Optimizing Technology Development and Adoption in Medical Imaging Using the Principles of Innovation Diffusion, Part I: Theoretical, Historical, and Contemporary Considerations

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Abstract The pioneering work performed in the social sciences on diffusion of innovation can be applied to medical imaging and shed valuable insights as to how innovation is analyzed and adopted within the population of end-users. Successful innovation must take into account unique stakeholder differences, changes in communication and social interactions, and shifting priorities in market economics. The dramatic changes currently underway in current medical imaging practice provides unique innovation opportunities to those individuals and companies which can utilize this knowledge and effect change in objective and reproducible means. Successful innovation should rely upon data-driven objective analysis, which can scientifically validate the inherent strengths and weaknesses of the innovation, when compared with the idea or technology it supercedes.

Keywords Innovation · Technology development · Data mining

There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new order of things.

Niccolo Machiavelli, *The Prince*

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Introduction

Adoption of a new idea, process, or technology is difficult, even when it can be demonstrated that the proposed innovation has objective and reproducible advantages over its predecessor. Innovation adoption typically takes place over years and can be understood through the scientific principles of “diffusion of innovation,” which can be applied to any technology or industry, including medicine. Technology is the lifeblood of medical imaging, and as a result, medical imaging is highly dependent upon innovation for its survival [1]. This innovation can be directed at any of the individual steps in the medical imaging cycle, which begins with exam ordering and ends with report communication. To date, innovation within medical imaging has been variable, with some steps such as image acquisition undergoing fundamental and repetitive innovation while other steps such as reporting remaining relatively quiescent for decades.

One common element that exists in all individual steps and permeates the collective medical imaging process is data, which can be numerical, pictorial, graphical, or textual in form. Any successful innovation or new technology development in medical imaging is dependent upon these data, whether these are numerical data related to radiation dose reduction, pictorial data related to image acquisition, graphical data related to contrast administration, or textual data related to report construction. The analyses of these data (i.e., data mining) lie at the core of evidence-based medicine, which is arguably at the core of contemporary medical innovation.

Successful adoption of innovation in medicine is often problematic and dependent upon a number of variables apart from the technology itself. Lessons can be learned through the scientific principles behind innovation diffusion

in order to understand challenges, identify potential points of conflict, and strategize successful implementation strategies. These timeless lessons transcend time and often prove the difference between adoption success and failure.

Historical Review

The earliest scholarly study of innovation diffusion was published by Gabriel Tarde in 1903 [2], which described the classic S-shaped curve in the rate of innovation adoption, along with the role of social status and opinion leadership.

Four decades later, two social scientists studying the adoption of hybrid seed corn among Iowa farmers published a seminal work on the diffusion of innovation [3]. The authors, Ryan and Gross, postulated five distinct groups of innovation adopters based upon economic status, risk tolerance, social interactions, and data assimilation (Table 1). The fastest adopting group was categorized as “innovators,” and these were an extremely small subset of the end-user population who tended to be adventuresome, extremely risk-tolerant, and socially disconnected. It was the interaction between the innovators and the second group, the “early adopters,” that allowed for these new technologies to become assimilated into the population at large. The early adopters served as opinion leaders who learned from the socially wayward innovators and in turn shared this vital information with their mainstream colleagues, largely by means of their well-formed social connections. In turn, the third and fourth groups, labeled as the “early and late majority,” incorporated these new technologies into their everyday business practices. Before adopting these technologies, however, they required a sense of personal trust due to their relative distrust of strangers and scientific theory. These majority groups utilized local learning channels for education and tended to be risk averse due to their conservative mindset and limited economic means. The fifth and final group was classified as traditionalists (or laggards) and was far and away the last group to embrace new technologies. Their reference point was largely in the past, and they served to remind their peers of past failures and the economic losses resulting from “untested technologies.”

Innovation diffusion theory in medicine came of age as the result of a study on the adoption of a new drug, tetracycline, which was performed by a group of Columbia

University researchers [4]. This analysis confirmed the fact that adoption followed an S-shaped curve and that interpersonal networks played a critical role in technology adoption. Physicians with a greater number of interpersonal networks tended to adopt the new drug more quickly than those without, proving that innovation diffusion is largely determined by social processes.

Rogers [5] went on to describe the five major stages of innovation adoption (Table 2).

Knowledge occurs when an individual learns of the existence of a particular innovation. *Persuasion* occurs when the individual forms a favorable or unfavorable attitude toward the innovation. *Decision* occurs when the individual engages in activities which lead to a chance to either adopt or reject the innovation. *Implementation* occurs when the individual puts the innovation into use. *Confirmation* occurs when an individual seeks reinforcement of an innovation decision already made, which may lead to a reversal of the original decision.

Predictors of Success

Rogers also introduced the perceived characteristics of innovations, which affect the overall success and rate of adoption (Table 3).

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes. While an objective advantage is beneficial, it is less important than the subjective perception of an advantage. The greater the perceived advantage of an innovation, the more rapid is its rate of adoption.

Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs to the adopting community. One must keep in mind that if the adopting community is heterogeneous in composition, the perception of compatibility may vary among different constituent groups.

Complexity is the degree to which an innovation is perceived as being difficult to understand and use. New ideas or technologies which are simple to understand are adapted more rapidly than innovations requiring new skills and understanding.

Triability is the degree to which an innovation may be experimented with on a limited basis. An innovation that is

Table 1 The five categories of innovation adoption

1. Innovators
2. Early adopters
3. Early majority
4. Late majority
5. Laggards (traditionalists)

Table 2 Five steps in innovation adoption

1. Knowledge
2. Persuasion
3. Decision
4. Implementation
5. Confirmation

Table 3 Predictors of innovation success

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1. Relative advantage
 2. Compatibility
 3. Complexity
 4. Triability
 5. Observability
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triable represents less uncertainty to the individual considering its adoption as it is possible to learn by doing.

Observability is the degree to which the results of an innovation are visible to others. The easier it is for potential adopters to directly observe innovation results, the greater the likelihood of adoption.

Innovation success can therefore be summarized by the following two statements:

1. An innovation has to be advantageous, compatible with the existing values and the needs of the adopting community, and simple to use.
2. An innovation which can be experimented with on a limited basis and is visible to others has a higher degree of adoption success.

Applicability in Contemporary Medical Imaging Practice

Most innovation in medical imaging tends to be incremental in nature, aimed at the modification or improvement of an existing technology. This tendency toward incremental innovation is largely due to market forces and the relatively risk-averse nature of large technology providers [6]. Simply stated, most vendors want to be able to accurately predict a return on investment for a proposed innovation, and in the absence of an established market (i.e., sales) for the technology, this becomes difficult to quantify.

On occasion, an innovation is groundbreaking, offering a uniquely different and new approach to performing a given task or process. Examples of such innovations in medical imaging include the creation of a new image acquisition technology (e.g., MRI), transition from analog to digital imaging data (e.g., PACS), and creation of new reporting transcription technologies (e.g., speech recognition). In all of these cases, the innovation offered improved deliverables; which could take the form of quality (e.g., improved diagnosis), workflow (e.g., automation), or timeliness (e.g., report turnaround time). In order for the innovations to achieve success, it is essential that the innovation provides measurable and reproducible improvements over its predecessor and is compatible with the values and needs of the adopting community of end-users.

As one postulates future innovation opportunity in medical imaging, it is important that the scientific principles

of innovation diffusion be considered and incorporated into the product development and adoption process. This requires an understanding of the differences and similarities of the end-user population, which can differ according to occupation, education/training, clinical experience, computer proclivity, practice type, and personality. In order to achieve a widespread adoption within a large and diverse population of end-users, the innovation must be perceived as having workflow, quality, or economic improvement while also possessing some degree of adaptability and flexibility in order to accommodate to end-user variability.

While the importance of social interactions has been historically established in innovation adoption, a number of unique changes must be considered in the current market. In medical imaging, the transition from analog to digital practice has produced profound changes in interpersonal communication. As imaging data have become widely accessible, physicians no longer are required to travel to the imaging department to access imaging and report data, resulting in decreased physician-radiologist consultations [7]. At the same time, the digitization of medical imaging has led to the emergence of teleradiology, which has provided improved quality of life for the radiologist community while also producing new commoditization and outsourcing pressures on service delivery [8]. As radiologists have become more isolated from their clinician colleagues, it has become apparent that new practice strategies are required to ensure that radiologists are seen as valuable and indispensable contributors to patient care.

While medical imaging and information system technologies have produced alterations in professional social interactions, social networking technologies and the Internet have also had a profound impact on communication. The ability to communicate on a 24/7 basis has dramatically transformed expectations on practice deliverables, with healthcare consumers expecting enhanced communication with their care providers, improved access to medical data, and greater involvement in clinical decision making. This has led to the creation of a number of new technologies which provide patients with single-source storage of individualized electronic medical data and decision support (www.healthvault.com; www.google.com/health)

Technology innovation in healthcare will continue to focus on data mining, which offers opportunities to improve workflow, quality, safety, and economics. In medical imaging, innovation possibilities extend throughout all steps in the imaging cycle including exam ordering, image acquisition, data retrieval, image processing, quality assurance, interpretation, reporting, and communication. This newfound ability to automate data collection and analysis in real time not only decreases the development time requirements for innovation but also changes the way a given innovation is observed and analyzed for predictability of

success. This will have a profound impact on the success of a number of quality-oriented healthcare initiatives such as evidenced-based medicine (EBM) and pay for performance (P4P). The same data-driven analytics which provide the requisite infrastructure for EBM and P4P will also create new innovation opportunities for automated feedback and alerts, customizable education, workflow automation, computerized decision support, and clinical outcomes analyses.

Conclusion

The pioneering work performed in the social sciences on diffusion of innovation can be applied to medical imaging and shed valuable insights as to how innovation is analyzed and adopted within the population of end-users. Successful innovation must take into account unique stakeholder differences, changes in communication and social interactions, and shifting priorities in market economics. The dramatic changes currently underway in current medical imaging practice provide unique innovation opportunities to those individuals and companies which can utilize this knowledge and effect change in objective and reproducible means. Successful innovation should rely upon data-driven objective analysis,

which can scientifically validate the inherent strengths and weaknesses of the innovation, when compared with the idea or technology it supercedes. By reading the proverbial tea leaves and identifying new and emerging trends in medical practice and economics, innovation opportunity is perhaps greater today than ever before.

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