

Coauthors' Contributions to Major Papers Published in the *AJR*: Frequency of Undeserved Coauthorship

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OBJECTIVE. Over half of the major papers published in the *American Journal of Roentgenology* (*AJR*) have five or more coauthors. This project was designed to evaluate the specific contributions of coauthors and the prevalence of undeserved authorship in major papers from institutions in the United States.

MATERIALS AND METHODS. Questionnaires were mailed to the first author of 275 major papers from institutions in the United States that were published in the *AJR* in 1992 and 1993. Questions focused on coauthors' contributions to research design, data collection, data analysis, and manuscript preparation, and on undeserving authorship.

RESULTS. One hundred ninety-six (72%) of the surveys were returned. Ninety-nine percent of first authors, 75% of second authors, fewer than half of third authors, and one third of fourth authors and beyond were said to have contributed to at least three of the following: research design, data collection, data analysis, and manuscript preparation ($p < .02$). A strong correlation was indicated between authorship position and contribution ($r = -.69$, $p < .001$), with a mean overall contribution of $63 \pm 17\%$ (mean \pm SD) for the first author, $20 \pm 12\%$ for the second author, $10 \pm 7\%$ for the third author, $7 \pm 6\%$ for the fourth author, and $5 \pm 5\%$ for all other authors. Coauthors were listed in decreasing order of contribution in 70% of articles. However, the last author was the second major contributor in 10% of articles with three or more authors.

The incidence of "undeserved" coauthors increased from 9% on papers with three authors to 30% on papers with more than six authors (mean, 17%; $r = .97$; $p < .001$). Undeserved authorship was attributed largely to individuals who contributed only cases (29%) or who created a sense of obligation or fear in the first author (40%). Manuscripts were more likely to include an undeserved coauthor when the first author was a nontenured staff member (45%) than when he or she was tenured faculty (28%) ($p < .02$). When decisions about authorship were made at project conception, there were fewer coauthors (3.9 versus 5.4, $p < .02$) and a lower incidence of manuscripts with undeserving coauthors (23% versus 47%, $p < .01$). The final manuscript was read by all coauthors in 80% of manuscripts, and all coauthors were thought to understand the manuscript to the extent they could publicly defend it in 78% of manuscripts. The most commonly cited reason that otherwise honest individuals accept undeserved authorship was academic promotion.

CONCLUSION. Undeserved authorship is a common and serious problem that is motivated primarily by academic promotion policies. The first two authors are said to account for the preponderance of work in almost all major papers.

The number of coauthors listed on scientific papers has dramatically increased over the past decade and has become an increasing problem in medical research, including radiology research [1-11], in which the average number of authors per paper has increased from 1.8 in 1950 to 4.4 in 1985 [4]. Major papers currently published in the *American Journal*

of Roentgenology (*AJR*) have an average of 4.8 coauthors because of both a decline in the number of papers with one and two authors and an increase in the number with five or more [4]. Despite this growth, the productivity of full-time academic radiologists has remained from 0.6 to 0.9 first-author papers per year per academic radiologist since 1960 [4].

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Multiple scientists may reasonably coauthor a single paper; however, multiple authorship becomes a problem when authorship is conferred on individuals who are undeserving [12], and authorship is often offered gratuitously [13]. In 1953, Alexander [14] wrote about the increasing authorship of manuscripts and warned against granting authorship to individuals who make only minimal contributions to the research. Irresponsible designation of authorship includes unjustified authorship in which individuals who have not earned the responsibility are listed as authors and incomplete authorship in which deserving contributors are excluded; the latter case is probably rare [15]. Deserved authorship is difficult to define. It is a principle more than a written rule, although ethical standards and guidelines for authorship have been developed by many organizations and societies as a result of past abuses [16–18]. Robert N. Berk, former editor in chief of the *AJR*, offered the following guidelines in an editorial on irresponsible authorship [1]:

Responsible coauthorship requires the coauthor to have made a substantial and specific intellectual contribution to the work. It indicates active participation with contribution of thought and effort, and it guarantees that the coauthor has the ability to defend the results and that he assumes responsibility for them....

To be listed as a coauthor, the person must have done one or more of the following: provided the idea (not just suggested that the first author work on a certain problem), designed the protocol, played a leadership role in the acquisition of the data, executed the study, analyzed the data, reviewed the literature, and/or written and revised the manuscript.

It is inappropriate to assign coauthorship as a courtesy (honorary coauthorship), as a gift (gratuitous coauthorship), or solely because the person is a member of a "team" (cronyism). Likewise, coauthorship is not indicated if the individual's only contribution was technical, financial, or editorial or if his sole involvement was having his name on the grant that supported the work. Coauthorship is not warranted if the person served only as a department or laboratory manager, chief of the service, or chairman of the department. Someone whose sole

contribution was to refer the cases included in the investigation or to carry out and interpret routine studies on these patients does not deserve to be listed as a coauthor. Recognition and appreciation for these various services should be given in an acknowledgment.

This project was designed to evaluate the specific contributions of coauthors, the reasons authorship is granted, and the prevalence of inappropriate authorship in major papers from institutions in the United States. The terms "author" and "coauthor" are used interchangeably in this manuscript without reference to a specific author position on the manuscript.

Materials and Methods

The 24 issues of the *AJR* published from January 1992 through December 1993 included 437 major papers in addition to other articles. Only the 286 major papers written by at least two authors from institutions in the United States were considered in this study. Foreign manuscripts were eliminated to avoid the confounding issue of cultural influence and custom on authorship trends.

A two-page questionnaire was developed that included 30 questions. One group of questions focused on the percentage of contribution by each coauthor (including the first author) to research conception and design, data collection, data analysis, writing and revision of the manuscript, and the overall project. Other questions included the following: What were the academic ranks of the authors? How many papers had each author published in peer-reviewed journals? Who performed the literature review? When was final authorship decided? Did all coauthors read the final manuscript? Did all coauthors understand the manuscript well enough to defend the contents? Was each coauthor "objectively" deserving? Would an acknowledgment alone have been sufficient for at least one coauthor? Why were undeserving coauthors included? Which authors were undeserving, and what was their academic position?

Fourteen questions about personal experience and opinions were also asked, including questions about undeserved authorship of other papers, acceptance of undeserved authorship, policies on inclusion of undeserved coauthors, opinions on frequency of undeserved authorship, significance of undeserved authorship, opinions on documenting coauthors' contributions in published articles, effect of such documentation on their own article in the *AJR*, opinions of editorial limits on number of coauthors, reasons for acceptance of undeserved authorship, and opinions on the definition of undeserved authorship. Space was provided and written comments were encouraged. (A copy of the questionnaire is available on request from the author.)

The first author was listed as the corresponding author on 207 (72%) of the manuscripts. In 79 articles, someone other than the first author was listed as the corresponding author. For nine of these 79 articles, a footnote indicated that the first author had moved to a foreign country, and these articles were excluded from the study. For the other articles, the institution was contacted by telephone to obtain the first author's current address. The first authors of two articles were identified by telephone as having moved to a foreign country, and their articles were excluded.

A cover letter, the first page of the manuscript, the questionnaire, and the excerpt on the definition of irresponsible authorship printed in the introduction [1] were mailed to the first author of the remaining 275 manuscripts. The study included 18 first authors of two papers and one first author of six papers who were asked to complete a separate questionnaire for each paper but to answer the questions about their opinions or personal experiences only once. Confidentiality was ensured by including a stamped return address envelope and asking respondents to return only the questionnaire.

Descriptive statistics, Pearson correlation coefficients and *p* values for linear regression, difference of means and proportions *t* tests, Pearson chi-square test, and analysis of variance were calculated from spreadsheet data using Microsoft Excel (Microsoft, Redmond, WA) and JMP (SAS Institute, Cary, NC).

Results

Table 1 provides an overview of the distribution of major papers in the *AJR* by number of authors and origin. Manuscripts from foreign institutions have more authors per manuscript than those from institutions in the United States (mean, 5.3 compared with 4.5, $p < .001$) because of both fewer manuscripts with only a few coauthors and more with over five coauthors. One hundred ninety-six (72%) of the questionnaires were returned, including three that had been mailed from foreign countries (these were excluded). The remaining 193 were tabulated and form the basis of this report. An adequate total number was available for analysis and uniform distribution by coauthor number when papers with more than six authors were grouped together. The first authors had published an average of 30 manuscripts (median, 15) in peer-reviewed journals over the course of their career. No relationship ($r = 0.03$) was seen between the number of papers published by the first author and the total number of coauthors on the manuscript studied.

Table 2 shows that assistant professors were the most common first authors (36%)

Coauthors' Contributions to Major Papers

No. of Authors	No. of Major Papers (%)	Institutions		Surveys	
		Foreign No. (%)	United States No. (%)	Mailed ^a	Returned
1	12 (3)	3 (2)	9 (3)	—	—
2	38 (9)	10 (7)	28 (9)	26	19
3	77 (18)	18 (13)	59 (20)	58	40
4	82 (18)	21 (15)	61 (21)	58	42
5	74 (17)	27 (19)	47 (16)	46	32
6	74 (17)	28 (20)	46 (16)	44	34
7-13	80 (18)	35 (25)	45 (15)	43	26
Total	437	142	295	275	193 ^b
Mean no. of coauthors ± SD	4.8	5.3 ± 2.2 ^c	4.6 ± 1.9 ^c		

^aExcludes nine single-author papers and 11 papers from institutions in the United States the first author of which had moved to a foreign address.

^bExcludes three questionnaires that were completed but returned from a foreign address because the author had moved.

^cDifference of means *t* test, $p < .001$.

Academic Position	No. of Papers (%)	Mean No. of Coauthors	Percentage of Papers with "Undeserved" Coauthors (Confidence Intervals)
Full professor	21 (11)	4.6	26 (7-45)
Associate professor	36 (19)	4.3	29 (13-46)
Assistant professor	66 (36)	4.5	41 (29-53)
Fellow	25 (13)	5.3 ^a	60 (40-80)
Resident	30 (16)	4.2	43 (26-61)
Student	3 (5)	4.1	33 (0-90)
Tenured faculty ^b	57 (31)	4.4	28 ^c
Nontenured faculty	124 (69)	4.6	45 ^c

^aAnalysis of variance, $p = .14$.

^bAssociate and full professors.

^cDifference of proportions *t* test, $p = .01$.

and that 34% of the first authors were residents, fellows, or students. Little difference existed in the mean number of coauthors based on academic rank with the exception of papers by fellows on which there were more coauthors (mean, 5.3), but this was not statis-

tically significant. Manuscripts were more likely to include undeserved coauthors (45% versus 28%, $p < .02$) when the first author was a nontenured staff member (resident, fellow, or assistant professor) than when an associate or a full professor was the first author.

Final authorship was decided at project conception in 42% of manuscripts, in the midst of the project in 29%, and at completion in 29%. Strong relationships existed between the time authorship was decided and the mean number of coauthors and the percentage of manuscripts with undeserved coauthors. When decisions were made at the conception of the project, there were an average of 3.9 coauthors, compared with 4.7 when decisions occurred in the midst of the project, and 5.4 when at completion (analysis of variance, $p < .001$). A lower incidence of manuscripts with undeserved coauthors was also found when authorship was decided during the conception and design of the project (23%) rather than in the middle (48%) or at the completion of the study (46%) ($p < .01$). For example, the final authorship was decided at conception in 58% of papers and at completion in 10% of papers with two or three coauthors, compared with 21% at conception and 47% at completion in papers with six or more coauthors.

Table 3 shows the percentage of coauthors contributing to the various stages of the

Coauthor Position	No.	Research Design ^a	Data Collection ^b	Data Analysis ^b	Manuscript Preparation ^a	Contributed to 3 or 4 Categories ^b
First	175	98	97	99	100	99
Second	175	76	77	71	83	75
Third	158	57	68	46	68	47
Fourth	121	37	47	35	61	31
Fifth-Tenth ^c	185	34	41	31	45	25

^a $r < -.80$, $p < .01$.

^b $r < -.90$, $p < .03$.

^cAverage for additional authors.

project. Complete information was provided in 175 (91%) of the surveys returned. A steady reduction occurred in the percentage of authors contributing to research design, data collection, data analysis, and manuscript preparation as the author position decreased, and the percentage contributing to at least three of the four categories decreased rapidly beyond the second author position ($p < .03$).

Table 4 provides complete information on the mean percentage contribution of each coauthor to research conception and design, data collection, data analysis, and manuscript preparation for papers with varying numbers of coauthors. A strong correlation ($r = -.69$, $p < .001$) existed between an author's position and overall contribution to the manuscript, with a significant decrease in contribution in all categories by all authors

beyond the second. The largest relative contribution of the first author was to manuscript preparation and the least was to data collection. The largest relative contribution of the second author was to research design and data collection and the least to manuscript preparation. The largest relative contributions of the third and fourth authors were to data collection and the least to manuscript preparation.

The average contribution from a particular coauthor position changed little as the total number of coauthors increased. For example, the mean contribution of the second author to data collection was 19–25% and the mean overall contribution of the third author was 8–11% for all numbers of coauthors. The range in overall contribution shown in the last column of Table 4 indicates that the second author never

contributed more than 50%, the third author more than 40%, and the others more than 30% in any of the 175 manuscripts. Coauthors were listed in decreasing order of overall contribution in 70% of manuscripts. The frequency of this pattern decreased with increasing numbers of coauthors (100% with two authors, 95% with three authors, 69% with four authors, 58% with five authors, and 50% with six or more authors; $r = .91$, $p < .01$). The last author was the second major contributor in 10% of manuscripts with three or more authors.

Figure 1 shows the overall contribution of 841 authors to 175 manuscripts. Linear regression analysis provides a strong fit to the data ($r^2 = .47$, $p < .001$). Although the number of authors and author position are important separately, only position is important when they are combined, probably

TABLE 4 Percentage of Contributions to Major Papers by Coauthors^a

Total No. of Authors	Author Position	No.	Research Design	Data Collection	Data Analysis	Manuscript Preparation	Overall Contribution Mean \pm SD (Range)
2	First	17	60	78	74	83	73 \pm 14 (50–95)
	Second		40	22	26	17	27 \pm 14 (5–50)
3	First	37	66	67	68	73	67 \pm 16 (50–92)
	Second		22	20	25	19	22 \pm 12 (5–40)
	Third		12	13	7	8	10 \pm 8 (0–40)
4	First	38	61	55	61	73	62 \pm 16 (37–90)
	Second		16	22	15	11	17 \pm 10 (0–40)
	Third		13	14	15	8	11 \pm 6 (0–30)
	Fourth		10	9	9	8	9 \pm 8 (0–30)
5	First	26	51	49	62	70	62 \pm 18 (30–90)
	Second		28	24	16	14	17 \pm 11 (3–45)
	Third		10	11	8	6	9 \pm 8 (0–40)
	Fourth		4	10	8	4	6 \pm 5 (0–22)
	Fifth		6	6	6	6	7 \pm 7 (0–30)
6	First	31	60	37	61	70	57 \pm 17 (30–95)
	Second		21	19	15	12	18 \pm 10 (3–35)
	Third		6	13	4	4	8 \pm 5 (2–20)
	Fourth		4	10	7	5	6 \pm 5 (0–20)
	Fifth, Sixth ^b		4	9	6	5	6 \pm 5 (0–20)
7–10	First	26	56	40	63	74	58 \pm 20 (25–90)
	Second		20	25	20	13	19 \pm 11 (3–40)
	Third		6	9	4	6	8 \pm 8 (0–30)
	Fourth		3	8	3	2	4 \pm 4 (0–15)
	Fifth–Tenth ^b		4	5	3	2	3 \pm 3 (0–10)
Mean	First	175	59	50	65	73	63 \pm 17
	Second	175	23	22	19	14	20 \pm 12
	Third	158	10	12	8	7	10 \pm 7
	Fourth	121	6	9	7	5	7 \pm 6
	Fifth–Tenth ^b	185	5	6	5	4	5 \pm 5

^aComplete data available for 175 papers published in the *AJR* in 1992 and 1993.

^bMean contribution for each additional author.

Coauthors' Contributions to Major Papers

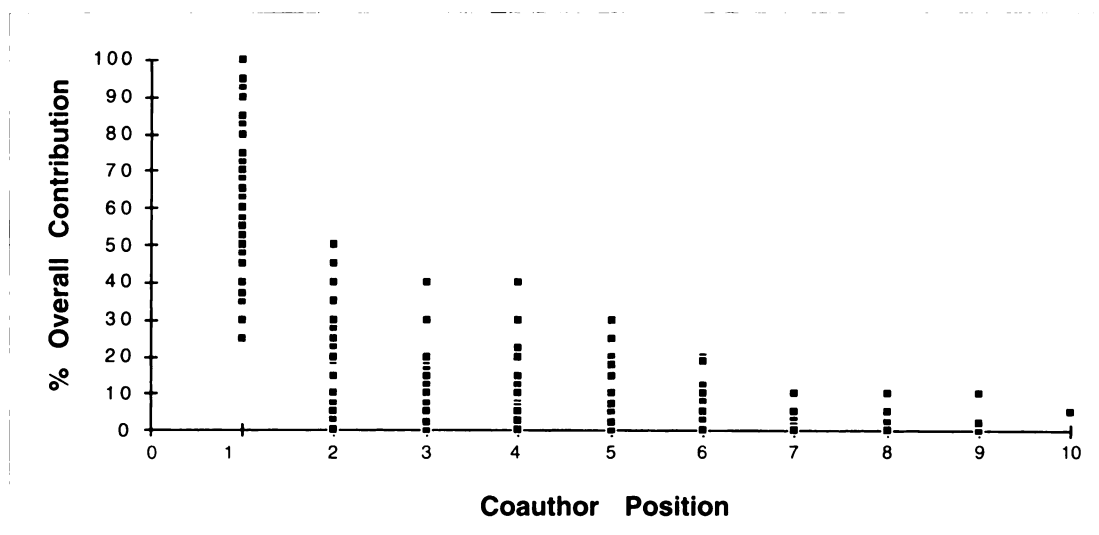


Fig. 1.—Manuscripts with two to 10 coauthors. Plot shows overall contributions of 841 coauthors of 175 major papers from United States institutions published in the *American Journal of Roentgenology* in 1992 and 1993 ($r = -.69, p < .001$). Overall contribution = first author's estimate of each coauthor's total contribution to research, including design, data collection, analysis, and manuscript preparation.

because total author number and author position are related, with total author number affecting contribution because it is related to author position.

Table 5 shows a consistent increase in the number of manuscripts with at least one coauthor making an overall contribution of 5% or less as the total number of coauthors increased. Of the 884 total authors on the 193 papers, 149 (17%) were not considered "objectively" deserving by the first author. Fifty-three percent reported that all coauthors listed on the manuscript were objectively deserving of authorship, and this correlated strongly with the total number of coauthors, reaching 30% on papers with

more than six authors. The percentage of undeserved coauthors also increased as the number of authors per paper increased. The first author of manuscripts with undeserving coauthors tended to have fewer publications (mean, 20; median, 11) than those without undeserving coauthors (mean, 36; median, 20; t test, $p < .005$, difference of means t test).

Of the 181 instances in which a specific reason for including an undeserved coauthor was indicated (more than one reason was indicated for some), 40% were from a sense of obligation or fear of offending someone; 29% were for only referring patients or cases; 10% were to gain favor, for repayment, or in hopes of reciprocation; 7% were

because of pressure from another coauthor; and 5% were because it was demanded. Of the undeserved coauthors, 50% were radiologists and 50% were clinicians. One quarter of the undeserved radiologists were section chiefs or chairmen. Twenty-eight percent of all the papers included at least one coauthor who only contributed cases or referred patients (6% of all authors).

When asked to respond to specific statements, 37% of respondents agreed that including at least one individual in the acknowledgment section rather than as a coauthor would have been sufficient. When asked about previous episodes of undeserved authorship, 63% reported that previous papers they published included inappropriate coauthors, and 43% reported they had themselves received gratuitous authorship in the past. Eighty-four percent agreed with the definitions of inappropriate authorship outlined in Dr. Berk's editorial [1] and when asked to respond to specific statements, 94% agreed that inappropriate authorship is "common," 81% that it is "a problem," 73% that it is "harmful," and 49% that it is "fraud."

When asked about specific solutions to the problem of inappropriate authorship, 33% agreed that the specific contribution of coauthors should be documented in published articles and 33% reported that fewer coauthors would have been listed on their manuscript had that been required. Forty-three percent agreed that editors should limit

Total No. of Coauthors	No. of Papers	Percentage with at Least One Coauthor Contributing 5% or Less ^c	Percentage with at Least One "Undeserved" Coauthor ^c	Percentage of "Undeserved" Coauthors ^c
2	19	5	0	0
3	40	35	25	9
4	42	54	29	12
5	32	87	59	16
6	34	91	53	16
7-10	26	100	74	30
Overall ^b	193	39	47	17

^aUndeserved coauthor = first author's classification of each coauthor as "objectively deserving of coauthorship" or not.

^bOverall contribution = first author's estimate of each coauthor's total contribution to the research including design, data collection, analysis, and manuscript preparation.

^c $r > .93, p < .005$.

the number of coauthors on articles. In response to an open-ended question, the most commonly cited reason for otherwise honest individuals accepting undeserved authorship was academic promotion.

Eighty percent of respondents reported that the final manuscript was read by all coauthors, and 94% reported that the copyright release form was signed by all coauthors. Seventy-eight percent believed that all the coauthors understood the manuscript to the extent that they could publicly defend it. Forty percent reported that only the first author reviewed the literature, 3% reported that the first author did not review the literature, and 57% said that both the first author and the others reviewed the literature when preparing the manuscript.

Discussion

The number of authors of medical articles, including radiology articles, has increased substantially over the past decades. For example, the mean number of authors of articles in the *New England Journal of Medicine* increased from 1.2 in 1930 to 2.9 in 1964, 3.9 in 1975, and 6.4 in 1989 [6, 8, 10, 13]. Perhaps most obvious has been the trend in case reports in which more authors than cases are common, with reports of one or two cases having four to eight authors [8, 19]. Several reasons exist for the growing numbers of coauthors on scientific articles, including the increased complexity of medical research and implementation of a collaborative multidisciplinary team approach that allows rapid data collection and provides varied expertise [1, 2, 4, 6, 8, 10, 11, 14, 20]. Although this team approach may justify some increase in authorship, the numbers often seem disproportional for the work represented [15]. Counting citations in the *Science Citation Index* fails to show any relationship between the number of authors and the frequency of citation, suggesting that an increased number of authors does not imply greater importance of the article [6]. The number of coauthors in multiinstitutional clinical trials is understandable, and it is tempting in complex studies to offer authorship to referring physicians and ancillary medical specialists to obtain the needed cooperation [6, 8, 9]. An additional contributing factor to increasing authorship is apparently the result of abuse by including undeserving individuals who have not made a substantive contribution [1, 6].

Scientific publications enhance knowledge and are crucial to the dissemination of information useful in the practice of radiology and the progress of research [3, 19, 21]. Radiologists are also motivated to publish to establish themselves as experts and to advance their careers [3, 21]. Promotions, tenure, salary, grant funding, resources, and recognition in academic medicine are closely linked to publication quantity, providing substantial pressure to publish frequently [1-3, 7, 12, 16, 21-24]. Academic promotion is more dependent on publications than on clinical activity or teaching excellence, and quantity outweighs quality [20, 23-25]. Writing can also enhance one's personal image and produce a sense of achievement [21]. These rewards and pressures provide a strong incentive to write, leading to wasteful publication and increasing authorship that provides a means of lengthening bibliographies without increasing productivity [2, 3, 6, 23]. Wasteful publication practices include divided and repetitive publications that increase the cost of review, publishing, and distribution and increase the volume and erode the quality of the scientific literature [2, 13, 15, 19, 25].

Questionnaire

Although 72% is a reasonable response rate, it is unknown how representative that percentage is of the entire population and what impact the other 28% would have had on the results. A major potential bias in this study was the sampling of only first authors of manuscripts. First authors were chosen because they should have been the most likely to know the full details of the project and the best able to provide complete information. I hope their responses were objective, but they may have been biased and overestimated their own contributions. The only way to further investigate that possibility would be to survey all the other authors and compare responses.

Foreign manuscripts were excluded as well as manuscripts authored at institutions in the United States by someone who has since moved to a foreign country. Most of these individuals were likely visiting fellows or faculty. Foreign manuscripts have more authors than those from institutions in the United States ($p < .001$, Table 1). Presumably cultural influences and traditions are contributing factors, but the reasons were not investigated in this study.

Most radiology articles published in this

country originate from faculty at academic institutions. The premise that a small percentage of radiologists is responsible for most published articles is supported by the result that first authors had published an average of 30 papers in peer-reviewed journals. The number published appeared to have no relationship to the number of coauthors, suggesting that authorship trends are not influenced by publication experience.

Published articles were evenly distributed by academic rank (Table 2), but manuscripts from fellows had more coauthors than the others (mean, 5.3) and had the highest percentage with undeserved coauthors (60%). Fellows are often new to an institution and are anxious to complete projects before they leave, both of which may be contributing factors to the inclusion of a larger number of coauthors. Manuscripts from residents and assistant professors were more likely to include undeserved coauthors, suggesting that inexperience may be associated with inappropriate coauthor selection, although these authors may simply be more critical of individuals who made minimal contributions.

Decisions about authorship made during the conception and planning stage were associated with fewer undeserved coauthors (23% versus 47%, $p < .01$) and a shorter list of authors (mean, 3.9) compared with decisions made in the midst of (mean, 4.7) or after completion of (mean, 5.4; analysis of variance, $p < .001$) the project. Individual responsibilities and the tentative order of coauthors should also be decided as soon as possible, preferably at the beginning of a study, to facilitate a successful working relationship and completion of the study [11, 16, 26]. Changes can be discussed and other coauthors added as the research progresses, but decisions about authorship should be finalized by the preparation of the first draft of the manuscript [6, 27].

This investigation primarily addressed the issue of coauthors' physical contributions and time commitment to the research project and publication. Assessing the value of intellectual contributions is controversial and complex. Projects whose success depends on individuals who have made small physical contributions but major intellectual contributions may be common, and the inclusion of such individuals as coauthors is questionable. Another issue is the training of more junior authors. A senior staff person may provide major support by time and effort yet allow a

Coauthors' Contributions to Major Papers

junior person such as a resident to take first authorship to encourage academic activities. The more junior first authors may be unaware of the time commitments of their mentors and may have overestimated their mentors' contributions in the study.

Authorship Contribution and Order

Although coauthors' contributions on individual manuscripts varied significantly, general trends noted included reduced participation in research design, data collection, data analysis, and manuscript preparation with decreasing coauthor position. Almost all of the first authors contributed to all four stages of the project. Three quarters of second authors contributed to at least three of the four categories, but fewer than half of third and less than one third of fourth authors and beyond contributed to more than two of the four stages (Table 3).

A dramatic decrease was noted in the overall contribution of coauthors as their position decreased, despite the total number of coauthors. Overall, the first two (and in some cases three) authors are usually responsible for the preponderance of work, with the first author typically contributing 60–70%; the second, 20–30%; and the third and beyond, 10% and less each (Table 4). In most (70%) cases, the authors were listed in decreasing order of overall contribution to the project, which is the most common pattern in the radiology literature. The last author was the second largest contributor in 10% of papers, with three or more authors suggesting they played the role of senior author, a trend that is more common in the medicine and surgery literature.

The term "senior author" is often used to describe the individual who supervises the study or who plays the most supportive role, such as a division or department director [26]. Some believe that if senior authors are not the first authors, they should be listed last, particularly if the study is based on development of a new technique or concept; accordingly, the first and last authors of a scientific article should receive most of the credit [3, 16, 28, 20]. Others hold that the senior author should be listed as the second author because the National Library of Medicine and the International Committee of Medical Journal Editors recommend listing only the first six authors in reference lists, and papers are often cited by the first three names followed by "et al." [3, 6, 7, 17].

Authorship position is an important deci-

sion, and although political factors and the complexity of research may complicate the decision, authorship order should be a joint decision of the coauthors and should be based on their relative contributions [3, 17, 18, 26, 27]. The first author should be the person who made the greatest contribution to the work, usually research design and performance or data analysis, and who usually generates the first draft and makes the largest contribution to manuscript preparation [16, 26, 28]. The remaining authors should be listed in decreasing order of contribution, although it is difficult to assess the contribution of the last author [6, 16, 28, 29] because some still consider it a place of honor. Because authorship order is established in many different ways, its meaning is unclear unless specifically stated by the authors in a footnote [18, 29].

The nature and extent of coauthors' contributions is therefore difficult if not impossible for readers, promotion committees, and funding agencies to determine, making it difficult to compare the bibliographies of researchers [6, 7, 18, 22]. Some suggestions for objective solutions have included mathematical formulas with numeric weighting factors based on authorship order and citation analysis [13, 26, 29]. Because of the variability in specific contributions, general rules are fraught with imprecision; however, the figures from Table 4 provide a general basis for evaluating an individual's bibliography. Assuming one point for each publication and the need to divide that credit among coauthors, the writer of a single-author paper would receive 1 point. Using a weighted scale, the first author on papers with two or three coauthors would receive 0.7 points, and the first author on papers with four or more coauthors, 0.6 points. The second author of a two-author paper would receive 0.3 points and the second author on all others, 0.2 points. All other authors would receive only 0.1 point. The above scale takes into account contribution of effort but not the intellectual contributions, overall impact, particular journal, or article length, but it does serve as a starting point for assessing bibliographies, and additional weighting factors could be applied to this scale.

The most meaningful measure of productivity is first-author papers, with some deserved credit for second-author papers but little substantive credit for the third author position and beyond. Chew [4] has suggested that first authorship of scientific papers is the

most suitable quantitative measure of research productivity because the number of first authorships is limited by the number of papers but the number of coauthors is limited only by the tolerance of the editor and the integrity of the authors.

Undeserved Authorship

Seventeen percent of all coauthors were not considered objectively deserving of authorship. The incidence was lower on papers with three and four authors (11%) and higher on manuscripts with seven to ten authors (30%). In fact, three quarters of manuscripts with more than six authors had at least one undeserved coauthor (Table 5). The first author on manuscripts with undeserved coauthors tended to have fewer prior publications, suggesting that irresponsible authorship is more likely on manuscripts with less-experienced first authors.

Two thirds of undeserved coauthors were included out of a sense of obligation, out of fear of offending a colleague, or for merely referring cases. Twenty-eight percent of manuscripts included at least one coauthor who only contributed cases. Only 12% of the undeserved coauthors were included because their inclusion was demanded or because of pressure from another coauthor. One in eight undeserved coauthors was a radiology section chief or chairman, and half of undeserved coauthors were nonradiologists. Most first authors (84%) agreed with the strict definitions of responsible authorship outlined by Dr. Berk [1] and believed undeserved authorship is a common and serious problem motivated primarily by academic promotion policies.

The irresponsible awarding of undeserved authorship falsely inflates a researcher's bibliography, apparent productivity, and originality and dilutes the recognition of deserving contributors [1, 3, 26]. The expectation of too many published articles from too many people influences investigators' behavior and promotes superficial studies with rapid results rather than long-term scientific investigations [2, 3, 20, 23]. Multiple authorship increases the opportunity for shortcuts and plagiarism because the responsibilities of authorship are diffused, and it promotes careless reporting and deception in data analysis and presentation [12, 30], lowering the credibility of the study [11]. Pressure to publish has also contributed to fraud in the scientific literature [24, 31] and in radiology research [32, 33].

Authors' Responsibilities

An author is someone who writes [26], but authorship requires more than preparing the manuscript. Authorship in its simplest definition requires both participation in and understanding of the research [34]. Guidelines offered in the 1950s were simple: "If a person has rendered service of major importance, his name should be included with those of the authors of the paper" [35]. The level of participation that merits authorship in the current academic environment must be carefully considered. Authorship implies an intellectual contribution, thorough knowledge of the investigation, and meaningful participation in the creative process of producing a paper [1, 3, 6, 8, 16, 19].

More important than providing credit, authorship denotes public responsibility for the work and an ability to defend the contents [1, 3, 7, 8, 10, 12, 16, 17, 27]. This responsibility makes individuals accepting gratuitous authorship susceptible to charges of fraud if the material is found to be fabricated, exaggerated, or plagiarized [1, 19, 27]. Authorship therefore cannot be conferred but must be earned because it implies the capacity to participate in a discussion or defense of the methods, data, and conclusions [16, 19, 27, 36]. Increasing authorship dilutes this responsibility [7], and one major concern is the decreasing likelihood that all authors can actually take public responsibility for the work, leading to an associated loss of accountability [11]. Coauthorship, like sole authorship, should imply responsibility for a paper and not simply endorsement of portions of it, and all authors should bear equal responsibility [13]. Coauthors who are unable because of limited expertise to accept full responsibility for the contents of the manuscript should indicate those limitations in a footnote or should be listed in the acknowledgments. Each portion of an article must be attributable to at least one author, and all coauthors must be willing to accept responsibility within their area of expertise [16, 17, 27]. All coauthors should be involved in the writing and final review of the manuscript to verify the accuracy of the methods, results, and conclusions [10, 16, 27, 32].

Many believe that individuals providing only research space, equipment or technology, funding, administrative support, clinical cases, or suggestions or who serve only as ad hoc consultants should not be included as coauthors despite their importance to the work [1, 16, 17, 36]. Supervision of the research group alone is not sufficient for

authorship [26]. Individuals who conceive but do not further participate in a project or who contribute only to the revision of a manuscript are not deserving of authorship [16]. Although data collection is essential to any project, routine interpretation of studies or participation as an assignment of employment does not justify authorship [8, 10, 17, 27]. Some have suggested, however, that authorship may be justified in studies in which data collection is the most time-consuming and difficult aspect of the research if it involves an intellectual contribution or to encourage responsible, quality work [3, 8]. Recruiting readers for a study may be difficult if authorship is not offered as a payback for their time-consuming jobs. Some have even alluded to the legitimacy of including individuals responsible for funding or laboratory space as coauthors [6]. The acknowledgments paragraph is the appropriate place to denote appreciation for editorial review, medical writers, scientific counseling, technical help, and the assistance of individuals who do not contribute sufficiently to the intellectual content of the paper to justify authorship [7, 8, 13, 16, 17, 37].

Solutions

Perhaps the standards of appropriate authorship have not been clearly enough stated by scientific organizations [15]. Editors have jointly developed specific guidelines for authorship in an attempt to eliminate honorary, frivolous, and irresponsible authorship and in response to research fraud in which coauthors were too remote from the work to exercise the responsibility authorship demands [7, 9]. The International Committee of Medical Journal Editors, in which both the *AJR* and *Radiology* participate, has issued guidelines on authorship since 1985 [17, 37]. The current recommendations (1993) suggest that each author must have made a sufficient contribution to take public responsibility for the content and must have made substantial contributions to conception and design or analysis and interpretation of the data, to drafting the article or revising it critically for important intellectual content, and to final approval of the version to be published [17]. The Association of University Radiologists Ad Hoc Committee on Standards for the Responsible Conduct of Research (1993) suggests that authorship requires a substantial contribution to two of the following: research conception and design, data collection, data analysis, drafting the manuscript, and manuscript revision;

and that all coauthors must approve the final manuscript [16]. The *AJR* requires signature of all authors on a form stating they "have made substantive and specific intellectual contributions to [the] article and assume full responsibility for its content." If these guidelines were followed, most manuscripts would include only two or three authors [8].

Part of the problem is that the only choice for crediting an individual is granting authorship or acknowledgment, when credit is often obscured in small type or buried at the end of a paper [14]. Some have suggested that the specific contribution of each coauthor be clearly stated in a footnote, or that the principal authors who drafted the manuscript be followed on the masthead by individuals collaborating or assisting with the study with a clear definition of their contributions [1, 14, 15, 34]. In this way, those not deserving of true authorship, such as clinical investigators, statistical consultants, and technical editors, could be listed on the masthead, but their limited contribution would be explicitly stated [34]. Rules could be devised to determine appropriate categories for each discipline. Although this system would be complex, it would be more accurate and truthful than the current system and might discourage inclusion of undeserved coauthors [1, 34].

Editors are sensitive to the needs of readers and authors and could define guidelines for authorship, limit the number of coauthors, and request documentation of authors' contributions to justify the assignment of authorship [1, 7, 10, 14, 17, 26, 37]. In fact, some journals have introduced restrictions on the number of authors to be listed on the byline [7, 9]. Unfortunately, absolute guidelines are difficult to develop, and editors alone cannot enforce policies or curtail inappropriate authorship [8, 21, 31]. Promotion committees and granting agencies and departments should develop realistic productivity standards that emphasize quality, not quantity, and enforce guidelines for appropriate authorship to deter the pressures to publish and to slow down this "publishing mania" [1, 19, 21, 32].

Some have suggested that a ceiling should be set on the number of published articles considered when applying for funding or promotion [23]. Authors would submit only their most important work, perhaps three in a given year or a total of 10, and long bibliographies would no longer be valuable. Such a policy might encourage more substantive quality research [3]. Perhaps the greatest success in

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reducing irresponsible authorship will come from rigorous self-restraint by researchers rather than by bureaucratic sanctions [13].

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