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Mapping the Literature of Radiation Therapy

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Objective: This study characterizes the literature of the radiation therapy profession, identifies the journals most frequently cited by authors writing in this discipline, and determines the level of coverage of these journals by major bibliographic indexes.

Method: Cited references from three discipline-specific source journals were analyzed according to the Mapping the Literature of Allied Health Project Protocol of the Nursing and Allied Health Resources Section of the Medical Library Association. Bradford's Law of Scattering was applied to all journal references to identify the most frequently cited journal titles.

Results: Journal references constituted 77.8% of the total, with books, government documents, Internet sites, and miscellaneous sources making up the remainder. Although a total of 908 journal titles were cited overall, approximately one-third of the journal citations came from just 11 journals. MEDLINE and Scopus provided the most comprehensive indexing of the journal titles in Zones 1 and 2. The source journals were indexed only by CINAHL and Scopus.

Conclusion: The knowledgebase of radiation therapy draws heavily from the fields of oncology, radiology, medical physics, and nursing. Discipline-specific publications are not currently well covered by major indexing services, and those wishing to conduct comprehensive literature searches should search multiple resources.

INTRODUCTION

This study sought to characterize the literature of radiation therapy (radiotherapy), a specialty area of radiologic technology, through use of citation analysis. It is an installment in the Mapping the Literature of Allied Health Project of the Nursing and Allied Health Resources Section (NAHRS) of the Medical Library Association. Begun in 1993, the goal of the project is to identify and describe the literature of the allied health professions, including well-known professions such as physical therapy and occupational therapy and lesser-known professions such as cytotechnology, perfusion, and diagnostic sonography. The information obtained from this research can be of value to librarians working in collection development, reference, and instruction, as well as to faculty, students, researchers, and practitioners in the respective disciplines. This paper opens with a brief history of radiation therapy as a therapeutic modality and a summary of the radiation therapist profession, followed by the findings of the present study.

BACKGROUND

Radiation therapy, along with surgery and chemotherapy, is one of modern medicine's most powerful weapons in the fight against cancer. When its use for both for curative and palliative purposes is considered, ''more than half of cancer patients require radiotherapy during at least one point in their care'' [1]. Radiation therapy is usually administered externally through the use of high energy X-ray beams or internally by placing radioactive substances in or next to a tumor, a method referred to as brachytherapy.

EC Supplemental Table 6 is available with the online version of this journal.

Highlights

- The *International Journal of Radiation Oncology, Biology, and Physics* was the most frequently cited journal, contributing 12.7% of the total journal references over the 3-year study period.
- Conversely, more than 80% of the journal titles were cited 3 times or less, and nearly 59% were cited only once.
- Two society publications that were used as source journals ranked in the upper quarter of Zone 2, suggesting that radiation therapy as a profession is still early in the process of developing a culture of scholarship and research.
- Despite being widely viewed as top databases in the health sciences, neither MEDLINE nor CINAHL provided full coverage of the most frequently cited journals in radiation therapy.

Implications

- The top ranking journals may be of greatest use to scholars and researchers, while journals that focus on applied research, which may rank somewhat lower, may be of most use to practitioners.
- By providing valuable insight into the nature of the radiation therapy literature, this study supports the radiation therapy profession in its drive toward developing a culture of scholarship and research.
- Improved coverage of the source journals and the Zones 1 and 2 journals by the major health sciences bibliographic databases is essential for greater access to the literature of this fast-growing profession.

The origin of external radiation therapy can be traced to the discovery of a ''new kind of rays'' by German physicist Wilhelm Conrad Röntgen in November 1895 [2]. The first use of X rays for therapeutic purposes is often attributed to Emil H. Grubbé, a student at the Hahnemann Medical College in Chicago, who reported that he used X rays to treat a patient with inoperable breast cancer in January 1896 [3], a claim which has since been disputed [4–6]. The first reliable record of the administration of X rays for therapy is likely that of Victor Despeignes of Lyon, France, who in July 1896 treated a fifty-two-year old male with stomach cancer, followed by that of Leopold Freund of Vienna, who treated a five-year old girl with hirsutes in November 1896 [4]. Regardless of who can claim first usage, it is clear that the late nineteenth century medical community was eager to adopt this new technology as a means of therapy well before its biological effects were fully elucidated.

In the decades immediately following Röntgen's discovery, the use of X rays for therapeutic purposes was at risk of being abandoned due to the high rate of morbidity and mortality resulting from the massive doses that were administered [7] and to the inability of the relatively low energy X rays to reach tumors in deep tissues. These issues were eventually overcome through a succession of technological developments, including the Coolidge vacuum tube, circa 1913; dosage fractionation in the 1920s; a unit of measure for X rays, the röntgen, in 1928; and the linear accelerator, a machine that could generate megavoltage X rays capable of reaching deep tissues, in the late 1950s [1, 7]. In the ensuing years, the linear accelerator underwent several generations of improvements, and today it remains the ''workhorse'' of the radiation therapy department [8]. More recently, methodologies such as intensity-modulated radiation therapy (IMRT), image-guided radiation therapy (IGRT), and proton therapy have been developed. These and other emerging technologies have rendered radiation therapy one of the most precise and technologically complex modalities available to modern medicine.

The origins of brachytherapy, or internal radiation therapy, can be traced to the discovery of radium, a naturally occurring radioactive element, by Polish-born physicist Maria Skłodowska Curie and her husband, Pierre Curie, in 1898, and the 1901 accidental discovery of the effects of radium on human tissue by the Curies' contemporary Henri Becquerel, when he suffered a skin burn ten days after carrying a vial of radium in his shirt pocket for six hours [9]. Brachytherapy has the advantages of causing less damage to skin and surrounding tissues than externally applied X rays and being better able to reach deep-seated tumors. Nowadays, radioactive substances are ''sealed in needles, seeds, wires, or catheters…[and] placed directly into or near a tumor,'' thus the alternate name ''implant radiation therapy'' [10]. Brachytherapy is used for the treatment of prostate and cervical cancer, as well as cancers of the head and neck, soft tissue sarcomas, and other conditions [11].

The contemporary radiation oncology team consists of numerous health care professionals working in collaboration. Heading the team is the radiation oncologist, the physician specialist who devises the treatment plan in concert with the patient and the primary care provider. The medical physicist is responsible for setting up, calibrating, and maintaining radiotherapeutic equipment and for overseeing treatment planning programs. Working with the medical physicist, the medical dosimetrist (often a radiation therapist with additional training) calculates the exact dose of radiation to be administered to the tumor site. The radiation therapist, whose profession is the focus of this study, is responsible for administering the actual radiation treatment. The team is rounded out by other health care professionals such as oncology nurses, social workers, dentists, physical therapists, nutritionists, and support personnel [8, 12].

Radiation therapists are employed in a variety of settings, including hospitals, university medical centers, cancer centers, and outpatient clinics [13]. In the United States, the duties of the radiation therapist include conducting a treatment simulation, daily administration of treatments for one to seven weeks, treatment documentation, patient assessment, patient education, and quality assurance [8, 14]. Radiologic technologists in the United States are certified by the American Registry of Radiologic Technologists (ARRT). ARRT provides certification in five primary disciplines: radiography, nuclear medicine technology, radiation therapy, magnetic resonance imaging, and sonography, plus specialty areas such as bone densitometry, cardiac-interventional radiography, computed tomography, mammography, vascular sonography, and radiologist assistant [15].

In August 2012, the ARRT website listed 123 recognized educational programs for radiation therapy, of which 102 were located in the United States, 16 in Canada, and 5 in Australia [16]. Historically, an academic degree has not been required for ARRT certification, but as of January 1, 2015, eligibility to sit for the primary category certification exams will require an associate or higher degree from an accredited institution [15]. Graduates of non-degree-granting programs, such as hospital-based programs, may still be eligible for ARRT certification through an articulation agreement with a degree-granting institution or by earning an academic degree elsewhere [15]. In many states, radiation therapists must also be licensed [17].

The major professional organization for radiation therapists in the United States is the American Society of Radiologic Technologists (ASRT), which represents technologists in all areas of radiologic technology, including the many specialty areas [18]. According to the 2010 ASRT Radiologic Technologist Wage & Salary Survey, radiation therapists ranked third in earnings among all categories of radiologic technologists, with an average annual salary of $79,125, behind only medical dosimetrists ($95,279) and radiologist assistants ($100,004) [19]. An aging population and

advancing technologies that promise to make radiation therapy safer and more effective will result in an increasing demand for radiation therapists and rapid employment growth over the next 20 years [13].

With radiation therapy described in 2008 as a ''neophyte academic profession'' [20], it was no surprise that no previously published bibliometric studies for radiation therapy were found. However, a study was identified that analyzed all peer-reviewed articles published in one journal, *Radiation Therapist*, between 1992 and 2009 [21]. The sixty-six articles in the study were categorized in one of five broad subjects: treatment planning and delivery, professional issues, patient care, education, and management. Workplace affiliation and educational level of the primary authors were also examined. Although the results reflect the publishing history of just one particular journal, this study could serve as a springboard for additional research.

METHODS

The study followed the methodology described in the NAHRS mapping protocol [22], with slight modifications as described below. Briefly, the method involved gathering references from all articles published over the course of three years by a select group of journals considered central to the discipline (the ''source journals''). All references were entered into a database, followed by subsequent analysis.

The first step of the study was to select the journals that would serve as the source of data for the study. This is the most critical step of the process because this decision directly influences the results obtained. Criteria for consideration as a source journal included coverage of all areas of the radiation therapy profession, intended audience includes practicing radiation therapists, English language, inclusion of original research, peer-review status, and if possible, domestic publication.

A prime candidate for source journal was *Radiation Therapist*, the discipline-specific journal published semi-annually by ASRT. Since this was the only domestic publication found that focused on the radiation therapy profession, the search was broadened to include journals published in Canada or the United Kingdom. Strategies to identify additional source journals included searching for publications from other professional societies, conducting a subject search in a bibliographic index and sorting by publication, searching library catalogs and research guides from libraries at institutions that offer programs in radiation therapy, searching standard collection development tools such as Ulrich's Periodicals Directory and WorldCat, and consulting with a faculty member of a radiation therapy program.

Two additional journals were ultimately selected to serve as source journals. The *Journal of Radiotherapy in Practice* is published quarterly by Cambridge University Press in the United Kingdom. International in coverage and wide in scope, its audience includes ''any practitioner working in radiotherapy and oncology or a science related field,'' including radiation therapists, oncologists, dosimetrists, medical physicists, clinical scientists, and others [23]. The final source journal, the *Journal of Medical Imaging and Radiation Sciences* is published quarterly by Elsevier for the Canadian Association of Medical Radiation Technologists, the Canadian counterpart to ASRT. Prior to 2008, this journal was known as the *Canadian Journal of Medical Radiation Technology*. Although it covers all areas of radiologic technology, approximately 42% of the articles in this journal were determined to be relevant to radiation therapy. With the help of the director of the radiation therapy program at the author's institution, articles were hand-selected from this journal for inclusion in the study.

Once the source journals were identified, a database was created using Microsoft Excel. The following information was collected for each cited reference: source journal, publication year, volume/issue, article number, reference number, format of cited reference, and publication year of cited reference. The journal title was also recorded for all references to journal articles.

References were categorized as one of five formats, ranked hierarchically: ''Journal,'' ''Government Document,'' ''Book,'' ''Internet,'' and ''Miscellaneous.'' The ''Government Document'' category was limited to materials published by national, state, and local governments, including legislation, regulations, legal cases, statistics, and official reports. Resources emanating from international bodies, such as the United Nations or the International Commission on Radiation Units and Measurements (ICRU), were not included in the government category. References from government websites directed at the general public—such as press releases, news reports, and consumer health web pages—were categorized as Internet. The ''Miscellaneous'' category encompassed all references that did not fit into any other category, such as personal communications, internal reports, posters and presentations, meeting abstracts, dissertations and theses, Education Resources Information Center (ERIC) documents, and newspapers.

References that qualified as more than one format were placed into the higher ranking format. For example, an official government report published as a book or on a website was considered a ''Government Document,'' whereas journals published by governmental bodies were categorized as ''Journal.'' References lacking publication dates were verified whenever possible, including those that were listed as ''in press.'' Dates for Internet resources were recorded as either the date of the original document or the date accessed, whichever was earlier.

References were collected from the three source journals for the years 2008, 2009, and 2010 and manually entered into the Excel database. All references from all articles published in the *Journal of Radiotherapy in Practice* and *Radiation Therapist* in those three years were included, except for book reviews, historical reprints, and letters to the editor. All articles

Table 1
Contributions by source journal

	Rad Ther		J Radiother Pract		J Med Imaging Radiat Sci		Total
Number of references	1,883	(34.8%)	1,824	(33.7%)	1,709	(31.5%)	5,416
Number of articles	74		75		67		216
Average number citations per article	25.4		24.3		25.5		—
Number of issues	10		12		20		42
Average number articles per issue	7.40		6.25		3.35 (selected articles)		—
Publication frequency	Semi-annual		Quarterly		Quarterly		—
Number of years included in study	5		3		5		—

Rad Ther = *Radiation Therapy.*
J Radiother Pract = *Journal of Radiotherapy in Practice.*
J Med Imaging Radiat Sci = *Journal of Medical Imaging and Radiation Sciences.*

included in the study from the *Journal of Medical Imaging and Radiation Sciences* were hand-selected on the basis of their relevancy to the profession of radiation therapy. Because *Radiation Therapist* was published semi-annually and less than half the articles from the *Journal of Medical Imaging and Radiation Sciences* were selected for inclusion, data from two additional years—2007 and 2011—were added for those two journals, resulting in approximately the same number of citations from all three source journals.

Following completion of data entry, authority work was conducted on the list of cited journal titles to correct for typographical errors and changes in journal titles. In the case of journal title changes, all references were recorded under the most recent title.

Once all references were entered into the database, the data were sorted and analyzed. The total number of references from the three source journals was tallied, followed by a breakdown by format type and publication date. In addition, all references to journal articles were sorted alphabetically by journal title.

At this point, Bradford's Law of Scattering was applied to the data. In his 1950 book, Bradford noted that ''articles of interest to a specialist must occur not only in the periodicals specializing on his subject, but also…in other periodicals, which grow in number as the relation of their field to that of his subject lessens'' [24]. Bradford went on to explain that ''it is possible to arrange periodicals in zones of decreasing productivity…and the numbers of periodicals in each zone will increase as their productivity decreases'' [24]. He proposed that for any given discipline, relevant articles would be found most frequently in the small, nuclear zone of very productive periodicals; somewhat less frequently in the middle zone of less productive but still important journals; and much less frequently in the last, very broad zone of journals that are of ''constantly diminishing productivity'' [24]. By applying Bradford's law to the data obtained in this study, it was possible to identify the journals that were most frequently cited by authors writing on radiation therapy topics and that were presumably most important to this discipline.

Finally, indexing coverage for 2012 of all journal titles in the first and second zones by five major bibliographic indexes was determined. Owing to their status as major bibliographic databases in the health sciences, MEDLINE (US National Library of Medicine) and CINAHL (EBSCO) were automatically included in the study. Two multidisciplinary databases of importance to researchers in the sciences, Science Citation Index Expanded (Thomson Reuters) and Scopus (Elsevier), were also included. Rounding out the group was Academic Search Premier (EBSCO), a popular, multidisciplinary database widely used in general academic settings. The 2012 lists of journals indexed by each database were checked for each journal title in Zones 1 and 2, with results recorded as a dichotomous yes/no value. Title-by-title indexing coverage was analyzed, as well as the overall performance of each database.

RESULTS

A total of 5,416 references was collected for analysis. As shown in Table 1, contributions from *Radiation Therapist* and the *Journal of Radiotherapist in Practice* were nearly equal at 34.8% (1,883/5,416) and 33.7% (1,824/5,416), respectively, while the contribution from the *Journal of Medical Imaging and Radiation Sciences* was slightly lower at 31.5% (1,709/5,416). Likewise, the number of articles from the first 2 source journals was nearly equal at 74 and 75, respectively, while that from the third journal was slightly lower at 67. The average number of cited references per article from all 3 journals combined was approximately 25.

The breakdown by format of the 5,416 cited references is shown in Table 2. With journals accounting for 77.8% (4,211/5,416) of all references, it is apparent that use of this format far outranked that of all other formats. When data from each source journal were examined separately, it appears that articles published in *Radiation Therapist* used somewhat fewer references to journal articles and somewhat more references to books and Internet resources than the other 2 source journals.

Table 2
Format types by source journal and citation frequency

	Source journal							
	Rad Ther		J Radiother Pract		J Med Imaging Radiat Sci		Total	
Cited format type	No.	%	No.	%	No.	%	No.	%
Journal articles	1,325	70.4%	1,476	80.9%	1,410	82.5%	4,211	77.8%
Books	209	11.1%	104	5.7%	86	5.0%	399	7.4%
Government documents	26	1.4%	54	3.0%	34	2.0%	114	2.1%
Internet	268	14.2%	78	4.3%	116	6.8%	462	8.5%
Miscellaneous	55	2.9%	112	6.1%	63	3.7%	230	4.2%
Total citations	1,883	100.0%	1,824	100.0%	1,709	100.0%	5,416	100.0%

The profession of radiation therapy clearly relies heavily on the most current information available, as depicted in Table 3. References from the most recent decade (2001–2011) constituted the vast majority at 71.5% (3,874/5,416), and references from the most recent 2 decades (1991–2011) came to 94.2% (5,100/5,416), leaving just 5.0% (269/5,416) of references from the 3 decades between 1961 and 1991. A very small number of references (0.4%; 24/5,416) were to ''historical'' (pre-1961) materials. The dates for 0.4% (23/5,416) of references could not be determined. As might be expected, the number of references to Internet materials jumped dramatically in recent years. Just under 2% of all Internet references were dated between 1991 and 2000; 14% were dated between 2001 and 2005; and a whopping 81% were dated between 2006 and 2011.

As described above, the journal titles were recorded for all references to journal articles. They were then sorted according to frequency of citation, producing a final list of journals in which the most frequently cited journal appeared first, followed by the second most frequently cited journal, and so on, ending with journal titles that were cited only once. Overall, 908 unique journal titles were cited. The most frequently cited journal—the *International Journal of Radiation Oncology, Biology, and Physics*—was cited 534 times over the study period. In contrast, 80.1% (727/908) of the journal titles were cited 3 times or less, and 58.9% (535/908) of the journal titles were cited only once over the course of the study.

In applying Bradford's Law of Scattering, the total number of journal references (4,211) was divided by 3 to create 3 roughly equal zones (Table 4). The first zone, consisting of just 11 titles, produced approximately one-third of all citations to journal articles. The 84 journals in the second zone together generated another one-third of the journal article references. The third and largest zone, consisting of 813 journal titles, produced the final one-third of journal article references.

The journal titles in Zone 1 are listed in Table 5 in decreasing order of the number of references received. Table 5 also provides the indexing coverage in 2012 of each Zone 1 journal title by the five bibliographic databases: MEDLINE, CINAHL, Science Citation Index Expanded, Scopus, and Academic Search Premier. The complete list of journal titles in Zones 1 and 2 can be found in the online only Table 6.

The results indicated a wide range of indexing coverage of the Zone 1 and 2 journals, from 41.0% to 96.8% (Table 7). As expected, coverage by MEDLINE was excellent, indexing 93.7% (89/95) of the Zone 1 and 2 journals. However, MEDLINE did not index any of the 3 source journals. In contrast, coverage by CINAHL was substantially lower at 41.0% (39/95), although it did index 2 of the 3 source journals. Coverage by Science Citation Index Expanded was somewhat lower than MEDLINE at 86.3% (82/95), and again it did not index any of the source journals. The most comprehensive coverage was provided by Scopus, which indexed 96.8% (92/95) of the titles,

Table 3
Publication date of cited references, overall and by format

	Cited format type											
	Journal articles		Books		Government documents		Internet		Miscellaneous		Total	
Publication year (range)	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2006–2011*	1,389	33.0%	92	23.1%	40	35.1%	374	81.0%	75	32.6%	1,970	36.4%
2001–2005	1,566	37.2%	143	35.8%	44	38.6%	66	14.3%	85	37.0%	1,904	35.2%
1991–2000	1,019	24.2%	126	31.6%	18	15.8%	9	1.9%	54	23.5%	1,226	22.6%
1981–1990	175	4.2%	26	6.5%	2	1.8%	0	—	7	3.0%	210	3.9%
1971–1980	34	0.8%	4	1.0%	3	2.6%	0	—	4	1.7%	45	0.8%
1961–1970	13	0.3%	1	0.3%	0	—	0	—	0	—	14	0.3%
Pre-1961	15	0.4%	7	1.8%	1	0.9%	0	—	1	0.55	24	0.4%
Unknown	—	—	—	—	6	5.3%	13	2.8%	4	1.7%	23	0.4%
Total	4,211	100.0%	399	100.0%	114	100.0%	462	100.0%	230	100.0%	5,416	100.0%

* 2006–2010 for *Journal of Radiotherapy in Practice.*

Table 4
Distribution by zone of cited journals and cited journal references

Zone	Cited journals		Cited journal references	
	No.	%	No.	%
1	11	1.2%	1,397	33.2%
2	84	9.3%	1,407	33.4%
3	813	89.5%	1,407	33.4%
Total	908	100.0%	4,211	100.0%

including 2 of the source journals. Finally, Academic Search Premier performed well despite its broad scope, indexing 51.6% (49/95) of the Zone 1 and 2 titles.

DISCUSSION

With over a third of references dating from the past 5 years and over 70% of them from the past decade, it is apparent that currency of information is of utmost importance to the field of radiation therapy. With regard to format, the journal article was used predominantly, with references to books, government documents, Internet resources, and miscellaneous materials being utilized much less frequently. In the future, the percentage of references to Internet resources may increase as more information becomes available online.

A cursory review of the journal titles of Zone 1 reveals that this profession draws heavily from the literature of the radiology and oncology medical specialties, as well as medical physics, for its knowledgebase. General medicine journals such as *Lancet, BMJ,* and *New England Journal of Medicine* rank high in the Zone 2 list, as do a number of nursing journals. Of particular note is the large number of citations from the top-ranking journal, the *International Journal of Radiation Oncology, Biology, and Physics*. This publication is the major scientific research journal of the American Society for Radiation Oncology (ASTRO), an organization that serves all members of the radiation oncology team, including physicians, biologists, nurse practitioners, physician assistants, and practice administrators [25]. At 534 citations, this journal alone accounted for 12.7% of the total number of journal article citations, far outdistancing the second most frequently cited journal. Its top ranking suggests that this journal is critical to the development of the knowledgebase for the radiation therapy profession.

Of the three source journals, only one, the *Journal of Radiotherapy in Practice*, appears in Zone 1, while both *Radiation Therapist* and the *Journal of Medical Imaging and Radiation Sciences* appear in the top quarter of Zone 2. The ranking of the latter two journals may to some degree be a reflection of their intended audience and content. As publications of the US and Canadian professional organizations for radiologic technology, the target audience for these journals is primarily individuals who are practicing in the clinical arena, many of whom are educated at the associate or baccalaureate level. As such, these publications focus on addressing the interests and concerns of radiation therapists working in the field and therefore may place greater emphasis on practical (applied) research than theoretical (basic or ''pure'') research. Consumers of practical research typically use the results of that research in their daily work, rather than for generating more scholarship. In contrast, consumers of theoretical research, who are themselves likely to be scholars and writers, often with advanced degrees, generally use that research to produce more research and more scholarly articles. Thus, publications with a strong focus on theoretical research may ultimately be cited more frequently than publications that have a strong focus on practical research.

As a profession matures, it begins to assume greater responsibility for contributing to its own knowledgebase [20, 26]. When it comes to academic research, radiation therapy is a relative newcomer and as such, is only just beginning to develop a culture of scholarship and publication among its members [20]. As more radiation therapists engage in scholarly research, it is likely that its society publications will experience a gradual shift toward publishing more theoretical research. It will be interesting to conduct an update of this study in ten years to see if this forecast comes to fruition, as evidenced by a rise in the ranking of these two journals.

Although intellectual access to the journal literature of radiation therapy is available through several bibliographic databases, those wishing to conduct a comprehensive search should consult multiple resources for complete coverage. An interesting finding of the study pertained to the coverage of the journal literature of this discipline by MEDLINE and CINAHL, two of the most commonly used databases in the health sciences. Owing to its widespread availability at no cost via the PubMed interface and its sophisticated thesaurus and rich indexing, MEDLINE is an ideal first choice for conducting a literature search in this field. However, it is notable that none of the three source journals used for this study were indexed by MEDLINE. Although coverage by MEDLINE is not listed in the mapping protocol as a criterion for selection as a source journal, it is nevertheless surprising that none of the source journals were indexed by this database. Likewise, although CINAHL, a database designed specifically for the nursing and the allied health professions, indexed two of the three source journals, including the two society publications, it covered only three of the eleven Zone 1 journals and only thirty-six of the eighty-four Zone 2 journals. An early goal of the NAHRS allied health mapping project was to identify the degree to which the major indexing services covered the allied health literature and ''to influence increased bibliographic access to the core literature'' [27] when indicated. This study reiterates the need to continue to encourage database producers to improve coverage of publications that are central to the allied health professions.

Limitations of the study

Despite utilizing a time-tested methodology, this study nevertheless had some limitations. The most

Table 5
Zone 1 journals (n=11), listed in decreasing order of frequency cited, and indexing by selected bibliographic databases

	Cited journal	# of references	MEDLINE	CINAHL	SCIE	SCOPUS	ASP
Zone 1							
1	Int J Radiat Oncol Biol Phys	534	Y	N	Y	Y	Y
2	Radiother Oncol	191	Y	N	Y	Y	Y
3	J Clin Oncol	175	Y	Y	Y	Y	N
4	Radiography	88	N	Y	N	Y	N
5	Cancer	74	Y	N	Y	Y	Y
6	Med Phys	60	Y	N	Y	Y	Y
7	J Radiother Pract	57	N	N	N	Y	N
8	Clin Oncol (R Coll Radiol)	57	Y	N	Y	Y	Y
9	Radiology	57	Y	N	Y	Y	N
10	Semin Radiat Oncol	53	Y	Y	Y	Y	N
11	Br J Radiol	51	Y	N	Y	Y	Y
Percent Zone 1 journals indexed		—	81.8% (9/11)	27.3% (3/11)	81.8% (9/11)	100.0% (11/11)	54.5% (6/11)

SCIE=Science Citation Index Expanded.
ASP=Academic Search Premier.

important of these was the selection of source journals, a decision which directly affects the raw data collected and results obtained. Every attempt was made to select source journals that met the stated criteria and that together accurately represented the scope of the discipline. A radiation therapy program director/educator was consulted for advice in selecting the source journals and in hand-selecting articles from the *Journal of Medical Imaging and Radiation Sciences*.

Another limitation was the occasional difficulty in determining the format of a given reference, especially with regard to materials published on the Internet. Fortunately, there was rarely any difficulty in determining the format of greatest interest, the journal article. The number of references from each of the other formats was proportionately small and will quite likely remain so as the profession matures.

Finally, because the publication years under study differed between the source journals (2008–2010 for one source journal, and 2007–2011 for the other two source journals), the percent of references in the 2006–2011 segment was slightly underestimated. However, this does not affect the practical implications of the results, which is that the profession depends heavily on the most recently published literature.

CONCLUSIONS

This study is the first of its kind to characterize the literature of the profession of radiation therapy and to identify the journals most frequently cited by authors writing in this discipline. The results will particularly benefit health sciences librarians charged with making collection management decisions, especially those involving journal subscriptions. The results will also help reference and instruction librarians in performing mediated literature searches, answering reference queries, providing instruction to radiation therapy faculty and students, and providing consultations to health care professionals conducting research for coursework or clinical care.

However, the greatest beneficiaries of this research may well be members of the radiation therapy profession itself, including faculty, students, researchers, and practitioners. Insomuch as a profession may be defined as having a distinct body of knowledge and that body of knowledge in turn defines the profession [26], this study represents an important step in arriving at an understanding of the knowledgebase of radiation therapy. In a profession characterized by rapid technological advances, practitioners, researchers, and educators must remain abreast of changes in the field through regular forays into the current journal literature. The results of this study will help them identify those journals whose output they may wish to monitor on a regular basis, as well as guide their choice of databases in which to conduct literature searches.

Like other allied health professions, radiation therapy is ''undergoing a process of 'professionalization,' through education, establishment of standards of practice, obligatory registration and self-regulation'' [20]. These changes, as well as the greater emphasis being placed across health care on evidence-based practice, will no doubt result in a concomitant increase in scholarly activity by radiation therapists. Simultaneously, a shortage of qualified physicians

Table 7
Indexing coverage of Zones 1 and 2 journals (n=95) by selected bibliographic databases

	MEDLINE		CINAHL		SCIE		Scopus		ASP	
	No.	%	No.	%	No.	%	No.	%	No.	%
Indexed	89	93.7%	39	41.0%	82	86.3%	92	96.8%	49	51.6%
Not indexed	5	5.3%	56	59.0%	13	13.7%	3	3.2%	46	48.4%
Number of source journals indexed	0		2		0		2		0	

and the desire of many radiation therapists for greater challenge in their chosen field have fueled the development of an advanced practice option for radiation therapy [28]. As the overall profile of the radiation therapist is elevated, so will the expectation be raised for a greater degree of self-directed scholarly activity by members of that profession [20]. The results of this study support radiation therapists in achieving a better understanding of the literature of their own field, which supports their goal of a greater degree of involvement in research and scholarship in the field. In the end, the ultimate beneficiaries will be the patients whom the radiation therapist seeks to serve and who are so deeply touched by the vital contributions of members of this critical profession.

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