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Application of Innovation Economics to Medical Imaging and Information Systems Technologies

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Introduction

The practice of medicine has become extremely technology dependent, and this is especially the case for radiology [1]. Advances in medical imaging and information systems technologies have transformed radiology practice through the creation of new medical imaging techniques (e.g., molecular imaging), data delivery and presentation [e.g., picture archival and communication system (PACS)], and clinical decision support (e.g., CAD). Yet, despite the long-standing history of medical imaging and information technology (IT) innovation, the past few years have been relatively barren. This recent lack of innovation has led to a trend towards commoditization, which is particularly evident in information system technologies, such as PACS and RIS, which just a decade ago, were viewed as groundbreaking and innovative technologies [2]. The recent economic decline has served as a deterrent to R & D expenditures, further perpetuating the cycle of innovation decline [3]. In order to combat this trend in declining innovation, it is necessary to understand the principles of innovation, learn from past successes and failures, and proactively apply this knowledge to ongoing trends in medical practice and economics for guiding future innovation.

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Classification Schema

Innovation can be classified according to the type, degree of novelty, and nature of the innovation [4–8]. The four *types* of innovation include product or service innovations, process innovations, marketing innovations, and organizational innovations. From the perspective of individual radiology end users (e.g., technologists and radiologists), product and service innovations are of greatest importance, since they have the greatest impact on job performance and healthcare economics. The three degrees of *innovation novelty* include innovations which are new to the firm (or institution), new to the market, and new to the world. The three classical types of innovation *nature* are incremental, radical, and disruptive. These three innovation categories tend to be the most commonly referred to when discussing innovation in medical technology and will be the focal point for further discussion in this article. Incremental innovations are by far the most common form of medical technology innovations and build on existing knowledge [9, 10]. Radical innovations produce fundamental changes in products, services, or processes [11, 12]. Disruptive innovations change the very basis of practice through breakthrough and transformational change [13]. It is safe to say that conventional medical imaging and IT vendors primarily focus on incremental innovations because they tend to be easily to quantify, are less risk averse, and easier to market. From the technology vendor's perspective, innovations can impact business in three principle ways. They can cannibalize existing business, create new markets, or disrupt (i.e., steal) market share from competitors.

Invention Is Not Innovation

The innovation process typically consists of two separate and distinct components: invention and implementation. Invention represents the creation of new knowledge or ideas, which leads to creation of intellectual property (IP), which becomes patentable. While companies traditionally place great financial value on IP, the ability to generate remuneration from IP requires sales/licensing agreements to third parties or litigation (for patent infringement).

Traditionally, inventions are commonly derived from universities and research institutions, which in turn transfer the IP to commercial entities (i.e., industry), which possess the ability to commercialize the idea into a product (i.e., implementation). In reality, the majority of inventions do not become innovations, even by companies with large IP portfolios and superb R & D teams. A case in point of a company with great inventions but lacking in implementation can be found with Xerox's famous Palo Alto Research Center (PARC), which was the first company to develop a personal computer, graphical-oriented monitor, word processing software, workstation, laser printer, local area network, and handheld mouse. While the inventions derived from this venture were inspiring and impressive, the lack of commercialization resulted in shocking lost opportunity. Competitors such as Apple, IBM, Hewlett-Packard, and Microsoft exploited the ideas from Xerox PARC into their own successful technologies, proving that a good idea does not represent innovation unless it is successfully developed into a commercialized product.

The First Mover Advantage Theory

This theory states that the first company entering a new market will gain market share and as a result of this newfound competitive advantage will be able to defend its leadership position over new entrants [14]. This theory has been promoted by Andy Grove, the former CEO of Intel who said, "the first mover and only the first mover, the company that creates while others dither, has a true opportunity to gain time over its competitors, and time advantage is the surest way to gain market share."

While this theory was accepted in the past, the new industrial model has changed the rules of innovation and market economics. Before the Internet, companies which were first to enter a market had a distinct advantage over their competition, and through continuous technology refinement could predictably prosper. With the advent of the Information Age, rapid innovation has changed market dynamics, with success less dependent upon first to market, but more predicated by the nature of the innovation. Companies like Google, Facebook, Apple, and Amazon have exploited quality deficiencies in existing service or product deliverables through successful innovation to rapidly steal market share and gain economic dominance in a relatively short period of time. The long-term success and continued economic viability of these companies will depend upon continuous horizontal and vertical innovation. There are many examples of companies that have failed to take advantage of their first mover advantage status and failed to continuously innovate, perhaps the most glaring example is Kodak, which was first to market with the digital camera, yet failed in its commercialization efforts. In the end, Kodak squandered its first mover advantage, extensive IP portfolio, and decades of market leadership to the point of becoming insolvent. What was once a company of tremendous innovation, became an also ran, largely due to its inability to adjust to changing market dynamics and consumer expectations.

Does Superior Technology Always Win?

While visionary ideas and engineering execution are required to create radical innovation, the economic success of this innovation is never guaranteed. This requires marketing skill and expertise in order to convince the marketplace that the innovation has merit. At the same time, continuous product or service refinement is necessary to ensure that the innovation remains viable and superior to the competition.

An example where radical innovation and introduction of a superior technology was eclipsed by the competition can be illustrated with computer-assisted tomography (CT), which was first introduced in 1972 by EMI, a British firm that successfully patented all the key knowledge and intellectual property. One would think that the creation of a truly innovative technology with patent protection would insulate the company and its products from external competition and provide long-term market success.

After a few years of commercialization, other medical imaging equipment manufacturers entered this new and emerging market, realizing the vast economic potential. EMI believed it was relatively immune to external competition due to its first mover advantage, superior technology, and intellectual property protection. A competing company [General Electric (GE)] realized that it could not successfully compete based upon image quality, so it decided to change the dynamics of competition, by focusing on technologist productivity through increased CT scanner speed. This was a savvy response to evolving workflow demands in the medical imaging community, which at the time was being challenged to increase patient throughput and revenue by decreasing exam times. After a few years, GE was successful in usurping the competitive advantage EMI had initially established and

became the market leader in CT technology. The lesson to be learned is that innovation and superior technology do not guarantee long-term market success. While successful innovation creates a unique opportunity for a company and its products, understanding the customers' needs and evolving changes in the market are essential for continued economic success. In order to be successful over the long term, innovation must be dynamic, continuous, and superior to its competition.

Innovation and the End User

In addition to serving as the consumer of the commercialized innovation, end users also play a vital role in providing feedback and guidance with respect to R & D, commercialization strategy, and product refinement. While often simplistically viewed as a homogeneous group, end users are in fact quite heterogeneous. From a marketing perspective, end users can be simplistically divided into three distinct groups: users, purchasers, and influencers [15]. In order to be economically viable, an innovation should appeal to all three groups; each of which has its own priority system. For medical imaging, user groups (e.g., community practice radiologists and technologists) tend to primarily view innovation from a workflow perspective, while purchaser groups (e.g., radiology and hospital administrators) view innovation primarily from an economic perspective, and influencer groups (e.g., academic radiologists and researchers) often focus on quality. An example of a successful IT innovation which accomplished all three priorities is PACS, which has been shown to improve workflow and productivity, decrease operational costs, and improve quality [16–18].

In an attempt to gauge the economic viability of a proposed innovation, many companies will seek out the opinions of potential customers through focus, user, and advisory groups. The problem with this approach, however, is that users tend to focus on the “here and now” [19, 20]. They predicate their thoughts and opinions based upon their existing needs and experience (i.e., in the present), as opposed to future requirements, which could be far different from the conventional norm. As a result, the utility of user feedback is largely limited to incremental innovation, which is primarily focused on relatively small and predictable refinements to existing products or services. If one was to provide users with a novel idea which extends outside of their comfort and knowledge zones, it will in all likelihood be rejected, in lieu of maintaining the status quo (which provides some level of comfort and assurance). As a result of this bias against novelty, radical and disruptive innovations are often initially rejected [21]. Short of empirical evidence as to the derived benefits of the proposed innovation, even early adopter end users will be hesitant to embrace radical or disruptive innovation. Simply stated, proposed innovation which goes beyond one's frame of reference is often subject to rejection and as a result may not achieve commercialization without a powerful champion willing to buck conventional thought.

In the current consolidated and mature market of medical imaging and IT vendors and economically challenging times, most companies have become largely risk-averse [22]. With shrinking R & D budgets and focus on the near-term economic bottom line, this has led to an environment largely focused on incremental innovation [23]. The end result is that radical and disruptive innovations which previously served to drive change and prosperity have been relatively quiescent; contributing to the commoditization of medical imaging technologies and services [2].

Incremental Vs. Radical Innovation

As previously stated, incremental innovation is the basis of what traditional medical imaging and IT companies use to foster technology development and refinement. By utilizing existing knowledge, resources, and products, the company creates and/or modifies its existing products or services to expand its market niche. Due to the fact that this type of innovation is synergistic with the existing status quo and company directives, it is considered to be *competence enhancing*. Incremental innovation provides an economic framework for established companies to continue to operate in a relatively safe (i.e., risk averse) manner, by maintaining and furthering its existing products and services. In doing so, incremental innovation tends to discourage any novel ideas or products which could potentially replace existing knowledge, resources, or products. The end result is the companies and its thought leaders tend to adapt a culture which promotes maintenance of the status quo, as opposed to a culture of creativity and novel thinking. If market conditions change requiring adoption of more novel ideas, these companies often compensate by externally purchasing these novel resources; through IP licensing, acquisitions, or external hiring of critical thought leaders. While this may in theory serve as a viable alternative to internal (i.e., organic) radical innovation, successful assimilation of these newly acquired novel resources is often problematic due to the preexisting culture of risk adversity and resistance to novel change. There are many examples of medical imaging and IT companies which adhere to this strategy; acquiring smaller and more innovative companies and then failing to assimilate the newly purchased knowledge and ideas into existing products and services. The end result is the stifling of radical innovation, perpetuation of the status quo, and lack of brand differentiation, which eventually can lead to commoditization.

Radical innovation, on the other hand, is *competence destroying* because it relies upon entirely new knowledge and/or resources. The status quo is no longer prioritized and instead becomes sublimated in favor of new, novel, and unconventional ideas. By its very nature, radical innovation tends to be risky, independent of existing resources, and involves large-scale technological advancements. If successful, radical innovation will likely render existing products and services which are noncompetitive and even obsolete. This fear of cannibalizing one's existing products and services is a principle factor in encouraging larger, traditional companies in rejecting radical innovation, until it has a proven and established place in the market. Smaller companies seeking to gain market share (and with less to lose) tend to embrace radical innovation by fostering a culture receptive to new and divergent ideas and relatively devoid of rigid bureaucracy.

A relevant example of two companies whose market success went in entirely different directions based upon innovation strategies are Kodak and Apple. After dominating the photography market for several decades (and once perceived as a radical innovator), Kodak became steeped in a culture of risk adversity and was captive to its existing products, bureaucracy, and internal resources. As the photography market underwent fundamental change with the shift from analog to digital technology, Kodak struggled in spite of its vast IP. Competitors to Kodak began to steal market share and customers, while Kodak failed to adapt and innovate. The last asset of value was its IP portfolio, which had been squandered and underutilized in new product creation.

Apple, on the other hand, was a company which went from boom to bust to boom, in a matter of a few years, due to its ability to reinvent itself through radical technology innovation and a risk-embracing culture. The commercialization of the original Apple computer (which in large part stole many novel ideas from Xerox PARC) represented a radical innovation; transforming the company from a fledgling, garage-based entity to an industry leader, which was seen as an extension of the evolving counterculture. Over the next few years, the company became relatively complacent, reliant on its existing products, and conventional in its corporate culture. After falling behind its competition including IBM and approaching bankruptcy, the company reinvented itself through radical innovation, in the process transforming the telephone, tablet, and music industries. Ironically, in the course of this radical innovation and transformation, Apple went from solely creating products to a company that created both products and services. While doing so, it also created a mystique and unique brand differentiation, allowing it to charge higher prices than its competitors, furthering its profit margins.

Future Trends and Innovation Opportunities

If we want to define innovation opportunities in medicine, we should begin by identifying ongoing and future trends. These trends include personalized medicine (i.e., genetically focused diagnosis and treatment), computerized decision support, quality-centric economics, patient empowerment, telemedicine, social networking and gaming, and medical nanotechnology. A common denominator for all of these trends is data, which will utilize large databases to perform real-time analytics to facilitate improved disease prevention, diagnosis, and treatment. At the same time, this diverse medical data can be used to create customizable and multidisciplinary applications for healthcare providers, consumers (i.e., patients), and payers.

Since nature abhors a vacuum, the current environment of passive incremental innovation will likely be replaced by one of aggressive and radical innovation. The conventional medical imaging and IT vendors who have been reluctant to embrace radical innovation will in all likelihood be subjugated by companies who have established cultures of innovation in data mining and analytics outside of the medical domain. Companies like IBM, Microsoft, and Google have already begun to implement medical data warehouses, artificial intelligence applications, and data analytics. In the absence of radical innovation by the "traditional" medical imaging and IT companies, these data-centric companies will continue to expand their purview in order to grow their markets and profit centers.

The prerequisite for these large-scale data analytical tools will be the standardization of medical data. At the present time, traditional medical imaging and IT vendors maintain a distinct innovation advantage due to the fact that existing data are largely non-standardized and proprietary in nature. In addition, these traditional medical imaging and IT companies produce data-generating technologies throughout the various steps in the medical imaging cycle. Once this data become standardized and are no longer proprietary, the opportunity for these "non-traditional" vendors to exploit this existing superiority in data mining and analysis will expand, opening the door to innovation from non-traditional companies. The resulting data-driven innovation opportunities will expand in a number of areas including automated quality assurance [24], context and user-specific automated workflow [25], data reconciliation [26–29], quality and radiation safety scorecards [30, 31], disease-specific social networks [32], gaming [33], and customizable education and training [34].

Another potential source of future innovation is the large and diverse group of clinical users, which have the potential to become a valuable (and currently underutilized) source of medical imaging and IT innovation. These are the professionals who best understand where existing clinical inefficiencies

exist and can reliably predict how future technology development can improve existing quality, safety, and workflow limitations. The clinical entities which have access to large data pools and internal IT resources could in theory utilize this data access and internal clinical knowledge to their advantage through "in house" or internal innovation. This could occur on a small-scale basis within individual hospitals or group practices or extend to large service providers, such as integrated healthcare networks, health maintenance organizations, and large teleradiology groups (who provide clinical service and have access to data from hundreds of medical imaging providers).

These alternative sources of innovation provide a more likely source of radical innovation than their traditional counterparts, due to the fact that they have no legacy products to support. In the end, the marketplace and its end users will determine the intrinsic value of innovation, irrespective of the innovation source.

References

1. Reiner BI, Siegel EL, Siddiqui K: Evolution of the digital revolution: a radiologist perspective. J Digit Imaging 16:324–330, 2003
2. Reiner B, Siegel E: Decommoditizing radiology. J Am Coll Radiol 3:167–170, 2009
3. Reiner B: Radiology report innovation: the antidote to medical imaging commoditization. J Am Coll Radiol in press, 2012
4. Saren MA: A classification and review of models of the intra-firm innovation process. R & D Manage 14:11–24, 1984
5. Malerba F, Orsenigo L: Schumpeterien patterns of innovation are technology-specific. Res Policy 25:451–478, 1996
6. Popadiuk S, Choo CW: Innovation and knowledge creation: how are the concepts related? Int J Inform Manage 26:302–312, 2006
7. Aberanthy WJ, Utterback JM: Patterns of industrial innovation. Technol Rev 80:40–47, 1978
8. Johne FA, Snelson PA: Success factors in product innovation: a selective review of the literature. J Prod Innovat Manag 5:114–128, 1988
9. Ali A: Pioneering versus incremental innovation: review and research propositions. J Prod Innovat Manag 11:46–61, 1994
10. Ettlie JE, Bridges WP, O'Keefe RD: Organization strategy and structural differences for radical versus incremental innovation. Manage Sci 30:682–695, 1984
11. Hall JK, Martin MJC: Disruptive technologies, stakeholders and the innovation value-added chain: a framework for evaluation radical technology development. R&D Manage 35:273–284, 2005
12. Lettl C, Herstatt C, Gemuenden HG: Learning from users for radical innovation. Int J Technology Management 33:25–45, 2006
13. Hwang J, Christensen CM: Disruptive innovations in healthcare delivery: a framework for business-model innovation. Health Affair 27:1329–1335, 2007
14. Kerin RA, Varadarajan PR, Peterson RA: First-mover advantage: a synthesis, conceptual framework, and research propositions. J Marketing 56:33–52, 1992
15. Kim WC, Mauborgne R: Blue ocean strategy. Harvard Bus Rev 82:76–84, 2004
16. Reiner BI, Siegel EL, Carrino JA: Workflow optimization: current trends and future directions. J Digit Imaging 15:141–152, 2002
17. Siegel EL, Reiner BI: Workflow redesign: the key to success with PACS. AJR 178:563–566, 2002
18. Reiner BI, Siegel EL, Hooper FJ, et al: Radiologist productivity in the interpretation of CT examinations: a comparison of PACS with conventional film. AJR 176:861–864, 2001
19. O'Connor GC: Market learning and radical innovation: a cross case comparison with eight radical innovation projects. J Prod Innov Manag 15:151–166, 1998
20. Teece DJ, Pisano G, Shuen A: Dynamic capabilities and strategic management. Strategic Manage J 18:509–533, 1997
21. O'Connor GC, McDermott CM: The human side of radical innovation. J Eng Technol Manage 21:11–30, 2004
22. Reiner BI: Intellectual property in medical imaging and informatics: the independent inventor's perspective. J Digit Imaging 1:3–8, 2008
23. Reiner BI: Optimizing technology development and adoption in medical imaging using the principles of innovation diffusion. Part 1: theoretical, historical, and contemporary considerations. J Digit Imaging 5:750–753, 2011
24. Reiner BI: Automating quality assurance for digital radiography. J Am Coll Radiol 7:486–490, 2009
25. Reiner B: Automating radiologist workflow. Part II: hands free navigation. J Am Coll Radiol 11:1137–1141, 2008
26. Reiner BI: Medical imaging data reconciliation. Part 1: innovation opportunity. J Am Coll Radiol 9:622–625, 2011
27. Reiner BI: Medical imaging data reconciliation. Part 2: clinical order entry/imaging report data reconciliation. J Am Coll Radiol 10:720–724, 2011
28. Reiner BI: Medical imaging data reconciliation. Part 3: reconciliation of historical and current radiology report data. J Am Coll Radiol 11:768–771, 2011
29. Reiner BI: Medical imaging data reconciliation. Part 4: reconciliation of radiology report and clinical outcome data. J Am Coll Radiol 12:858–862, 2011
30. Reiner BI: Quantifying radiation safety and quality in medical imaging. Part II: the radiation scorecard. J Am Coll Radiol 9:615–619, 2009
31. Reiner BI: Quantifying radiation safety and quality in medical imaging. Part III: the quality assurance scorecard. J Am Coll Radiol 10:694–700, 2009
32. Tweet MS, Gulati R, Aase LA, et al: Spontaneous coronary artery dissection: a disease-specific social networking community initiated study. Mayo Clin Proc 86:845–850, 2011
33. Reiner B, Siegel E: The potential for gaming techniques in radiology education and practice. J Am Coll Radiol 2:110–114, 2008
34. Reiner B: Automating radiologist workflow. Part III: education and training. J Am Coll Radiol 12:1191–1195, 2008