Lin⁵, Christopher G. Slatore^{1,2}, Donald R. Sullivan^{1,2}, Meeta Prasad Kerlin^{3,6}, Kathleen D. Liu^{7,8†}, Rebecca M. Baron⁹, Carolyn S. Calfee^{10,11}, Lorraine B. Ware^{12,13}, Scott D. Halpern^{3,6}, Michael A. Matthay¹⁴, Margaret S. Herridge¹⁵, Sangeeta Mehta¹⁶, and Angela J. Rogers¹⁷

¹Division of Pulmonary and Critical Care and ⁵Center for Policy and Research in Emergency Medicine, Department of Emergency Medicine, Oregon Health & Science University School of Medicine, Portland, Oregon; ²Health Services Research & Development, VA Portland Health Care System, Portland, Oregon; ³Palliative and Advanced Illness Research Center and ⁶Division of Pulmonary, Allergy and Critical Care, Department of Medicine, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; ⁴Division of Cardiovascular Medicine and ¹⁷Division of Pulmonary, Allergy and Critical Care Medicine, Department of Medicine, Stanford University School of Medicine, Stanford, California; ⁷Division of Nephrology and ¹⁰Division of Pulmonary, Critical Care, Allergy, and Sleep Medicine, Department of Medicine, ⁸Division of Critical Care Medicine, Department of Anesthesia and Perioperative Care, ¹¹Department of Anesthesia and Perioperative Care, and ¹⁴Cardiovascular Research Institute, University of California, San Francisco, San Francisco, California; ⁹Division of Pulmonary and Critical Care Medicine, Brigham and Women's Hospital, Boston, Massachusetts; ¹²Department of Medicine and ¹³Department of Pathology, Microbiology, and Immunology, Vanderbilt University, Nashville, Tennessee; and ¹⁵University Health Network and ¹⁶Sinai Health System, Interdepartmental Division of Critical Care Medicine, University of Toronto, Toronto, Ontario, Canada

ORCID ID: 0000-0001-7450-3717 (K.C.V.).

Abstract

Rationale: Gender gaps exist in academic leadership positions in critical care. Peer-reviewed publications are crucial to career advancement, and yet little is known regarding gender differences in authorship of critical care research.

Objectives: To evaluate gender differences in authorship of critical care literature.

Methods: We used a validated database of author gender to analyze authorship of critical care articles indexed in PubMed between 2008 and 2018 in 40 frequently cited journals. High-impact journals were defined as those in the top 5% of all journals. We used mixed-effects logistic regression to evaluate the association of senior author gender with first and middle author gender, as well as association of first author gender with journal impact factor.

Measurements and Main Results: Among 18,483 studies, 30.8% had female first authors, and 19.5% had female senior authors. Female authorship rose slightly over the last decade (average annual

increases of 0.44% [$P < 0.01$] and 0.51% [$P < 0.01$] for female first and senior authors, respectively). When the senior author was female, the odds of female coauthorship rose substantially (first author adjusted odds ratio [aOR], 1.93; 95% confidence interval [CI], 1.71–2.17; middle author aOR, 1.48; 95% CI, 1.29–1.69). Female first authors had higher odds than men of publishing in lower-impact journals (aOR, 1.30; 95% CI, 1.16–1.45).

Conclusions: Women comprise less than one-third of first authors and one-fourth of senior authors of critical care research, with minimal increase over the past decade. When the senior author was female, the odds of female coauthorship rose substantially. However, female first authors tend to publish in lower-impact journals. These findings may help explain the underrepresentation of women in critical care academic leadership positions and identify targets for improvement.

Keywords: authorship; publications; critical care; gender factors; leadership

(Received in original form October 11, 2019; accepted in final form January 13, 2020)

*Co-first authors.

†K.D.L. is Associate Editor of *AJRCCM*. Her participation complies with American Thoracic Society requirements for recusal from review and decisions for authored works.

Supported by NIH grant 5K12HL133115 (K.C.V. and A.L.L.); NIH grant K07CA190706 (D.R.S.); NHLBI grants HL123004, HL126456, and 140026 (M.A.M.); NIH grant HL103836 (L.B.W.); NIH grant DK113381 (K.D.L.); NIH grant HL140026 (C.S.C.); and NIH grant K23 125663 (A.J.R.). This material is the result of work supported with resources and the use of facilities at the VA Portland Health Care System in Portland, Oregon. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. The Department of Veterans Affairs did not have a role in the conduct of the study; in the collection, management, analysis, or interpretation of data; or in the preparation of the manuscript. The views expressed in this article are those of the authors and do not necessarily represent the views of the Department of Veterans Affairs or the U.S. government.

Author Contributions: K.C.V., D.O., and A.J.R. contributed to the conception of this study; all authors contributed to its design. D.O. contributed to data acquisition. K.C.V., D.O., and A.L.L. contributed to the analysis of data. K.C.V., A.L.L., C.G.S., S.M., and A.J.R. contributed to interpretation of data. All authors have contributed to drafting the article for important intellectual content and have provided final approval of the version to be published.

Am J Respir Crit Care Med Vol 201, Iss 7, pp 840–847, Apr 1, 2020

Copyright © 2020 by the American Thoracic Society

Originally Published in Press as DOI: 10.1164/rccm.201910-1957OC on January 22, 2020

Internet address: www.atsjournals.org

At a Glance Commentary

Scientific Knowledge on the

Subject: Gender gaps exist in academic leadership positions and scholarly activities in critical care. Publication of peer-reviewed research is crucial to career advancement, and yet little is known about gender differences in authorship of critical care research.

What This Study Adds to the Field:

This study found that among more than 18,000 critical care clinical research and basic science studies published in 40 frequently cited journals between 2008 and 2018, women comprised 30.8% of first authors and 19.5% of senior authors, with minimal change over the last decade. When the senior author was female, the odds of female coauthorship rose substantially. However, compared with male first authors, female first authors tend to publish in lower-impact journals. These findings suggest factors that may contribute to the underrepresentation of women in academic leadership positions and scholarly activity in critical care, and they may help identify potential targets for improvement within the field.

Women comprise between 20% and 50% of the critical care medicine workforce, depending on the geographic region (1). However, with respect to their participation in the workforce, women are underrepresented in scholarly critical care activities, including speaking at and chairing critical care conferences (2–5), participating in guideline panels and editorial boards (4, 6–8), and serving in academic leadership positions (9). Several factors contribute to this gender gap. For example, unconscious bias, gender discrimination, and a lack of female mentors and role models are all associated

with the underrepresentation of women in academic medicine (10). In addition, invitations to participate in scholarly activities such as conferences and guideline panels are often extended to scientists who publish within the field, highlighting the importance of academic publishing for career advancement (4).

It is unknown whether gender differences exist in the authorship of critical care research. Because publication of peer-reviewed research is crucial to career advancement (11), a better understanding of female authorship of critical care research may offer potential mechanisms for the observed gender gap in academic and scholarly critical care activities and provide insight into the degree to which this gap might be expected to close (12).

Therefore, we sought to describe gender differences in authorship of critical care research over time and to evaluate whether senior author gender is associated with the gender of first and middle authors. In addition, we evaluated whether female first authorship is associated with the odds of publication in lower-impact journals. We hypothesized that 1) female senior authors would be more likely than male senior authors to publish with women in the first and middle author positions, and 2) female first authorship would be associated with publication in lower-impact journals. Some of the results of these studies were previously reported in the form of an abstract (13).

Methods

Data Source

PubMed is an international online database of over 27 million citations of medical publications that is maintained by the National Center for Biotechnology Information through the U.S. National Library of Medicine (14). For this study, 40 frequently cited medical and scientific journals that publish clinical and basic science critical care research were identified by consensus opinion of all authors (Table E1 in the online supplement). Within these 40 journals, two authors and practicing intensivists with

experience in both clinical and basic science/translational research (K.C.V. and A.J.R.) independently identified 25 critical care research studies (13 clinical and 12 basic science/translational studies) over the last two decades that were considered important to the field of critical care (Table E2).

Two authors (K.C.V. and A.J.R.) then identified relevant search terms referenced in the titles or abstracts of the 25 selected critical care articles. A total of 26 search terms were selected and agreed on by coauthors; these terms were then used to extract all original critical care research articles from PubMed between November 2008 and October 2018 (Table E3). This reverse engineering approach was developed by coauthors in an effort to maximize academic rigor and replicability of our study selection methods. For these analyses, a year was defined as November to October. From PubMed, we retrieved each study's PubMed identifier, study type (e.g., clinical trial or observational study), article title, date of publication, and author list. We included original research articles, systematic reviews, clinical practice guidelines, and consensus reports. We excluded from analyses all editorials, commentaries, letters, news, and retractions (15).

Author Identification and Journal Characteristics

Authors were categorized as first, middle, or senior authors on the basis of author sequence. The first author, senior author, and up to 15 middle authors were identified. Because co-first and co-senior authorships were not consistently identified across different journals, author sequence was used to determine first and senior authorship (15). Author gender was determined by matching authors' first names to entries in a previously validated Genderize database containing 216,286 names across 79 countries and 89 languages (15, 16). The gender of authors whose names were not included in the Genderize database were identified by manual Internet searches of authors' professional websites, including photographs of authors and/or references to authors by male or female pronouns. Manuscripts with missing gender for first or senior authors were

Correspondence and requests for reprints should be addressed to Kelly C. Vranas, M.D., Oregon Health & Science University, 3181 S.W. Sam Jackson Park Road, Mail Code UHN67, Portland, OR 97239. E-mail: vranas@ohsu.edu.

This article has a related editorial.

This article has an online supplement, which is accessible from this issue's table of contents at www.atsjournals.org.

excluded. Authors with the highest number of critical care publications (regardless of authorship position) during the study period were included in analyses of the “100 most prolific authors.”

Characteristics of Publications

Studies were classified by the impact factor of the journal (i.e., high impact or lower impact), the geographic region of the corresponding author, and whether the study was a clinical trial based on MeSH (Medical Subject Headings) annotations (17). We defined high-impact journals *a priori* as those in the top 5% of all scientific journals indexed in 2017, which corresponded to an impact factor of 6 or higher as ranked by the 2017 InCites Journal Citation Reports (18, 19). Journals without an impact factor in 2017 were considered lower-impact journals. We identified the region of the corresponding author using the country code top-level domain assigned to corresponding authors' e-mail addresses (20). E-mail addresses of corresponding author e-mails were extracted from PubMed or obtained via manual review of included studies. Countries of corresponding authors were then grouped into geographic regions (i.e., Asia, Australia/New Zealand, Europe, North America, or Other). Countries and/or regions grouped in the Other category were those with <5% of studies attributable to corresponding authors from those locations. See the online supplement for further details about methods used to determine the region of the corresponding author.

In addition, we chose *a priori* to examine female first and senior authorship in the three highest-impact journals based on impact factor (*New England Journal of Medicine*, *The Lancet*, and *JAMA*). Studies were also classified by publication in either clinical or basic science journals. As determined by consensus of coauthors, clinical journals were defined *a priori* as those that publish observational clinical studies and/or randomized controlled trials, with or without basic science or translational studies. In contrast, basic science journals were defined as those focused on basic science or translational studies.

Statistical Methods

We first calculated the percentages of women in first and senior author positions across included studies. To evaluate temporal trends in female first and senior authorship,

we performed simple linear regression analyses of the proportion of first and senior authors during each year of the study. We confirmed the validity of the linearity assumption by comparing the fitted line from our model with a locally weighted scatterplot smoothing plot. We used descriptive statistics as appropriate to examine the proportion of female middle authors in studies with more than two authors.

We then performed several distinct multivariable analyses. In the first and second analyses, the primary exposure was senior author gender, and the primary outcomes were first author and middle author gender, respectively. Middle author gender was defined as the presence or absence of at least one female middle author. Covariates in the first model included journal domain (i.e., clinical or basic science), type of study (i.e., clinical trial or other), year, and region of corresponding author. The second model included these same covariates and an additional covariate of the number of middle authors. In the third analysis, the primary exposure was first author gender, and the primary outcome was journal impact factor (i.e., high vs. lower impact). Covariates in this model included senior author gender, journal domain, type of study, year, and region of the corresponding author.

Finally, we performed an exploratory analysis to evaluate factors associated with senior author gender. Covariates in this model included journal domain, type of study, year, and region of the corresponding author. For all analyses, we performed mixed effects logistic regression to test for adjusted differences in outcomes. Because publications are not independent events, we included a random effect of senior author to account for clustering of publications. All statistical tests were two sided, and a P value <0.05 was considered statistically significant. All analyses were performed using Stata version 15 software (StataCorp). The study was considered exempt from review by the Stanford University Institutional Review Board.

Results

We extracted 18,483 critical care research articles published between November 2008 and October 2018. Using the Genderize database, we identified the gender of 75.4% of 12,687 unique first authors across 14,190 publications and 74.2% of 9,792 unique

senior authors across 14,406 publications. After manually identifying missing author gender for the remaining authors, we identified the gender of 96.5% of first authors and 94.0% of senior authors. At the publication level, we identified gender of the first author for 17,033 studies (92.2%) and gender of the senior author for 16,902 studies (91.5%) (Figure 1).

Trends over Time

Across all publications during the study period, 30.8% and 19.5% had female first and senior authors, respectively. Between 2008 and 2018, there was a small but significant increase in the proportion of female first and senior authors of critical care publications (Figure 2). The proportion of female first authors rose from 27.5% in 2008 to 32.6% in 2018, with an average annual increase of 0.44% (95% confidence interval [CI], 0.23–0.65%; $P < 0.01$). The proportion of female senior authors increased from 18.9% in 2008 to 21.4% in 2018, with an average annual increase of 0.51% (95% CI, 0.22–0.80%; $P < 0.01$). Female authors accounted for only 11 of the top 100 most prolific authors of critical care research during the study period (Figure 3).

Manuscript Characteristics and Authorship Position by Gender

Women were first and senior authors in 30.4% and 20.1% of high-impact journals, respectively (Table 1). Nearly one-third (30.2%) of all publications did not include any female middle authors. Women comprised 29.9% of first authors of studies published in clinical journals, compared with 34.6% of basic science journals. Europe and Australia/New Zealand had the highest percentages of female first and senior authors, respectively, whereas Asia had the lowest percentage of female first and senior authors (Table 1). Among studies published in *New England Journal of Medicine*, 20.2% had female first authors and 32.4% had female senior authors. In *The Lancet*, 21.3% and 25.8% of first and senior authors were women, respectively, compared with 27.1% and 19.5% in *JAMA*.

Among the 17,251 publications with more than two authors, 25.5% of middle authors were women. Female and male senior authors included a similar mean number of middle authors in each publication (mean $\pm$ SD, female senior authors, 5.6 ± 4.1 ; male senior authors,

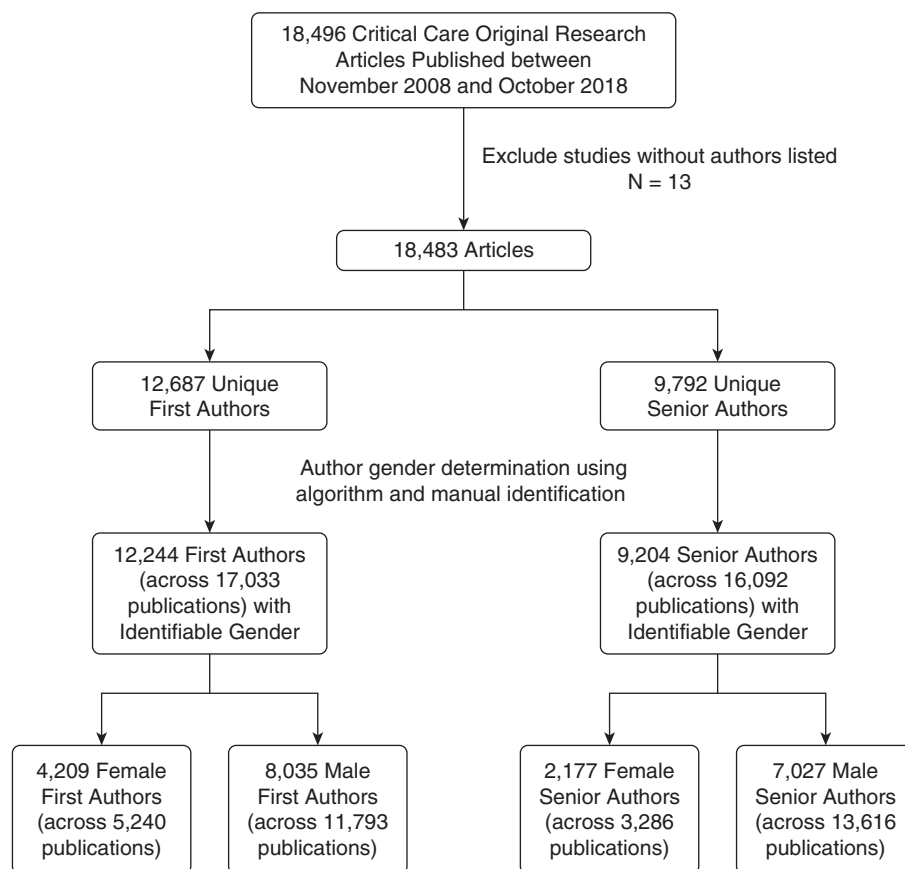


Figure 1. Inclusion and exclusion criteria for selection of critical care research articles published between 2008 and 2018.

5.7 ± 3.9 ; $P = 0.30$). In unadjusted analyses, which included 14,935 studies that had more than two authors and nonmissing gender for both first and senior authors, female first and senior authors published with a significantly higher proportion of female middle authors than male first and senior authors, respectively (first author,

30.4% vs. 23.8% [$P < 0.01$]; senior author, 30.6% vs. 24.8% [$P < 0.01$]).

Multivariable Analyses

The odds of female first authorship nearly doubled when the senior author was female rather than male (adjusted odds ratio [aOR], 1.93; 95% CI, 1.71–2.17) (Table 2). Similarly,

publications with a female senior author had a 48% increase in odds of including any female middle authors (aOR, 1.48; 95% CI, 1.29–1.69) (Table 2). Female first authors had higher odds than male first authors of publishing in lower-impact journals (aOR, 1.30; 95% CI, 1.16–1.45) (Table E4). In exploratory analyses, female senior authorship was not significantly associated with journal domain, type of study, year, or region of the corresponding author (Table E5).

Discussion

In this study, we found that women comprised less than one-third of first authors and less than one-fourth of senior authors of critical care research published between 2008 and 2018. Furthermore, the increase in the proportion of women in first or senior author positions over the last decade has been minimal. Although female first authors more often publish in lower-impact journals than male first authors do, female senior authors have substantially higher odds of collaborating with other women. These findings suggest factors that may contribute to the underrepresentation of women in academic leadership positions and scholarly activity in critical care, and they may help identify targets for improvement within the field.

Our findings are consistent with several recent studies confirming an existing gender gap in academic publishing (12, 21, 22). For example, of the 27.3 million researchers who authored 5.5 million research papers indexed in the Web of Science between 2008 and 2012, over 70% were men (21, 23). A 2016 study found that the number of female first authors of original research in six high-impact journals increased from 27% in 1994 to 37% in 2014. However, this study also reported that since 2009, female first authorship in those same journals had either plateaued or declined, suggesting that underrepresentation of research by women in high-impact journals remains an important concern (12).

Multiple factors could contribute to these observations. First, most journals do not conduct double-blind review of submitted manuscripts, which has been shown to favor increased representation of female authors by overcoming unconscious biases and gender stereotypes (12, 24, 25). A minority of journal editors, members of editorial boards, and participants in the development of clinical guidelines are

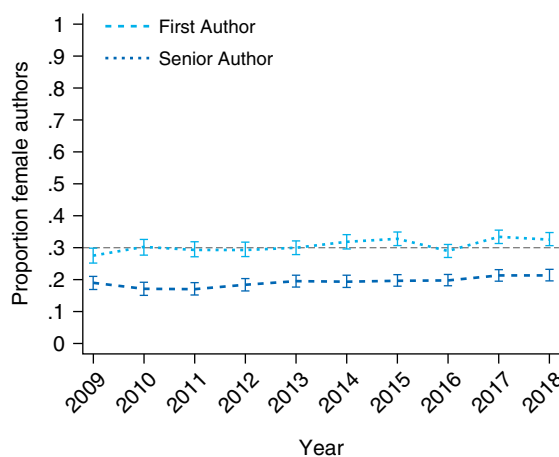


Figure 2. Trends in female first and senior authorship of critical care research between 2008 and 2018.

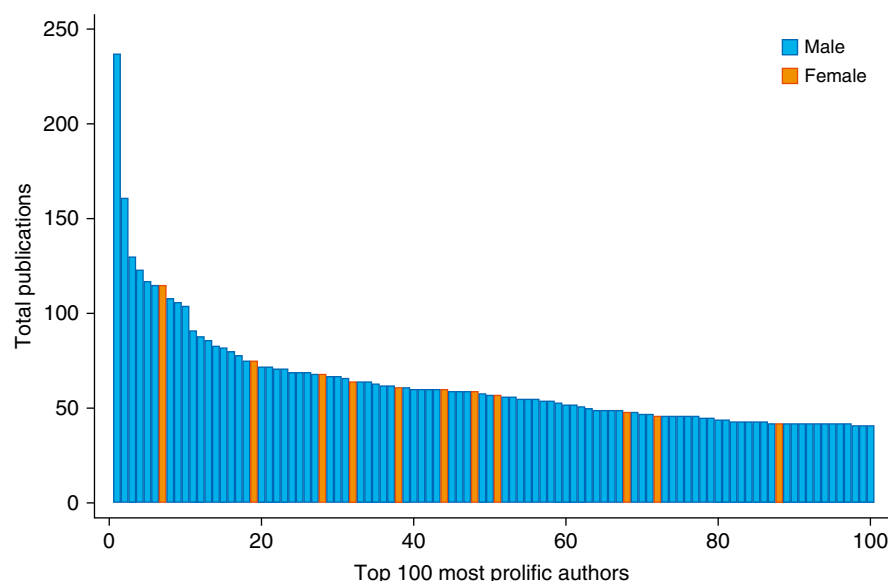


Figure 3. Top 100 most prolific authors of critical care research between 2008 and 2018. “Most prolific authors” is defined as authors with the highest number of critical care research publications (regardless of authorship position) during the study period.

women, which may adversely affect women’s success in publishing their research in a particular journal (4, 5, 7, 12).

The “confidence gap” between men and women observed in other industries may also contribute to a reluctance of female scientists to submit their manuscripts to high-impact journals. A widely cited Hewlett-Packard survey found

that the company’s female employees applied for promotion only when they believed they met 100% of the qualifications required for a particular position, whereas male employees applied when they believed they could meet 60% of the job requirements (26). Similarly, a *Science* audit of the gender of its published authors noted that the journal received one-third fewer

manuscripts from female authors than would be expected on the basis of the number of women in their respective fields (27). A parallel signal has been observed in NIH grant applications: Women tend to have lower application rates than men, but similar success rates (12, 28).

Moreover, a recent study found that clinical articles in which the first and last authors were both women were significantly less likely to use positive terms to describe their research findings than articles in which the first and/or last author was a man (29). These gender differences in the positive framing of research findings was most pronounced in the highest-impact journals and suggest one possible mechanism for our findings that female first authors were more likely to publish in lower-impact journals. Publishing first-author work in lower-impact journals could lead to less opportunity for career advancement, including NIH grants at the crucial assistant professor-to-associate professor stage, and thus could contribute to a vicious cycle in which underrepresentation of women in higher ranks of academia leads to poor participation as peer reviewers and authors, leading to fewer publications, less funding and awards, and ultimately less advancement (30, 31).

In addition, the persistent gap in female authorship of critical care research has been slow to improve. This finding mirrors the slow rate of increase in the proportion of female intensivists over the last several decades—a number that has lagged behind the growing number of female medical graduates worldwide (32). For example, in the United States, pulmonary/critical care fellowships have had among the slowest rates of increase in the proportion of female fellows since 1991, with women representing only 32.6% of all pulmonary/critical care fellows in 2016 (33). Similarly, a 1995 survey of graduates from intensive care medicine training programs in Australia and New Zealand identified 13 of 120 respondents (11%) as women (34); a follow-up study in 2015 found that women comprised 18.7% of the total fellowship of the College of Intensive Care Medicine of Australia and New Zealand (32).

More broadly, gender inequality exists in leadership positions across specialties within academic medicine. According to the Association of American Medical Colleges, women comprise only 24% of all division chiefs, 24% of vice chairs, 15% of

Table 1. Proportions of Female First and Senior Authors of Critical Care Research Articles Published between November 2008 and October 2018

	Percentage of Female First Authors (95% CI)	Percentage of Female Senior Authors (95% CI)
Overall	31 (30–32)	20 (19–20)
Impact factor		
Top 5%	30 (29–32)	20 (19–21)
Lower 95%	31 (30–32)	19 (18–20)
Domain		
Clinical	30 (29–31)	20 (19–20)
Basic science	35 (33–36)	20 (18–21)
Region		
North America (United States/Canada)	32 (30–33)	21 (20–22)
Asia	25 (23–27)	17 (15–19)
Australia/New Zealand	30 (26–33)	22 (19–25)
Europe	32 (30–33)	18 (17–19)
Other	35 (32–39)	22 (19–25)
Clinical trial	30 (28–32)	21 (19–23)
Highest-impact journals		
<i>New England Journal of Medicine</i>	20 (15–26)	32 (25–40)
<i>The Lancet</i>	21 (14–28)	26 (18–34)
<i>Journal of the American Medical Association</i>	27 (21–33)	20 (14–25)

Definition of abbreviation: CI = confidence interval.

Table 2. Multivariable Analysis Evaluating the Association of Senior Author Gender with First and Middle Author Gender across Critical Care Research Articles Published between 2008 and 2018

	Odds of Female First Authorship (95% CI)	Odds of Female Middle Authorship* (95% CI)
Senior author gender [†]		
M	Reference	Reference
F	1.93 (1.71–2.17)	1.48 (1.29–1.69)
Year	1.03 (1.01–1.04)	1.02 (1.00–1.04)
Number of middle authors	—	1.47 (1.44–1.51)
Domain		
Clinical	Reference	Reference
Basic science	1.29 (1.15–1.44)	1.10 (0.97–1.24)
Location of corresponding author		
North America (United States/Canada)	Reference	Reference
Asia	0.68 (0.59–0.77)	0.28 (0.24–0.32)
Europe	1.09 (0.98–1.22)	0.90 (0.80–1.02)
Australia/New Zealand	0.91 (0.70–1.18)	1.01 (0.76–1.33)
Other	1.21 (0.96–1.51)	0.87 (0.67–1.12)
Clinical trial		
No	Reference	Reference
Yes	0.98 (0.84–1.14)	1.00 (0.84–1.19)

Definition of abbreviation: CI = confidence interval.

Statistically significant comparisons are shown in bold.

*In 14,935 publications with more than two authors and nonmissing gender of both first and senior authors.

[†]Primary exposure.

department chairs, and 16% of medical school deans (35). A 2014 analysis of more than 90,000 physician faculty at U.S. medical schools found that women were significantly less likely than men to achieve full professor status, even after adjusting for experience, productivity, specialty, and age (36).

In 2018, the American Thoracic Society published a workshop report identifying several factors that contribute to this gender gap within the fields of pulmonary, critical care, and sleep medicine: 1) gender climate (e.g., implicit and perceived gender bias), 2) disproportionate burden of family responsibilities among women faculty, 3) the lack of women in leadership positions, 4) poor retention of women, and 5) the lack of gender equality in compensation (37). Several strategies have been implemented to address gender inequality in academic medicine. For example, the University of California, Davis School of Medicine established the Women in Medicine and Health Science program to help women overcome barriers to career advancement. This program includes explicit advocacy for women's advancement in leadership positions and the collection of

employee data to inform institutional decisions and actions. In the first 10 years of the program, the percentage of female faculty doubled from 18% to 36%, with a concomitant increase in the number of female full professors and department chairs (38). The NIH Office of Research on Women's Health has also implemented several successful initiatives to promote the careers of women in biomedical sciences. These include programming to support researchers returning to the workforce after a qualifying hiatus, as well as the NIH Working Group on Women in Biomedical Careers that assists with mentoring and networking opportunities (39). Finally, leading journals have made commitments to address gender imbalances in academic publishing, such as setting diversity targets for commissioned content, peer reviewers, and editorial roles (21) and providing training to editors on diversity initiatives and unconscious gender bias (21, 40).

In particular, mentorship is associated with increased career satisfaction, faculty retention, research productivity (including publication and grant success), and career advancement (41). Women are less likely

than their male colleagues to have a mentor across varying levels of training and are often less satisfied with their mentorship experiences (42–44). Our study adds to the literature by demonstrating that female senior authors are significantly more likely than male senior authors to publish with female first and middle authors, suggesting that women may mentor and collaborate with other women more often than men do. These findings highlight the potential value of efforts to increase the pool of women in senior academic positions available to serve as mentors for both junior and midcareer female faculty, who are particularly vulnerable to attrition from academic medicine (42, 44).

The importance of women advancing to senior author positions also raises the potential benefits of sponsorship by current academic leadership. Sponsors differ from mentors in that sponsors have both the position and the power to advocate publicly for the advancement of nascent talent within their organization (45). Sponsorship programs are increasingly being used in the corporate world to help raise women's visibility, enhance their credibility, and advance them into upper levels of leadership (45, 46). In this way, sponsorship is one tool that may also help address the gender gap that exists in leadership positions and scholarly activities within critical care. For example, between 2010 and 2016, women comprised only 5–31% of speakers overall at five major critical care conferences worldwide (5). Women have also been notably absent from the development of high-impact critical care consensus statements and clinical practice guidelines in recent years (4, 47, 48). Our findings may galvanize both men and women in positions of leadership to be more proactive in mentoring and sponsoring female scientists to help increase the number of female senior investigators in the field.

Strengths of our study include the large sample size and the identification of the gender of 97% and 94% of first and senior authors, respectively. Our study also identified potentially important geographic differences in the authorship of critical care research, which should be explored in future research. This study also has limitations. Although we included 40 frequently cited journals, a substantial body of literature exists beyond these journals. It is possible that the 26 search terms used to identify

critical care research did not identify all relevant studies published between 2008 and 2018. There is also a risk of publication type, name, or gender misclassification, as well as a risk of bias resulting from the reverse engineering approach used to identify studies.

Importantly, the actual difference in rates of female first authorship in high-versus low-impact journals was small before adjustment and represents only one possible factor contributing to the gender gap in academic critical care. In addition, residual confounding likely exists despite our

adjustment for potential confounders. For example, we were unable to account for institutional or cultural differences that may influence the ability of both women and men in academic critical care to obtain grant funding and/or publish research. Finally, the true denominator of women pursuing careers in academic critical care worldwide is unknown.

Conclusions

Women comprise less than one-third of first authors and less than one-fourth of senior authors of critical care research, with

minimal increase over the past decade. Although female first authors tend to publish in lower-impact journals more often than male first authors do, female senior authors have substantially higher odds of collaborating with other women. These findings improve our understanding of the gender gap in authorship of critical care literature and help identify potential targets for improvement within academic critical care medicine. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

References

- Venkatesh B, Mehta S, Angus DC, Finfer S, Machado FR, Marshall J, et al. Women in Intensive Care study: a preliminary assessment of international data on female representation in the ICU physician workforce, leadership and academic positions. *Crit Care* 2018;22:211.
- Metaxa V. Is this (still) a man's world? *Crit Care* 2013;17:112.
- Weinacker A, Stapleton RD. Still a man's world, but why? *Crit Care* 2013;17:113.
- Mehta S, Burns KEA, Machado FR, Fox-Robichaud AE, Cook DJ, Calfee CS, et al. Gender parity in critical care medicine. *Am J Respir Crit Care Med* 2017;196:425–429.
- Mehta S, Rose L, Cook D, Herridge M, Owais S, Metaxa V. The speaker gender gap at critical care conferences. *Crit Care Med* 2018;46:991–996.
- Morton MJ, Sonnad SS. Women on professional society and journal editorial boards. *J Natl Med Assoc* 2007;99:764–771.
- Amrein K, Langmann A, Fahrleitner-Pammer A, Pieber TR, Zollner-Schwetz I. Women underrepresented on editorial boards of 60 major medical journals. *Gen Med* 2011;8:378–387.
- Erren TC, Gross JV, Shaw DM, Selle B. Representation of women as authors, reviewers, editors in chief, and editorial board members at 6 general medical journals in 2010 and 2011. *JAMA Intern Med* 2014;174:633–635.
- Wehner MR, Nead KT, Linos K, Linos E. Plenty of moustaches but not enough women: cross sectional study of medical leaders. *BMJ* 2015;351:h6311.
- Edmunds LD, Ovseiko PV, Shepperd S, Greenhalgh T, Frith P, Roberts NW, et al. Why do women choose or reject careers in academic medicine? A narrative review of empirical evidence. *Lancet* 2016;388:2948–2958.
- Reed DA, Enders F, Lindor R, McClees M, Lindor KD. Gender differences in academic productivity and leadership appointments of physicians throughout academic careers. *Acad Med* 2011;86:43–47.
- Filardo G, da Graca B, Sass DM, Pollock BD, Smith EB, Martinez MA. Trends and comparison of female first authorship in high impact medical journals: observational study (1994–2014). *BMJ* 2016;352:i847.
- Vranas KC, Ouyang D, Lin A, Slatore CG, Kerlin MP, Liu K, et al. Gender differences in authorship of critical care literature [abstract]. *Am J Respir Crit Care Med* 2019;199:A4168.
- U.S. National Library of Medicine. PubMed [accessed 2018 Oct 22]. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/>.
- Ouyang D, Sing D, Shah S, Hu J, Duvernoy C, Harrington RA, et al. Sex disparities in authorship order of cardiology scientific publications. *Circ Cardiovasc Qual Outcomes* 2018;11:e005040.
- Demografix ApS. Determine the gender of a first name [accessed 2018 Oct 22]. Available from: <https://genderize.io>.
- U.S. National Library of Medicine. MeSH: Clinical trial [publication type] [accessed 2018 Oct 24]. Available from: <https://www.ncbi.nlm.nih.gov/mesh/68016430>.
- Koya University, Directorate of Quality Assurance. InCite JCR Clarivate analytics. 2017 [accessed 2018 Nov 12]. Available from: <https://sites.google.com/a/koyauniversity.org/dqa/incite-jcr-thomson-reuters>.
- University of Texas MD Anderson Cancer Center. What is considered a good impact factor? [accessed 2019 Jun 10]. Available from: <http://mdanderson.libanswers.com/faq/26159>.
- Public Technical Identifiers. Internet Assigned Numbers Authority (IANA) [accessed 2019 Nov 15]. Available from: <https://www.iana.org/>.
- Lundine J, Bourgeault IL, Clark J, Heidari S, Balabanova D. The gendered system of academic publishing. *Lancet* 2018;391:1754–1756.
- Ouyang D, Harrington RA, Rodriguez F. Association between female corresponding authors and female co-authors in top contemporary cardiovascular medicine journals. *Circulation* 2019;139:1127–1129.
- Larivière V, Ni C, Gingras Y, Cronin B, Sugimoto CR. Bibliometrics: global gender disparities in science. *Nature* 2013;504:211–213.
- Budden AE, Tregenza T, Aarssen LW, Koricheva J, Leimu R, Lortie CJ. Double-blind review favours increased representation of female authors. *Trends Ecol Evol* 2008;23:4–6.
- Kaatz A, Gutierrez B, Carnes M. Threats to objectivity in peer review: the case of gender. *Trends Pharmacol Sci* 2014;35:371–373.
- Chen Y. Opinion: women need both competency and confidence to break the glass ceiling. Washington, DC: Devex; 2018 Mar 6 [accessed 2019 Jul 26]. Available from: <https://www.devex.com/news/opinion-women-need-both-competency-and-confidence-to-break-the-glass-ceiling-92265>.
- Berg J. Looking inward at gender issues. *Science* 2017;355:329.
- Waisbren SE, Bowles H, Hasan T, Zou KH, Emans SJ, Goldberg C, et al. Gender differences in research grant applications and funding outcomes for medical school faculty. *J Womens Health (Larchmt)* 2008;17:207–214.
- Lerchenmueller MJ, Sorenson O, Jena AB. Gender differences in how scientists present the importance of their research: observational study. *BMJ* 2019;367:l6573.
- Clark J, Horton R. What is *The Lancet* doing about gender and diversity? *Lancet* 2019;393:508–510.
- van den Besselaar P, Sandström U. Vicious circles of gender bias, lower positions, and lower performance: gender differences in scholarly productivity and impact. *PLoS One* 2017;12:e0183301.
- Hawker FH. Female specialists in intensive care medicine: job satisfaction, challenges and work-life balance. *Crit Care Resusc* 2016;18:125–131.
- Stone AT, Carlson KM, Douglas PS, Morris KL, Walsh MN. Assessment of subspecialty choices of men and women in internal medicine from 1991 to 2016 [letter]. *JAMA Intern Med* 2020;180:140–141.
- Harrison GA, Byth PL, D'Este CA. The third five-year survey of fellows (by examination) of the Faculty of Intensive Care, Australian and New Zealand College of Anaesthetists. *Anaesth Intensive Care* 1998;26:401–410.

35. Association of American Medical Colleges. The state of women in academic medicine: the pipeline and pathways to leadership, 2015-2016. 2016 [accessed 2019 Nov 14]. Available from: <https://www.aamc.org/data-reports/faculty-institutions/data/state-women-academic-medicine-pipeline-and-pathways-leadership-2015-2016>.
36. Jena AB, Khullar D, Ho O, Olenski AR, Blumenthal DM. Sex differences in academic rank in US medical schools in 2014. *JAMA* 2015;314:1149–1158.
37. Thomson CC, Rieker KA, Bates CK, Jena AB, Borok Z, McCallister JW, *et al*. Addressing gender inequality in our disciplines: report from the association of pulmonary, critical care, and sleep division chiefs. *Ann Am Thorac Soc* 2018;15:1382–1390.
38. Bauman MD, Howell LP, Villablanca AC. The women in medicine and health science program: an innovative initiative to support female faculty at the University of California Davis School of Medicine. *Acad Med* 2014;89:1462–1466.
39. Plank-Bazinet JL, Bunker Whittington K, Cassidy SK, Filart R, Cornelison TL, Begg L, *et al*. Programmatic efforts at the national institutes of health to promote and support the careers of women in biomedical science. *Acad Med* 2016;91:1057–1064.
40. Berg J. Measuring and managing bias. *Science* 2017;357:849.
41. Sambunjak D, Straus SE, Marusic A. Mentoring in academic medicine: a systematic review. *JAMA* 2006;296:1103–1115.
42. Farkas AH, Bonifacio E, Turner R, Tilstra SA, Corbelli JA. Mentorship of women in academic medicine: a systematic review. *J Gen Intern Med* 2019;34:1322–1329.
43. Osborn EH, Ernster VL, Martin JB. Women's attitudes toward careers in academic medicine at the University of California, San Francisco. *Acad Med* 1992;67:59–62.
44. DeCastro R, Griffith KA, Ubel PA, Stewart A, Jagsi R. Mentoring and the career satisfaction of male and female academic medical faculty. *Acad Med* 2014;89:301–311.
45. Travis EL, Doty L, Helitzer DL. Sponsorship: a path to the academic medicine C-suite for women faculty? *Acad Med* 2013;88:1414–1417.
46. Hewlett SA, Peraino K, Sherbin L, Sumberg K. The sponsor effect: breaking through the last glass ceiling. Boston, MA: Harvard Business Review Research Report; December 2010.
47. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, *et al*. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA* 2016;315:801–810.
48. Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, Fan E, *et al*. ARDS Definition Task Force. Acute respiratory distress syndrome: the Berlin Definition. *JAMA* 2012;307:2526–2533.