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Global evolution of female authorships in anesthesiology articles: an affiliation-based, longitudinal, scientometric analysis

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Abstract

Background Although a gender gap in anesthesiology articles has been reported in certain subsets of anesthesiology literature, a comprehensive analysis is still lacking. Our objective was to conduct a scientometric analysis of the evolution of gender equity among anesthesiology authors worldwide, including all available affiliations. We hypothesized that gender inequity has diminished over time, with relevant differences among countries.

Methods The MEDLINE/PubMed 2024 Baseline Repository was queried for all articles whose authors were affiliated with a department of anesthesiology. Author positions were sequenced into first, co-authors, and senior authors. Gender was inferred using online classification tools (genderize.io and gender-api.com). Geolocation was identified through text mining of the first author's affiliation. The primary endpoint was the evolution of female authors from 1987 to 2023, calculated descriptively and by average annual growth rates. Secondary endpoints included the proportion of female authors in first or senior author position, the influence of senior authors' gender on first authors' gender, geographical differences, and future projections of parity (defined as 50% female authors).

Results Among 374,301 anesthesiology articles and 7,574 journals, the proportion of female authors increased from 13.6% (1987) to 34.3% (2023) with an average annual growth of 0.57% (95%-confidence interval 0.38% – 0.77%). First authors were female in 30.0% and senior authors in 20.7%, with increases from 11.7% (1987) to 36.9% (2023), and from 11.0% (1987) to 25.9% (2023), respectively. Female authors were overall more likely to be first authors when the senior author was also female. In 2023, only Thailand and Portugal had a percentage of female authors over 50%. Tunisia achieved the highest average annual growth rate of female authors at 2.28% (95%-CI 1.51% – 3.06%). Based on the assumption that current trends continue unchanged, overall gender parity is estimated to be achieved by 2050, for first authors by 2043 and for senior authors by 2072.

Conclusions Despite an increase in recent decades, women are still underrepresented as authors in academic anesthesiology, particularly in leading authorship positions. While relevant differences between countries exist, strategies addressing this gender gap at a country-specific level are needed to promote female authorship in academic anesthesiology.

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Keywords Gender parity, Gender equity, Scientometrics, Authorship trends, Female authorship, Anesthesiology

Background

The medical profession has always been and still is male-dominated [1]. Although the proportion of female medical professionals has increased in recent years [2, 3], women remain underrepresented in leading academic positions and academic publications [4–6]. This gender disparity is also evident in the authorship metrics of academic publications in anesthesiology [7].

Recent studies revealed both progress but persistent inequities, demonstrating an increase in female authorship in various contexts [7]: In high-impact journals, the proportion rose from 37.3% to 45.7% between 2008 and 2018 [8]. In 2018 alone, female representation across eleven leading journals ranged from 36% to 39% [9]. Similar trends were observed in two prominent U.S. journals regarding first and senior authorship [10, 11], a well-known Canadian journal (from 1954 to 2017 with a gradual increase of female authorships) [12], and a well-known French journal (between 2015 and 2019) [13]. Whilst these studies yielded valuable insights [7], they exhibited two relevant restrictions. The observation periods were limited, and the journal-based approaches employed meant that a large number of publications were excluded due to the examination of only a select group of journals [14]. Therefore, there is still no comprehensive global analysis of gender equality in authorship in anesthesiology over time.

Our objective was to conduct a scientometric analysis on the evolution of gender equity in anesthesiology authorship worldwide by including all available affiliations, hypothesizing that gender inequity has diminished over time and that differences among countries vary. Moreover, we sought to investigate the influence of senior authors' gender on first authorship assignments.

Methods

This study exclusively utilized publicly available scientometric data, without involving personal or sensitive information. Therefore, the study did not have to be registered, nor was patient consent required. The Institutional Review Board of the University Hospital Regensburg waived the need for an Ethics approval (no. 24–3995-180).

Data collection

The MEDLINE/PubMed 2024 Baseline Repository, released on 14 December 2023, served as the primary source of metadata [15]. It contained a total of 36,555,430 articles and 160,828,967 authorships spanning the period from 1900 to 2023. Records were processed using the Python library pubmed parser 0.4 and converted into an

efficient database format (PostgreSQL 14.13) to facilitate access and analysis.

We adopted an affiliation-based approach with the objective of ensuring the inclusion of articles published by anesthesiologists not only in a small number of selected journals but also in non-traditional anesthesia journals [14]. Thereby, we followed the data collection which has been used in several scientometric studies before to identify all articles whose authors were affiliated with a department of anesthesiology [14, 16]. The affiliation field was searched for variations of the terms 'anesthesia' and 'anesthesiology' by string-matching based on regular expressions (Supplemental File S1) to capture different linguistic forms (e.g. 'anesthesia' in American English or 'anaesthesia' in British English) as well as common prefixes [16]. The final subset comprised articles in which at least one author was affiliated with an anesthesiology department, as indicated by the author's institutional affiliation in the article metadata. Due to the limited availability of data for the period preceding 1987 (Fig. 1), articles from that time-frame were excluded from the final analysis.

Data processing

The author records were subjected to text mining to identify valid forenames, again utilizing a sequence of regular expressions (Supplemental File S1). Where forenames were deemed invalid or absent from the repository, data was retrieved from Elsevier's SCOPUS to supplement the repository. Entries containing only initials were excluded from the analysis.

The sequences of authors were divided into three position categories: first author, co-authors, and last author. Last author was assumed to be the senior author, and both first and senior were considered to be leading author positions. When first authorships were shared, the author listed first was regarded as the first author. When senior authorships were shared, the author listed last was regarded as the senior author. If a publication had only one author, this author was considered only as first author.

Binary gender classification (female or male) was employed based on the authors' forenames using two validated providers, genderize.io and gender-api.com [17, 18]. Each provider supplied probability scores with their classifications. In line with recent scientometric studies [19–21], a 60% probability threshold was used for gender classification. Any forename record below this threshold resulted in the gender being counted as unknown. In case of a discrepancy regarding a specific record, we selected

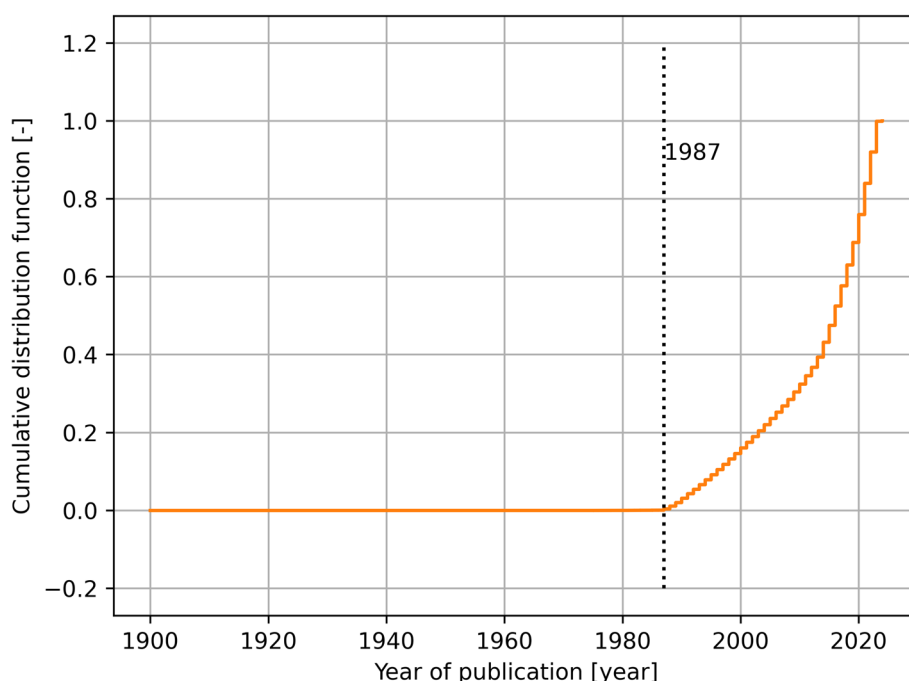


Fig. 1 Cumulative distribution function of yearly count of anesthesiology-related articles identified from the MEDLINE/PubMed 2024 Baseline Repository

the gender estimate from the provider with the higher probability score.

Each publication was allocated to a country based on the first authors' affiliation. Inconsistent country names were homogenized, e.g., "Germany" and "Deutschland" were both assigned to Germany. Articles from "Korea" were checked for their addresses to distinguish between North and South Korea as was done for "Ireland" to distinguish between Ireland or Northern Ireland. Duplicate names such as Mexico (either as a country or as "New Mexico" in the US) were assigned based on addresses. Articles from "England", "Scotland", "Northern Ireland", or "Wales" were matched to the United Kingdom. In case of incomplete country information [22], articles were assigned based on the state or city, e.g., for US states or Japanese cities. Furthermore, affiliation strings were scanned for two-letter country codes as well as US state names. Further verification involved cross-referencing tokens with three-letter country codes. If all attempts to assign a country were unsuccessful, this publication was not assigned to a country.

Endpoints

The primary endpoint was the evolution of the proportion of female authors in anesthesiology articles from 1987 to 2023. Secondary endpoints were the proportion of female and male authors at different authorship positions over time; the influence of senior authors' gender on the gender of first authors; the proportion of female authors by geographical region and its change over

time; and future projections of gender parity among authors (defined as 50% female authors), both globally and by country, assuming that current trends continue unchanged.

Gender interdependence between first and senior authors was analyzed for articles with gender data available for both positions. Countries with fewer than ten articles between 1987 and 2023 were excluded from analysis. For regression analysis and evaluation of trends, data were excluded if a country had fewer than three articles per year or fewer than five annual data points in total.

Statistical analysis

Data were presented descriptively as counts or percentages. Mean values were presented $\pm$ standard deviation. Two-tailed tests were used with a significance threshold of 5%. Odds ratio (OR) and Pearson's correlation coefficient were given with the 95% confidence interval (95%-CI).

For the primary endpoint, we calculated counts and percentages, and average annual growth rates as

$$\frac{1}{N} \left(\sum_{i=1988}^{2023} G_i - G_{i-1} \right) \quad (\text{with } N \text{ as the number of periods and } G \text{ as the yearly absolute percentage growth})$$

For the secondary endpoints, the χ^2 -test was used to assess the influence of the senior authors' genders on the gender of the first author and logistic regression analysis was carried out to determine changes of this influence over time. Ordinary least squares linear regression was

applied to predict future trends. Fits were presented with R-squared (R^2) and standard error (SE).

Data processing, graphical illustration and statistical analyses were performed with R 4.3.3 (R Core Team 2024, Vienna, Austria) and Python 3.11 (Python Software Foundation) with its libraries ggplot2 3.5.1 and matplotlib 3.9.2, geopandas 0.14.2, seaborn 0.13, geotext 0.4, geoPy 2.4.1, geograpy3 0.2.7, and Nominatim, respectively.

Results

Between 1987 and 2023, a total of 374,301 anesthesiology articles in 7,574 different scientific journals were identified, accounting for 1.0% of the 36,555,430 articles indexed during this period. They comprised 2,246,209 authorships from 202 different countries. In 90.6% of authorships (2,034,485 out of 2,246,209), a forename could be identified (of which 95,311 unique forenames). Gender was successfully determined in 96.8% of remaining authors (1,970,286 out of 2,034,485). The remaining 64,199 could not be classified. Of these, 38,581 authors (1.9% out of 2,034,485) were excluded on the basis of a gender classification probability below the 60% threshold.

21,354 articles (5.7%) had only one author, counted as first author only. The average number of authors per article was 6 ± 9 . First and senior authors' genders were finally available in 85.2% (318,859 out of 374,301) and 85.9% (303,019 out of 352,947 of all articles, respectively. Information on the gender of both the first and senior authors was available simultaneously in 81.7% of articles with more than one author (288,371 out of 352,947).

Evolution over time

Overall, 29.4% of authors (578,621 out of 1,970,286) were female. While this share was 13.6% (296 out of 2,173) in 1987, it increased to 34.3% (73,824 out of 215,193) in

2023 (Fig. 2), given an average annual increase of 0.57% (95%-CI 0.38%–0.77%).

Leading authorship positions

Female authors held leading authorship positions (first or senior) in 43.0% of articles (124,077 out of 288,371; Fig. 3a). This share increased from 22.2% (108 out of 487) in 1987 to 50.9% (12,998 out of 25,519) in 2023, indicating an average annual increase by 0.80% (95%-CI 0.34%–1.26%; Fig. 3b).

Female first authors accounted for 30.0% (95,726 out of 318,859) and female senior authors for 20.7% of articles (62,674 out of 303,019; Fig. 3a). The share in articles with female first authorship increased from 11.7% (75 out of 640) in 1987 to 36.9% (10,051 out of 27,236) in 2023 with an average annual increase by 0.70% (95%-CI 0.28%–1.12%). The share of female senior authors increased from 11.0% (62 out of 564) in 1987 to 25.9% (6,885 out of 26,609) in 2023 with an average annual increase by 0.39% (95%-CI 0.09%–0.69%; Fig. 3b).

Influence of first and last authorships

The most common authorship pairing was male-first-male-senior, comprising 57.0% of all articles (164,294 out of 288,371). This was followed by female-first-male-senior with 22.3% (64,411 out of 288,371), male-first-female-senior with 12.3% (35,339 out of 288,371), and female-first-female-senior author positions with 8.4% (24,327 out of 288,371; Fig. 3a). Over time, the male-first-male-senior group showed an average annual change of -0.79% (95%-CI -0.83% – -0.74%). Conversely, the other groups demonstrated steady growth: female-first-male-senior increased by 0.41% annually (95%-CI 0.38%–0.43%), female-first-female-senior by 0.26% (95%-CI 0.25%–0.29%), and male-first-female-senior by 0.11% (95%-CI 0.09%–0.14%; Fig. 3b). The absolute number of articles for each authorship pairing from 1987 to 2023 is depicted in Fig. 3c and d.

Female authors were overall more likely to be first authors when the senior author was also female, compared to when senior author was male (40.8% vs 28.2%; $P < 0.001$; OR 1.76; 95%-CI 1.72–1.79). The influence of the senior author's gender on the first author's gender and vice versa remained stable over time, with no significant changes observed ($P = 0.8$ and $P = 0.3$, respectively).

Country-specific data

In 343,412 articles, a country was assignable (91.7% of 374,301). The geographical distribution of overall female proportions and the evolution of gender equity over the past three-and-a-half decades are shown in Fig. 4a and b. The top three countries in terms of female representation among authors in anesthesiology articles were Thailand (52.2% female authors out of 880 articles;

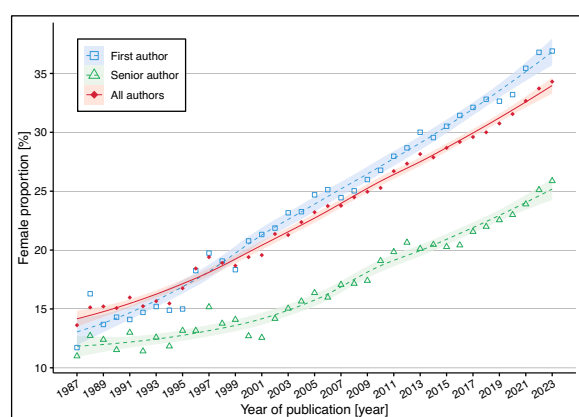


Fig. 2 Proportion of female authors in anesthesiology articles (1987–2023) by author role: All authors (◆, red), first authors (□, blue), and senior authors (△, green). Lines represent local regression smoothed trends, with 95% confidence intervals shaded in respective semi-opaque colors

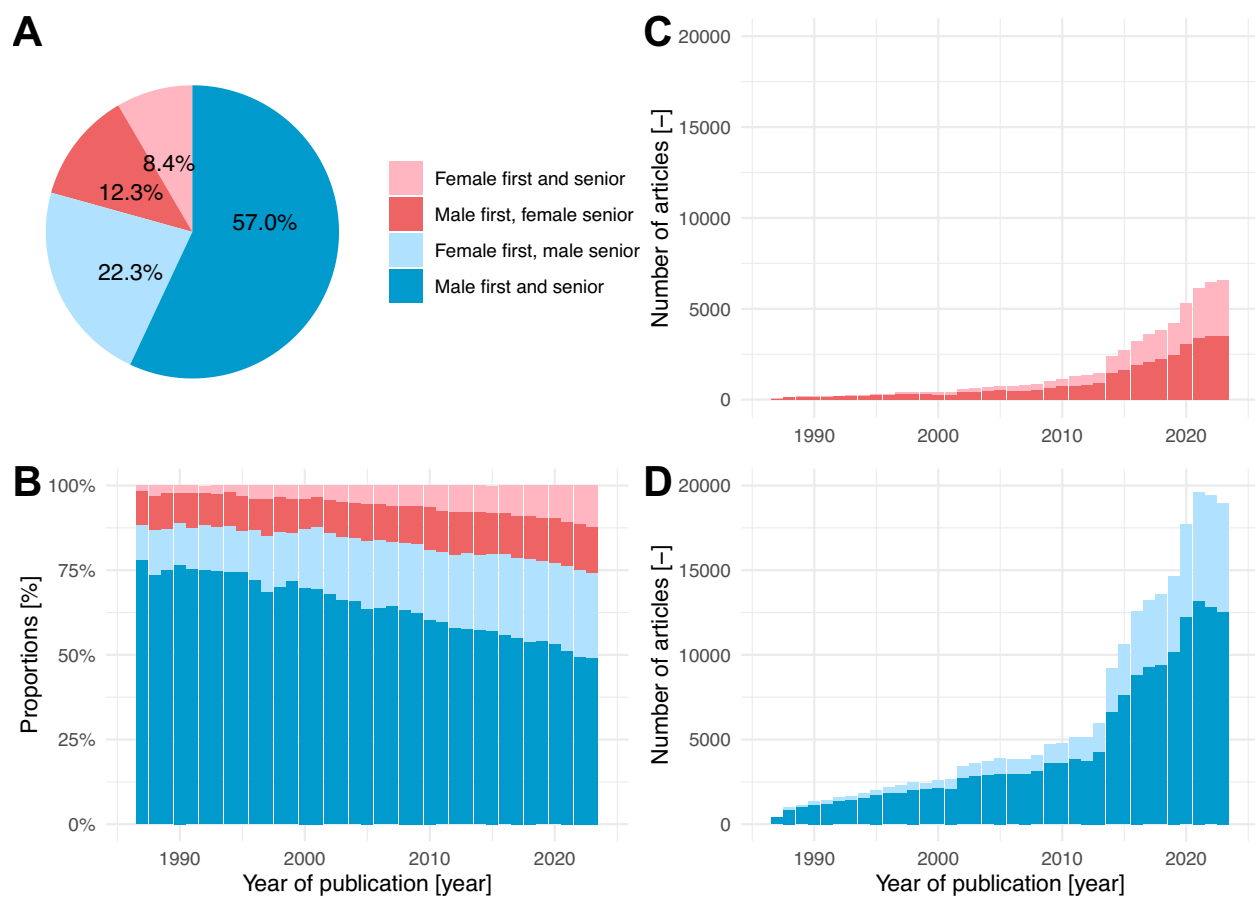


Fig. 3 Gender trends in leading author positions in anesthesiology articles (1987–2023): **(A)** Proportion of female authors in first and senior author roles, **(B)** trends in gender distribution among leading authors, **(C)** number of articles with female senior authors, and **(D)** number of articles with male senior authors

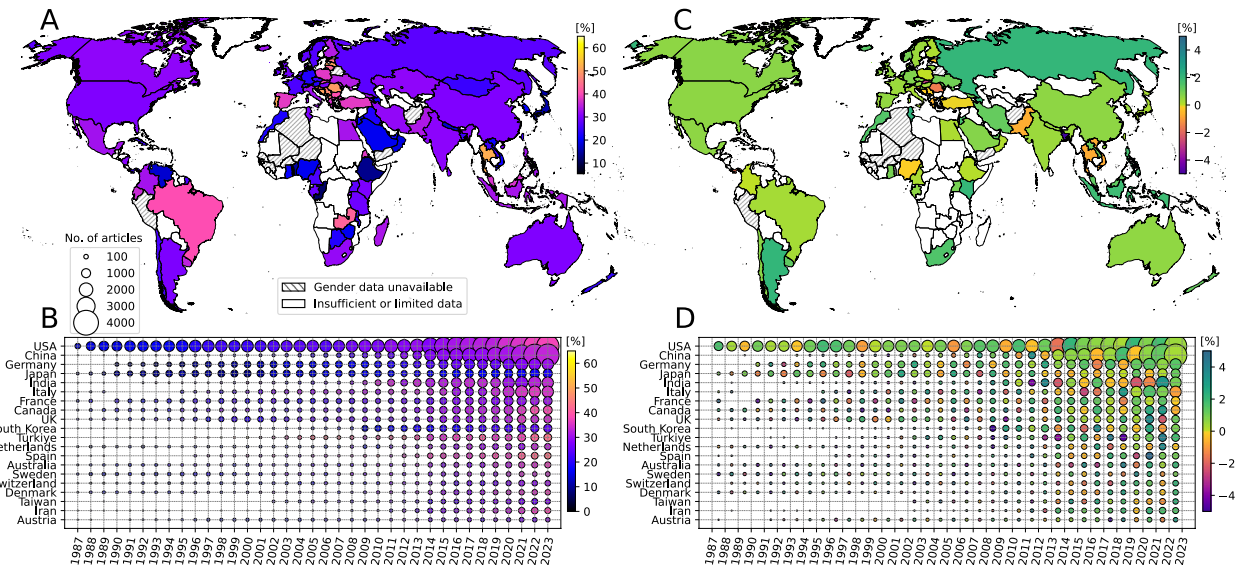


Fig. 4 Country-specific geographic analysis of female proportions in anesthesiology articles (1987–2023): **(A)** Global distribution, **(B)** trends for the top 20 countries by total article count, **(C)** average annual growth, and **(D)** annual growth trends for the top 20 countries by total article count

95%-CI 48.9%–55.5%), Portugal (51.8% female authors out of 769 articles; 95%-CI 48.2–55.3%), and Romania (49.7% female authors out of 567 articles; 95%-CI 45.6–53.8%). The top three countries in terms of average yearly increase in female representation among authors in anesthesiology articles were Tunisia (2.28%; 95%-CI 1.51%–3.06%), Argentina (2.15%; 95%-CI 0.91%–3.38%), and Russia (2.09%; 95%-CI 0.87%–3.32%).

Projection of gender parity

Assuming that current trends continue unchanged, the overall gender parity is estimated for 2050 (Fig. 5). Parity in first authors will be reached in 2043 and in senior authors in 2072, respectively. Among the top twenty publishing countries (Table 1), Iran is estimated to reach parity among authors in 2033, with a past annual growth in female authors of 1.23%. The Netherlands will be second in 2037 (1.03%), followed by Spain in 2038 (0.57%). Other countries will not reach gender parity before the 2040's decade. Regression fits are presented in Supplemental File S2.

Discussion

Despite a decline in gender inequity in anesthesiology articles between 1987 and 2023, parity has not yet been achieved. In 2023, female authors accounted for only a third of authorships in anesthesiology publications worldwide. Based on the assumption that current trends continue unchanged, estimates project that overall parity in authorship will not be realized until 2050, though some countries are likely to achieve it sooner.

The present findings align with recent literature, which revealed a gradual increase in the proportion in female co- and first authorship, while gender disparity at higher career levels persists [7]. Gender parity among medical students has already been reached in many countries [23, 24], and the global medical and anesthesia workforce has approached parity since around 2010 [25, 26]. But still, female authors remain underrepresented in anesthesiology articles. This likely reflects the delayed relevance of publishing in clinical careers, as research prominence typically increases only at later stages [27]. Notably, gender gaps are even wider in leadership roles such as

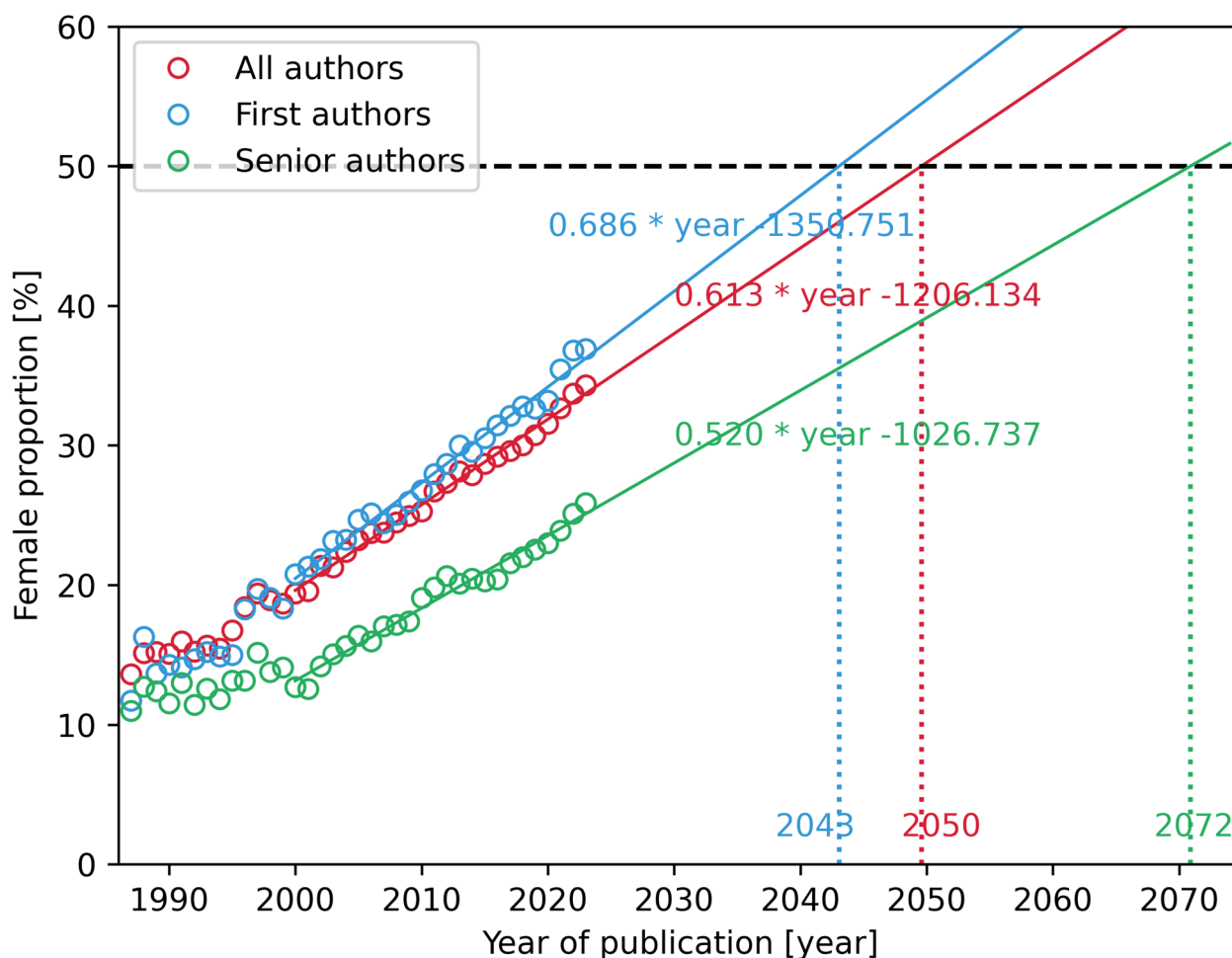


Fig. 5 Projection of gender parity (i.e. 50% female authors) on all authorships (red), first authorships (blue) and senior authorships (green) by linear regression (2000–2023)

Table 1 Projected year of gender parity in authorship of anesthesiology articles for the top 20 countries by total article count, based on current trends and estimated by linear regression slopes of annual gender proportion trends

	Estimated year of gender parity	Average annual growth in female authors with 95%-CI [%]	Coefficient of determination	Standard Error
Iran	2033	1.23 (0.93 – 1.53)	0.78	0.14
Netherlands	2037	1.03 (0.81 – 1.24)	0.82	0.10
Spain	2038	0.57 (0.39 – 0.75)	0.67	0.09
Canada	2043	0.70 (0.59 – 0.80)	0.90	0.05
United States of America	2045	0.64 (0.57 – 0.70)	0.95	0.03
Australia	2048	0.61 (0.48 – 0.74)	0.81	0.06
China	2050	0.63 (0.55 – 0.70)	0.94	0.04
Germany	2050	0.77 (0.71 – 0.83)	0.97	0.03
United Kingdom	2052	0.56 (0.47 – 0.65)	0.89	0.04
Denmark	2054	0.51 (0.33 – 0.69)	0.62	0.09
India	2058	0.44 (0.24 – 0.64)	0.50	0.10
Switzerland	2058	0.57 (0.41 – 0.73)	0.71	0.08
Sweden	2058	0.48 (0.34 – 0.63)	0.71	0.07
Austria	2060	0.57 (0.45 – 0.69)	0.81	0.06
France	2065	0.47 (0.38 – 0.56)	0.85	0.04
South Korea	2073	0.51 (0.37 – 0.65)	0.73	0.07
Italy	2077	0.29 (0.16 – 0.41)	0.53	0.06
Taiwan	2087	0.35 (0.21 – 0.49)	0.58	0.07
Japan	2145	0.25 (0.17 – 0.34)	0.65	0.04
Türkiye	-	-0.02 (-0.24 – -0.19)	0.00	0.10

editor-in-chief or editorial board position [7]. Given that last authorship is traditionally associated with seniority [28], our data suggest that it may take another generation to achieve gender parity in these roles. Prior studies by Miller et al. and Pagel et al. also reported a slower rise in senior female authors compared to first authors [10, 11] —a trend confirmed by our findings. Miller et al. and Rong et al. also identified a robust correlation between female lead authors and female authors in other roles [8, 10], which aligns with our findings that the gender of the last author correlated significantly with that of the first. This supports the idea that women in leadership positions foster greater gender equity. Likely, women in academic anesthesiology are more promoted through female networks. Given that authorship is a form of academic currency with implications for recognition, institutional status, funding, and career progression, it is conceivable that leadership and academic positions have been utilized to reinforce existing hierarchies or to advance personal careers through questionable authorship practices [29]. This possibility merits further investigation in the context of persistent gender imbalances.

Evidently, the proportion of female first authors in anesthesiology articles has increased over time. Rong et al. observed an increase from approximately 20% (2008) to around 30% (2018) across five high-impact journals [8]. Similarly, Miller et al. identified an increase from 20% (2002) to 30% (2017) in two US-American journals [10] as did Pagel et al. from 4% (1967) to 33% (2017) [11]. A

recent systematic review by De Cassai et al. confirmed this trend, reporting increases in female first authorship from 7% to 17% in anesthesiology and critical care medicine [7]. However, all these studies including those in the systematic review share a key limitation: They were based on selected journals, which restricts the generalizability of their findings. Anesthesiology-related research is published across a wide range of journals [16], with a significant proportion appearing outside of specialty-specific journals [30]. In addition, most prior studies were limited to short timeframes.

The strength of the present affiliation-based approach lies in its broader scope. By not restricting the analysis to selected journals or limited periods, it enables a more comprehensive assessment, as demonstrated by the large number of included articles and journals. Of great importance is the accuracy of results, which depends heavily on the precision of the data query, since specificity in scientometric studies cannot be empirically validated. However, careful data curation can improve sensitivity, as previously demonstrated in anesthesiology-related research [16, 30]. Another advantage is the possibility of country-specific analyses to gain a comprehensive understanding of the global extent of authorship disparities in anesthesiology.

In this context, our data show that the proportion of female authors is highly heterogeneous and not intuitively distributed across different countries. It is relevant to acknowledge that comparison between countries may

be limited due to different social, political, cultural, historical and legal contexts [7]. Therefore, each country's own trend over time may be more valuable, as it provides at least some insight into its authorship situation by eliminating some country-specific characteristics. Furthermore, it is worth noting that only two countries had a proportion of female authorship exceeding 50% by 2023. Even more countries show a declining trend in female authorship. Nevertheless, it should be noted that our approach of assigning countries based on the first author's affiliation may not accurately reflect the complexity of international collaborations. While it is likely that international collaboration has increased substantially in recent years, data is only available for publications in pediatric anesthesia [16].

Limitations

Affiliation-based analyses have their restrictions that should be considered when interpreting results. Journal counts may be influenced by name changes or inconsistencies in the source database, although such effects are usually minor. Affiliation data before 1987 were sparse due to incomplete digitization, and MEDLINE only began including multiple affiliations per author after 2014 [30], leading to less comprehensive data for co- and senior authors in earlier years. Moreover, our analysis has specific limitations: First, articles were identified based on the association of at least one author with an anesthesiology department. Given the interdisciplinary nature of anesthesiology, our dataset likely includes research from related fields, such as critical care and surgery, in addition to anesthesiology-specific studies. Second, gender identification was not possible for all authors. Although genderize.io and gender-api.com are validated tools and widely applied [19–21, 31], they rely mostly on public databases (e.g., birth records) that may introduce country-specific biases [32]. The typically used threshold of 60% for binary gender classification balances the risk of bias by systematic exclusion of authors from under-represented regions with the desire for high accuracy [19–21]. As demonstrated in Supplemental Table S3, this predominantly occurred among authors from China. Third, we were unable to identify or include non-binary authors. The utilization of automated large-scale gender classification based on forenames is inherently limited to a binary framework, which may not accurately reflect authors' self-identified gender or biological sex at present. Despite the obvious incongruity between this approach and contemporary gender theories, it remains the sole feasible method for large-scale classification. Fourth, although we included all types of articles, we could not distinguish between them due to the poor data quality [22]. Authorship practices might vary substantially across different article types.

Conclusions

This affiliation-based scientometric analysis revealed a gradual increase in female authorship in anesthesiology-related articles over an extensive time period, including first and senior author roles. However, based on the assumption that current trends continue unchanged, parity will still be decades away, particularly in leading positions. Considerable heterogeneity was observed between countries, highlighting the diverse pace and extent of progress. Efforts at a country-specific level are needed to address the gender gap at multiple levels and foster a more inclusive and representative academic community in anesthesiology.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12871-025-03407-1>.

Supplementary Material 1: Supplemental File S1. Regular expressions for identification of anesthesiology-related articles among affiliation data from the MEDLINE/PubMed 2024 Baseline Repository (Python code and PostgreSQL queries) and for identification of valid forenames in MEDLINE/PubMed author data (Python code)

Supplementary Material 2: Supplemental File S2. Per-country linear regression fits of yearly numbers of anesthesiology-related articles from 2000 to 2023

Supplementary Material 3: Supplemental File S3. Number of excluded authors per country because the gender classification probability was below 60%. Only the 20 highest countries with the highest count are listed

Acknowledgements

This work was supported by the Clinical Scientist Program of the Faculty of Medicine, University of Regensburg.

Authors' contributions

CM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JR: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. AS: Formal analysis, Investigation, Writing – review & editing. MN: Formal analysis, Investigation, Writing – review & editing. PP: Conceptualization, Writing – review & editing. AD: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing. All authors reviewed the manuscript.

Funding

The costs for using genderize.io and gender-api.com were borne privately by authors AD and CM. Open access charges were funded by the Open Access Publication Funds of the Goettingen University, who had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

The datasets and the generated codes are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study did not need to be approved by an Institutional Review Board. It did not include data from patients.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 14 August 2025 / Accepted: 29 September 2025

Published online: 13 October 2025

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