Characteristics and Trends of Radiology Research: A Survey of Original Articles Published in *AJR* and *Radiology* between 2001 and 2010[1]

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Purpose: To determine the characteristics and trends of the original articles published in two major American radiology journals, *AJR American Journal of Roentgenology* (*AJR*) and *Radiology*, between 2001 and 2010.

Materials and Methods: This was a retrospective bibliometric analysis that did not involve human subjects and was exempt from institutional review board approval. All 6542 original articles published in *AJR* and *Radiology* between 2001 and 2010 were evaluated. The following information was abstracted from each article: radiologic subspecialty, radiologic technique used, type of research, sample size, study design, statistical analysis, study outcome, declared funding, number of authors, affiliation of the first author, and country of the first author. In addition, all the variables examined were presented along with the trend over time.

Results: The most common subspecialty of study was abdominal (1219 of 6542, 18.6%), followed by vascular/interventional (804 of 6542, 12.3%). A total of 3744 (57.2%) original articles used magnetic resonance (MR) imaging or computed tomography (CT), 5495 (84.1%) were clinical research articles, 3060 (46.8%) had sample size of more than 50, 4087 (62.5%) were retrospective, 4714 (72.1%) performed statistical analysis, 6225 (95.2%) showed positive study outcome, 4784 (73.1%) were not funded, 3942 (60.3%) had four to seven authors, and 5731 (87.6%) were written by the primary author who was from a department of radiology or radiology-related specialties. The United States published 45.5% (2975 of 6542) of the articles, followed by Japan ($n = 525$, 8.0%), Germany ($n = 485$, 7.4%), and South Korea ($n = 455$, 7.0%). In the time trend analysis, the following variables showed a significantly positive trend: cardiac subspecialty, CT and MR imaging as the radiologic techniques, type of research as other (nonbasic, nonclinical), sample size of more than 50, four to seven as the number of authors, medicine-related department of the first author, and South Korea and Italy as countries of the first author. On the other hand, pediatric subspecialty, combined (basic and clinical) type of research, and number of authors fewer than four showed a significantly negative trend.

Conclusion: The bibliometric analysis of the *AJR* and *Radiology* journals with articles published between 2001 and 2010 revealed characteristics and trends of the current radiology research that may provide useful information to researchers and editorial staff in radiology.

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Bibliometry is a quantitative technique of evaluation of scientific articles published in a defined cohort of journals over a given period of time (1,2). One can understand the characteristics and developmental trends in scientific publications within a specific field through bibliometric analysis (2,3). Although several bibliometric studies in the field of radiology have been performed from the early 1990s to the mid-2000s (4–10), little is known about the recent trends in the general radiology literature.

The purpose of our study was to determine the characteristics and trends of the original articles published in two major American radiology journals, *AJR American Journal of Roentgenology* (*AJR*) and *Radiology*, between 2001 and 2010.

Materials and Methods

Our study was a retrospective bibliometric analysis that did not involve human subjects and was exempt from the need for institutional review board approval.

Article Review and Analysis

The *AJR* and *Radiology* journals were reviewed to obtain information about the characteristics of the articles published between 2001 and 2010. Only original articles based on the contents of the online journals, which were identical to those in the printed version of *Radiology* and contained both print and online-only articles for the *AJR*, were included in the analysis. Original articles were considered reports that investigated clearly stated objectives or hypotheses and contained specifically articulated methods and results sections. Other forms of publication (case report, review article, pictorial assay, clinical perspective, state of the art, editorial, letter, technical note, quiz, educational material, book review, commentary, and news) were excluded from the analysis. Our analysis included all original articles registered in online archives (both print and online-only articles).

For the purposes of analysis, the following information was abstracted from each article: *(a)* radiologic subspecialty (abdominal, breast, cardiac, chest, genitourinary [including the retroperitoneum and obstetrics], musculoskeletal [including the spine], neuroradiology/head and neck, pediatric, vascular/interventional, or miscellaneous [not conforming to one of the above categories, including whole-body imaging, nuclear medicine, physics, basic science, radiation oncology, contrast media, and radiation protection]); *(b)* radiologic technique used (conventional radiography, ultrasonography (US), computed tomography [CT], magnetic resonance [MR] imaging, angiography, mammography, interventional radiology, nuclear medicine, mixed [more than one radiologic technique used], or other [not conforming to one of the above categories]); *(c)* type of research (basic, clinical, both, or other [public health, social questionnaire, financial investigation, computer programming, or physics]); *(d)* sample size (none, ≤20, 21–50, or >50); *(e)* study design (prospective [including experimental studies] or retrospective [including no available information]); *(f)* statistical analysis (present [authors stated the method of statistical analysis used or reported *P* values] or absent); *(g)* study outcome (positive [the studied variables produced beneficial or significant results] or negative); *(h)* declared funding (government, private, or none); *(i)* number of authors (fewer than four, four to seven, or more than seven); *(j)* affiliation of the first author (radiology [including radiology, nuclear medicine, and other imaging-related specialties], medicine or related specialties [including internal medicine, pediatrics, psychiatry, neurology, dermatology, etc], surgery or related specialties [including surgery, obstetrics and gynecology, orthopedics, anesthesiology, pathology, etc], or other [including basic science, epidemiology, laboratory, research, etc]); and *(k)* country of the first author (for the purpose of our research, the country of the first author was considered as the country of the origin of the article).

Nine study investigators, including four trainees working in the department of radiology (Y.J.K., A.H., S.J.Y., and D.H.G., with 1, 2, 3, and 4 years of residency, respectively) and five radiologists (S.B., K.J.L., Y.L.S., E.J.Y., and D.Y.Y., with 2, 5, 9, 12 and 17 years of experience respectively), initially reviewed the same 200 articles independently to ensure consistency of data abstraction. Any disagreements were resolved in a consensus meeting. No formal interobserver reliability testing was conducted between the investigators for the first 200 articles; however, disagreements were rare. After initial pilot abstraction, the total number of articles was divided randomly into nine samples and manually reviewed by the

Advance in Knowledge

- Analysis of 6542 original articles published in *AJR American Journal of Roentgenology (AJR)* and *Radiology* between 2001 and 2010 showed that *(a)* CT or MR imaging was used in 57.2% of the original articles that account for a growing proportion of radiology research; *(b)* only 26.9% of articles were funded, a proportion that is remarkably low in comparison with other specialties; and *(c)* the proportion of U.S. contributions to *AJR* and *Radiology* continues to contract and is currently less than half (45.5%) of all articles.

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Potential conflicts of interest are listed at the end of this article.

Table 1

Radiology Subspecialty in the Original Articles Published in *AJR* and *Radiology* between 2001 and 2010

Radiologic Subspecialty	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total*
Abdominal	110	103	132	151	111	143	110	139	115	105	1219 (18.6)
Breast	47	53	53	38	53	73	45	68	64	52	546 (8.3)
Cardiac†	17	19	40	35	61	39	46	87	47	53	444 (6.8)
Chest	41	57	64	67	70	59	46	87	47	53	556 (8.5)
Genitourinary	45	48	47	62	42	50	46	78	60	63	541 (8.3)
Musculoskeletal	51	59	66	90	69	80	51	75	77	63	681 (10.4)
Neuroradiology/head and neck	63	56	63	57	62	54	47	75	80	82	639 (9.8)
Pediatric‡	48	47	36	37	30	18	27	22	28	35	328 (5.0)
Vascular/interventional	83	85	71	82	120	73	54	87	67	72	804 (12.3)
Miscellaneous	79	83	67	30	80	50	116	62	83	134	784 (12.0)
Total	584	610	639	659	698	639	588	753	662	710	6542 (100)

* Data in parentheses are percentages.

† Significant increase during the study period.

‡ Significant decrease during the study period.

above-mentioned investigators. Questionable cases were decided by all of the study investigators in consensus.

Statistical Analyses

For the trend analyses, ordinary linear regression was used for each variable. Statistical analyses were performed by using software (Stata/SE 11.0; Stata, College Station, Tex), and a P value of .05 was considered to indicate a statistically significant difference.

Results

The *AJR* and *Radiology* journals published 2971 and 3571 original articles, respectively, in 120 issues of each journal between January 2001 and December 2010. The average number of original articles per issue was 27.3 during these 10 years (Table 1).

The abdominal field was found to be the most productive field, accounting for 18.6% (1219 of 6542) of publications, followed by vascular/interventional field (n = 804, 12.3%). On the contrary, pediatric (n = 328, 5.0%) and cardiac (n = 444, 6.8%) fields had the lowest number of articles. In the time trend analysis, cardiac subspecialty demonstrated a significant increase (P = .026), while pediatric subspecialty demonstrated a significant decrease (P = .032) (Table 1).

MR imaging and CT were the most frequently used modalities (30.0% [n = 1963] and 27.2% [n = 1781] of studies, respectively). The number of investigations using MR imaging and CT increased from 260 (44.5%) articles in 2001 to 442 (62.3%) in 2010, which is a significant increase (P = .004 for CT and P = .008 for MR imaging) (Table 2).

Other variables, including type of research, sample size, study design, statistical analysis, study outcome, declared funding, number of authors, and affiliation of the first author, are summarized in Table 3. Variables that demonstrated a significant increase during the time studied were other (nonbasic, nonclinical) type of research (P = .039), sample size of more than 50 (P = .009), four to seven authors (P = .028), and articles in which the first author was from a medicine-related department (P = .034). On the other hand, variables that demonstrated a significant decrease over the time studied were combined (basic and clinical) type of research (P = .038) and number of authors fewer than four (P = .001) (Table 3).

The countries of the first authors are presented in Table 4. The United States was the leader with the most publications (n = 2975, 45.5%), followed by Japan (n = 525, 8.0%), Germany (n = 485, 7.4%), and South Korea (n = 455, 7.0%). South Korea (P < .001) and Italy (P = .008) showed significant increases during the past decade in terms of the proportion of articles contributed to the journals, while Austria (P = .021) showed a significant decline (Table 4).

Discussion

The scientific literature represents the accumulated experience, recent advance in knowledge, and new information, usually in the form of original scientific articles. Findings of some previous bibliometric studies, closely related to the aim of our report, have been published describing the publication trends in radiologic research. Increased volume of material (11), increased publication from authors outside the United States in the American radiology journals (7–9), increased publication from authors in nonradiologic specialties (7), and increased funded research (7) have been noted in prior bibliometric studies of the radiology literature.

In our survey, bibliometric analysis was based on two major American radiology research journals, the *AJR* and *Radiology*. They were selected as very valuable radiology journals because of their high impact factors, general radiologic focus, and sponsorship by two

Table 2

Radiologic Modality Used in the Original Articles Published in *AJR* and *Radiology* between 2001 and 2010

Radiologic Modality	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total*
Conventional radiography	20	14	12	22	14	12	3	16	10	15	138 (2.1)
US	59	55	52	45	52	46	26	51	46	42	474 (7.2)
CT†	115	121	161	178	184	188	175	257	182	220	1781 (27.2)
MR imaging†	145	163	200	189	214	207	173	227	223	222	1963 (30.0)
Angiography	4	2	16	10	3	7	2	2	3	2	51 (0.8)
Mammography	19	21	20	12	18	25	23	24	27	16	205 (3.1)
Interventional radiology	62	58	88	78	83	60	36	68	51	74	658 (10.1)
Nuclear medicine	17	10	17	16	13	16	15	37	14	23	178 (2.7)
Mixed	96	103	41	72	54	56	81	43	65	55	666 (10.2)
Other	47	63	32	37	63	22	54	28	41	41	428 (6.5)
Total	584	610	639	659	698	639	588	753	662	710	6542 (100)

* Data in parentheses are percentages.

† Significant increase during the study period.

of the major North American radiology societies. Different results would have been obtained if all radiology journals had been examined.

Findings of our data coupled with the previously reported data sets show that the trend toward more international authors in both the *AJR* and *Radiology* journals continues. Steady increases in international contributions have been noted for both journals in recent decades (8,9). A study by Chen et al (9) found that 10% of original articles published in 1980–1982 in the *AJR* originated in countries other than the United States. The same report also showed this ratio increased to 25% in 1990–1992 and to 37% in 2000–2002. Our study findings show that the percentage of articles from international authors published in the two journals was more than half (all articles, 54.5% [3567 of 6542]; *AJR,* 53.1% [1577 of 2971]; and *Radiology,* 55.7% [1990 of 3571]) of all the articles published in 2001–2010. Although our data were collected from only two major radiology journals, similar patterns for U.S. publications have been noted in the scientific literature (12,13). Rahman et al (6) noted that the U.S. share of global radiology literature declined from 51.1% in 1991% to 37.7% in 2000. Within interventional radiology, the U.S. share declined from 69.4% in 1993% to 44.6% in 2003 (7).

There is no doubt that the United States leads the world in the number of medical research publications. However, its share of research articles in the field of radiology, as well as in other fields of medicine (13–15), has declined during the 1990s and 2000s (6–9). There are several possible reasons for this decline. One possibility is the changing research environment for academic radiologists in the United States, who have more clinical responsibilities, with consequent diminution of time, energies, and resources for research (16,17). Several studies (18,19) have demonstrated that increased clinical workload is associated with decreased research productivity of radiologists. Another factor may be the increasing challenge of obtaining research funding in the United States. Fang et al (20) documented the lack of academic support granted to American investigators, particularly compared with that of prior time periods. A study performed in the field of radiology (21), however, revealed that the total number of published U.S. radiology articles had been stable during 1996–2005, while National Institutes of Health funding had increased steadily in the same period. Finally, increased research activity of investigators outside the United States accounts in part for the increase noted in non–North American authors. Previous studies have noted a rapidly increasing number of publications by authors residing outside the United States, particularly Europe and parts of Asia (5,9,22). A recent study by Chow et al (22), which examined interventional oncology publications between 1996 and 2008, found exponential publication growth in Europe and Asia in the face of slowing rates of the U.S. publication.

The results of our study also showed that most radiology research published in *AJR* and *Radiology* from 2001 to 2010 was not funded. In our study, only 26.9% (1758 of 6542) of the surveyed investigations were funded, a proportion that is remarkably low in comparison with other specialties. One study documented that 77% of the original articles published in the major medical and neurologic journals in 1991 were funded (23). However, the proportion in our study is slightly higher than that previously reported in radiology. Mussurakis et al (10) reported that only 17% of original investigations published in *AJR* and *Radiology* in 1990 received funding. Recently, Ray et al (7) reported that 23.0% of interventional radiologic research in the major American radiology journals received funding during 2002–2003.

An interesting finding noted in our study was the evolution of the departmental affiliation of primary authors. Although radiologists still have the most

Table 3

Features of the Original Articles Published in *AJR* and *Radiology* between 2001 and 2010

Feature	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total*
Type of research											
Basic	65	59	88	53	87	56	78	97	57	80	720 (11.0)
Clinical	486	517	521	573	584	560	468	638	570	578	5495 (84.0)
Both†	16	26	11	23	8	2	15	10	4	5	120 (1.8)
Other‡	17	8	19	10	19	21	27	8	31	47	207 (3.2)
Sample size											
None	42	58	34	14	22	41	64	55	35	65	430 (6.6)
<20	89	107	115	148	162	91	82	107	90	101	1092 (16.7)
21–50	176	188	195	193	225	196	173	229	184	201	1960 (30.0)
>50‡	277	257	295	304	289	311	269	362	353	343	3060 (46.8)
Study design											
Prospective	180	304	245	152	338	328	244	247	230	187	2455 (37.5)
Retrospective	404	306	394	507	360	311	344	506	432	523	4087 (62.5)
Statistical analysis											
Present	384	473	436	430	501	388	463	645	535	459	4714 (72.1)
Absent	200	137	203	229	197	251	125	108	127	251	1828 (27.9)
Study outcome											
Positive	565	592	599	636	643	611	567	713	614	685	6225 (95.2)
Negative	19	18	40	23	55	28	21	40	48	25	317 (4.8)
Declared funding											
Government	79	70	45	57	117	33	98	141	78	111	829 (12.7)
Private	86	102	91	77	82	70	99	116	75	131	929 (14.2)
None	419	438	503	525	499	536	391	496	509	468	4784 (73.1)
No. of authors											
<4†	84	78	64	69	67	66	49	65	47	49	638 (9.8)
4–7‡	334	372	392	387	394	341	371	478	444	429	3942 (60.3)
>7	166	160	183	203	237	232	168	210	171	232	1962 (30.0)
Department of first author											
Radiology or related specialties	527	541	559	596	610	557	518	675	547	601	5731 (87.6)
Medicine or related specialties‡	36	35	25	27	29	22	45	46	48	53	366 (5.6)
Surgery or related specialties	10	7	11	17	19	16	10	12	13	14	129 (2.0)
Other	11	27	44	19	40	44	15	20	54	42	316 (4.8)
Total	584	610	639	659	698	639	588	753	662	710	6542 (100)

* Data in parentheses are percentages.

† Significant decrease during the study period.

‡ Siignificant increase during the study period.

prominent role in radiology research, we found 12.4% (811 of 6542) of articles with a nonradiologist as the first author, particularly in *Radiology* (541 of 3571, 15.4%). In a similar study, Ray et al (7) reported that 19.5% of articles in the American interventional radiology literature were primarily authored by nonradiologists during 2002–2003. One contributing factor to this finding must be the growth in multidisciplinary collaborative studies among radiologists and clinicians from other medical specialties in which the first author was not a radiologist. Additionally, many nonradiologists who are performing radiologic or radiology-related research may be choosing to submit their publications to radiology journals.

In our series, most (all, 60.3% [3942 of 6542]; *AJR,* 67.5% [2005 of 2971]; and *Radiology,* 54.2% [1937 of 3571]) articles had four to seven authors. The number of authors per article in the *AJR* is not a significant criterion for evaluating the publication trends, because the *AJR* imposes a limit on the number of authors, up to seven. A clear trend toward articles with more authors has been previously reported. Analysis of the citations received by *AJR* and *Radiology* showed that 34.0% of the articles had four or more authors in 1975, and 61.0% had four

Table 4

Country of the First Author in the Original Articles Published in *AJR* and *Radiology* between 2001 and 2010

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total*
United States	320	301	290	306	281	264	271	352	283	307	2975 (45.5)
Japan	50	50	65	55	57	62	34	52	53	47	525 (8.0)
Germany	33	53	47	44	73	61	40	45	40	49	485 (7.4)
South Korea†	23	30	29	38	46	40	39	63	63	84	455 (7.0)
The Netherlands	10	21	19	29	39	20	32	35	29	29	261 (4.0)
France	18	23	21	24	21	19	14	20	21	27	208 (3.2)
Switzerland	13	20	21	19	31	22	19	28	16	18	207 (3.2)
United Kingdom	17	14	22	15	16	35	27	19	17	16	198 (3.0)
Italy†	12	11	14	25	19	15	18	21	32	27	194 (3.0)
Canada	19	12	8	14	17	27	13	23	18	33	184 (2.8)
Austria‡	14	22	29	16	17	19	13	11	8	7	156 (2.4)
China	7	5	19	21	17	8	9	14	21	26	147 (2.2)
Belgium	11	9	14	6	18	12	8	9	8	6	101 (1.5)
Spain	7	5	4	10	7	4	5	8	8	2	60 (0.9)
Taiwan	7	4	7	1	8	1	4	12	8	4	56 (0.9)
Israel	2	3	5	5	5	7	6	7	4	6	50 (0.8)
Turkey	0	3	4	7	2	5	9	6	4	5	45 (0.7)
Australia	5	3	5	6	3	2	5	0	1	1	31 (0.5)
Finland	4	2	3	3	2	1	2	4	4	2	27 (0.4)
Brazil	0	1	2	3	6	5	2	4	4	0	27 (0.4)
Other	12	18	11	14	13	10	18	20	20	14	150 (2.3)
Total	584	610	639	659	698	639	588	753	662	710	6542 (100)

Note.—Ranking is based on the total number of original articles published between 2001 and 2010. Statistical analysis was performed only in countries in which more than 100 articles were published during a 10-year period.

* Data in parentheses are percentages.

† Significant increase during the study period.

‡ Significant decrease during the study period.

or more authors in 1985 (11). Our data showed that proportion of articles with four or more authors during 2001–2010 was 90.3%. Several reasons exist for the growing numbers of authors on scientific articles, including the increased complexity of medical research and implementation of a collaborative multidisciplinary team approach. An additional contributing factor to increasing authorship is apparently the result of abuse, that is, inclusion of honorary authors who have not met authorship criteria. Recently, a study of articles published in *Radiology* and *European Radiology* (24) reported the prevalence of honorary authorship of 26.0%.

Our study had a number of limitations. First, as mentioned earlier, only two major radiology journals were eval uated. One might appropriately question the generalizability of the findings, because the sample of the journals studied represents only a fraction of the total world literature in radiology. Second, a somewhat subjective characterization of articles may be present in the results, although almost all the variables examined are based on directly available journal content and any questionable cases were decided by consensus of all study investigators. Third, use of the affiliation of the first author to assign a country of origin is another consideration. Previous studies have shown that the first author makes the most meaningful contribution and is the most deserving of the credit (25,26). In some studies that were conducted as joint collaborations of mixed teams of international researchers, only the country of the first author was included as the origin of research, thus potentially undercounting the contribution of other authors from different countries.

In conclusion, our bibliometric analysis of *AJR* and *Radiology* journals during 2001–2010 revealed characteristics and trends of the current radiology research that may provide useful information to researchers and editorial staff in radiology.

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