

# The Scientific Literature in Diagnostic Radiology for American Readers: A Survey and Analysis of Journals, Papers, and Authors

Felix S. Chew<sup>1</sup>

The scientific literature in diagnostic radiology for American readers was surveyed by studying the recent growth of its journals, papers and authors. The number of journals has increased rapidly, following the growth in the production of papers. Of the 36 scientific diagnostic radiology journals available at a university medical center, 18 began publication in 1973 or later. The proliferation of new journals should moderate as the size of the American diagnostic radiology research community stabilizes and the newer journals publish a growing share of the papers. Citation analysis, a method of studying interrelationships between papers and journals, showed that citations from papers published in clinical journals to papers published in diagnostic radiology journals accounted for 6% of total citations made in those clinical journals. This observation indicates that research in diagnostic radiology has considerable relevance to research in clinical medicine. Although the number of papers from American diagnostic radiology researchers increased from 468 papers in two journals in 1960 to 2861 papers in 16 journals in 1984, the number of researchers increased more rapidly, resulting in a decline in aggregate productivity. At the same time, the average number of authors per paper increased from 2.15 in 1960 to 4.36 in 1985. The first authorship of a scientific paper appears to be the most suitable quantitative measure of research productivity. Study of a sample of 130 diagnostic radiology researchers showed that, on average, each researcher published 3.8 papers as first author in the 5 years from 1980 to 1984. The most prolific 15% of the authors published 52% of the papers.

As diagnostic radiology has grown and evolved, so has its scientific literature. Rapid advances made possible by technological progress and a more sophisticated understanding of the human organism have generated an abundance of new information. This study examines the literature that conveys this information. The proliferation of new journals is studied first, and then the interrelationships between the literatures of diagnostic radiology and the clinical specialties are considered. The productivity and size of the American diagnostic radiology research community over 25 years are described. The trend towards multiple-author of papers is quantified and examined. A profile of contributors to diagnostic radiology journals and the distribution of their individual prolificacy is developed.

## Materials and Methods

### *Journals*

The number of diagnostic radiology journals readily available in the libraries of the State University of New York (SUNY) Health Science Center at Syracuse with format, content, and editorial policy appropriate for scientific papers was determined. The rate of proliferation of these journals was derived from their publication history. The criterion for ready availability was the ability to find actual issues of the journals. Selection factors for acquisition of particular journals were not examined; in general, the library system sought the largest collection of the most useful journals possible within its financial limitations.

The relationships between the scientific literature of diagnostic radiology and the biomedical

Received February 24, 1986; accepted after revision June 9, 1986.

<sup>1</sup> Department of Radiology, Health Science Center at Syracuse, State University of New York, 750 E. Adams St., Syracuse, NY 13210. Address reprint requests to F. S. Chew.

*AJR* 147:1055-1061, November 1986  
0361-803X/86/1475-1055

© American Roentgen Ray Society

literature as a whole were studied by means of citation analysis [1]. Attention was focused on the use of nonradiologic research and knowledge in diagnostic radiology research and on the use of radiologic research and knowledge in nonradiologic research. A citation is the event that occurs when one paper (the cited paper) is used as a reference by another paper (the citing paper). A citation indicates that the cited paper, in at least one instance of the citing paper, has relevance to research subsequent to its publication, and implies a close link between the subjects of the two papers. If all of the citations made and received by all of the papers published in a particular journal are examined as a group, then the relationship of that journal to other journals can be described in terms of how frequently the other journals cite and are cited by the studied journal [1]. The *Journal Citation Reports (JCR)* of the *Science Citation Index (SCI)* [2] list data from which these relationships can be derived. Only those journals that were mentioned in the 1984 volumes of the *JCR* were included in the present study. Many journals, including most foreign ones, were excluded because data on their citations were unavailable. By using the method of Garfield [3], a core group of 10 diagnostic radiology journals was identified on the basis of the greatest number of citations received in 1984. The names of the 50 journals that cited these core journals most frequently and the names of the 50 journals that were cited by these core journals most frequently were obtained from data in the 1984 *JCR*.

#### Papers

Growth in the number of papers written by the American diagnostic radiology research community as a whole was studied in relation to the size of the research community during the 25 years from 1960 to 1984. The number of papers written by the American group was estimated by counting the number of papers published in journals that accepted predominantly original research contributions from American academic departments of radiology. These journals were *American Journal of Roentgenology (AJR)*, *Radiology*, *Journal of Nuclear Medicine*, *Investigative Radiology*, *Pediatric Radiology*, *Journal of Clinical Ultrasound (JCU)*, *Journal of Computer Assisted Tomography*, *Clinical Nuclear Medicine*, *Gastrointestinal Radiology*, *Skeletal Radiology*, *Journal of Computed Tomography*, *Cardiovascular and Interventional Radiology*, *Urologic Radiology*, *Journal of Ultrasound in Medicine*, and *American Journal of Neuroradiology (AJNR)*. Data were collected only about the number of papers, not about their length, quality, or subject material. Because none of these journals restricted itself to American contributions, this approach overestimated the number of papers from American researchers by counting papers from foreign radiologists as well as those from radiation oncologists and clinicians. The number of papers was underestimated by not counting papers published in other serials such as clinical journals or official journals of foreign radiologic societies. The number of full-time academic faculty in diagnostic radiology as reported by the American Medical Association in the annual medical education issues of *JAMA* was used as the number of American researchers in diagnostic radiology. The number of researchers in diagnostic radiology was overestimated by including academic radiation oncologists and underestimated by not counting researchers who were not full-time academic radiologists.

The growth of two diagnostic radiology journals, *AJR* and *Radiology*, was followed for the years 1950 to 1985. At 5-year intervals, the papers and authors in the July, August, and September issues were counted and multiplied by 4. The distribution of papers with more than one author was observed. No attempt was made to describe the time required for publication, the subject material, or the length or quality of the papers.

#### Authors

A sample of researchers in diagnostic radiology during a 5-year period was studied to observe the literary prolificacy of researchers individually. An arbitrary sample was obtained from the July 1982 issue of *AJR*, a large and eminent journal devoted exclusively to diagnostic radiology. Obtaining the sample in this way virtually excluded researchers in radiation oncology, physics, instrumentation, and related disciplines. The 130 authors of papers listed in the table of contents made up the sample; the authorship or coauthorship of a research paper in diagnostic radiology was considered strong presumptive evidence of significant research activity in that field. There were 34 first authors and 96 coauthors. Affiliation with a department of radiology or nuclear medicine was indicated by 106 of the researchers. Of the remaining 24 researchers, 13 were in surgery or related specialties, five were in medicine or related specialties, five were in pathology, and one was in basic science. By the end of the 5-year period being studied, 89 researchers were certified by the American Board of Radiology: three were certified in 1959 or earlier, 17 in 1960–1969, 18 in 1970–1974, 31 in 1975–1979, and 20 in 1980–1984 [4]. Those who were certified in 1980–1984 were presumed to be in training for a portion of the years studied. No attempt was made to establish whether each researcher was actively engaged in research for all of the 5 years studied.

For each researcher in the study sample, the number of papers published as first author in a journal of diagnostic radiology listed in the *Cumulated Index Medicus* [5] was counted for each year from 1980 to 1984. Papers coauthored by the researcher or published in other journals were not counted. A 5-year prolificacy profile was constructed by calculating the total number of publications for each researcher for the 5 years studied. The prolificacy of researchers in relation to the year of board certification was also studied.

#### Results

##### Journals

There were 36 scientific diagnostic radiology journals readily available in the libraries of SUNY Health Science Center at Syracuse in 1985. As shown in Table 1, nine journals began publication in the 62 years from 1896 through 1957. The number of journals in publication doubled to 18 only 14 years later in 1971 and doubled again to 36 only 13 years after that. Nearly all of these journals were published in North America and Europe, and in the English language.

##### Citation Analysis

Ten core journals of diagnostic radiology were identified as those that received the most citations in 1984 (Table 2). Six journals were general in scope; four were subspecialized: two in neuroradiology, one in nuclear medicine, and one in CT. As a group, they published 2641 papers in 1984 and made 42,029 citations, for an average of about 16 references per published paper. They were cited 48,385 times in 1984, which was 85% of the times the 35 diagnostic radiology journals covered in the 1984 *SCI* were cited. Other diagnostic radiology journals evidently received too few citations to reach the threshold for *SCI* coverage. Included among the 10 core journals were those with the longest publication histories, the greatest number of papers published per year, and the largest circulations.

TABLE 1: Scientific Journals of Diagnostic Radiology Available at a University Medical Center

| Year of First Publication | Journal Title (Place of Publication)   |
|---------------------------|--|
| 1896                      | <i>British Journal of Radiology</i> (London)   |
| 1897                      | <i>RöFO: Fortschritte auf dem Gebiete der Röntgenstrahlen und der Nuklearmedizin</i> (Stuttgart) |
| 1906                      | <i>AJR. American Journal of Roentgenology</i> (Baltimore)  |
| 1915                      | <i>Radiology</i> (Easton, PA)  |
| 1921                      | <i>Acta Radiologica: Diagnosis</i> (Stockholm)   |
| 1933                      | <i>Diagnostic Imaging in Clinical Medicine</i> (Basel)   |
| 1949                      | <i>Clinical Radiology</i> (Edinburgh)  |
| 1957                      | <i>Australasian Radiology</i> (Sydney)   |
| 1957                      | <i>Journal of Nuclear Medicine and Allied Sciences</i> (Torino)                                  |
| 1958                      | <i>Annales de Radiologie</i> (Paris)   |
| 1959                      | <i>Nuklearmedizin. Nuclear Medicine</i> (Stuttgart)  |
| 1960                      | <i>Journal of Nuclear Medicine</i> (New York)  |
| 1963                      | <i>Radiologic Clinics of North America</i> (Philadelphia)  |
| 1966                      | <i>Investigative Radiology</i> (Philadelphia)  |
| 1966                      | <i>Seminars in Roentgenology</i> (New York)  |
| 1970                      | <i>CRC Critical Reviews in Diagnostic Imaging</i> (Boca Raton, FL)                               |
| 1970                      | <i>Neuroradiology</i> (Berlin)   |
| 1971                      | <i>Seminars in Nuclear Medicine</i> (New York)   |
| 1973                      | <i>JCU. Journal of Clinical Ultrasound</i> (Denver)  |
| 1973                      | <i>Journal of the Canadian Association of Radiologists</i> (Montreal)                            |
| 1973                      | <i>Pediatric Radiology</i> (Berlin)  |
| 1976                      | <i>Clinical Nuclear Medicine</i> (Philadelphia)  |
| 1976                      | <i>European Journal of Nuclear Medicine</i> (Heidelberg)   |
| 1976                      | <i>Gastrointestinal Radiology</i> (Berlin)   |
| 1976                      | <i>Skeletal Radiology</i> (Berlin)   |
| 1977                      | <i>Computerized Radiology</i> (Elmsford, NY)   |
| 1977                      | <i>Journal of Computed Tomography</i> (New York)   |
| 1977                      | <i>Journal of Computer Assisted Tomography</i> (New York)  |
| 1978                      | <i>Cardiovascular and Interventional Radiology</i> (Berlin)                                      |
| 1979                      | <i>Urologic Radiology</i> (New York)   |
| 1980                      | <i>AJNR. American Journal of Neuroradiology</i> (Baltimore)                                      |
| 1980                      | <i>Seminars in Ultrasound, CT and MR</i> (New York)  |
| 1981                      | <i>Radiographics</i> (Easton, PA)  |
| 1982                      | <i>Journal of Ultrasound in Medicine</i> (Philadelphia)  |
| 1982                      | <i>Magnetic Resonance Imaging</i> (New York)   |
| 1984                      | <i>Seminars in Interventional Radiology</i> (New York)   |

TABLE 2: 1984 Core Journals of Diagnostic Radiology

| Journal                       | Papers Published in 1984 | Citations in 1984 |      |
|-------------------------------|--------------------------|-------------------|------|
|                               |                          | Received          | Made |
| <i>Radiology</i>              | 647                      | 17,792            | 9769 |
| <i>AJR</i>                    | 499                      | 11,656            | 7527 |
| <i>J Nucl Med</i>             | 193                      | 5756              | 4346 |
| <i>Br J Radiol</i>            | 205                      | 3692              | 2934 |
| <i>J Comput Assist Tomogr</i> | 267                      | 2875              | 3133 |
| <i>Invest Radiol</i>          | 158                      | 1588              | 3127 |
| <i>Clin Radiol</i>            | 102                      | 1370              | 1427 |
| <i>Neuroradiology</i>         | 94                       | 1345              | 1410 |
| <i>AJNR</i>                   | 163                      | 1148              | 2858 |
| <i>RöFO</i>                   | 313                      | 1163              | 5498 |

The 50 journals that cited the core diagnostic radiology journals most frequently in 1984 included the core journals and 18 other diagnostic radiology journals (Table 3). There were seven journals devoted to other aspects of radiology and 15 medical, surgical, or multidisciplinary clinical journals.

These 50 journals cited the core journals 22,327 times, or 46% of all of the citations to the core journals in 1984. Citations to the core journals represented an average of 32% of total citations made in the 28 diagnostic radiology journals. Citations to the core were an average of 9% of total citations made in the journals devoted to other aspects of radiology. Citations to the core were an average of 6% of total citations made in the clinical journals.

The 50 journals cited most frequently in the bibliographies of papers published in the core diagnostic radiology journals in 1984 included the 10 core journals and seven other diagnostic radiology journals (Table 4). There were three journals devoted to other aspects of radiology, 15 medical and multidisciplinary clinical journals, 14 surgery journals, and one general science journal. These 50 journals were cited 24,099 times in the core journals, which made up 51% of all of the citations made by the core journals in 1984. For the 17 diagnostic radiology journals, citations in the core journals represented an average of 29% of their total citations received. For the three other radiology journals, citations in the core journals were an average of 8% of all citations received.

TABLE 3: The 50 Journals That Cited the Core Diagnostic Radiology Journals Most Frequently in 1984

|   |                               |   |                                     |
|---|-------------------------------|---|-------------------------------------|
| 1. <i>Radiology</i>                     | 13. <i>Ann Radiol (Paris)</i> | 25. <i>Med Phys</i>                     | 38. <i>Int J Appl Radiat Isot</i>   |
| 2. <i>AJR</i>                           | 14. <i>Clin Nucl Med</i>      | 26. <i>J Ultrasound Med</i>             | 39. <i>Strahlentherapie</i>         |
| 3. <i>RoFO</i>                          | 15. <i>Neuroradiology</i>     | 27. <i>Surg Clin North Am</i>           | 40. <i>South Med J</i>              |
| 4. <i>Invest Radiol</i>                 | 16. <i>Clin Radiol</i>        | 28. <i>J Urol</i>                       | 41. <i>J Can Assoc Radiol</i>       |
| 5. <i>J Comput Assist Tomogr</i>        | 17. <i>Cancer</i>             | 29. <i>Acta Radiol [Diagn] (Stockh)</i> | 42. <i>Phys Med Biol</i>            |
| 6. <i>J Nucl Med</i>                    | 18. <i>J Comput Tomogr</i>    | 30. <i>Clin Gastroenterol</i>           | 43. <i>Am J Gastroenterol</i>       |
| 7. <i>AJNR</i>                          | 19. <i>J Neurosurg</i>        | 31. <i>Skeletal Radiol</i>              | 44. <i>Mt Sinai J Med (NY)</i>      |
| 8. <i>Radiol Clin North Am</i>          | 20. <i>Radiologe</i>          | 32. <i>Clin Chest Med</i>               | 45. <i>Radiat Res</i>               |
| 9. <i>Br J Radiol</i>                   | 21. <i>Eur J Nucl Med</i>     | 33. <i>Gastrointest Radiol</i>          | 46. <i>Proc Soc Photo Opt Instr</i> |
| 10. <i>Int J Radiat Oncol Biol Phys</i> | 22. <i>JCU</i>                | 34. <i>Nerosurgery</i>                  | 47. <i>Diagn Imaging Clin Med</i>   |
| 11. <i>Semin Nucl Med</i>               | 23. <i>Med Clin North Am</i>  | 35. <i>Am J Cardiol</i>                 | 48. <i>Comput Radiol</i>            |
| 12. <i>CRC Crit Rev Diagn Imging</i>    | 24. <i>Semin Roentgenol</i>   | 36. <i>Pediatr Radiol</i>               | 49. <i>Chest</i>                    |
|   |                               | 37. <i>Surg Neurol</i>                  | 50. <i>Clin Orthop</i>              |

Note.—Given in order of decreasing frequency of citation.

TABLE 4: The 50 Journals That the Core Diagnostic Radiology Journals Cited Most Frequently in 1984

|                                  |                                   |   |                                     |
|----------------------------------|-----------------------------------|---|-------------------------------------|
| 1. <i>Radiology</i>              | 13. <i>Circulation</i>            | 25. <i>Surgery</i>                      | 38. <i>Arch Neurol</i>              |
| 2. <i>AJR</i>                    | 14. <i>J Urol</i>                 | 26. <i>Acta Radiol [Diagn] (Stockh)</i> | 39. <i>Pediatrics</i>               |
| 3. <i>J Nucl Med</i>             | 15. <i>JAMA</i>                   | 27. <i>Am J Cardiol</i>                 | 40. <i>Am J Med</i>                 |
| 4. <i>J Comput Assist Tomogr</i> | 16. <i>Lancet</i>                 | 28. <i>Br Med J [Clin Res]</i>          | 41. <i>Urology</i>                  |
| 5. <i>Br J Radiol</i>            | 17. <i>Arch Surg</i>              | 29. <i>Ann Intern Med</i>               | 42. <i>Am Rev Respir Dis</i>        |
| 6. <i>Cancer</i>                 | 18. <i>Clin Radiol</i>            | 30. <i>Gastrointest Radiol</i>          | 43. <i>Clin Orthop</i>              |
| 7. <i>Invest Radiol</i>          | 19. <i>Am J Surg</i>              | 31. <i>J Pediatr</i>                    | 44. <i>J Thorac Cardiovasc Surg</i> |
| 8. <i>AJNR</i>                   | 20. <i>Ann Surg</i>               | 32. <i>Br J Surg</i>                    | 45. <i>Phys Med Biol</i>            |
| 9. <i>N Engl J Med</i>           | 21. <i>Radiol Clin North Am</i>   | 33. <i>Int J Radiat Oncol Biol Phys</i> | 46. <i>Clin Nucl Med</i>            |
| 10. <i>RoFO</i>                  | 22. <i>Gastroenterology</i>       | 34. <i>Neurology</i>                    | 47. <i>Stroke</i>                   |
| 11. <i>Neuroradiology</i>        | 23. <i>J Bone Joint Surg [Am]</i> | 35. <i>Science</i>                      | 48. <i>Surg Neurol</i>              |
| 12. <i>J Neurosurg</i>           | 24. <i>Surg Gynecol Obstet</i>    | 36. <i>JCU</i>                          | 49. <i>Med Phys</i>                 |
|                                  |                                   | 37. <i>Semin Nucl Med</i>               | 50. <i>Semin Roentgenol</i>         |

Note.—Given in order of decreasing frequency of citation.

For the medical and multidisciplinary clinical journals, citations in the core journals were 1% of all citations received. For the surgery journals, citations in the core journals were 4% of all citations received.

For each individual core diagnostic radiology journal, the single journal that cited it most frequently was itself. The proportion of self-citedness ranged from 6 to 19% of all citations received. The journal most frequently cited by eight of the core journals was *Radiology*; such citations represented 11 to 18% of all citations made. The *British Journal of Radiology* and the *Journal of Nuclear Medicine* cited themselves most frequently and *Radiology* next most frequently.

*Radiology* and *AJR* received 64% and 63%, respectively, of their total citations from diagnostic radiology journals, and made 43% and 45%, respectively, of their total citations to diagnostic radiology journals. Of the total citations received by the *Journal of Nuclear Medicine*, 31% were in clinical nuclear radiology journals and 9% in other diagnostic radiology journals. Of the total citations made by the *Journal of Nuclear Medicine*, 23% were made to clinical nuclear radiology journals and 9% were made to other diagnostic radiology journals. Of the total citations received by *Neuroradiology* and *AJNR*, 43% and 67%, respectively, were from diagnostic radiology journals, and 35% and 13%, respectively, were from clinical neurology, neurosurgery, and psychiatry journals. Of the total citations made by *Neuroradiology* and *AJNR*, 46% and 40%, respectively, were made to diagnostic radiology

journals, and 20% and 21%, respectively, were made to clinical neurology, neurosurgery, and psychiatry journals.

#### Papers

The numbers of papers from the American diagnostic radiology research community increased from 468 papers in two journals in 1960 to 2861 papers in 16 journals in 1984. At the same time, the number of researchers increased from 510 in 1960 [6] to 3457 in 1984 [7]. The increase in papers lagged behind the increase in researchers (Fig. 1), resulting in a decline in the average number of papers per researcher per year (Table 5). Since 1975, the productivity has been returning towards the 1965 level.

The number of papers published yearly in *AJR* and *Radiology* combined increased from 368 in 1950 to 1148 in 1985 at a linear rate. The number of authors of papers increased from 664 in 1950 to 5000 in 1985 at an exponential rate. The ratio of authors to papers, or the mean number of authors per paper, increased from 1.80 in 1950 to 4.36 in 1985 (Table 6). A clear trend towards papers with more than one author was evident in the declining percentage of papers with one or two authors and the rising percentage of papers with five or more authors (Table 7). In 1950, 75% of the papers had one or two authors, and 2% had five or more. In 1985, 19% had one or two authors, and 42% had five or more.

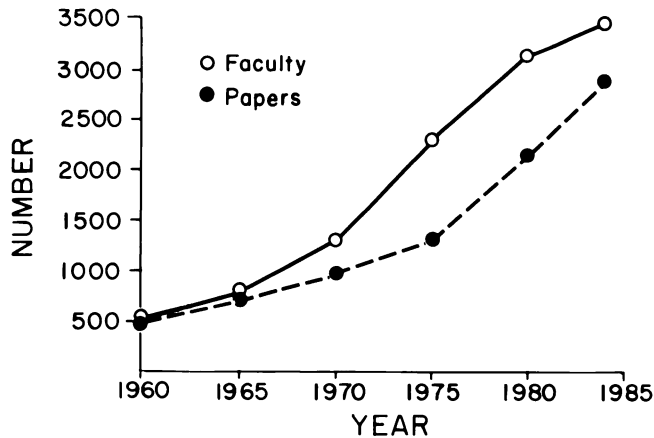


Fig. 1.—Increases in numbers of full-time American diagnostic radiology faculty and papers they publish.

TABLE 5: Estimated Yearly Research Productivity of Full-Time American Academic Diagnostic Radiologists

| Year | Academic Radiologists | Papers | Papers per Radiologist |
|------|-----------------------|--------|------------------------|
| 1960 | 510                   | 468    | 0.92                   |
| 1965 | 764                   | 710    | 0.93                   |
| 1970 | 1288                  | 955    | 0.74                   |
| 1975 | 2275                  | 1294   | 0.57                   |
| 1980 | 3113                  | 2118   | 0.68                   |
| 1984 | 3457                  | 2861   | 0.83                   |

TABLE 6: Growth of *AJR* and Radiology

| Year | Papers | Authors | Authors/Papers |
|------|--------|---------|----------------|
| 1950 | 368    | 654     | 1.80           |
| 1955 | 392    | 788     | 2.01           |
| 1960 | 468    | 1008    | 2.15           |
| 1965 | 632    | 1440    | 2.28           |
| 1970 | 780    | 1944    | 2.49           |
| 1975 | 840    | 2620    | 3.12           |
| 1980 | 1068   | 3768    | 3.53           |
| 1985 | 1148   | 5000    | 4.36           |

Note.—Combined data.

### Authors

Over the 5-year period studied, the 130 researchers in diagnostic radiology in the study sample published 492 papers in diagnostic radiology journals, an average total of 3.8 papers per researcher over 5 years. The distribution of prolificacy was such that the top 5% published 21% of the papers, the top 15% published 52%, and the top 50% published 94% (Table 8).

The three radiologists who were board certified before 1960 published six papers (1% of the total number of papers), the 17 certified in 1960–1969 published 53 (11%), the 18 certified in 1970–1974 published 110 (22%), the 31 certified in 1975–

1979 published 187 (38%), and the 20 certified in 1980–1984 published 90 (18%). The 24 researchers without radiology or nuclear medicine affiliations published five papers (1%). The remaining 41 papers (8%) were written by the 17 researchers affiliated with departments of radiology or nuclear medicine who were not listed in the directory [4]. Of the 90 papers published by radiologists certified in 1980–1984, 23 were published in the years of or preceding board certification and were presumably written while the authors were in training. Thus, 5% of all papers were written by radiologists-in-training, and 86% were written by board-certified radiologists.

Examination of the number of papers published in relation to the number of years the first author was past board certification showed that those radiologists 1 to 5 years past board certification during the study period published 158 papers, those 6 to 10 years past board certification published 190, those 11 to 15 years past board certification published 49, and those 16 or more years past board certification published 24.

The number of papers published annually varied considerably from year to year for most individuals. Only 11% of the authors published at least one paper in each of the 5 years of the period studied; only 3% published at least two papers in each year. For most researchers in most years, no papers were published. The most prolific researcher published eight papers as first author in 1 year.

### Discussion

#### Journals

The scientific literature of diagnostic radiology represents the accumulated knowledge and experience of 90 years of diagnostic medical imaging. It is a living and growing resource, a contemporaneous record that can be followed nearly a century into the past. The principal function of the scientific literature is to present new information, usually in the form of original scientific papers. Science grows exponentially. New data and ideas provide further opportunities for investigation, and successfully completed investigations result in papers. Publication of papers is an inherent feature of the scientific process, and consequently there is a continually growing need for suitable journals [8, 9]. Existing journals can increase their size, publish more frequently, divide into parts, and issue supplements. New journals are started when existing journals no longer fill the needs of growing numbers of contributors and more selective readers. In general, the newer journals are aimed at a specific audience and are narrower in scope, smaller, and issued less frequently than their established counterparts. The proliferation and growth of diagnostic radiology journals has followed the increase in the number of researchers in the specialty. The proliferation of new journals should moderate; the growth in the size of the diagnostic radiology research community has slowed, and existing journals can accommodate more papers than they now publish.

The sample of journals found during this survey represents only a fraction of the total world literature in diagnostic radiology. Libraries have limited space and money; conse-

TABLE 7: Distribution of Authorship in *AJR* and *Radiology*

| Year | Authors per Paper |    |    |    |    |     |    |
|------|-------------------|----|----|----|----|-----|----|
|      | 1                 | 2  | 3  | 4  | 5  | 6-7 | 8+ |
| 1950 | 52                | 23 | 20 | 3  | 2  | 0   | 0  |
| 1955 | 42                | 30 | 15 | 12 | 1  | 0   | 0  |
| 1960 | 41                | 26 | 17 | 11 | 3  | 2   | 0  |
| 1965 | 31                | 34 | 20 | 9  | 3  | 3   | 0  |
| 1970 | 22                | 34 | 27 | 11 | 5  | 2   | 0  |
| 1975 | 12                | 27 | 27 | 16 | 10 | 8   | 0  |
| 1980 | 15                | 16 | 24 | 20 | 13 | 10  | 3  |
| 1985 | 5                 | 14 | 20 | 19 | 17 | 17  | 8  |

Note.—Combined data. Distribution given as percentages. Rows do not all add up to precisely 100% because of rounding.

TABLE 8: Prolificacy of 130 Diagnostic Radiology Researchers Over 5 Years (1980-1984)

| Number of Researchers | Total Number of Papers Published As First Author | Percentile Rank |
|-----------------------|--|-----------------|
| 39                    | 0  | 15              |
| 21                    | 1  | 38              |
| 12                    | 2  | 51              |
| 5                     | 3  | 57              |
| 11                    | 4  | 63              |
| 7                     | 5  | 70              |
| 10                    | 6  | 77              |
| 4                     | 7  | 82              |
| 3                     | 8  | 85              |
| 3                     | 9  | 87              |
| 1                     | 10   | 89              |
| 3                     | 11   | 90              |
| 3                     | 13   | 93              |
| 2                     | 14   | 95              |
| 1                     | 15   | 96              |
| 1                     | 16   | 97              |
| 2                     | 17   | 98              |
| 1                     | 18   | 99              |
| 1                     | 21   | 99.6            |

Note.—Percentages discussed in the text are not derivable directly from this table's data, because of differences due to rounding.

quently, they select for their patrons the largest and most carefully edited journals. Many foreign journals, particularly those not published in English and those with irregular publication schedules, would have relatively little interest for most American readers. The number of journals worldwide devoted to radiology is approximately 200 (Figley MM, personal communication).

#### Citation Analysis

Clinical diagnostic radiology is relevant to nearly every aspect of clinical medicine. Not unexpectedly, citation analysis demonstrates that diagnostic radiology research is relevant to clinical research. The scientific literature of diagnostic radiology is used in the research papers of other clinical specialties, and the literature of other clinical specialties is used in the research papers of diagnostic radiology. As a group, diagnostic radiology journals are cited by clinical journals proportionally more often than clinical journals are cited by diagnostic radiology journals.

The observed concentration of the citations to and from the diagnostic radiology literature among a relatively small number of journals is in keeping with bibliometric principles [10].

#### Papers

A research paper is not so much a parcel of truth and knowledge as it is a record of scientific work [11]. One way to measure scientific work is to count papers. The present study shows that although the number of papers written by the American diagnostic radiology research community increased steadily between 1960 and 1975, it lagged behind the growth in the size of the research community (Fig. 1). This has resulted in apparent decreases in unit productivity. Since 1975, the productivity has begun to return to the 1960 and 1965 levels. This lag may be due in part to the time required for new researchers to begin and complete research projects and shepherd them into publication. The most productive researchers are those who are 5 to 10 years beyond the completion of their training (as punctuated by board certification). This suggests that the aggregate productivity of the diagnostic radiology research community will approach the 1965 level, climb above it as a result of the demographic effect of a large cohort of researchers moving into their most productive years, and then decline as they pass their peak. Another relevant factor is that the modern scientific paper in diagnostic radiology has become much more carefully constructed, reviewed, and edited than in earlier years [12], so that the unit of measurement has been changing. This may be counterbalanced by the greater sophistication of modern researchers and more powerful research tools now available.

In diagnostic radiology, there are many more avenues for significant research than there are researchers. For example, the literature on CT is far from exhaustive in terms of the usual radiologic concerns: radiologic-anatomic-pathologic correlations; pitfalls in interpretation; technique and procedure; clinical indications; and usefulness and efficacy relative to alternative techniques. Nevertheless, many of the most prolific researchers have quit that research field to explore the same concerns in MR imaging. The amount of research that is accomplished is a function of the number of researchers, not a characteristic of diagnostic radiology.

### Authors

A small proportion of highly prolific authors write most of the papers in diagnostic radiology. There are many more marginal and occasional researchers. This distribution of prolificacy is in agreement with the observation that, in general, the proportion of researchers in science with a particular number of publications over a unit of time decreases as the inverse square or cube of the number of publications [8-11]. This is related to the notion of cumulative advantage, in which the likelihood of publishing a paper is increased in relation to the number of previously published papers. Therefore, the most difficult step for a neophyte researcher is bringing the first paper to publication. The distribution of annual prolificacy and the small proportion of researchers publishing at least one paper each year as first author suggest that 1 year is too short an interval for assessing research performance in diagnostic radiology. Furthermore, the time required for publication, once a research project has been successfully completed and a manuscript submitted, typically ranges from 4 to 6 months [12]. If a manuscript is submitted to more than one journal before acceptance, the interval from first submission to publication is much longer. The decline in prolificacy of researchers who are more than 10 years beyond the completion of training may be related to changes in career orientation.

### Multiple-Author Papers

The increasing complexity of diagnostic radiology may be, in part, responsible for the trend towards collaborative research and multiple-author papers. The complex case material most likely to form the basis for research is also most likely to involve many subspecialists whose cooperative research efforts will yield papers with many authors. Such a pattern can occur in teaching hospitals where there are many subspecialists and full-time academic faculty for whom there are considerable job-related incentives to publish and to publish frequently. An illusion of exceptional productivity may result if a researcher is a coauthor of several papers. The difficulties in trying to evaluate the productivity of a researcher whose portfolio bulges with dozens of papers of which the researcher is one of many authors is familiar enough to be the subject of humor [13]; the problem is real and likely to worsen. In 1985, coauthors outnumbered first authors by a factor greater than 3 (Table 6). This does not necessarily imply that a researcher who has made a substantive contribution to a project and the paper that reports it should not receive the credit of coauthorship or that such coauthorship is without value. However, a researcher's coauthorships represent a contribution to the literature as a whole primarily in

the sense that the researcher's participation enhanced the prolificacy of the first author. The notion that more authors per paper produce better papers is untested. In evaluating the productivity of a researcher, there is a case for considering only the hard currency of first authorship. The number of first authors 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 themselves. This has permitted an exponential increase in authors with only a linear increase in papers.

### ACKNOWLEDGMENTS

The editorial assistance of Annemarie Relyea-Chew is gratefully acknowledged. Data from the *Journal Citation Reports* of the *Science Citation Index* were used with permission of the publisher, the Institute for Scientific Information.

### REFERENCES

1. Garfield E. *Citation indexing: its theory and application in science, technology, and humanities*. New York: Wiley, 1979
2. Garfield E, ed. *SCI journal citation reports, science citation index 1984 annual*, vols. 15, 16. Philadelphia: ISI Press, 1985
3. Garfield E. Journal citation studies. 45. Surgery journals: another operation in citation analysis. *Current Contents* 1985;(21):3-18
4. American Board of Medical Specialties. *ABMS directory of certified radiologists*. Evanston, IL: ABMS, 1985
5. National Library of Medicine. *Cumulated index medicus*. Bethesda, MD: U.S. Dept. of Health and Human Services, 1980-1984
6. Wiggins WS, Leymaster GR, Taylor AN, Tipner A. Medical education in the United States and Canada. *JAMA* 1960;174:1424-1476
7. American College of Radiology. *Manpower IV: a report of the ACR Committee on Manpower*. Chevy Chase, MD: Am. Coll. Radiol., 1985
8. Price DJD. *Little science, big science*. New York: Columbia Univ. Press, 1963
9. Price DJD. *Science since Babylon*. New Haven, CT: Yale Univ. Press, 1961
10. Garfield E. Bradford's law and related statistical patterns. *Current Contents* 1980;(19):5-12
11. Price DJD. The development and structure of the biomedical literature. In: Warren KS, ed. *Coping with the biomedical literature: a primer for the scientist and clinician*. New York: Praeger Scientific, 1981:3-16
12. Figley MM. Publication in radiology: challenges to tradition. *Radiology* 1985;157:633-636
13. Scheible W, Resnick D, Brahmé F, Forrest J, Andre M. "Author inflation" or "CV creep." *AJR* 1985;144:863