



ORIGINAL ARTICLE

Gender Equality in High-Quality Anesthesiology Research – A Descriptive Bibliometric Study on Scientific Authorships

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Abstract

Background: As in other scientific disciplines, medicine has undergone a huge movement in sex distribution due to an increasing number of women entering the field. The effects of this shift on gender equality in anesthesiology research are discussed in this study.

Authorships in medical publications provide information of the grade of the author within the medical discipline. As a result, they can be used as indicators for integration within medical research. The central aspect of this analysis included the examination of the assignment of authorships between male and female researchers in anesthesiology research.

Methods: This bibliometric study analyzed 159.535 authorships from 43.468 original research articles in high-impact anesthesiology journals, listed in the Web of Science from 2008 to 2019. The analysis included the assignment of authors to sexes on the basis of the first names of the authors. Authorships of unisex and undefined authors were excluded.

The female authorship proportion (FAP) and the female authorship odds ratio (FAOR) for all authorships were determined. The Prestige Index (PI) represents prestigious female authorships.

We analyzed the female representation in anesthesiology research on a global, national- and journal-level. The average annual growth rate of the female authorship proportion, citation rates and the productivity between the genders were examined.

Results: Female authors accounted for 33.2% of all authorships. The female odds are 1.1 (95% CI 1.07 to 1.13) for first authorship-, 1.26 (95% CI 1.23 to 1.29) for co-, and

0.59 (95% CI 0.57 to 0.61) for last authorships. The average annual growth rate was 2.2% overall, 2.3% for first-, 2.0% for co- and 1.8% for last authorship. Women lacked prestigious authorships (average PI = -0.28), especially in large collaboration articles (PI = -0.99 for articles > 15 authors). Female scholars published fewer articles compared to men (38.4% [n = 46.470] female authors held 33.2% [n = 52.966] of the authorships) and articles with female principal authors had slightly lower citation rates (female last author: 13.8 citations/articles, male last author: 14.2 citations/articles). There are transnational and journal-specific differences for women in securing prestigious authorship.

Conclusion: The data analysis suggests an average integration of women into high-impact anesthesiology research. With many women at an early stage of their careers and few female group leaders, anesthesiology research represents the existing global career dichotomy between sexes. This gender gap will potentially decrease, as early career researchers may be in academic leadership positions in the future.

Keywords

Gender gap, Female authorship proportion, Odds ratio, Citation rates, Productivity

List of Abbreviations

AAGR: Average Annual Growth Rate; FAOR: Female Authorships Odds Ratio; FAP: Female Authorship Proportion; PI: Prestige Index

Key Points

- Anesthesiology research reflects the global career dichotomy between men and women, with

higher odds of securing prestigious authorships for male researchers.

- The lack of female authors in leadership positions accentuates at the highest level of productivity and in collaboration articles with high citation rates.
- Female researchers publish mostly as first authors as anesthesiology research is characterized by female junior researchers and mostly male group leaders.
- With an increasing average annual growth rate of the proportion of female authorship, the gender gap in anesthesiology research will potentially decrease in the future.

Introduction

As the distribution of sexes in medicine has made a huge shift in recent decades, gender disparities in working environments remain. As in many other scientific disciplines [1], academic medicine shows differences in career paths between men and women [2].

With a continuously growing number of women graduating from medical school in the last 25 years [3], we also see a significant increase of women entering the field of anesthesiology within that time [4,5]. Bissing, et al. points out, that the count of female physicians among anesthesiology faculty members increased by approximately 2.0% per year since 2006 [4]. Following the “pipeline theory” [3], the rising number of women graduating from medical school would lead to an equally increasing number of women in academic leadership positions [4]. However, despite the comparatively high increase of female physicians in anesthesiology, we see a disproportionately lower number of women in leadership positions [3]. This gender-specific career dichotomy is known as the “leaky pipeline” [6]. This phenomenon is not exclusive to anesthesiology, but can be discovered in many disciplines within medical research [7-13].

The existence of female underrepresentation in leadership positions in anesthesiology may surprise, as it is generally seen as a specialty with flexible working hours and the possibility of part-time employment [14], making it an attractive discipline favoured by both sexes similarly.

To further investigate the gender-specific career dichotomy in anesthesiology, this study aimed to identify gender disparities in high-impact anesthesiology research, based on the distribution of female authors among specific authorships.

In this study, 159.535 authorships out of 43.468 original articles published in 127 anesthesiology journals were analysed. As authorships in medical publications can be used for the quantification of scholastic activity

and the grade of the author within the medical discipline [8-10,15], they serve as indicators for the integration of women in anesthesiology research. Therefore, the central aspect of this analysis included the examination of the assignment of authorships between male and female researchers in anesthesiology publications.

Generally, in original medical articles, the assignment of authorships underlies the concept that the first author participates the most, while the last author is usually considered the responsible senior scientist [16,17]. Co-authors make the smallest contribution and earn less appreciation for the work [16,17]. Following this concept, each authorship is connected to an increasing level of reputation with the most prestige for first and last authorships and the lowest for co-authorships [9,17,18]. Additionally, in original articles, early-career scientists usually publish as first or co-authors, while reputable senior scientists publish as last authors [17]. As a result, the distribution of authorships between men and women allows us to determine the academic position of each author and can be used as a tool to detect the integration of female scientists in anesthesiology research.

In this study, we analysed the distribution of different authorships and their prestige levels among male and female authors in anesthesiology research. Additionally, the odds ratios of female authorship, sex-specific citation rates, international differences, journal-specific aspects, gender disparities in collaborative articles and scholarly productivity between sexes were investigated.

Methods

Data collection

Original research articles from high-impact anesthesiology research journals formed the centre of this study. To acquire data, a title search using the search terms (WC = “Anesthesiology” AND language: English AND document types: Article) was performed [9]. The articles were acquired on May 31, 2019 from the Web of Science Core Collection. Overall, the analysis included articles published from January 1, 2008 to May 30, 2019. The data for the bibliometric analysis were gathered using the SQL server-based platform GENDERMETRICS.NET [19]. To generate groups of authors, article authorships were grouped by name and first names [20]. In total, 121.016 authors were included in the analysis.

Assignment of sexes

Sex identification was performed using a data table, including data on gender determination of 77.818 forenames (male, female and unisex) [19]. Collectively, 47.667 male authors (39.4%), 29.681 female authors (24.5%), 6.495 unisex authors (5.4%) and 37.173 undefined authors (30.7%) were identified. Authorships of unisex and undefined authors (n = 80.992) were not

considered [9]. Therefore, 159,535 male and female authorships were included in the analysis. An authorship recognition rate above 60.0% and at least 750 male/female authorships were set to select countries and journals for sub-analysis [9]. On account of the high rate of unisex names, China, Taiwan and South Korea were excluded from the analysis [9].

Definition and interpretation of the Female Authorship Proportion (FAP) and Female Authorship Odds Ratio (FAOR)

We incorporated first, co- and last authorships, with co-authorships being defined as authorships between one first and one last authorship [9,20]. Single-author articles were counted as first authorships [10], while for co- and last authorships only articles with at least two or three authors could be considered [20].

The proportion of female authorships (FAP) was determined as the ratio between the count of female authorships and the sum of female and male authorships combined, and is presented as a percentage [20].

To visualize the distribution of female authors for each authorship position, the odds ratio for female authors for each specific authorship (first, co- and last authorship) was defined as the female authorship odds ratio (FAOR). The FAOR is determined as the quotient between the female odds for a specific authorship and the male odds for this specific authorship [20]. The FAOR represents the female odds of maintaining specific authorship types compared to male odds [9]. The corresponding confidence intervals are set at a confidence level of 95% [9].

The FAOR-triplets are used to exemplify the significant higher female odds to secure a certain authorship [9]. The FAOR-triplet (-, =, +) indicates that women have significantly lower (-) odds for first authorship, equal (=) odds for co-, and significantly higher (+) odds for last authorships [9]. In conclusion, the FAP measures the representation of female authorships among the sum of all authorships [9]. The FAOR indicates the specific distribution of female authorships among all first, co- and last authorships [9].

Prestigious authorships represented by the prestige index

The Prestige Index (PI) is used to represent the distribution of prestigious female authorships in contrast to prestigious male authorships [8,9]. It is defined as the “prestige-weighted average of the FAOR excess ϵ_t calculated over all kinds of authorships t ” (first, co-, last authorship) [20]. The FAOR excess is calculated, in case that $FAOR_t \geq 1$, by $\epsilon_t = wt (FAOR_t - 1)$. In case that $FAOR_t < 1$, it is calculated by $\epsilon_t = wt (1 - 1/FAOR_t)$ with wt being the weighting factor [9]. As the first and last authorships provide a higher reputation [8,17,18,20], they are considered to be more prestigious than co-

authorships. Following this hypothesis, first and last authorships were weighted positively ($w_{first} = w_{last} = 1$), in contrast to co-authorships, which were weighted negatively ($w_{co} = -1$) [9,18,20]. Accordingly, higher female odds for co-authorships and lower female odds for first and last authorships reduce the Prestige Index, while lower female odds for co-authorships and higher female odds for first and last authorships increase the Prestige Index [9]. A gender-equal distribution of prestigious authorships is characterized by a value of 0, while values above 0 indicate an excess, and values below 0 indicate a deficit of prestigious authorships held by women [9,20].

Analysis of trend and correlation

The average annual growth rate (AAGR) was used to represent the annual growth of the FAP and of the female portion for specific authorships [9]. The potential linear correlation between the FAP and Prestige Index on a country- and journal-specific level was measured using the Pearson correlation [9]. We used Kruskal Wallis and post-hoc multi-comparison tests to test the null hypothesis, claiming that the non-normally distributed citation rates of different article groups originate from the same distribution [9,20]. The significance threshold was set at $P < 0.05$ [20].

Results

Present global status of female authorships in anesthesiology research

At the global level, this analysis revealed a female underrepresentation with an FAP of 33.2% (Figure 1A, bottom), with proportionally more first and co-authorships (both 35.1%) and significantly fewer last authorships (24.3%). According to this, the associated FAORs for female authors are 1.1 (95% CI 1.07 to 1.13) for first authorships, 1.26 (95% CI 1.23 to 1.29) for co-authorships and 0.59 (95% CI 0.57 to 0.61) for last authorships (Figure 1A). The global FAOR pattern (+, +, -) exemplifies this distribution of authorships, with significantly higher female odds for first authorships and co-authorships and significantly lower odds for last authorships. This is also shown by the Prestige Index, which is -0.28 on average. This negative value represents the deficiency of prestigious authorships held by women (Figure 1A, bottom).

The time trend recorded a change in the FAOR triplet from (+, +, -) to (=, +, -) in 2010, 2012, 2013, 2014 and 2017 (Figure 1A). This change represents the decreasing female odds of securing prestigious first authorships during these years. In all other years between 2008 and 2019, female scholars had a higher chance of first authorships compared to men. Since 2018, the FAOR triplet has changed to (+, +, -) again.

Overall, the FAP shows a moderate increase with a total AAGR of 2.2%, with the highest growth rate for

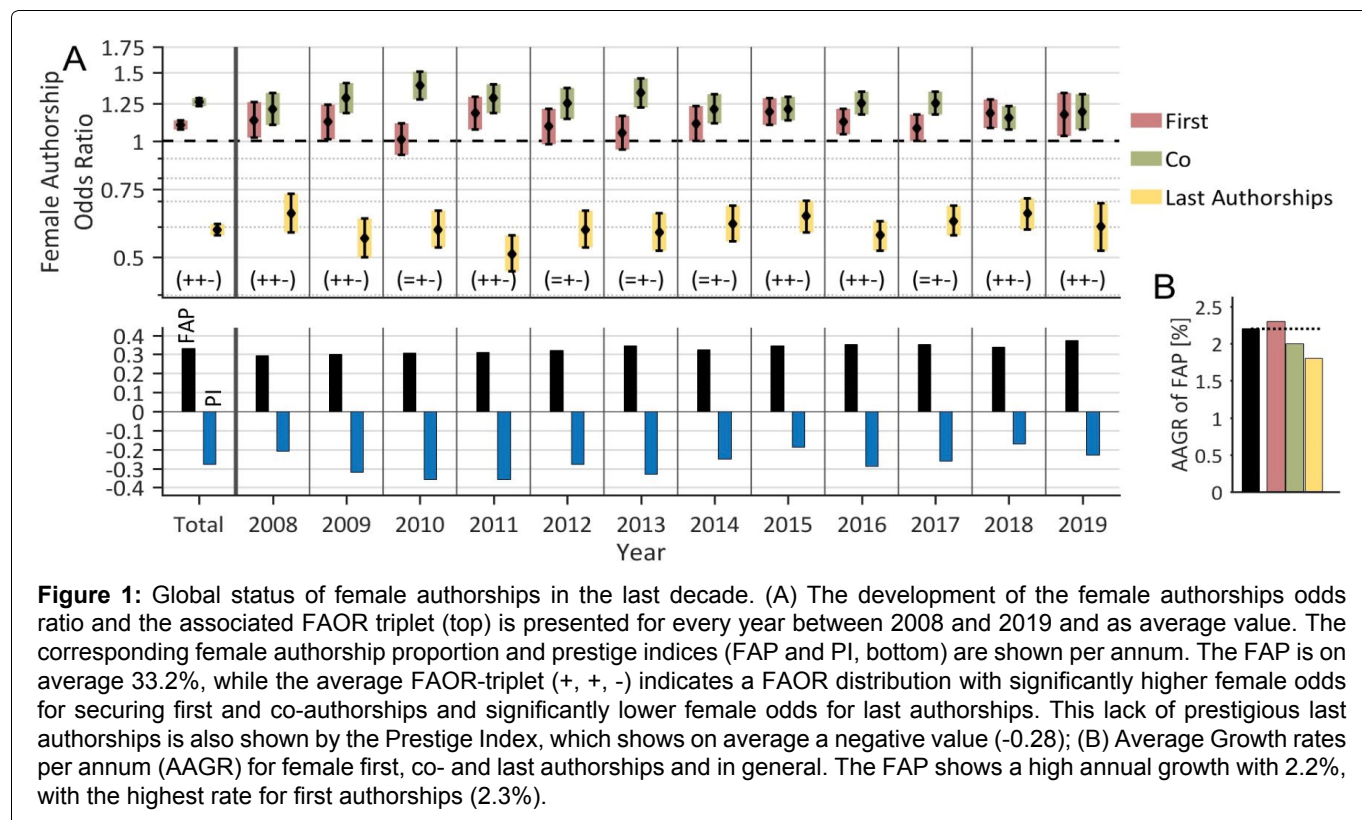


Table 1: Country classification.

Name of Country	Prestige Index	Proportion of Female Authorships	FAOR-triplet	No. Articles	No. Authorships
Turkey	0.14	42.7%	(+, -, =)	987	3902
Netherlands	0.14	29.2%	(+, -, -)	1613	4599
Israel	-0.04	32.7%	(=, =, =)	387	1111
Brazil	-0.07	47.3%	(=, =, =)	711	2607
Canada	-0.15	36%	(+, +, -)	3074	9974
Egypt	-0.18	25%	(=, =, =)	585	1330
Greece	-0.27	50.4%	(=, =, -)	212	1074
Germany	-0.36	26.2%	(+, +, -)	2966	9906
United States	-0.38	31.6%	(=, +, -)	14303	53408
Switzerland	-0.38	27.8%	(=, +, -)	1011	2523
Spain	-0.4	47.4%	(=, +, -)	901	3582
France	-0.5	28.7%	(=, +, -)	1912	7864
Italy	-0.92	41.9%	(-, +, -)	1659	6155
Japan	-0.96	20.9%	(+, +, -)	2468	10418

Countries are arranged in descending order depending on their Prestige Index from higher PI to lower PI. The No. Authorships represents the count of all included male or female authorships of a specific country, while No. Articles represents all considered articles for the country. Additionally, the country-specific FAP and the corresponding FAOR-triplet are assigned to each country.

first authorships (2.3%), followed by co- (2.0%) and last authorships (1.8%) (Figure 1B). In particular, the high growth rate of prestigious first authorship caused the Prestige Index to increase from -0.35 in 2011 to -0.22 in 2019 (Figure 1A).

Country-specific differences for female authors

By considering the country-specific female representation of authorships, we find a distribution of FAPs from 50.4% in Greece to 20.9% in Japan (Table 1).

The differences in female authorship odds ratios are also shown by the country-specific FAOR-triplets, as they vary from the unfavourable FAOR-triplets (-, +, -) and (=, +, -) in Italy, the United States, Switzerland, Spain and France to the more favourable FAOR-triplet (+, -, =) in Turkey. Only Israel, Brazil and Egypt provide gender-neutral odds for all authorships with the FAOR-triplet (=, =, =). However, the predominant number of countries show FAOR-patterns with significantly lower female odds for last authorships and equally high female odds for first

authorships compared to men (Table 1). As a result, there is no single country in which women have higher odds of securing last authorships. Besides Israel, Brazil and Egypt, only Turkey provides at least equal female odds for ensuring last authorships compared to men (FAOR-triplet [+ , - , =]). Prestige Indices range from very low Prestige Indices in Japan (Prestige Index = -0.96) and Italy (Prestige Index = -0.92) to slightly positive Prestige Indices in Turkey and the Netherlands (both Prestige Index = 0.14). There is no linear correlation between the FAP and the Prestige Index of the countries ($r [14] = 0.21, P > 0.05$).

Female representation among high-impact journals

Among high-impact anesthesiology journals, the FAP ranges from 47.1% in the British Journal of Anaesthesia to 23.8% in the Annals of Cardiac Anaesthesia (Table 2).

The journals show a range of different FAOR-patterns, with two predominant triplets: (+, =, -) (9 of 32 [28.13%]) and (=, +, -) (8 of 32 [25.0%]). Corresponding to the predominant triplets, we see higher or equal female chances for first authorships in 28 out of 32 journals. Concomitantly, there is no journal in which women

Table 2: Journal classification.

Journal	Prestige Index	Proportion of Female Authorships %	FAOR-triplet	No. Articles	No. Authorships
Indian Journal of Anaesthesia	0.20	43.2	(+, =, =)	511	1,414
European Journal of Pain	0.04	38.5	(+, =, -)	1,610	2,851
A&A Practice	0.03	34.5	(+, =, -)	283	977
Pain	-0.02	41.1	(+, =, -)	2,913	16,292
Korean Journal of Anesthesiology	-0.02	36.8	(+, =, -)	306	889
A&A Case Reports	-0.04	31.1	(+, =, -)	461	1,660
Revista Brasileira de Anestesiologia	-0.07	42.9	(=, =, =)	509	2,162
Journal of Neurosurgical Anesthesiology	-0.08	30.8	(=, =, =)	457	2,042
Anaesthesia Critical Care & Pain Medicine	-0.10	27.0	(+, =, -)	223	1,622
The Clinical Journal of Pain	-0.12	44.0	(+, =, -)	1,263	6,153
Anaesthesia, Pain & Intensive Care	-0.14	39.6	(=, =, =)	302	905
Current Opinion in Anesthesiology	-0.19	26.1	(+, =, -)	452	913
Pain Physician	-0.20	28.8	(-, =, =)	914	3,605
Turkish Journal of Anaesthesiology & Reanimation	-0.22	42.8	(=, =, -)	241	1,042
Annals of Cardiac Anaesthesia	-0.24	23.8	(=, =, -)	331	1,259
Pain Medicine	-0.25	39.1	(=, +, -)	1,981	9,306
Pediatric Anesthesia	-0.26	39.7	(+, +, -)	1,439	6,511
Journal of Clinical Anesthesia	-0.26	32.1	(=, +, -)	1,156	4,857
Saudi Journal of Anaesthesia	-0.27	29.6	(=, =, -)	373	998
Pain Practice	-0.30	33.1	(=, +, -)	761	3,525
European Journal of Anaesthesiology	-0.32	32.3	(+, +, -)	1,074	5,357
Journal of Cardiothoracic and Vascular Anesthesia	-0.32	25.0	(=, +, -)	2,268	11,578
Canadian Journal of Anesthesia/ Journal canadien d'anesthésie	-0.33	32.6	(=, +, -)	935	4551
BMC Anesthesiology	-0.34	31.7	(=, +, -)	965	4,239
Anesthesia and Analgesia	-0.34	29.8	(+, +, -)	3,839	19,129
Journal of Anesthesia	-0.48	25.6	(+, +, -)	1,488	6,418
Regional Anesthesia & Pain Medicine	-0.50	26.2	(=, +, -)	907	4,300
Journal of Clinical Monitoring and Computing	-0.52	24.3	(=, +, -)	849	3,676
Anesthesiology	-0.55	29.3	(-, +, -)	2,389	15,004
Minerva Anestesiologica	-0.76	34.5	(-, +, -)	1,020	1,923
JA Clinical Reports	-0.80	26.8	(+, =, -)	224	1,017
British Journal of Anaesthesia	-2.38	47.1	(-, +, -)	2,239	5,081

Journals are ordered descendingly according to their Prestige Indices. All considered articles and number of authorships are presented with the corresponding FAP and FAOR triplet of the specific journal.

exceed male odds for prestigious last authorships. Only five journals provide equally distributed odds for last authorships between genders. There are no journals with higher male odds for unfavourable co-authorships.

We find three journals (Revista Brasileira de Anestesiologia, Journal of Neurosurgical Anesthesiology, Anaesthesia, Pain & Intensive Care) providing equal odds for men and women regarding all authorships (FAOR triplet [=, =, =]). The most unfavourable FAOR pattern (-, +, -) for female researchers is shown by Anesthesiology, Minerva Anestesiologica and the British Journal of Anaesthesia.

The low female odds for last authorships are also reflected by the Prestige Index, which is on average negative (Prestige Index = -0.32). Minerva Anestesiologica (Prestige Index = -0.76), JA Clinical Reports (Prestige Index = -0.80) and the British Journal of Anaesthesia (Prestige Index = -2.38) have the lowest number of female researchers in prestigious authorship positions. We only find three journals with positive Prestige Indices, with the best odds for female authors in the Indian Journal of Anaesthesia (Prestige Index =

0.20), European Journal of Pain (Prestige Index = 0.04) and A&A Practice (Prestige Index = 0.03).

There is no linear correlation between the FAP and the Prestige Index of the Journals ($r[32] = -0.082$, $P > 0.05$).

Female authors in multiauthor articles

To analyse the female proportion in multiauthor articles, we examined the female authorship proportion for articles with various numbers of authors per article. The FAP grows with an increasing author count from 30.0% (1 to 3 authors per article) to 40.0% (< 15 authors per article) (Figure 2, bottom). There is a significant change in FAORs with an increasing number of authors per article. While the female odds for first and last authorships decrease, the FAOR for co-authorships increases with the number of authors per article. The correlation between the number of authors per article and the FAOR is also shown by the change of the FAOR triplet from (+, +, -) (1 to 3 authors per article, 4 to 6 authors per article, 7 to 9 authors per article) to (=, +, -) (10 to 12 authors per article, 12 to 15 authors per

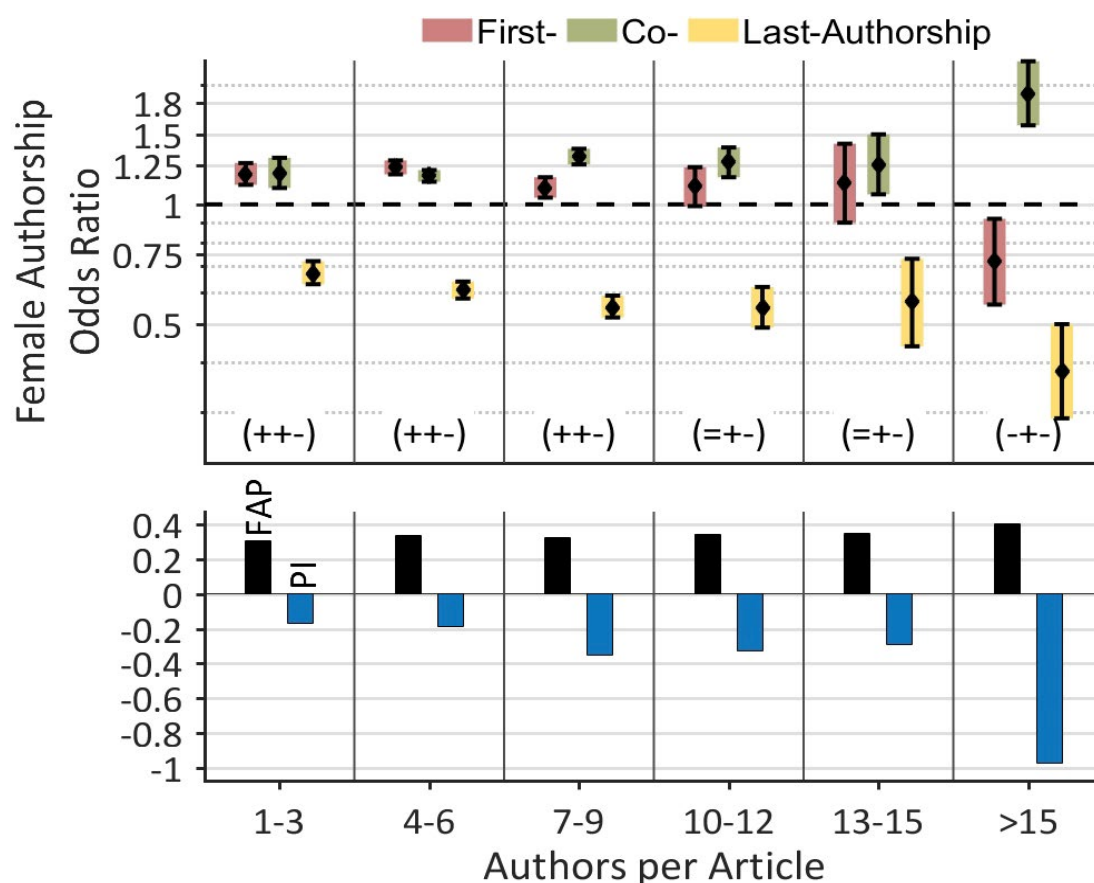


Figure 2: Representation of female authorships in articles with increasing count of authors. Articles were arranged in ascending order after their number of authors involved. The female authorship proportion increases concomitantly with the higher count of authors (FAP = 30% for 1-3 authors per article; FAP = 40% for > 15 authors per article), while the female authorship odds ratio for first and last authorships decreases. This lack of prestigious authorships in multiauthor articles is also shown by the change of the FAOR triplet from (+, +, -) for articles with 7-9 authors, to (=, +, -) for articles with 13-15 authors, to finally (-, +, -) for articles with more than 15 authors. The resultant development of the Prestige Index shows a radical decrease for articles with more than 15 authors. Hence, female authors have significantly lower odds for prestigious authorships in large multiauthor articles.

article) to the unfavourable triplet (-, +, -) for more than 15 authors per article (Figure 2). Concomitantly, the Prestige Index decreases radically to -0.99 (> 15 authors per article), illustrating a significant lack of prestigious authorships for female scholars in large collaboration articles. In conclusion, the FAP increases with a higher count of authors per article, while the odds for female scholars for prestigious authorships decrease.

Citation rates and differences in productivity between the sexes

Citation rates between articles with male or female key authors show minor differences. Both, articles with male or female last author, exceed the mean citation rate of 13.4 citations per article, while articles with male last authors are slightly more common to be cited (14.2 citations per article) than articles with women holding last authorships (13.8 citations per article) (Figure 3A). Articles with a male or female first author are nearly equally often cited with 13.4 citations per article for men and 13.5 citations per article for women.

The analysis of articles with shared key authorships show the highest citation rates for male first/female last

and female first/male last authorship articles, with a citation rate of 14.3 citations per article for both (Figure 3A). Articles with a combination of male first/male last authorship have, on average, a higher citation rate (14.2 citations per article) than female first/female last authorship articles (13.7 citations per article). Articles with single male authors have a citation rate of 6.4 citations per article, female single author articles are less often cited with a citation rate of 4.7 citations per article (Figure 3A).

The correlation between citation rates and the number of authors per article demonstrates statistically higher citation rates with an increasing count of authors per article (Figure 3B). Differences in citation rates between sexes appear in articles with more than 10 authors per article. In the group “10 to 12 authors per article”, female last authorship articles have the highest citation rate compared to all other key authorships (Figure 3B). With an increasing count of authors per article, key male authorship articles become more commonly cited. Among large collaboration articles with more than 15 authors, articles with male last authorship have the highest citation rate (Figure 3B).

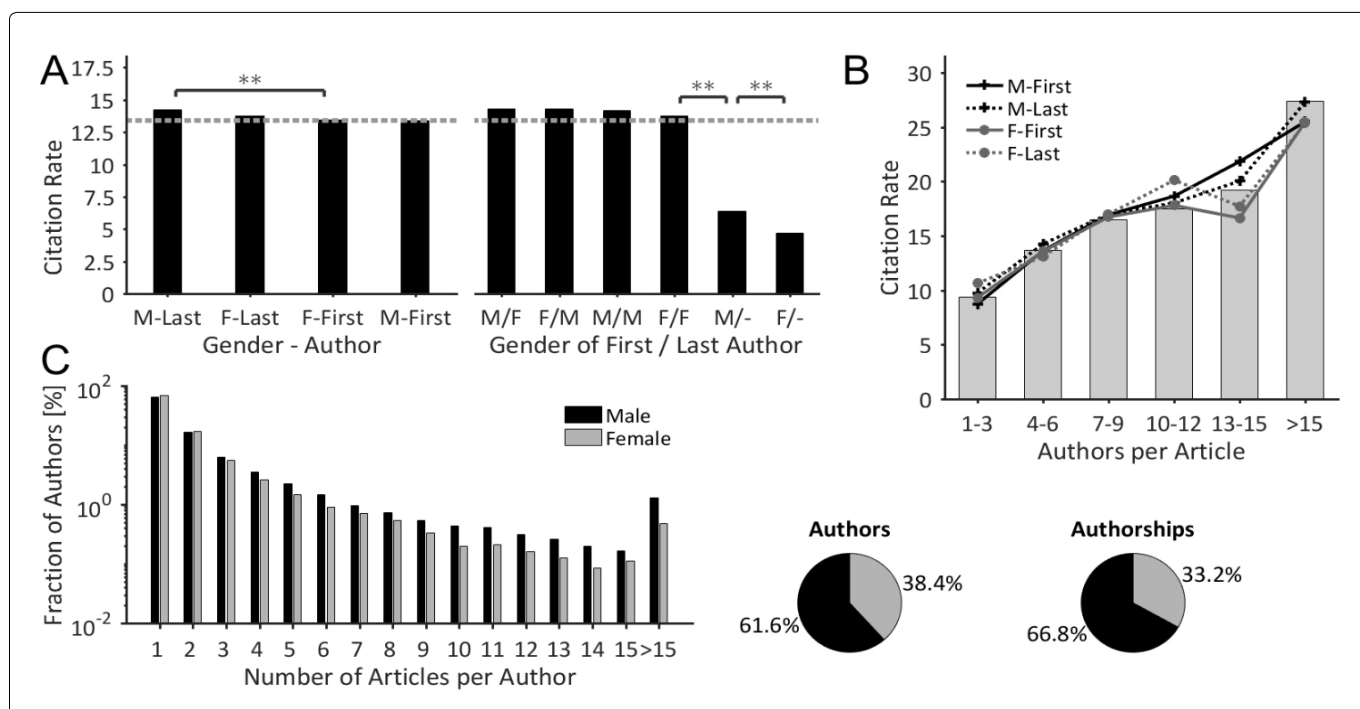


Figure 3: Gender-specific citation rates and productivity. (A, left) The citation rates are ordered in descending order, to outline the highest and lowest citation rates between the sexes. Articles with men holding the last authorship show slightly higher citation rates than articles with women holding the last authorship (M-Last: 14.2/F-Last: 13.8). We see no difference in citation rates for articles with male or female first author, as they are on average both within the mean citation rate of 13.4 citations/article (dotted line); (A, right) When analyzing combined authorships, articles with male-first/female-last and female-first/male-last authorships (both 14.3 citations/article) document the highest citation rates and are above the average citation rate. Articles with a single male or female author generate comparatively the lowest citation rates, whereby single-male author-articles are cited more often than single-female author-articles; (B) Average citation rates of articles, depending on the count of authors per article (bars) and the gender of their key author (lines). The more authors involved in an article, the higher the citation rates. Articles with more than 15 authors and with a male last author have the highest citation rate. Overall, differences in citation rates between the sexes seem minor and appear especially for articles with more than 12 authors; (C) Gender-dependent count of articles per author. Only the sub-groups “author has 1 article” and “author has 2 articles” are dominated by women, while all other sub-groups with authors who have published more than two articles are dominated by men. Especially at the highest level of productivity, the group of authors who have published more than 15 articles, we see a lack of female authors. Overall, 61.6% of all authors are male and they are responsible for 66.8% of all the authorships.

Observing the scientific productivity between the two sexes, there is a significant lack of female authors at the level of highest productivity. Women only outnumber men in the subgroup “author has one article” (69.3% female authors/64.8% male authors) and “author has two articles” (17.2% female authors/16.4% male authors) (Figure 3C). In all other subgroups with authors who have published more than two articles, male authors are overrepresented (Figure 3C). Accordingly, 1.3% of male researchers and only 0.5% of female researchers have published more than 15 articles, illustrating the lack of female authors at the highest level of productivity. Collectively, 61.6% of male authors hold 66.8% of all authorships (Figure 3C).

Discussion

Integration of women and gender-specific career dichotomy

With an FAP of 33.2% (Figure 1A), the integration of women in anesthesiology research is average compared with previous studies [7-11,20-25]. While the FAP of anesthesiology research corresponds very similarly to the female authorship proportion for the whole area of science (30.0%) [26], we find significantly higher female authorship proportions in the research fields of Alzheimer’s disease and dementia (42.1%) [11], schizophrenia (37.6%) [8], epilepsy (39.4%) [9], and dermatology (43.0%) [10], indicating a comparatively larger lack of female representation in high-impact anesthesiology research.

Further analysis of female authorships showed a clear disproportion between the odds for female authors for first-, co-, and last authorships. Female authors had higher odds of holding first- and co-authorships and lower odds of securing last authorship positions (FAOR triplet [+ , + , -]). This FAOR-distribution represents the globally predominant pattern [9]. In accordance with other research areas [8,9,20], the disadvantageous FAORs for co- and last authorship cannot be compensated by the high FAOR for first authorships [9,21]. This is also shown by the Prestige Index, which shows an averaged negative value (-0.28). This non-compensable mismatch in the distribution of authorships indicates a significant deficit of prestigious authorships for female authors.

In anesthesiology research, female researchers are less productive than male researchers, as is the case in many other fields of medical research [7-11]. This discrepancy in publishing is more distinct in anesthesiology research (38.4% female authors hold 33.2% of the authorships) than in other disciplines such as epilepsy [9] (43.8% female authors hold 39.4% of the authorships) and dermatology [10] (47.2% female authors hold 43.0% of the authorships).

This mismatch in the distribution of female

authorships and underrepresentation in terms of productivity reflects a gender-based career dichotomy, with a vast majority of male group leaders and female researchers mostly in hierarchical lower positions as first- or co-authors [17,27-29]. Following the assumption that academic publishing is crucial for career advancement within the scientific system [8,30,31] and that last authorships are a sign of effective group leadership [9,17,18], female authors face more and higher barriers to career building and academic success than their male counterparts.

The career dichotomy in anesthesiology research is also shown by the comparatively high proportion of female first- and co-authors (both 35.1%), as these positions are mainly given to early career researchers [9,17]. Additionally, the large number of male group leaders occupying the last authorship position forces female authors into more unfavourable academic positions, such as co-authorships. With significantly more female early career scientists as first- or co-authors and just a few female group leaders, the distribution of authorships in high-impact anesthesiology research reflects the global scientific system [8,18,20].

Reasons for underrepresentation

The career dichotomy in anesthesiology research is multifactorial and complex. According to a 2018 report, female researchers suffer systemic barriers as well as unconscious gender bias in terms of selection and chances to rise to top academic ranks [32].

Moss-Racusin, et al. showed in their study on hiring preferences of science faculties that participants who sent applications with male names were more likely to be hired and were offered larger salaries than participants who sent the identical application with a female name [33]. In addition, sex-specific career objectives may drive women away from academic anesthesiology. Accordingly, women sense a smaller desire for professional advancement than men do and anticipate more negative outcomes and conflicts in connection with leading roles [34]. Generally, women adopt teaching roles more often and are more likely to be discouraged from training in highly compensated subspecialties or research [35].

To ascent to higher academic ranks and leadership positions, researchers are forced to fit clinical work and research into a rigid timetable. As women still spend more time on family responsibilities [36], they may risk career advancement within their child-rearing years. After returning to the workforce, they must focus on providing clinical services, as men of the same age have advanced their careers to leadership positions in research and administration. Moreover, women with children report higher obstacles to achieve academic careers and less institutional encouragement than men with children [37]. Even women without children

show fewer ambitions to strive for leadership positions, because of the linkage between the female gender and the suspected desire to have children [38]. Numerous factors, such as a remuneration gap between the sexes [39], workplace discrimination [14] and the lack of role models and mentors [40] contribute to this sex-specific gap.

Moreover, even when women ascent to leading positions, they face more barriers and risks because of the glass cliff phenomenon [41]. This metaphor describes the fact that women are often placed in precarious leadership positions, with a high probability of failure, making it more difficult for female heads of departments to secure their position [41].

Stable representation of the FAP and lack of prestigious authorships for women in multiauthor articles

There is a slight positive correlation between the FAP and the number of authors per article. As a result, we find a stable representation of FAP in large collaboration articles with more than 15 authors per article, which are statistically the most commonly cited articles (Figure 3B). This stable female representation in highly cited articles is especially remarkable, because it may explain the almost equivalent and gender-independent citation rates in multiauthor articles (Figure 3B). In most other disciplines, we find a significantly higher citation rate of articles with male key authors [7,8,11,20,22,42]. The citation rates between the sexes can be a sign of the progressive integration of women into anesthesiology research.

In accordance with other scientific fields, we find a lack of women holding prestigious authorships with a higher author count per article (Figure 2) [9,21]. The absence of female first and last authors accentuates especially in articles with more than 15 authors (Figure 2). For large collaboration articles, the odds of women securing co-authorships increase dramatically compared with all other articles with less than 15 authors (Figure 2). This correlation points out the status of women as mostly early career scientists, as they usually hold the role of co-authors in large collaboration articles [17].

Publication rates effected by gender and structural position

In line with other scientific disciplines [8-10,20,43], we see a discrepancy between genders in terms of productivity. On average and compared to their male colleagues, female researchers are less productive, leading to a large gap at the highest level of productivity (Figure 3C). On a gender-based order of the count of articles per author, women only outnumber men in the sub groups of “one article per author” and “two articles per author”, demonstrating their role as mainly early career researchers with just a few publications

(Figure 3C). In contrast, men are overrepresented in every other subgroup, especially at the highest level of productivity with more than 15 articles per author (Figure 3C). This disproportionate male output reflects their role as senior scientists, as they usually have a higher publication rate than early career researchers [44,45]. This correlation shows that a main factor affecting women’s productivity is the linear relationship between a high publication rate and a high academic rank [45], which are primarily occupied by male scientists [8,9,20]. Overall, the lower number of women as heads of academic departments does not categorically mean that they have fewer chances to be promoted to these higher ranks [4]. Rather, it is a sign of a smaller pool of suitable candidates, as those positions are mainly assigned to well reputable scientists [4].

Correspondingly, women showed productivity rates in their mid-careers comparable to or outrunning those of their male colleagues, while men had higher overall publication rates [30] indicating that men outrun women at a later stage of their careers.

Another reason for the publication gender gap is the presumption that women participate comparatively more in other academic pursuits, such as teaching and hospital service roles for promotion, which can be quantified less easily than the publication rates [43]. However, men are more likely to rely on the traditional publication rate as a marker for advancement [43].

Non-Correlation between FAP and Prestige Index on a country-specific level

The country-specific analysis revealed distinct regional differences between the FAPs and FAORs (Table 1). Turkey, the Netherlands, Israel and Brazil offer the best conditions for female authors to secure prestigious authorships, whereas France, Italy and Japan provide benefits for men. Turkey shows an equal distribution of prestigious last authorships between men and women. The Netherlands compensate for the low rate of last female authorships with high rates of first female authorships. Israel and Brazil show equally high authorship odds for male and female researchers (FAOR-triplet [=, =, =], Prestige Index = -0.04 [Israel], Prestige Index = -0.07 [Brazil]). In contrast, Japan has a noticeable role in anesthesiology research, with the lowest FAP of 20.9% and a negative Prestige Index (Prestige Index = -0.96). This less-advanced integration of female scientists in Japan is also shown by the Global Gender Gap Report 2020, where Japan is ranked 121st out of 153 countries worldwide [46].

As in previous studies, the FAP and the Prestige Index of countries did not correlate significantly ($r = 0.21$, $P > 0.05$) [7-11,21-23]. Accordingly, countries with a high proportion of female authorships must not have similarly high chances of securing prestigious authorships for women. Italy is a notable example of this

non-correlation in anesthesiology research. On the one hand, the country shows a high proportion of female authorships (FAP = 41.9%), on the other hand, the Prestige Index shows a negative value (Prestige Index = -0.92). On the contrary, Turkey features an almost similar FAP of 42.7%, but shows a significantly higher Prestige Index (Prestige Index = 0.14). Additionally, Turkey provides with the FAOR-triplet (+, -, =) a more advantageous environment for female researchers, with significantly higher female odds for prestigious authorships than Italy.

Lack of prestigious authorships for women in journals

Among individual journals, we find a female underrepresentation in terms of prestigious authorships. The distribution of FAOR triplets shows uniformity, as in 27 out of 32 journals female researchers have lower odds of prestigious last authorships. Interestingly, the odds between the genders for first- and co-authorships are more balanced, as only four journals provide higher male odds for first authorships. However, these balanced odds cannot compensate for the low female odds for last authorships, as we find a Prestige Index, that is on average negative (Prestige Index = -0.32).

The Prestige Index varies strongly between different journals (Δ Prestige Index = 2.58), whereas the range of FAP between journals is moderate (Δ FAP = 23.3). Accordingly, there was no significant correlation between the FAP and the Prestige Index of a journal. Hence, a large number of female authors do not increase the odds of prestigious authorships for women.

The female odds in the related journals illustrate the global gender-specific order of research groups [10]. According to that, and as some journals are country-specific [47], we find parallels between journals and the associated countries. Brazil is a notable example, as it provides gender-neutral odds for all authorships on a country level and on the journal level (Revista Brasileira de Anestesiologia FAOR triplet [=, =, =]) and shows a high FAP (Brazil FAP = 47.3%, Revista Brasileira de Anestesiologia FAP = 42.9%). On the other hand, Italy shows one of the lowest Prestige Indices observed at both the journal and country level (Minerva Anestesiologica Prestige Index = -0.76, Italy Prestige Index = -0.92).

Methodical limitations

The full algorithmic approach is limited by the lack of personal data on the authors, such as academic rank, academic degree, authors age, or their employment status [9,10,20]. The investigation period is limited to articles published after 2006, due to the prevailing usage of initials instead of first names before the year 2006 [9,19]. On account of the time-delayed occurrence of citations, there is a difference on the impact on citation rates, with older articles having a higher-impact

[20,48]. Another limitation is the first name-based gender determination, as China, Taiwan and South Korea showed a high rate of unisex names that could not be considered in the analysis.

In conclusion, we did not differ between larger articles with many authors and smaller articles with only a few authors as all last authorships were valued equally prestigious [7].

Conclusions

In conclusion, the outcomes of this study demonstrate the average integration of women into high-impact anesthesiology research. The stable FAP and almost gender-neutral citation rates are indicators of advanced integration, while the constantly negative Prestige Index represents the lack of prestigious authorships held by female scholars, especially in high-impact collaboration articles. Additionally, in all examined countries and journals, female authors never had higher odds of prestigious last authorships compared to men.

Overall, this constellation represents the existing career dichotomy between genders, with many female researchers at an early stage of their careers and few female scholars in leading academic positions [4]. With a high influx of women at the beginning of their career this gender gap will potentially decrease in anesthesiology research, as early career researchers may be future academic leaders [4]. With an annual increase of 2.2% in FAP, with the highest rates for first authorships (2.3%), this trend is likely to continue.

However, despite the increase in female first authorships, studies have reported persistent career disparities between men and women [4,27,49,50].

The time trend in the next years will show whether occupational equality for women can be achieved in anesthesiology.

Acknowledgements Related to This Article

Conflict of interest declaration

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interests in the subject matter or materials discussed in this manuscript.

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