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A 35-Year Analysis Of Gender Trends In Radiology Authorship

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A 35-Year Analysis of Gender Trends in Radiology Authorship

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Abstract

Purpose: To describe trends in authorship among female radiologists, compared to their overall representation in radiology, and to investigate the tendency of female first authors to publish with female last authors.

Material and Methods: We collected and analyzed data on gender of first and last authors for all original research and guest editorial articles from three main radiology journals - *Radiology*, *American Journal of Roentgenology (AJR),* and *Academic Radiology*. We restricted our analysis to authors with M.D. (medical doctorate) degrees from academic institutions within the United States. Manuscript data were collected for years 1978, 1998, 2008, and 2013. We obtained data on female participation in academic medicine and radiology residencies from the American Association of Medical Colleges. We used a logistic regression model to identify significant trends over time and a chi-square test of independence to determine significant relationships between gender of first and last authors.

Results: We determined gender for 4,214 (99.2%) authors of original research and editorials with M.D. degrees. The proportion of original research articles published by women as first authors increased from 8.3% in 1978 to 32.4% in 2013 ($p < .003$), and the proportion of original research articles with women as last authors increased from 6.5% in 1978 to 21.9% in 2013 ($p < .004$). In 1980, 19.2% of radiology residents were women

and in 2013 26.9% of radiology residents were women. In 1978, women represented 11.5% of radiology faculty at academic institutions and in 2013 they represented 28.1%.

Demonstrated by logistic regression model, there was a higher representation of women as both first and last authors over time (first author OR = 1.043, $p < .001$; last author OR = 1.036, $p < .001$). There was a statistically significant relationship between the gender of first and last authors of original research articles and guest editorials ($p < .001$).

Conclusion: Over the last 35 years, there has been a statistically significant upward linear trend of female M.D. participation in academic radiology literature authorship. However, the number of female last (senior) authors lags behind the participation of women in clinical and academic radiology. Women are more likely to publish with senior authors of the same gender.

We propose that female radiology residents receive an increased level of support to stimulate their interest and participation in research. Such intervention would allow the field to benefit from the creativity of both genders.

Background

In 1882, women were recognized as important colleagues in medicine and even then it seemed a "marvel that there could be so much and so long sustained opposition to what now we regard as the obvious" (1). In the 1940's and around the time of World War II, strong campaigns in the U.S. beckoned women into medicine (Cleveland Medical College briefly opened its doors to women) and in general into the "work of men" by mixing patriotism with women's rights (2). Women first challenged the old and common notion that they were unfit for medicine by arguing that their stereotype – nurturer – was good for medicine and made them natural doctors. Soon, however, a few women such as Marie Zakrzewska, founder of the New England Hospital for Women and Children in 1862, challenged their cultural stereotype directly and rejected the Victorian ideal of femininity. This very first generation of U.S. women physicians felt that all physicians must put sentimentality aside because too much sympathy can cloud the ability to reason and thus physicians must instead develop their rationality and their expertise in scientific knowledge (2). Since then, the participation of women in medicine has increased considerably.

According to Association of American Medical Colleges (AAMC) data, in 1962 5.5 percent of graduating medical students were women as compared to 49.3 percent in 2008 and 48.0 percent in 2013 (3). Despite a general upward trend of women participation in medicine, they continue to be underrepresented in several specialties (4), including Diagnostic Radiology (5). In 1990 there were 26 percent women in radiology and there

is still only 27 percent women in radiology today (6). In the 1990's there was evidence that women might become more likely than men to begin academic medical careers, but surprisingly today they still remain underrepresented, especially at senior faculty level (4). It has been suggested that underrepresentation of women in certain specialties may affect quality of patient care, teaching and research (7).

Table 1. Percentage of women by specialty and academic rank in the U.S. (AAMC 2013-2014 https://www.aamc. org/members/gwims/statistics)

	Residents	Instructors	Ass. Prof.	Assoc. Prof.	Full Prof	Faculty
Pediatrics	71	70	59	46	30	52
Internal Medicine	43	49	42	32	17	35
Surgery	38	31	24	16	8	18
Orthopedic Surgery	14	15	17	11	5	12
Radiology	27	38	33	28	20	30
Total	46	51	43	32	19	36

Advancement in science, technology, engineering, and mathematics (STEM), including academic medicine, is largely driven by scholarly accomplishments such as peer-reviewed original research publications, presentations at national meetings, and appointment to editorial boards (8, 9). Women have authored medical literature for

centuries, especially in the late 1800s, when women physicians in Russia took advantage of social upheaval to prolifically demonstrate their scholarly abilities through medical literature (10). Yet, women struggled to be accepted during the professionalization of medicine, when the field shifted to favor scientific objectivity and rationality (11). Of late, women have never published at the same rate as men; previous studies of authorship and editorship in academic medical literature quantitatively demonstrate a lag in female participation relative to female representation in academic medicine. These studies have mainly focused on the field of internal medicine, with some reports regarding orthopedic surgery, dermatology, family medicine, and radiation oncology (12-79). Concomitantly, despite nearly equal representation of both genders during medical school, female students are less likely to be interested in research or to participate in major research programs. After medical school, there is a further decline in women interested in research, suggesting experiences in medical school have a negative impact on women's relationship with academic work (80).

This contrasts the fact that gender-diverse work environments have been shown to produce higher quality research (81, 82). When women are introduced to project teams, even the men they work with produce higher quality work as measured by amount of citations (81). Therefore, the concern has been raised that the underrepresentation of women in many specialties reflects a wasted opportunity to benefit both genders (83, 84).

To meaningfully modify indicators of gender disparity, one must first document and then strive to understand the reasons for the problem. It was the primary aim of this study to

describe publication performance of women in radiology over the last 35 years, focusing on the three major radiology journals. The secondary aim was to evaluate if women are more likely to have female mentors based on first and last authorship of publications.

Materials and Methods

Crystal Lynne Piper was responsible for development of the hypothesis, procedures, methods, database, data collection & management for this study. Her work was critiqued and advised by the co-authors of this project: Dr. Howard Forman, Dr. Christoph Lee, and Dr. John Scheel. Two colleagues in addition to Crystal contributed to data collection.

Three major radiology journals published in the United States were included in this study: *Radiology*, *Academic Radiology*, and *The American Journal of Roentgenology*. Journals were chosen based on journal impact factor (6.3, 1.9, 2.9 respectively in the Journal Citation Reports of 2014) and expert opinion that they were general radiology journals covering the entire discipline (not subspecialty).

To examine gender variance and trends in gender variance among authors of original research articles and invited editorials, we extracted data for calendar years 1978, 1988, 1998, 2008, and 2013. We restricted our analysis to first and last authors with M.D. degrees from U.S. institutions, as documented in the publication. Only non-editorial board members were included in our analysis.

Gender was determined by inspection of his or her first name. For cases where author's gender was not determinable by first name, we performed Google searches and made phone calls to colleagues at their institution. For *The American Journal of Roentgenology*, we also used Google searches to determine academic degrees.

We obtained data on female participation in academic medicine and radiology residencies from the American Association of Medical Colleges. Resident data was not available for all years of interest and therefore previously published data from similar years were used (3, 6, 85).

Statistical Analysis

We tabulated and graphed data using Microsoft Excel (2010 Microsoft Corporation, Microsoft Excel, Version 14.4.8, Redmond, Washington). We used logistic regression in SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Mac, Version 22.0. Armonk, NY: IBM Corp) to examine trends in gender of authors over time (significance if $p < 0.05$). We used the chi square test for independence to find the relationship between first and last authors gender to see if women tend to publish with other women.

Results

A total of 4214 authors of original articles and editorials who held M.D. degrees and were publishing from U.S. institutions were identified in *Radiology*, *Academic Radiology*, and *The American Journal of Roentgenology* during 2013, 2008, 1998, 1988 and 1978. Of these 4214, 2198 were first authors and 2016 were last authors. The gender of the author was determined for 99.2%. Overall, 22.0% of publications had female first authors, and 13.8% had female last authors. An analysis of the data according to year

demonstrated that the number of articles published by female radiology investigators has increased in the last 35 years (figures 2a-d). The proportion of original research and editorials written by females with M.D. degrees as first authors has increased from 8.33% to 32.35%. Likewise, the proportion of original research articles and editorials whose senior authors were women with M.D. degrees increased from 6.54% to 21.90%.

We also collected and analyzed the work done by authors from the same sources and years who did not have M.D. degrees. The proportion of articles by female non-M.D. first author investigators increased from 3.95% to 45.92% and the proportion of articles by female non-M.D. last author investigators increased from 17.24% to 31.18%, though to a lesser degree compared to those with M.D. degrees.

To approximate change over time, we fit a logistic regression model treating author gender as the outcome and year as a numeric predictor. First authors with M.D. degrees plotted over time became more likely to be female each year (OR = 1.043, $p < .001$). First author non-M.D.s were also more likely to be female over time (OR = 1.075, $p < .001$). The relationship for non-M.D.s is stronger than that for M.D.s; non-M.D.s increased more than M.D.s (OR = 1.031, $p = .026$). Last authors with M.D. degrees plotted over time tended to be increasingly female as well (OR = 1.036, $p < .001$). Last authors without an M.D. were not more likely to be female over time (OR = 1.002, $p = .804$). There is a relatively higher increase in first authorship for non-M.D.s compared to M.D.s, and the increase is lower for last authors compared to first authors. This relationship is

stronger among M.D.s than among non-M.D.s (OR = 1.033, p = .003). Across all groups, more articles were authored by women over time (p < .001).

We determined the gender for all 90 guest editorials written by U.S. medical doctorates in 2013, 2008, 1998, 1988, 1978 in *Radiology* and *The American Journal of Roentgenology* and *Academic Radiology*. Overall, 17.1% of first authors were women. In 1978, one female first author of a guest editorial made up the 20.0% women. In 1988, there were 14.7%, in 1998 there were 16.7%, and in 2013 there were 31.3%. However, there were too few total editorials and therefore no statistically significant trend (p = .565).

Next, we performed a subgroup analysis for the three radiological journals included in this study. Overall, significant trends of increased female representation were evident for *Radiology* and *The American Journal of Roentgenology* but not for *Academic Radiology* (p = .027, .002, .606 respectively and detailed in table 3). The proportions of first and last authors who were women increased most sharply in the *American Journal of Roentgenology* (slope of 0.61 from 1978-2013). In 2013, in the three major radiology journals, women collectively made up 32.4% of first authors and 21.9% of last authors of original research and editorials.

Last, we analyzed whether women first authors were more likely to publish with female last authors (table 4), using this as a measure of the proportion of women mentored by women. Women represented 22.7% of first and 13.2% of last authors, 19% female first authors published with female senior authors, 11% of male first authors published with

female senior authors. The odds ratio for female first authors compared to male first authors for publishing with women as senior authors was 1.83. Table 4 data and chi square analysis demonstrate a statistically significant association between first author gender and last author gender ($p < 0.001$) which suggests a tendency for men to publish with men and women to publish with women.

Figure 1: Gender distribution of Diagnostic Radiology Faculty Members and Residents Compared to Medical School Graduates Over Time. Data from previously published Association of American Medical Colleges Data. (3, 6). "Medical Students" refers to all U.S. medical school graduates; "Radiology Residents" refers to diagnostic radiology residents in the United States; "Radiology Faculty" refers to U.S. diagnostic radiology instructors, assistant professors, associate professors, and full professors detailed in table 2. "Radiology Chairs" refers to chairpersons of departments of diagnostic radiology in the United States.

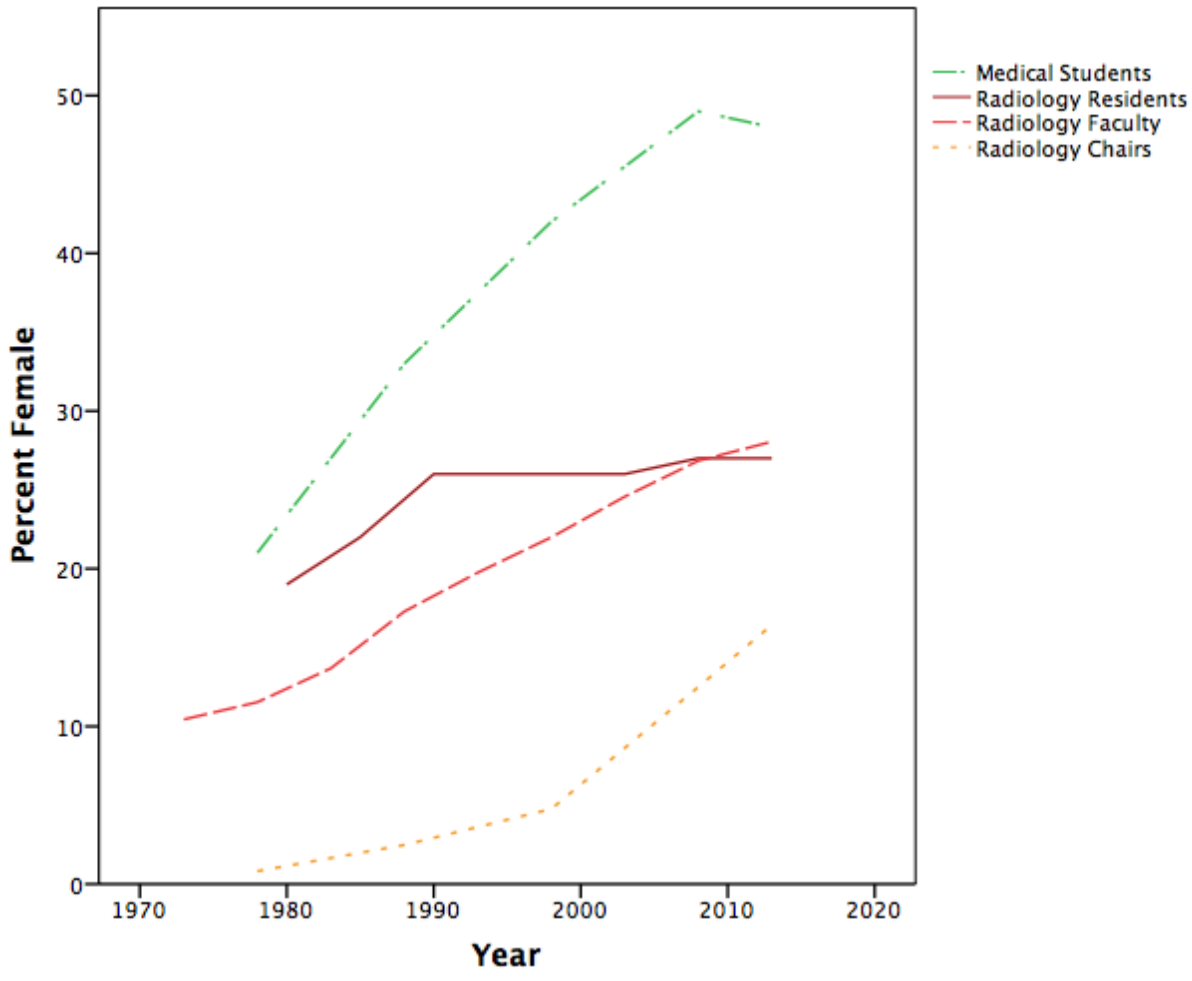

Table 2: Percentage of women in medical school and radiology leadership positions for various years (3, 6, 85).

	Med. Grads	Rad. Residents	Rad. Instructors	Rad. Assist. Profs	Rad. Assoc. Profs	Rad. Profs	Rad. Faculty	Rad. Chairs
1973							10	
1978	21		19	15	9	4	12	1
1980		19						
1983							14	
1985		22						
1988	33		23	25	15	7	17	2
1990		26						
1993							20	
1998	42		33	28	20	11	22	5
2003		26					25	
2008	49	27	35	31	24	17	27	13
2013	48	27	38	31	25	20	28	16

Figures 2a through 2d: Publications by Female Physicians who were first and last authors of published original research and guest editorials in radiology journals.

Figure 2a: This figure compares percent of radiology publications authored by women to the percent radiology residents who are women. Recently, female *first* authors in radiology surpassed the percent of female *residents*.

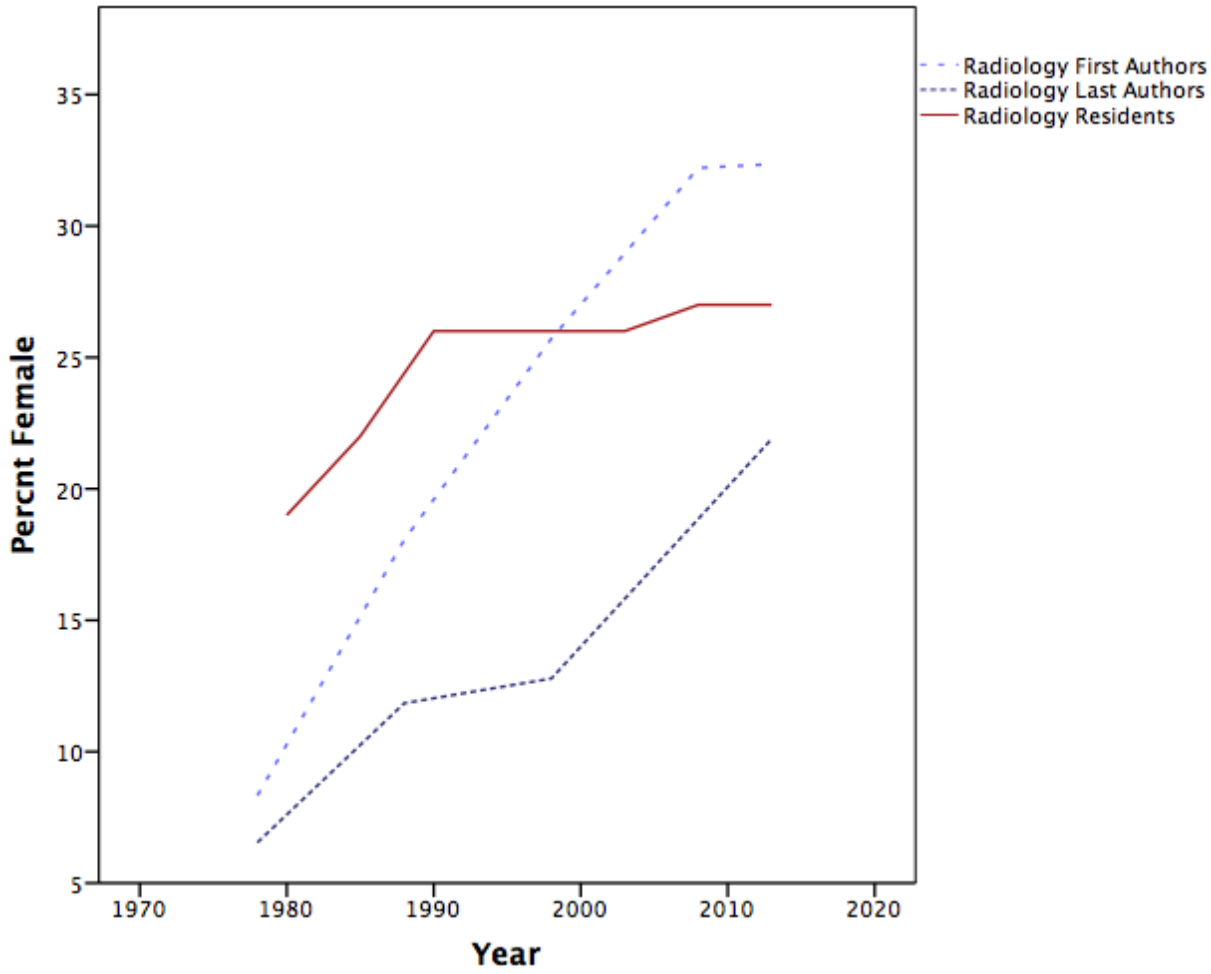

Figure 2b: This chart builds on the above by comparing the proportion of radiology publications authored by women to that of both residents and faculty. While the proportion of female *faculty* has increased to a level comparable to radiology residents, the amount of publications by *senior* female authors remains discordant with their representation in radiology.

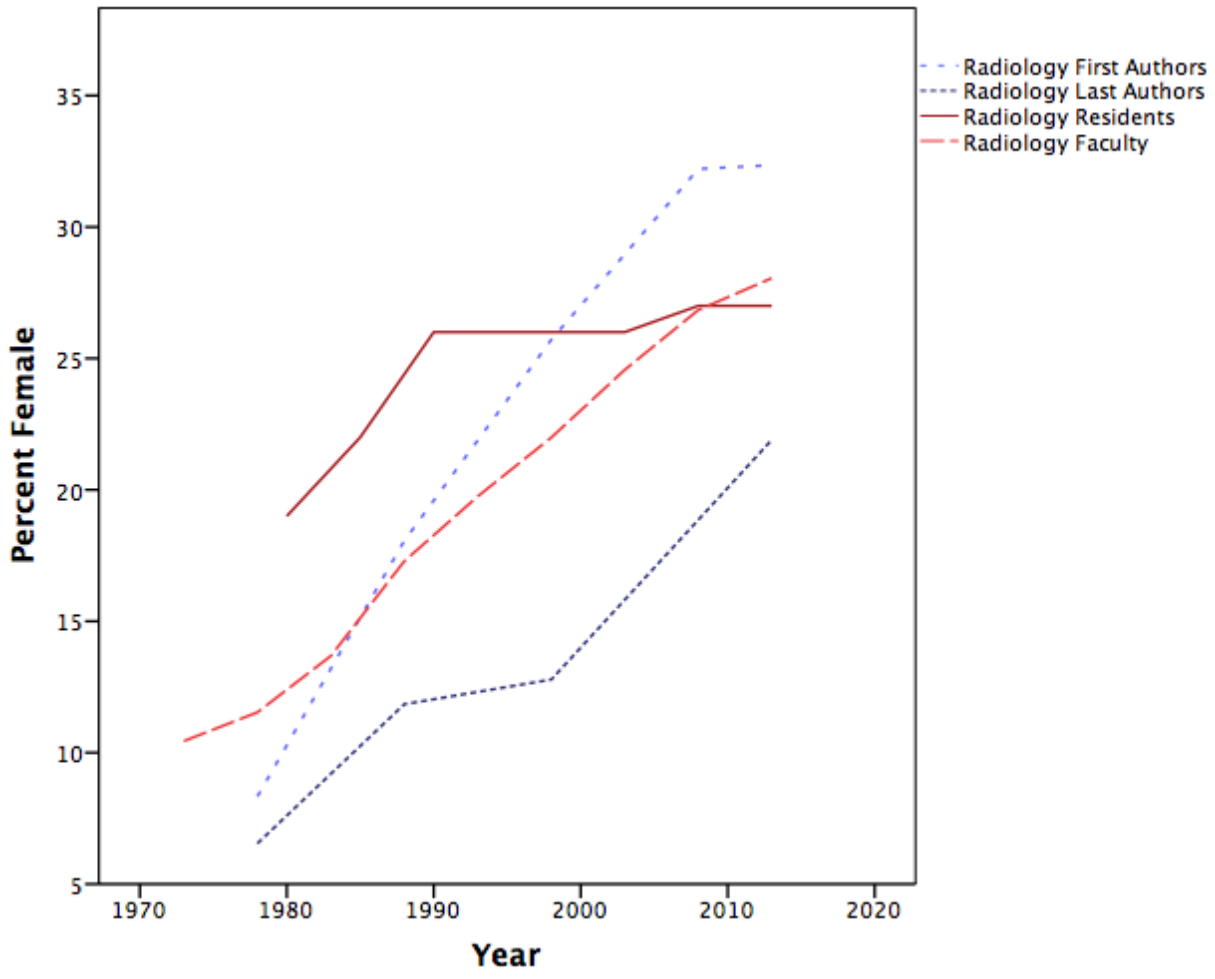

Figure 2c: This figure further adds the proportion of graduating medical students that are female to the comparison of female representation in radiology and radiology authorship. Women are no longer underrepresented in *medical school*, but are far from represented in the *field of radiology*.

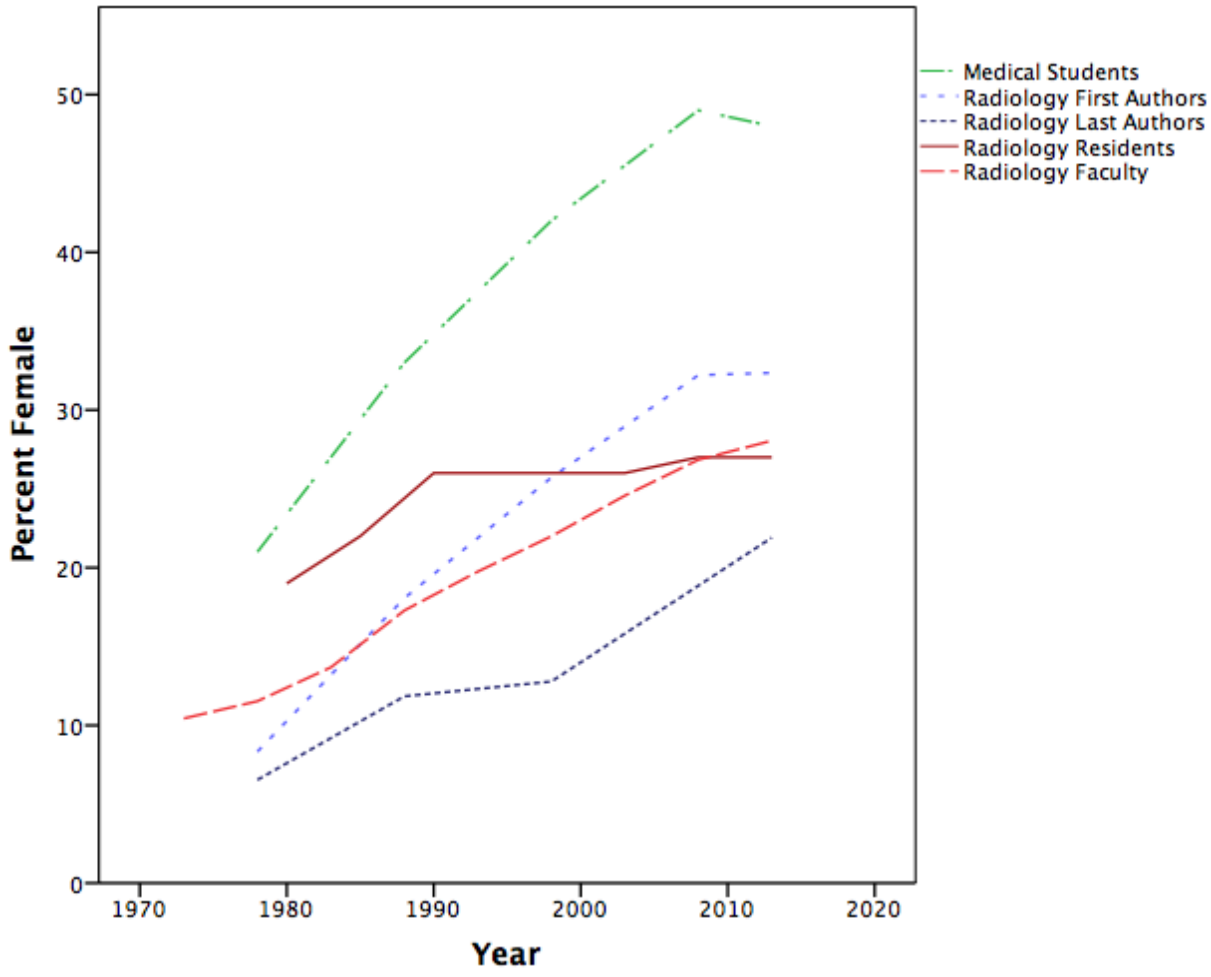

Figure 2d: This figure simplifies the above by displaying only the lines depicting proportions of women graduating from medical school compared to radiology publications authored by women. The increase in female *first* author publications is similar in shape to that of *medical student graduates* (slope = 0.79 and 0.70, respectively).

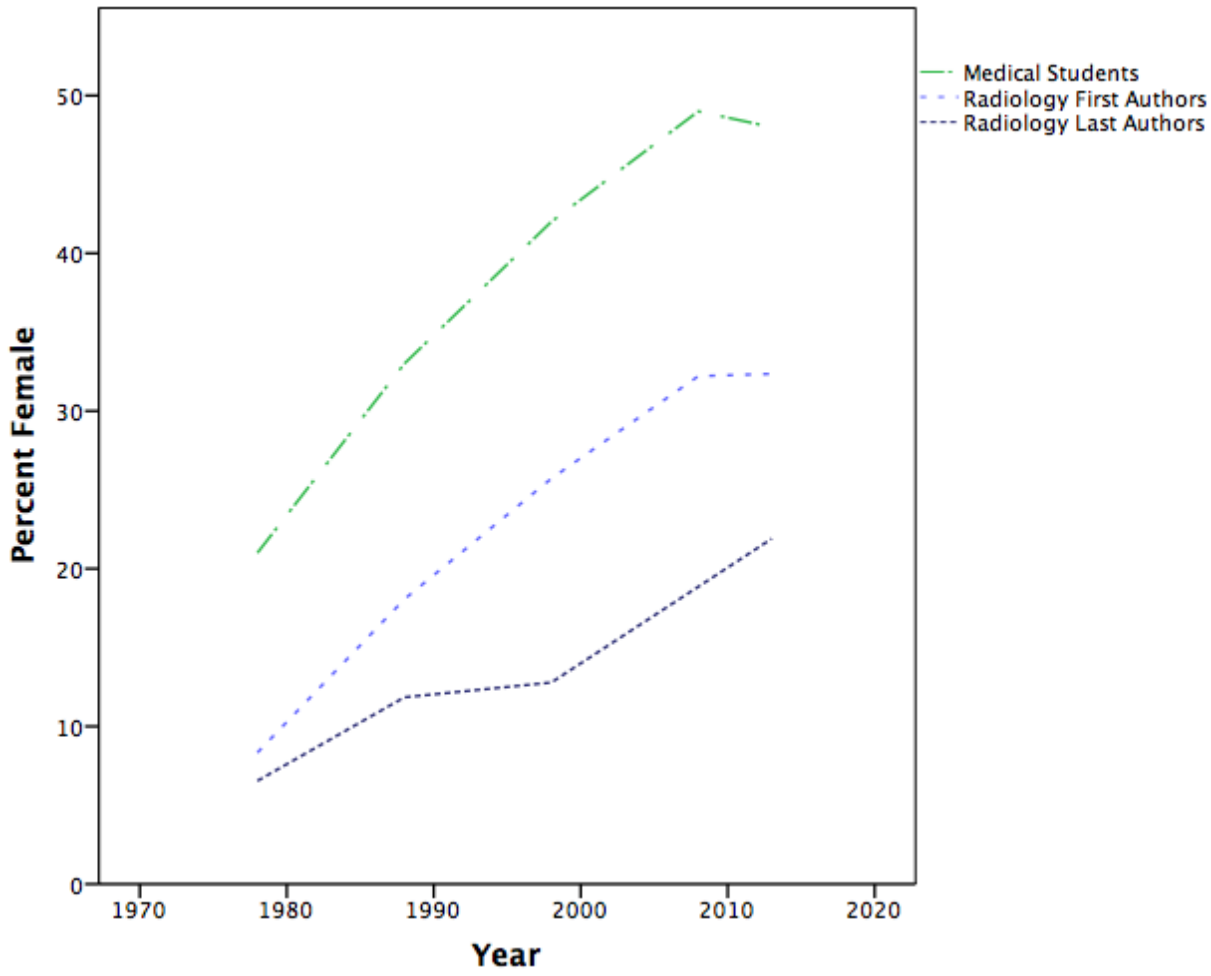

Table 3. Representation of Female Physician-Investigators among First and Last Authors of Published Original Research and Editorials in 3 U.S. Radiology Journals.

		1978	1988	1998	2008	2013	Slope	P Value	CI Lower	CI Upper
Medical School Graduates										
	Total	14391	15919	15958	16168	18157				
	Female	3085	5215	6650	7969	8721				
	Percent Female	21.4%	32.8%	41.7%	49.3%	48.0%	0.7929	**0.0045**	0.4674	1.1184
Overall Authors										
First Author	Total	420	692	420	326	340				
	Female	35	125	108	105	110				
	Percent Female	8.3%	18.1%	25.7%	32.2%	**32.4%**	0.7034	**0.0023**	0.4729	0.9338
Last Author	Total	382	591	399	297	347				
	Female	25	70	51	56	76				
	Percent Female	6.5%	11.8%	12.8%	18.9%	**21.9%**	0.4142	**0.0038**	0.2535	0.5750
	Percent Female	7.5%	15.2%	19.4%	25.8%	27.1%	0.0056	0.0007	0.0044	0.0068
Editorials										
Total	Total	5	34	15	12	16				
	Female	1	5	1	2	5				
	Percent Female	20.0%	14.7%	6.7%	16.7%	31.3%	0.2182	**0.5652**	-0.8594	1.2958
Radiology										
First Author	Total	219	461	202	139	113				
	Female	21	81	48	41	28				
	Percent Female	9.6%	17.6%	23.8%	29.5%	24.8%	0.4931	**0.0273**	0.1046	0.8817
Last Author	Total	203	375	183	124	120				
	Female	11	44	21	17	24				
	Percent Female	5.4%	11.7%	11.5%	13.7%	20.0%	0.3338	**0.0301**	0.0607	0.6069
Journal Total	Percent Female	7.6%	15.0%	17.9%	22.1%	22.3%	0.4133	**0.0049**	0.2384	0.5882
American Journal of Roentgenology										
First Author	Total	201	231	175	146	163				
	Female	14	44	50	47	63				
	Percent Female	7.0%	19.0%	28.6%	32.2%	38.7%	0.8504	**0.0022**	0.5747	1.1261
Last Author	Total	179	216	172	129	158				
	Female	14	26	24	28	29				

	Percent Female	7.8%	12.0%	14.0%	21.7%	18.4%	0.3530	**0.0206**	0.1028	0.6031
Journal Total	Percent Female	7.4%	15.7%	21.3%	27.3%	28.7%	0.6085	**0.0007**	0.4735	0.7435
Academic Radiology										
First Author	Total			43	44	64				
	Female			10	17	19				
	Percent Female			23.3%	38.6%	29.7%	0.3133	**0.6056**	-5.2679	5.8944
Last Author	Total			44	46	69				
	Female			6	11	23				
	Percent Female			13.6%	23.9%	33.3%	0.6787	**0.1051**	-0.7575	2.1150
Journal Total	Percent Female			18.4%	31.1%	31.6%	0.4989	**0.1924**	-1.4775	2.4753

Table 4. First Author Gender by Last Author Gender Cross-tabulation, Pearson Chi Square Analysis of First and Last Author Gender. This figure demonstrates that according to chi square analysis, there is a statistically significant association between first author gender and last author gender ($p < 0.001$) -- there is a tendency for men tend to publish with men and women to publish with women.

			Last Author Gender		Total
			F	M	
First Author Gender	F	Count	76	321	397
		% of Total	4.3%	18.3%	22.7%
	M	Count	155	1200	1355
		% of Total	8.8%	68.5%	77.3%
Total		Count	231	1521	1752
		% of Total	13.2%	86.8%	100.0%

Discussion

This is the first study to show the underrepresentation of women as senior authors in radiology research. There has been a significant increase in the proportion of articles published by women in radiology as first and last authors over the last 35 years. However, the number of faculty and senior authors is disproportionate to the number of women in academic radiology. Encouragingly, the number of radiology articles first-authored by women is now appropriately, if not overly, representative.

This study is also the first of any specialty to analyze the relationship between first and last author as a proxy for mentorship.

Data from the Association of American Medical Colleges indicate that a relatively small percentage of female faculty members serve as professors and role models for the large number of both male and female residents in radiology (figure 1 and table 2). The cumulative trends over time were depicted by curves comparing the increase in female representation among radiology authorship, radiology residents and students enrolled in medical school (figures 2a and 2b). Table 4 demonstrates that there is a statistically significant association between first author gender and last author. That is, there is a tendency for men to publish with men and women to publish with women. The phenomenon of underrepresentation of women in academic medicine is likely a multi-factorial problem, and may be due to a combination of subtle gender bias, discrimination, and lack of mentorship. In order to benefit from the best of both genders, a multi-facetted

approach should be taken addressing all of these aspects.

Our data supports many other similar data analyses, which demonstrate that women are not as academically productive as their male counterparts. Yet, it has been shown that they have the same ability (86) and therefore the premise of this apparent contradiction deserves sound investigation. Interestingly, minorities in general (underrepresented racial/ethnic minorities) are less likely to participate in research; which has been linked to the underrepresentation of minorities among faculty (87). In a landmark study conducted by Moss-Racusin *et al.* (88), the authors performed a psychological experiment on faculty at leading U.S. universities by giving them identical student application materials. Applications were randomly assigned a male or female name. The faculty, regardless of their own gender, rated male applicants as significantly more competent and worthy of hire compared to identical female applicants. The faculty also recommended offering higher starting salaries and career mentorship to the male applicants. This experiment supports several observational studies which show that women in the sciences earn a lower salary for the same job and have a more difficult time achieving academic rank (89, 90). Low female participation in certain disciplines has been linked to those that require greater amounts of financial support (82). Male gender has been associated with an increased likelihood of receiving federal grants (91). Interestingly, our data show that women authorship is not significantly increasing in *Academic Radiology*, a journal mostly comprised of basic science reports which are more likely to have grant funding. Further, evidence supports that the gender of editorial board members affects their peer-review habits (17, 92) and that notable bias exist among reviewers (93-95). Budden *et al*

(2007) found that simply blinding reviewers of author gender significantly increased the number of accepted papers first-authored by women (96).

Some studies hypothesize that when women take risks by choosing fields with lower job security (for example, the field of ecology offers few jobs to graduating students) or where they are severely underrepresented (e.g. surgery), they tend to out-perform their male counterparts in terms of numbers and impact of publications. Women's higher level performance in these fields may reflect self-selection of certain personality types that are able to overcome the barriers affecting other women.

It may be that both lack of grant funding and bias of editorial boards limit the number of publications by women. In addition to these setbacks, women also experience less mobility in leadership (82, 97). It has been speculated that discrimination against women is in part responsible for their lag in leadership roles in academic medicine and the sciences in general, even when academically productive (97). In 2006, women held zero percent of top research leadership positions at the Veterans Administration and held only 27% at the National Institutes of Health (98). Wenneras *et al.* (1990) found that in order to be evaluated as similarly competent when applying for research grants in Sweden, women had to be 2.5 times more productive than their male counterparts (99). Consequently, in order to have a successful academic career as a female researcher, one needs to out-perform male colleagues. This, is in addition to the traditional psychosocial pressures women in the workforce face perhaps more than men (i.e. childcare), characterize discrimination against women. Magnavita *et al.* (2013) recently published

that female radiologists experience less control over their work and receive fewer rewards for work similar to their male counterparts. Women felt less satisfied by their jobs as radiologists, and were more likely to suffer from anxiety and depression than their male peers (100). Thus, the field of radiology and possibly other specialties as well, may not be creating healthy working environments for both genders. In doing so, radiology may be missing out on some of the best medical school graduates and may not be realizing the true academic potential of female colleagues.

It is important to document specific gender discrepancies in the field of radiology, as we do here, with the ultimate aim of determining root causes and catalyzing program reform. It is unlikely the subject-matter of radiology that makes the field inhospitable to women, so one is left to speculate what factors unique to radiology make it particularly sociologically unattractive.

A popular belief that the female mind is intrinsically different from the male and fixed as such with little regard to social construction was coined the "Different Voice View" as a result of Carol Gilligan's book from 1982, *In a Different Voice: Psychological Theory and Women's Development (101)*. This limiting and narrow reductionist's perspective is balanced by what might be termed the "Perfect Storm View", which purports that things such as constant social pressure on women to hide aptitude and generate self-doubt push women to self select certain lifestyles over others (102). Therefore, the differences between women and men are inconstant, changeable and constructed by both social and biological factors (103). There is ample work supporting women's ability to perform in

the same disciplines and at the same level as men and also descriptions that show discrimination to be a more compelling reason for why women occupy fields of medicine disproportionately. The very concept of gender is a construction, an idea, and has been critiqued as being a hurtful binary partitioning of people into groups, which serve only to create a sexual hierarchy that is ultimately the premise of inequality and discrimination (104).

There are two reasons why gender parity is important: 1) having women in science makes medicine better and 2) we have a moral obligation to ensure it. In support of the first point, not only is the research produced by gender-diverse teams better quality, but it also asks better scientific questions based on the diverse perspectives offered by women (81, 82). Women's status as relative newcomers to the field of medicine enables them to see the field and its practices with a less entrenched perspective, which in turn enables them to identify challenges within the field and develop mutually beneficial solutions even more so than their male counterparts. A good example of a mutual benefit would be paternity leave given as a by-product of women asking for maternity leave. This would be a fantastic change in the field, one that men would appreciate as much as women. Further, research choices are biased to one's own gender and research into women's issues may be underrepresented if women are underrepresented (105). However, this general kind of reasoning, which argues that gender parity is justified by consequentiality – that we need more women in science because it will lead to better -- truer -- scientific conclusions is flawed when followed to its conclusion. It suggests that morality can be judged solely on outcome. *Consequentialist* reasoning entails that results justify the

means, even if the means may be considered immoral. This approach contrasts with deontological ethics (reason 2 above), which places a value on justice and fairness. Gender parity in medicine is necessary both because it produces better research and also because it is just and fair.

One study found twelve men between 1999-2004 who published over 30 articles. However, no women during that time had more than 3 published papers; thus illustrating a productivity gap which keeps science male-driven despite increasing numbers of female participants (106). Analyses such as this demonstrate a puzzle begging to be solved: what is the glass-ceiling (107) and how do we get women equal opportunity and representation in science and medicine? In 1998, it was suggested that differences in motivation and reasons for pursuing a career in medicine might be gender-related. The same article asked that we also consider harassment, institutional support, and family obligations as explanations for women's decreased rate of publication (108). Even greater financial debt upon graduation has been linked to female medical students (5). A more recent study found less sexual harassment and no correlation between gender, motivation, and mentoring, but did find that women have more family responsibilities. However, taking many of these factors into consideration, and at all levels of productivity, women were still slower than men to increase their salary and advance their careers (109).

Women have been shown to have fewer invitations to write but equal numbers of presentations (110). This suggests that while they are clearly substantive enough to present research in equally weighted numbers, they are not getting the voluntary

opportunities that are handed out by colleagues, rather than more clearly earned by content. Although it has been shown many times that publishing is imperative to advancement in academic medicine and that this may be an important factor to consider when attempting to ensure equal opportunity, female surgeons have been shown to self-report fewer numbers of publications while research showed that they actually published more than men, had the same number of "high quality" projects -- such as randomized controlled trials -- and had similar amounts of funding. Therefore, their delinquent advancement to leadership roles in surgery could not be explained simply in terms of numbers and productivity (97).

The Implicit Association Test, which looks for subconscious associations between words, found that female names are less likely to be associated with proactive, self-reflecting, self-regulating, non-reactive qualities that are logical and goal oriented. This unconscious bias against women because of assumed implicit stereotypes generates discrimination of women. They may not be held to the same expectations and they may not be considered for leadership roles (111, 112). Similarly, a Swedish study showed that when women publish qualitative, rather than quantitative work, they get better ranks, especially from other women (94). Women can be as responsible as men for perpetuating opportunity-limiting biases about women.

Our study looked at last authors as a proxy for mentors of the first authors on manuscripts. Previous studies have suggested that humans tend to view the work of people similar to themselves more favorably than the work of strangers and simply

knowing more about an author makes their work more favorable (92, 94). Therefore, the tendency to work with kinsmen may explain the development of a glass-ceiling for minorities. We did the chi square analysis demonstrating that women tend to work with each other because lag in publication rates and limited advancement of women may be a result of gender-biased mentorship; men in the sciences may have better and more mentorship than women (113). Mentorship is thought to be one of the most crucial activities enabling academic career advancement, especially for women (114, 115). Wenneras *et al.* (1990) also showed that, when being judged as competent ("competence score" determined by peer-reviewers based on authors curriculum vitae, bibliography and research proposal), having an affiliation with a committee member (perhaps a proxy for an important mentor) could compensate for the bias implicit in gender (99).

Interestingly, women tend to be evaluated more fairly when they make up at least 25 percent of a group (116). At this level and above, women are less likely to be stereotyped and the perception of the job itself changes. Leadership, for instance, becomes a human trait rather than a male trait (116). The field of radiology, with a flat line of 27 percent female residents in both 2008 and 2013, hovers close to an environment that may be less fair to women. In 2001, chairmen still felt that the core reasons for the lack of female leaders in academic medicine was primarily due to stereotyped gender roles, sexism at work, and a void of mentors (114). Clearly, the gender gap is neither driven by lack of interest in the field nor ability to perform in the field. Rather, gender discrepancy may be more related to women's *perception* of happiness, satisfaction, and respect in the field, and ultimately to whether the field of radiology is healthy for high performing women.

The field of radiology will benefit from the types of perspectives and work that women bring to their careers.

How can radiology begin approaching a solution to this problem? Including women in academics opens doors for other qualified women. When women were included on selection committees of NIH Pioneer Awards, the number of women awardees increased from zero to 50 percent, which argues against the notion that women are less interested in scholarly endeavors in fields such as radiology (117). The same argument has been used to explain the low rates of women in sports before title IX, yet there has been a 10-fold increase in female participation in sports since (98). An analysis that found few women in science at the VA hospitals in 2012 asked that we consider the possibility of an unconscious bias that devalues women in our culture as a whole (98) and noteworthy scientists have described discrimination as being the main reason for stunted advancement of women in the sciences (117).

Evidence that women can be as productive as men in math and engineering research was presented by McGregor *et al.* (2008) with a discussion hypothesizing a tendency for women to collaborate and publish with other women (118). Our cross-tabulation demonstrates that women do, indeed, tend to work with one another. This could be explained by a general propensity to work with others with whom one can relate on a personal level. Therefore, women might tend to work with women, men with men, and people from similar ethnic and national origins might choose to collaborate with each other. This phenomenon could account for the "glass-ceiling" that minorities often feel.

Another possibility is that women are not invited to work with men and therefore are left to work with each other. If women have a more difficult time joining project teams, this would explain why there are fewer publications by women. Future research could explore this by seeing if women tend to work with women of non-M.D. degrees more than men. Perhaps women are forced to work within their gender and therefore must find peers outside of their field for collaboration. In support of this possibility, Taira *et al.* (2008) found that in surgical literature, female first authors were less likely to have a medical degree (97).

This topic lends itself well to a discussion of mentorship and the importance of mentorship for deconstructing social constraints. Rather than interest and aptitude, career path decisions are most distinctly influenced by colleagues (119). Our results suggest that women tend to publish with other women. This can be explained in two possible ways: (1) Women prefer to work with each other, or (2) women are not invited to work with men and so are left to work with each other. While further work will be needed to determine the true nature of this observation, we do know that mentoring of women does not necessarily need to come from other women. Women can be participants in the discrimination of women and the perpetuation of gendered biases similar to men (84, 120). Actually, it may be beneficial for women to be mentored by men (121) and, therefore, our findings that demonstrate women's tendency to publish with other women may indicate an opportunity for men to become better mentors of women. Women need to be mentored for leadership roles, encouraged to participate on committees, panels, and expert task forces. Women especially need to be mentored as abstract graders and journal

reviewers (7). Mentorship does increase research productivity (122) and can be formalized and evaluated without being forced and assigned. Chairmen are encouraged to provide lists of good mentors to the mentees so that mentees can "shop" for the most suitable relationship (123).

Mentors do not have a formal definition or rubric to follow; a 2006 systematic review of mentorship concluded that we are in need of more practical recommendations on mentoring (124). More recent literature describes mentors as playing a useful role in manuscript and grant application review; mentors both edit manuscript and help with career planning (125). Mentors serve as role-models, facilitate networking, and provide advice on appropriate career progress (123). Donovan *et al.* (2010) spoke directly to the field of radiology about the benefits of mentoring. She suggests mentoring can effectively ameliorate the female-specific problems that Magnavita *et al.* (2013) brought to our attention: decreased research productivity and decreased job satisfaction (100). Mentoring has been shown to increase not only the number of publications, but also the h- and m- indices and citations (126).

Donovan (2010) also noted that female radiologists often have a difficult time finding mentors, but also reassuringly reported that program directors in radiology agree that mentorship will help their female members pursue academics and leadership. Notable examples include Stanford University's Radiology Department, which published their description of a highly rated mentorship program in *Academic Radiology* (127). Similarly, the Beth Israel Deaconness Hospital Radiology Residency program director

published bulleted lists of recommendations on how to become and connect with a successful mentor (128). Mainiero *et al.* (2007) warn that mentoring will safeguard the future of radiology, and suggests that program attention, by way of seminars, workshops, and courses on mentoring might be beneficial. Workshops and structured evaluations can also increase research productivity (123). Zerzan *et al*. (2009) speaks to the mentee, through a useful checklist to facilitate mentor relationship management.

Another way to help women overcome biases and barriers in academia is to create formal writing groups. A recent writing group at the University of Pennsylvania School of Medicine that focused on teaching women how to approach scholarly work was able to increase publication productivity 3-fold in participants (113). Certainly, this reinforces the need for specific and sometimes didactic mentoring that helps women develop the same skill sets perhaps more often given casually to their male classmates (112). The Yale Psychiatry Program developed a course for residents that addresses these issues in a very formal rubric. The course was well received by the participants and provides a viable model for other programs (129).

Thoughtful interventions, such as the one done by Dr. Valantine *et al.* (2014) at Stanford University, have proven extremely successful when measured. When formal interventions within diversity and leadership were implemented in 2003, satisfaction of women faculty increased from 48% to 71% in 2008 and the number of women faculty grew by 74%. Noteworthy components of this intervention included: it was not directly targeted at women; it explained the link between diversity and excellence; it discussed

strategies for avoiding “cognitive errors” and gender bias when evaluating candidates; it gave unrestricted funding for protected research time so that family-career balance could be achieved; and it had skill-building classes that taught faculty how to write. The only part of the intervention that was restricted to women only was a networking group (130).

An often-broached topic related to the career choices of women is the impact of family (131). Although comfortably discussed in gendered discussions, this may become an un-gendered topic as more women obtain leadership roles and parenthood becomes a more equally shared responsibility. However, at this time, there is some evidence to support that women may lag in productivity during child-rearing years and then try to “catch up” later (132). Interestingly, this seemed to be associated with women producing fewer but higher quality publications. The publication of this analysis was coupled with a concern that the h-index, which mostly measures number of publications, could serve an injustice to female scientists.

Social conditioning of women may be responsible for their different approach to the world of academics. Lack of confidence has often been associated with women when they are a minority. For instance, women are more likely to give poster rather than oral presentations (133) and feel less confident even while outperforming their male counterparts (134). Virginia Valian believes that "simply raising expectations for women in science may be the single most important factor in helping them make it to the top" (116).

In conclusion, academic radiology may be neglecting women in medicine and losing a valuable resource. Not only do women now make up a large percentage of the "best and brightest" (135) medical students, they may also offer diverse perspectives that enhance the field of medical science (7). Further, it is simply unethical to allow bias and discrimination to keep anyone from achieving their full academic potential. Based on current information, the best initial solution to this problem is to ask those in leadership roles to self reflect on the gender representation of journal editorial boards, professorship, and leadership roles and to determine whether both genders are recruited in comparable numbers and evaluated based on performance (7). Famously, the 1970's writer Dorothy Dinnerstein, admonished that:

> The most potent sources of sexual conservationism (sexual arrangements where there is a division of responsibility, opportunity, and privilege between male and female humans) are buried in the dark, silent layers of our mental life: it is the burial that keeps them potent. To articulate them openly, to see them in the light of full awareness, is a necessary condition for growth toward liberty – away, in other words, from tightly, coercively predefined modes of feeling and action – between women and men. (136)

Simply bringing awareness to the problem of gender bias in radiology will help decrease its power (137). But most proactive for initially approaching this multifaceted problem is the implementation of high quality, unbiased mentorship in the effort to keep medicine a moral endeavor, grounded in ethics.

Limitations

Limitations of this study include the possibility that a traditionally gendered name was not assigned to a person of that gender; there are likely some errors of assumption in our data collection. We assume the last author is the senior author. We only included M.D. degrees in our analysis, we excluded European equivalents and D.O. degrees. We did not consider corresponding authors. It is possible that non-radiologists published in radiology journals and therefore affected our generalization that these authors are representative of the specialty. We counted every article, not every author; therefore it is possible, though very unlikely, that particularly prolific authors weighted their gender. We only looked at three radiology journals, not all journals in the field. Some specialties may be better at recruiting women, for instance Breast Imaging may have more female authorship.

Future Directions

In the future, it would be interesting to compare editorial board gender profiles to this work. Of note, the proportion of authors who were women increased most sharply in *AJR* (from 7.0% and 7.8% in 1978 to 38.7% and 18.4% in 2013 for first and last authors, respectively) compared to the other two journals studied here. It would be interesting to see if the editorial board gender profiles correlate to this observation. We included guest editorials in our analysis because they require invitation and, therefore, are an indicator of prestige. There were too few total guest editorials in our data set to find any statistically

significant relationship between the proportions of female authors and time (in 1978, 20.0% of physician authors of guest editorials were women compared to 31.3% in 2013). This could be analyzed again with more data. It would also be interesting to see the distribution of types of degree within the non-M.D. designation. Future work should also be dedicated to determining the reasons why the field of radiology in particular is less attractive and hospitable to women. Our data show an encouraging increase in the number of articles first-authored by women. This will be an interesting figure to monitor with hope that 10 years or so from now, those responsible authors will move up the ranks in radiology and become senior authors. Thus, we eagerly anticipate that within approximately a decade, the lag of senior authorship will disappear. Following, we would expect women to qualify and occupy more senior faculty positions, which in turn may help attract medical students to the field. It is possible however, that the increase in radiology publications first-authored by women is simply a by-product of more women being in medical school, which is supported by the shapes of the curves in figure 2d. It is possible that physicians in training participate in radiologic research but still reject the residency training. Regardless, the participation of young women on research teams in the field of radiology provides them with exposure to the field and therefore gives the field of radiology a chance to show how it is and how it can change.

Exemption and Conflicts of Interest

This study was approved by the Yale University Human Investigation Committee (HIC) for exemption from Institutional Review Board (IRB) review (HIC protocol # 1412015059) on January 7, 2015.

We have no conflicts of interest to report.

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