

# Author Gender Inequality in Medical Imaging Journals and the COVID-19 Pandemic

Elske Quak, MD • Gilles Girault • Marie Aude Thenint, MD • Kathleen Weyts, MD • Justine Lequesne, PhD • Charline Lasnon, MD, PhD

From the Department of Nuclear Medicine (E.Q., K.W., C.L.), Medical Library (G.G.), Department of Radiology (M.A.T.), and Department of Biostatistics (J.L.), UNICANCER, Comprehensive Cancer Centre François Baclesse, Avenue Général Harris, 14076 Caen, France; and Normandy University, UNICAEN, INSERM 1086 ANTICIPE, Caen, France (C.L.). Received November 25, 2020; revision requested December 14; revision received February 16, 2021; accepted February 17. **Address correspondence to** E.Q. (e-mail: [e.quak@baclesse.unicancer.fr](mailto:e.quak@baclesse.unicancer.fr)).

Conflicts of interest are listed at the end of this article.

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**Background:** Early reports show the unequal effect the COVID-19 pandemic might have on men versus women engaged in medical research.

**Purpose:** To investigate whether the COVID-19 pandemic has had an impact on scientific publishing by female physicians in medical imaging.

**Materials and Methods:** The authors conducted a descriptive bibliometric analysis of the gender of the first and last authors of manuscripts submitted to the top 50 medical imaging journals from March to May 2020 ( $n = 2480$ ) compared with the same period of the year in 2018 ( $n = 2238$ ) and 2019 ( $n = 2355$ ). Manuscript title, date of submission, first and last names of the first and last authors, journal impact factor, and author country of provenance were recorded. The Gender-API software was used to determine author gender. Statistical analysis comprised  $\chi^2$  tests and multivariable logistic regression.

**Results:** Percentages of women listed as first and last authors were 31.6% (1172 of 3711 articles) and 19.3% (717 of 3711 articles), respectively, in 2018–2019 versus 32.3% (725 of 2248 articles) and 20.7% (465 of 2248 articles) in 2020 ( $P = .61$  and  $P = .21$ , respectively). For COVID-19-related articles, 35.2% (89 of 253 articles) of first authors and 20.6% (52 of 253 articles) of last authors were women. No associations were found between first- and last-author gender, year of publication, and region of provenance. First and last authorship of high-ranking articles was not in favor of North American women whatever the year (odds ratio [OR], 0.79 [ $P = .05$ ] and 0.72 [ $P = .02$ ], respectively). Higher rates of female last authorship of high-ranking articles were observed in Europe ( $P = .003$ ) and of female first authorship of low-ranking publications in Asia in 2020 (OR, 1.38; 95% CI: 0.98, 1.92;  $P = .06$ ). Female first and last authorship of COVID-19–related articles was overrepresented for lowest-rank publications ( $P = .02$  and  $P = .01$ , respectively).

**Conclusion:** One in three first authors and one in five last authors were women in 2018–2019 and 2020, respectively. Although the first 2020 lockdown did not diminish the quantity of women-authored publications, the impact on the quality was variable.

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In many countries today, women make up half of medical students, and the number of female students choosing to pursue a career in medical imaging (radiology and nuclear medicine) is rising (1,2). However, the higher up the career ladder, the lower the proportion of women, a phenomenon known as the leaky pipeline (3). Compared with their male colleagues, women are underrepresented as authors, and leadership positions in medical imaging—either within institutions or within scientific organizations, committees, boards, or journals—are still dominated by men (4–6). Examples of challenges women face in general are male-dominated cultures and networks, lack of female mentors, and explicit and implicit gender biases in recruitment, research allocation, outcomes of peer reviews, and citations (7–10). Working mothers face the well-described maternal wall bias, where maternal stereotyping and discrimination undermine their professional performance (11).

Early reports on the effects of the COVID-19 pandemic on scientific research, all fields concerned, mention

the deleterious effect the pandemic might have on the careers of parents working in science, and in particular on the scientific output of female researchers (12–17). This is due to an unbalanced division of work, as women still perform the majority of household chores and care work, even in developed countries perceived as gender-egalitarian (18,19). Because schools and day-care facilities closed in many countries during the first COVID-19–related lockdown, the pandemic might thus eventually affect female career advancement, as the number and quality of publications in peer-reviewed journals one has authored are essential.

The purpose of this study was to investigate whether the COVID-19 pandemic might have an impact on scientific publishing by female physicians in medical imaging. We performed a descriptive bibliometric analysis of female first and last authorship over the 3-month period corresponding to the first lockdown period in most countries due to the COVID-19 pandemic.

## Abbreviation

OR = odds ratio

## Summary

The COVID-19 pandemic has not aggravated the gender imbalance in first and last authorship of medical imaging publications.

## Key Results

- In medical imaging, approximately one in three first authors (31.6%) and one in five last authors (19.3%) are women; this gender gap was similar for articles submitted during the first 2020 lockdown (32.3% [ $P = .61$ ] and 20.7% [ $P = .21$ ]).
- In 2020, the quality of publications shifted favorably for female European last authors ( $P = .003$ ), and an unfavorable tendency was observed for Asian first authors ( $P = .06$ ); women-authored publication quality did not change in North America ( $P = .60$  for first authors and  $P = .64$  for last authors).
- Female first and last authors of COVID-19–related articles were overrepresented in the lowest-ranking journals ( $P = .02$  and  $P = .01$ , respectively).

## Materials and Methods

This study was exempt from local institutional review board approval.

On August 19, 2020, we performed a PubMed search for the period from 2018 to 2020 to retrieve all articles published by the top 50 journals, ranked by impact factor, in the category “Radiology, Nuclear Medicine & Medical Imaging” of the 2018 edition of the Journal Citation Reports. Ranks 1 to 65 were included, excluding 15 radiation therapy and medical physics journals. The 2020 data were updated on November 26, 2020. The bibliographic references of articles were imported into the bibliographic data management software Reference Manager (Thomson Reuters). In addition to the usual bibliographic fields, an import filter was created to include the following data concerning PubMed bibliographic notices: date of submission, first and last names of all authors, and affiliation addresses. From this database, we extracted the references of manuscripts submitted from March to May for each year, corresponding to the first lockdown period in 2020 in most countries. This data set was exported to a spreadsheet (Excel, Microsoft), and the following variables were recorded for each entry: manuscript title, date of submission, first and last names of the first and last authors, journal impact factor, and country of provenance of the first and last authors. The Gender-API software (Gender-API.com) was then used to determine the gender of the first and last authors. In the event of missing data, entries were excluded. Countries were classified according to region (Africa, Asia, Europe, Middle East, North America, South America, and Oceania [which includes Australasia, Melanesia, Micronesia, and Polynesia]). COVID-19–related articles were retrieved in Excel by selecting article titles mentioning the terms *COVID*, *nCoV*, *SARS*, or *Corona*.

The main objective was to analyze the percentages of female first and last authorship (the most prestigious author positions) of articles submitted to peer-reviewed medical imaging journals during the COVID-19 pandemic as compared with the same period of the year in 2018 and

2019. Secondary objectives were to evaluate the percentages of female first and last authorship of COVID-19–related articles and the proportions of female authorship according to journal rank and author region of provenance. Article impact factors were categorized according to quartiles.  $\chi^2$  tests, with Bonferroni corrections when necessary, were used to analyze links between gender and the other qualitative variables. A multivariable logistic regression with analysis of variance was also performed in subgroups of regions to investigate the predominance of male or female first and last authorship according to journal rank and year. Graphic and statistical analyses were performed using XLSTAT software (XLSTAT 2007: Data Analysis and Statistical Solutions for Microsoft Excel, Addinsoft [2017]) and R Software (version 4.0.2, R Foundation for Statistical Computing). For all statistical tests, two-tailed  $P < .05$  was indicative of a statistically significant difference.

## Results

### Data Characteristics

A total of 7073 references of accepted articles with submission date from March to May were imported for the years 2018 ( $n = 2238$ ), 2019 ( $n = 2355$ ), and 2020 ( $n = 2480$ ). Gender of the first and/or last author could be determined for 1814 of 2238 (81.1%) references in 2018, 1897 of 2355 (80.6%) in 2019, and 2248 of 2480 (90.6%) in 2020. Country of provenance could be determined for 1814 (99.9%) references in 2018, 1885 of 1897 (99.4%) in 2019, and 2229 of 2248 (99.2%) in 2020. Articles were classified according to journal rank as A (impact factor, 5.07 to 10.975), B (impact factor, 3.858 to <5.07), C (impact factor, 2.948 to <3.858), and D (impact factor, <2.948). Data characteristics are presented in Table 1.

### First Authorship

**Univariable analysis.**—Female first authorship proportions were not different between the period of 2018–2019 and 2020 (1172 of 3711 articles [31.6%] and 725 of 2248 articles [32.3%], respectively;  $P = .61$ ). Of 253 COVID-19–related articles, 89 (35.2%) had female first authors. In 2020, 89 of 725 (12.3%) of articles submitted by a female first author were in regard to COVID-19 versus 164 of 1523 (10.8%) for male first authors ( $P = .32$ ).

Concerning journal rank, as compared with 2018–2019, women authored proportionally more articles in journals ranked A or D in 2020 and fewer in journals ranked B or C ( $P = .02$ ) (Fig 1). Concerning COVID-19–related studies, gender was associated with journal rank, with more female first authorship in rank D journals (31 of 164 articles [18.9%] vs 40 of 361 articles [11.1%] for female and male first authors, respectively;  $P = .02$ ) (Table 2).

Concerning the region of origin of first authors, 5637 of the 5959 articles (94.6%) came from Europe (2262 of 5959 articles [38.0%]), North America (1974 of 5959 articles [33.1%]), or Asia (1401 of 5959 articles [23.5%]) (Table 1).

**Table 1: Data Characteristics**

Variable	All Years ( <i>n</i> = 5959)	2018–2019 ( <i>n</i> = 3711)	2020 ( <i>n</i> = 2248)
<b>First-author gender</b>			
F	1897 (31.8)	1172 (31.6)	725 (32.3)
M	4062 (68.2)	2539 (68.4)	1523 (67.7)
<b>First-author region</b>			
Africa	10 (0.2)	7 (0.2)	3 (0.1)
Asia	1401 (23.5)	862 (23.2)	539 (24.0)
Europe	2262 (38.0)	1409 (38.0)	853 (37.9)
Middle East	125 (2.1)	63 (1.7)	62 (2.8)
North America	1974 (33.1)	1261 (34.0)	713 (31.7)
Oceania	96 (1.6)	60 (1.6)	36 (1.6)
South America	59 (1.0)	36 (1.0)	23 (1.0)
Missing	32 (0.5)	13 (0.4)	19 (0.8)
<b>Last-author gender</b>			
F	1182 (19.8)	717 (19.3)	465 (20.7)
M	4777 (80.2)	2994 (80.7)	1783 (79.3)
<b>Last-author region</b>			
Africa	11 (0.2)	7 (0.2)	4 (0.2)
Asia	1306 (21.9)	801 (21.6)	505 (22.5)
Europe	2226 (37.4)	1386 (37.3)	840 (37.4)
Middle East	121 (2.0)	64 (1.7)	57 (2.5)
North America	2108 (35.4)	1345 (36.2)	763 (33.9)
Oceania	107 (1.8)	66 (1.8)	41 (1.8)
South America	48 (0.8)	29 (0.8)	19 (0.8)
Missing	32 (0.5)	13 (0.4)	19 (0.8)
<b>Journal rank*</b>			
A	1502 (25.2)	891 (24.0)	611 (27.2)
B	1753 (29.4)	1104 (29.7)	649 (28.9)
C	1320 (22.2)	857 (23.1)	463 (20.6)
D	1384 (23.2)	859 (23.1)	525 (23.4)

Note.—Data are numbers of articles, with percentages in parentheses.

\* Journals were ranked according to impact factor, as follows: A, 5.07 to 10.975; B, 3.858 to less than 5.07; C, 2.948 to less than 3.857; and D, less than 2.948.

African, Oceanian, and South American data were insufficient to be independently included in the statistical analyses; therefore, they were grouped. Both in 2018–2019 and 2020, there were associations between first-author gender and the region of origin ( $P < .001$  and  $P = .04$ , respectively) (Fig 1). Concerning COVID-19–related articles, there was no association between region of origin and first-author gender (Table 2).

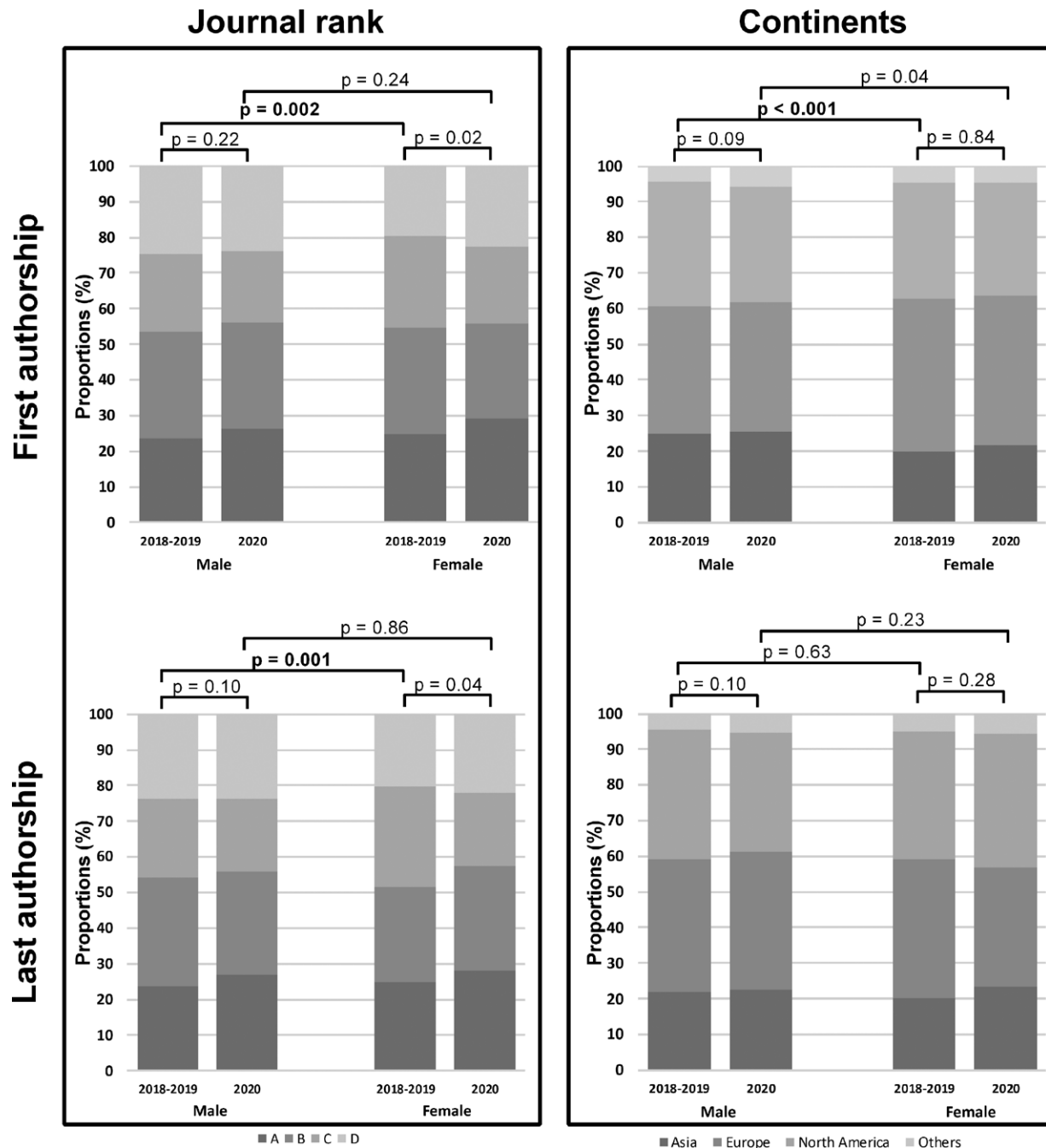
**Multivariable analysis.**—African, Oceanian, and South American data were insufficient to be included in the multivariable analysis. Therefore, multivariable analysis was performed on European, North American, and Asian data only.

In Europe, gender imbalances did not change in 2020. First authorship in journals ranked A or B was not in favor of women in North America (odds ratio [OR], 0.79; 95% CI: 0.62, 1) no matter the year, according to analysis of variance ( $P = .04$ ). First authorship in Asia tended to be in favor of women for journals ranked C or D in 2020 (OR, 1.38; 95% CI: 0.98, 1.92;  $P = .06$ ) (Fig 2, A).

## Last Authorship

**Univariable analysis.**—Female last authorship proportions were not different between 2018–2019 and 2020 (717 of 3711 articles [19.3%] and 465 of 2248 articles [20.7%], respectively;  $P = .21$ ). In 2020, 52 of 253 COVID-19–related articles (20.6%) listed women as last authors. In 2020, 52 of the 465 overall articles submitted by a female last author (11.2%) concerned COVID-19 versus 201 of the 1783 articles submitted by male last authors (11.3%) ( $P = .96$ ).

Concerning journal rank, the proportion of articles in rank A journals with a female last author was higher in 2020 as compared with 2018–2019 ( $P = .04$ ) (Fig 1). In 2018–2019, there was an association between gender and journal rank ( $P = .001$ ), with proportionally more female authors in rank C journals and more male authors in rank B. Concerning COVID-19–related articles, there were more articles with female last authors in rank D journals as compared with male last authors in 2020 (22 of 102 articles [21.6%] vs 49 of 423 articles [11.6%], respectively;  $P = .01$ ) (Table 2).



**Figure 1:** Bar charts show the results of univariable analysis of articles according to author gender, journal rank, and region for first and last authorship. *P* values were obtained with  $\chi^2$  tests with Bonferroni corrections, and bold values are statistically significant. Journals were ranked according to impact factor, as follows: A, 5.07 to 10.975; B, 3.858 to less than 5.07; C, 2.948 to less than 3.857; and D, less than 2.948.

Concerning the region of origin of last authors, most of the articles were again from Europe (2226 of 5959 articles [37.4%]), North America (2108 of 5959 articles [35.4%]), or Asia (1306 of 5959 articles [21.9%]) (Table 1). Both in 2018–2019 and 2020, last-author region of origin and gender were not associated ( $P = .63$  and  $P = .23$ , respectively) (Fig 1). Regarding COVID-19–related articles, region of origin and gender were not associated with regard to last-authorship (Table 2).

**Multivariable analysis.**—Last-author gender in Europe was associated with journal rank ( $P = .004$ ), with a tendency in favor of female authors in journals ranked A or B in 2018–2019 (OR, 1.20; 95% CI: 0.91, 1.59), but clearly favorable in 2020 (OR for ranks A and B in 2018–2019 = 1.20 multiplied by interaction term OR for ranks A and B in 2020 = 1.52, resulting in OR = 1.82,  $P = .003$ ) as compared with ranks C and D (Fig 2, B). Last authorship in rank A or B journals was not in favor of women in North America (OR,

**Table 2: COVID-19–related Articles Submitted from March to May 2020 according to Journal Rank, Region, and Author Gender**

Variable	First Authorship			Last Authorship		
	Female	Male	<i>P</i> Value	Female	Male	<i>P</i> Value
Overall	89/725 (12.3)	164/1523 (10.8)	.32	52/465 (11.2)	201/1783 (11.3)	>.99
Journal rank						
A	24/211 (11.4)	46/400 (11.5)	>.99	14/131 (10.7)	56/480 (11.7)	.88
B	12/193 (6.2)	35/456 (7.7)	.62	7/135 (5.2)	40/514 (7.8)	.40
C	22/157 (14.0)	43/306 (14.1)	>.99	9/97 (9.3)	56/366 (15.3)	.18
D	31/164 (18.9)	40/361 (11.1)	.022*	22/102 (21.6)	49/423 (11.6)	.013*
Region						
Europe	28/302 (9.3)	49/551 (8.9)	.95	8/155 (5.2)	67/685 (9.8)	.096
North America	22/227 (9.7)	43/486 (8.8)	.82	16/172 (9.3)	52/591 (8.8)	.96
Asia	24/155 (15.5)	48/384 (12.5)	.43	16/107 (15.0)	55/398 (13.8)	.89

Note.—Unless otherwise specified, data are numbers of articles related to COVID-19 out of total articles submitted, with percentages in parentheses. Journals were ranked according to impact factor, as follows: A, 5.07 to 10.975; B, 3.858 to less than 5.07; C, 2.948 to less than 3.857; and D, less than 2.948.

\* Statistically significant difference.

0.72; 95% CI: 0.54, 0.94), whatever the year according to analysis of variance ( $P = .007$ ). In Asia, no associations were observed between journal rank, year, and last-author gender.

## Discussion

Our study showed a gender imbalance in first and last authorship for articles submitted to the top 50 medical imaging journals in the months of March to May for the years 2018–2020. In 2018–2019, 31.6% of first authors and 19.3% of last authors were women. The first lockdown period due to the COVID-19 pandemic did not alter these findings, given that in 2020, 32.2% of first and 20.7% of last authors were women ( $P = .61$  and  $P = .21$ , respectively). In 2020, the proportion of articles in high-rank publications increased for female European last authors ( $P = .003$ ), and the proportion of articles in low-rank publications increased for female Asian first authors ( $P = .06$ ). Women-authored article quality did not change in North America ( $P = .64$  for last authors and  $P = .60$  for first authors). Female first and last authors of COVID-19–related articles were overrepresented in the lowest-rank journals ( $P = .02$  and  $P = .01$ , respectively).

The percentages of female first and last authorship found in this study correspond to findings from other groups (20–22). However, our study was not limited to the few most prestigious A-rank journals. The full panel of the top 50 medical imaging journals was included, as this can be considered the “playing field” when attempting to publish a study.

Do the percentages of female first and last authorship we found correspond to the gender disparity in the medical imaging workforce worldwide? Studies addressing this issue show that women make up 34% of radiologists globally, with large disparities between countries (2,23,24). In Europe, less gender disparity has been reported for the younger generations, as reflected in the membership of the European

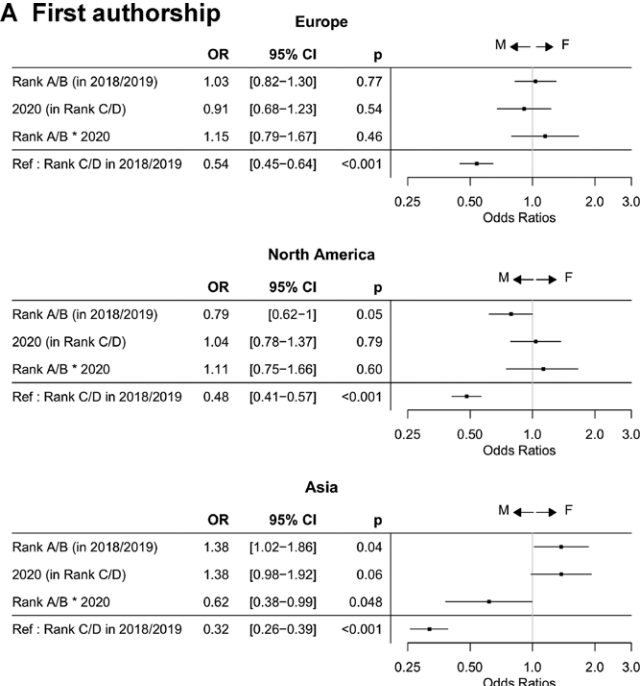
Society of Radiology (6). However, despite more women entering careers in medical imaging, they lag behind their male peers in career advancement (3,4,6,25,26).

Although gender bias in peer review has been reported (27,28), our study did not reveal a disproportionate underrepresentation of female authors in high-rank journals or overrepresentation in lower-rank journals, apart from an underrepresentation of North American female first and last authors in high-rank journals. The first 2020 lockdown seemed to have a positive effect on publication quality by female European last authors, and on the contrary, a negative effect on publication quality by female Asian first authors. An overrepresentation of female last authors of COVID-19–related articles was found in the lowest-rank journals. Explanations for these effects on quality rather than quantity of women-authored articles are probably multifactorial, and the degree to which they are related to the lockdown and the unbalanced division of household tasks remains to be explored. However, gender bias in grant allocations and nominations for senior and leadership positions might partly explain the low percentage of 20% female last authorship, as this position usually corresponds to the supervisor or principal investigator.

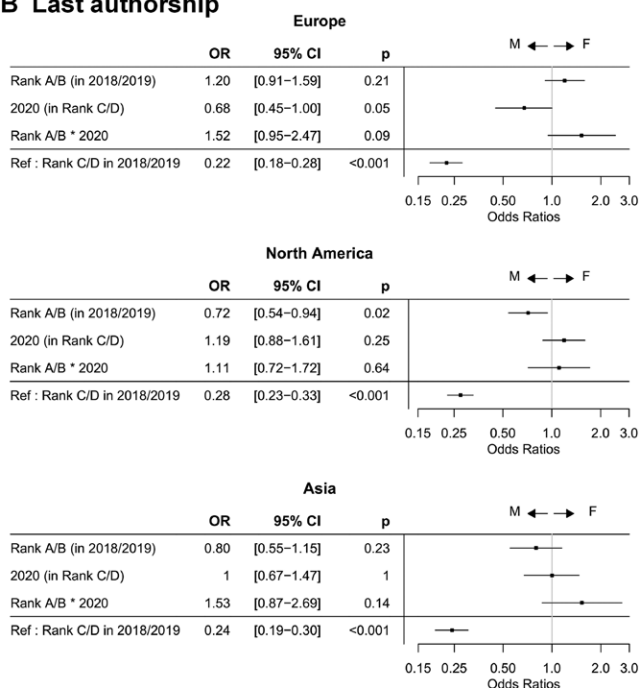
We acknowledge our study has limitations. First, the 2020 data are incomplete. Peer review and editorial decision making has not been completed for some of the articles submitted in the March–May 2020 period. Second, the non-COVID-19–related scientific work submitted during the lockdown was initiated largely before the pandemic, with first and last authorship assigned before. Third, at the time of writing, the COVID-19 pandemic is still ongoing. Our study is an early report with short-term data from spring 2020. Fourth, we used the online Gender-API platform to determine first and last author gender. Last, we chose to limit our study to articles submitted in the period from March to May. Therefore, national or regional disparities might have been overlooked.



# A First authorship



# B Last authorship



**Figure 2:** Forest plots show results of multivariable analysis of, A, first-author and, B, last-author gender according to region, journal rank, and year of publication. Reference values (Ref) correspond to rank C or D in 2018–2019. Error bars indicate 95% CIs. Journals were ranked according to impact factor, as follows: A, 5.07 to 10.975; B, 3.858 to less than 5.07; C, 2.948 to less than 3.857; and D, less than 2.948. F = favors female authorship, M = does not favor female authorship.

Male dominance in first and last authorship of imaging publications was evident in the top 50 medical imaging journals over the years 2018–2020. The first lockdown due to the COVID-19 pandemic in 2020 did not substantially alter this imbalance. Leaders and physicians should be aware of explicit and implicit gender biases that affect scientific publications (29).

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