Scientific Crisis in Radiation Therapy and Cancer Patient Care and Safety: A Life Threatening Gap between Research and Clinical Practice

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Abstract

Radiation therapy uses ionizing radiation to eradicate cancer from the body. In the last decade, the adoption of new technology significantly increased the sophistication by which radiation treatments are planned and delivered. New technology offers important benefits to patients and has significantly altered the social, or human, interfaces of the treatment environment. With a commitment to the positivist paradigm and quantitative research design, the medical field failed to respond quickly during a recent radiation overdose crisis that threaten cancer patient care and safety. This essay uses Kuhn's concept of the structure of scientific revolutions to discuss the radiation overdose crisis. It uses information transfer theories and models to explain and pin-point knowledge transfer as it applies to clinical practice in radiation therapy, information science, and medical librarianship. It suggests a new approach to research combining quantitative and qualitative research designs to expand creation of knowledge, improve clinical practices, and better support safe and accurate care of cancer patients.

Key words: radiation oncology; radiation therapy; radiotherapy error/s; radiotherapy safety; patient safety; medical librarian; knowledge transfer

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Radiation therapy is a cancer treatment modality aimed at destroying the deoxyribonucleic acid of tumor cells while minimizing effects in surrounding normal tissue. Annually, approximately one million patients in the United States (U.S.) receive radiation therapy as the primary or adjuvant treatment for malignant disease (Odle & Rosier, 2012). Radiation therapy is delivered in a variety of cancer care settings including university medical centers, regional health systems, physician owned clinics, and rural facilities. This form of treatment is prepared and delivered by an oncology care team consisting of radiation oncologists, medical physicists, dosimetrists, and radiation therapists as the foundational team members. Each member possesses knowledge of medical physics, radiation safety, and radiobiology.

In the last decade, new technologies resulted in treatment advances including intensity modulated radiation therapy, imaged guided radiation therapy, and stereotactic radiosurgery that transformed radiation oncology. These treatment advancements offer many benefits to cancer patients primarily by reducing the amount of normal tissue within the treatment volume. The reduction of normal tissue exposure results in fewer radiation induced side effects caused by tissue damage. Along with enhancing treatment, the integration of sophisticated technology significantly increased the complexity of radiation therapy planning and delivery. The complexity increased in relation to hardware, software, and human interfaces enmeshed in the treatment process (Yorke, Gelblum, & Ford, 2011).

In the last decade, the new technology preceded quality assurance and radiation safety research in many regards. A gap existed between technology integration and the creation of scientific knowledge that accounted for changes in communication pathways, work flows, time demands, and personnel roles caused by the clinical advancements. This gap between research and clinical practice prevented proper guidance in the field leading to grievous radiation overdoses (Marks et al., 2011).

To ensure the safe and effective treatment of cancer patients, knowledge creation must keep pace with medical advancements and address the impact of new technology adoption on social structure of the work environment. However, the production of new quantitative knowledge alone is not sufficient when changing, or improving, quality assurance and patient safety behaviors in the clinical setting. As Genuis (2007) points out, the goal must be successful knowledge transfer between scientists and clinicians in a manner that supports the assimilation and concrete use of knowledge in daily practice. To prevent errors and mistakes in the dynamic field of radiation oncology, effective transfer of new knowledge between research and clinical practice is vital to sustained, quality care of cancer patients. In this present essay, Kuhn's (2012) description of a scientific crisis preceding a scientific revolution is useful for explaining the recent period marred by reports of radiation overdoses and acknowledged errors in radiation therapy. Theories and models of information transfer provide a framework to pin-point opportunities for changes in science that can result in achievement of safe and effective treatment of cancer patients in the future.

A Kuhnian Paradigm Shift in Context

In January 2010, *The New York Times* featured a series of articles relaying personal stories of radiation overdoses in the state of New York, two of which were lethal (Bogdanich, 2010). The articles disclosed the crisis in radiation therapy involving a gap between research knowledge and technologically advanced clinical practice. The mass media exposure intensified public fear of ionizing radiation and accelerated the response to the field's crisis by professional organizations, agencies of patient advocacy, the government, and other stakeholders.

A number of professional organizations publically responded to the articles, acknowledging the errors and reassuring the public of the rarity of radiation therapy mistakes. Many of these same organizations testified at congressional hearings in March 2010. In June 2010, the U.S. Food and Drug Administration (FDA) met with radiation therapy equipment vendors and users to reevaluate the approval process for new radiation therapy devices and software. Prior to this recent radiation overdose crisis, the FDA provided a fast track approval process utilizing third-party reviewers (U.S. Food and Drug Administration, 2010). This is one explanation for the rapid integration of technology within the field.

New knowledge was needed to address the unintended consequences of advancing new technology on patient safety. The public exposure by the articles in *The New York Times* pushed radiation oncology professionals to collectively acknowledge the critical divide between research and clinical practice. As a result, many professional organizations actively participated in the development of patient safety research and initiatives. Rather than a pure focus on prescribed equipment parameter testing, new research began to consider the evaluation of social factors within the clinical environment (Chera et al., 2012). The decision to evaluate the relationship between humans and technology, and the impact of the work environment on job performance, is much more individualized investigations than were done earlier through the dominate lens of positivist science. The decision to include social factors ascertained through in-put from people signaled a paradigm shift in the Kuhnian sense. Prior to this crisis, quality assurance research primarily analyzed mechanical and dosimetric statistical data without consideration of evaluative input from people directly, and/or indirectly, involved in the treatment processes.

According to Kuhn (2012), scientific advancement often occurs in response to a crisis or when current knowledge fails to address problems within a field. As Kuhn asserts, when anomalies are recognized and further evaluated, a period of uncertainty follows. In this period of uncertainty, or crisis state, attitudes about the existing research paradigm change and scientific inquiry surges. As an alternate paradigm candidate comes forth, debate heightens. This anomaly-driven process of scientific revolution can be used to explain the period of recent events in radiation oncology. Once the field acknowledged the pattern of treatment errors, and the discrepancy between current quantitative research knowledge and actual clinical practice, many formal and informal communications and debates occurred about how to resolve the crisis. This life-threatening crisis demanded a paradigm shift in the science of radiation oncology and radiation therapy allowing opportunities for new quality assurance and patient safety research and practice to emerge.

The radiation oncology field took decisive action by increasing collaboration among professional organizations including the American Society for Radiation Oncology (ASTRO); American Association of Physicists in Medicine (AAPM); American College of Radiology; and, the American Society of Radiologic Technologists (ASRT). The formation of new multidisciplinary writing groups is one example of improved collaboration effort across disciplines and fields of science. The writing groups produced five safety oriented white papers and numerous academic journal articles. In June 2010, ASTRO and AAPM hosted a safety meeting titled *Safety in Radiation Therapy – A Call to Action*. Additionally, the *Target Safely* initiative was launched by ASTRO in 2010. Goals of this initiative include the development of a national error reporting system, stronger accreditation standards, support of the Consistency, Accuracy, Responsibility and Excellence in Medical Imaging and Radiation Therapy (CARE) Act, education of the public, and improved quality assurance and patient safety education efforts. In June 2014, ASTRO and AAPM participated in a congressional briefing to unveil the Radiation Oncology Incident Learning System. This national data collection system provides records of near misses and adverse events from which the field can learn to improve the safety of radiation therapy treatment delivery (American Society for Radiation Oncology, 2014).

According to Kuhn (2012) acceptance of a new paradigm, or lens through which to view science, causes scientists and scholars to let go of the previous perspective in order to reconstruct the field in the light of the new paradigm. In radiation therapy, the recent paradigm shift resulting from radiation overdoses is only the beginning of a transformative process. Newly created knowledge must be strategically transferred to practitioners in order to change behavior at the clinical level, and to minimize treatment errors. Theories of information and information transfer can be used to inform and pin-point opportunities for change.

Information Transfer: A Specific Form of Communication

The deliberate transfer of research knowledge to practitioners is essential in changing radiation therapy practice and minimizing harm to patients. To achieve this type of impact, an understanding of information, and information transfer, is necessary. Information is a difficult term to define, in part due to its overlapping concepts and varied applications (Case, 2002). In 1948, Shannon and Weaver defined information, or information transfer, in the seminal publication *The Mathematical Theory of Communication.* Their theory defines information as a combination of randomness, or entropy, and probability based on a fixed set of signal elements. The entropy associated with creating a message is desirable, but uncertainty generated from noise serves only to degrade the message. Noise must be extracted to discern the useful message (Shannon & Weaver, 1998). Nieva et al. (2005) address the problem of noise indicating that the massive amounts of medical research produced annually act as noise and emphasize the importance of packaging and tailoring research information to practitioners to reduce the signal-to-noise ratio. While the efforts of Shannon and Weaver are based in mathematics and telecommunication signal transmission, the information theory provided a foundation from which

Greer, Grover and Fowler (2013) developed the information transfer model that currently guides many information professions in providing information services to users of information.

Information transfer is, according to Greer, Grover, and Fowler (2013), a form of asynchronous communication that can be conceptualized in a graphical model that depicts a process of information transfer. Information transfer is characterized as a "recorded message transmitted on a medium that enables senders to transmit ideas to people who are not their contemporaries" (p. 71). The information transfer model differs from a conventional library service model in two significant ways. First, the information transfer model uses a circle symbol for both the information system and information user to show that the system reflects the needs of patrons. Secondly, the new model incorporates two-way arrows, emphasizing the manner in which the information system is designed to serve the needs of patrons. These differences made possible a paradigm shift away from a focus on quantifying sources to a service-orientated practice where the information user is valued above the information.

According to Greer, Grover, and Fowler (2013), information is not a static bundle of facts or data; rather, information progresses through a life cycle process. From this prospective, data is defined as elementary building blocks of information. "Information is thought of refined data which provides some added value to the user" (Rich, 1997, p. 14). Knowledge is the entanglement of information that has been processed and internalized. Such terms are important when considering the stages of the information transfer cycle. The 10-stage life cycle of information includes: creation; recording; reproduction; dissemination; bibliographic control; organization by disciplines; diffusion; utilization; preservation; and, deletion (Greer, Grover & Fowler, 2007, 2013). Each is a critical stage in the transfer of new knowledge as it allows for the utilization of information to serve society. These stages provide an outline that can be used to pin-point opportunities for changing research priorities in radiation oncology and radiation therapy.

Creation of knowledge. Radiation oncology arises from Western academic disciplines of mathematics and natural science. Radiation-related patient safety knowledge originates from a variety of sources. Residents and faculty of medical schools and doctorate level medical physics programs are key contributors to the creation of new knowledge in radiation oncology. The central role of the doctorate degree in scientific inquiry is demonstrated in the model of research and education infrastructure offered by Greer, Grover, and Fowler (2013). In this model, the Ph.D. degree is placed in the center signifying the central role that the Ph.D. process serves in the creation of new knowledge. Board certified radiation oncologists, medical physicists, and radiation therapists also participate in research and contribute to a specialized body of medical knowledge. Additionally, government agencies, health foundations, and healthcare delivery systems engage in knowledge creation, or sponsor scientific inquiry, to identify and solve problems that impact patient care.

Research efforts in natural sciences, such as oncology and radiation, and fields arising from natural science disciplines traditionally align with positivist epistemological assumptions. Positivism, a term first used by August Comte, supports deductive scientific inquiry within a closed system from which quantitative data are acquired and used to form predictive knowledge (Budd, 2001).

Until recently, radiation safety research followed the same positivist tradition as the medical profession. The majority of quality assurance and safety research in radiation therapy focused on hardware, software, and network connectivity. Prior research developed prescriptive quality assurance protocols and defined allowable tolerances as the basis of a quality control program. A retrospective approach to treatment error assessment prevailed and even that was difficult due to the absence of a national error reporting system (Yorke, Gelblum & Ford, 2011). The positivist research paradigm used to create radiation safety knowledge no longer met the needs of radiation oncology. A new approach with an emphasis on proactively finding high-risk processes was necessary to prevent the incidents, or propagation, of significant errors to cancer patients.

To solve the problem of radiation overdoses, examination of the entire radiation oncology system was needed. Research could no longer focus primarily on equipment testing and measurements. The complex environment, or social structure in which radiation therapy is delivered and the involved professionals, needed attention. As the research paradigm shifted, new knowledge in the areas of process engineering, human error, failure modes and effect analysis, standardization, and peer review techniques followed (Chera et al., 2012). Another important outcome from the paradigm shift is a heightened interest in nurturing a culture of safety. It is the duty of oncology professionals to self-report errors, which is now more likely to occur within a non-punitive and respectful environment where continuous improvement is the overarching objective (Marks et al., 2011).

Recording of new knowledge. According to Greer, Grover, and Fowler (2013), through the knowledge creation stage of the information transfer cycle, data is acquired. At the time of acquisition, the data is not highly meaningful. The analysis, synthesis, and contextualization of scientific data is used to cultivate meaning during the second stage of the cycle, the recording stage. In the recording stage, details of the research process and outcomes are organized into coherent, asynchronous reports. This stage is the first step towards preparing new medical knowledge for dissemination and ultimately for utilization in the clinical setting.

Examples of radiation safety recordings include white papers and task group reports. The production of radiation quality assurance and safety reports increased as the field faced its crisis. In 2009, the International Commission on Radiological Protection published report 112, which calls for a more proactive approach of quality management. From 2011-2014, ASTRO published five safety oriented white papers. The ASRT published a white paper titled *Radiation Therapy Safety: The Critical Role of the Radiation Therapist* (Odle & Rosier, 2012) to address issues surrounding state licensing of radiation therapists and other aspects of safety such as staffing levels and skill assessment. The ASRT white paper also reinforces the organization's support for the CARE Act, H.R. 1146 and S. 642. The CARE Act calls for federal educational and certification requirements for individuals practicing diagnostic medical imaging and radiation therapy. The Act was introduced to the U.S. House of Representatives in March 2013 and referred to the subcommittee on Health in April of 2013 (American Society of Radiologic Technologists, 2013).

Currently, radiation oncology awaits the release of the AAPM Task Group 100 report (TG100). The members of TG100 are designing a risk-based quality management program that advocates for the use of quality assessment tools such as process maps, failure modes and effects analysis, human factors engineering and fault tree analysis by all radiation oncology departments (Huq et al., 2008).

Reproduction prepares new knowledge for dissemination. The reproduction stage of the information transfer cycle (Greer, Grover, & Fowler, 2013) involves copying approved scientific manuscripts for the purpose of mass dissemination. Dissemination is a separate stage of the information transfer cycle, but the widespread use of electronic medical journals leaves very little division between the recording and dissemination stages.

Academic journals utilize a peer-review process to determine whether research should be reproduced. The peer-review process serves to maintain rigor of scholarly work though the review of research methods and conclusions. Relevancy of the submitted manuscript and it's alignment with the publication's defined purpose and audience are also considered. Once approved by a committee of peers, quality assurance, and radiation safety research is reproduced with the intent to disseminate the new knowledge through discipline-specific journals such as the *International Journal of Radiation Oncology, Biology, Physics* (IJROBP); *Practical Radiation Oncology* (PRO); *The International Journal of Medical Physics Research and Practice*; *Journal of Applied Clinical Medical Physics*; and, the *Radiation Therapist.*

The official journal of ASTRO is IJROBP, also referred to as the Red Journal. All issues, since Volume 1 (1975) are available online at the journal's website. Abstracts of the research articles are available to all individuals, but access to peer-reviewed full-text articles is limited to members of ASTRO, IJROBP print subscribers and those with access to a Science Direct library subscription. Practical Radiation Oncology (PRO) is a companion journal to IJROBP. It is recognized as the official clinical practice journal of ASTRO. The first published volume of this peer-reviewed journal occurred in January 2011, near the time the field united to address the radiation overdose crisis. A primary focus of PRO is patient safety and quality assurance. As with IJROBP, all volumes and issues are available online in full text to ASTRO members, PRO print subscribers, and individuals with access to a MEDLINE library subscription.

Other important radiation oncology journals include the AAPM's flagship journal, *The International Journal of Medical Physics Research and Practice*. The AAPM also provides an open-access journal titled the *Journal of Applied Clinical Medical Physics*. Lastly, the *Radiation Therapist* is a peer-reviewed journal published by ASRT, a professional association for radiologic technologists and radiation therapists.

Spreading new research to the masses through dissemination. The information transfer cycle defines dissemination as a one-way communication process that pushes knowledge, or an innovation, out to a large audience. The dissemination stage of the cycle is not credited with changing the thinking and behavior of individuals, however, it serves an important role in making individuals aware of new information. According to Lomas (1993), predisposing effect of dissemination aids the diffusion process where knowledge is internally formed.

A significant portion of radiation oncology and physics research is disseminated through discipline specific peer-reviewed journals. This mode of dissemination places the responsibility for seeking information on the information user. As Lomas (1993) points out, such action is taken by highly motivated and innovative information users. It is important to understand that while the information may be accessed, the information source is unaware of who accesses it.

Technology continually expands the paths by which research can be disseminated. Technology enhanced methods of informing professions of the existence of new research include mobile applications, email alerts, rich site summary feeds, podcasts, and social media such as Twitter and Facebook. Since 2005, *The New England Journal of Medicine* records weekly podcasts, available on the journal's website, which summarize recently published research. Professional organizations assist in disseminating new knowledge through continuing educational meetings. In this process, highly motivated professionals develop presentations from research findings. The tailored presentations are shared to a large audience of professionals through one-way communication. Examples of continuing education sessions focused on patient safety offered at the 2014 ASRT Radiation Therapy Conference include *Technology Does Not Drive Change, but Enables It: Effects of New and Upgraded Technology on Department Workflow* and *Developing Clinical Reasoning Skills in an Age of Technological Advances and Changes in Professional Practice*.

Organization of authoritative sources to enhance access. Research serves to answer questions useful in resolving problems in society, however, findings and conclusions from research activity are of little value unless information users can effectively retrieve research publications. The organization of information, so that it may be accessed, is according to Greer, Grover, and Fowler (2007) termed “bibliographic control” (p. 65). This broad term incorporates a range of technical activities that result in organized storage and opportunities for electronic retrieval of published sources. Bibliographic control is achieved in online catalogs through cataloging resources by title, author and subject.

During the cataloging procedure, the description of the subject is derived from standardized terms, or controlled vocabulary for searching online catalogues. MeSH is the controlled vocabulary thesaurus of the National Library of Medicine. It consists of descriptive terms organized in a hierarchy of varying levels of specificity. Examples of MeSH subject headings include: medicine; medical oncology; radiation oncology, and, radiology (U.S. National Library of Medicine, 2014). Key word terms are additional descriptors, or significant words, that appear in the resource’s title, abstract, subject headings, or text. These descriptors improve the search process. Through the bibliographic expertise of library and information science professionals, resources are organized in a manner that provides users with a variety of access points to locate resources.

Another mode of organizing information resources is through electronic databases. Similar to online catalogs, databases can be searched using bibliographic information. Online catalogs contain only periodicals. Discipline specific databases have a narrow focus. Specialized databases permit access to information in related subject areas. Databases that specialize in medical publications and scholarly journals include MEDLINE, PubMed, and CINAHL Complete. Point-of-care databases provides access to resources to guide clinical decisions. Up-to-Date is one example of this type of clinical database. It offers reviews of topics by recognized, peer reviewed experts who synthesize and summarize the evidence for the target audience of medical staff.

Diffusing knowledge for utilization. Acts of creating, disseminating, and organizing quality assurance and radiation safety publications do not guarantee they will be used to improve patient care (Genuis, 2007). The value of new knowledge created through research ascends not from simply making it available but when research is internalized and used. In the case of new research about radiation oncology, to improve the safety of radiation therapy treatment, the cancer care team must internalize and use the new quality assurance and safety research that has been created in recent years.

Quality assurance and radiation safety innovations diffuse in the minds of scholars and practitioners through a variety of educational networks. Doctorate level medical and physics educational programs are primary sites where research is read and studied, and information becomes knowledge added to the intellect of students. Diffusion (internalizing) extends beyond unilateral dissemination (spreading) of information. Knowledge diffusion is the point in the information transfer cycle where new knowledge is actively processed and produces changes in thinking and behavior (Lomas, 1993).

Knowledge processing activities, also known as diffusion of information, are essential in the preparation of future medical professionals. Radiation oncologists and medical physicists lead quality assurance and safety efforts of a radiation oncology department. For this reason, it is vital that graduates of professional programs possess the knowledge to develop an effective quality management program. Educational programs for radiation therapists are important points for diffusion of information to occur. Radiation therapists are the last stop before a radiation dose is delivered to a patient. A strong understanding of quality assurance and radiation safety fundamentals prepares student radiation therapists to think critically about clinical practice. What is taught and learned in educational programs is extended through professional organizations. Professional organizations assist in the diffusion of information process by hosting collaborative workshops, panel discussions, summer class sessions, and other opportunities that actively engage radiation oncology professionals in the learning process.

Use of diffusion and dissemination terminology seems to vary in publications about information transfer, but what is clear is that the transfer of new knowledge involves an awareness-building form of communication and a more intricate communication intended to change thinking and behavior (Lomas, 1993). The later requires the synthesis of new knowledge to create a unified understanding of the information, this describes the diffusion stage of the information transfer cycle.

Unfortunately, the translation rate of medical research conclusions and finding to clinical practice appears to be suboptimal. Reasons for modest diffusion outcomes in healthcare include economics, fragmented structure of professional organizations, and massive quantities of published research (Nieva et al., 2005). Another critique indicates that research is not contextually situated, which makes the application of research findings more difficult for practitioners (Genuis, 2007). The delivery of quality health care depends on timely access to information about the patient and medical evidence. Through partnerships among clinicians and medical librarians, timely access to better evidence can increase the rate of medical research translation and enhance patient care (Zipperer, 2004). Medical librarians and libraries are central in the social process necessary for communication of findings and conclusions in medical research.

One way to explain acceptance of new research-based information is using diffusion of innovation theory. Diffusion of innovations theory refers to an intentional social process through which an innovation, or new idea, is communicated to reduce uncertainty surrounding the decision to adopt, or reject, it (Rogers, 2003). Diffusion, as defined by Rogers (2003), is “the process by which an innovation is communicated through certain channels, over time, among the members of a social system” (p. 11). The theory of information transfer by Greer, Grover, and Fowler (2013), also identifies the social nature of information transfer asserting that social groups share a conception of reality. This shared view influences the various stages of the information transfer cycle. According to Lomas (1993), the complexity of diffusion is attributed to the social nature of the process; successful diffusion hinges on effectively addressing social barriers.

Research on the topic of diffusion of innovation employs educational philosophy and theories such as constructivism, generative learning theory, and adult learning theory as means of investigating acts of accepting or rejecting innovations and improving the outcomes of the diffusion process. Constructivism (Burger & Luckmann, 1990) identifies learning as an active process in which prior knowledge and experience provide a framework for assimilating new information. Kuhlthau (2004) presents a constructivist view of the information search process involving a series of stages individuals experience as they move through an active process of searching for information. Generative learning theory is closely related to constructivism as it draws on the use of prior knowledge to gain understanding of a new innovation or idea (Buttolph, 1992). Adult learning theory, developed by Knowles (1972), underlines the value of the learning process. This theory describes adult learners as internally motivated to learn relevant concepts to which they can bring their prior experience and knowledge to solve problems. These learning theories acknowledge the social essence of diffusion of information and offer rationale and guidance for the transformation of information into actionable knowledge.

Diffusion and utilization research findings identify ideal conditions for success. The diffusion of innovations theory evaluates the qualities of an innovation based on how a potential adopter perceives the relative advantage, compatibility, complexity, trialability, and observability of the innovation (Rogers, 2003). Except for complexity, each quality has a direct relationship with rate of adoption.

In addition to educational programs and related professional networking activities, interpersonal communication channels play a significant role in the success of diffusion of research findings. Evidence indicates the subjective evaluation of an innovation through communication among a homophilous community surpasses the influence of objective evaluation (Rogers, 2003). This applies to the medical community because it is a social structure within which peers influence the adoption or rejection of new ideas (Lomas, 1993). The strategic use of opinion leaders, or local knowledge brokers, serves to improve diffusion rates. Successful diffusion depends on the degree to which potential adopters perceive opinion leaders as credible (Rogers, 2003). Roger's assertion about subjective evaluations in the adoption of innovation process points to the importance of use of credible sources of authority.

It is not only important for the opinion leaders to be respected, the information source must also be perceived as credible by potential adopters. In the medical environment, this means the research design, methodology and outcomes must be sound. The competence and creditability of the source presenting the opportunity for new knowledge is also important to the success of diffusion as is tailoring the information into user-friendly packages within relevant clinical context (Lomas, 1993).

While there is much to indicate that opinions about an innovation transmit primarily through homophilous networks within a social system, the adoption rate of an innovation improves as communication extends to heterophilous communities. This is supported by Granovetter's (1973) ideas about the strength of weak ties. He posits that weak ties allow innovations to diffuse to a greater number of people at greater social distances. The strength of a tie is based on the length of time, emotional intensity, degree of intimacy, and reciprocity of the tie (Granovetter, 1973). The idea is that communication of an innovation must extend beyond a closed network, otherwise the diffusion efforts will have a finite influence. Achieving diffusion at greater social distances increases the chance of the diffusion reaching critical mass. Critical mass is the point at which the innovation has diffused enough to be self-sustaining (Rogers, 2003). This is an important milestone of diffusion.

Preservation and deletion of research. The final stages of the information transfer cycle are preservation and deletion of research reproductions. Quality assurance and radiation safety research is preserved and archived within university and medical libraries as well as at websites of professional organizations. The preservation of knowledge is essential to providing access to future information seekers (Greer, Grover & Fowler, 2013). For example, the preserved research is used in the training of radiation oncologist, medical physicists, and radiation therapists to ensure seminal articles and advancing research are placed in the hands of these future practitioners.

As quality assurance and radiation safety research loses relevancy, or fails to align with the mission of the information system, resources are removed. This, too, can be a budgetary decision. Academic journals and professional organizations like the American College of Radiology have defined parameters that are followed to retire, or sunset, scientific resources.

Conclusion

The commitment of all healthcare professionals is to do no harm. To accomplish this pledge in radiation oncology many factors must be considered. The continual creation of new knowledge beginning with research that asks applicable questions is necessary to inform the constantly evolving practice of radiation therapy. Research publication must provide a combination of statistical and narrative data to inform radiation therapy processes and to build knowledge relevant to isolation of high-risk activities. While quantitative research is essential to diagnosis and treat disease and illness, quantitative research alone is insufficient for informing clinical practice without the addition of qualitative research that investigates human and social issues. To achieve this new level of influence that will improve clinical practices and better support safe and accurate care of cancer patients, intentional, persistent and strategic steps must be taken to change scientific priorities. The information transfer cycle provides a framework that can be used to pin-point where changes can and must occur.

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