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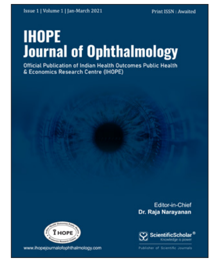

Review Article

Barriers and enablers for technology diffusion in ophthalmology at not-for-profit advanced eye care institute

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ABSTRACT

Managed care and insurance have penetrated ophthalmic services for patient care and continue to affect out-of-pocket spending related to eye care. In such a scenario, understanding technology diffusion is crucial from the perspective of both technology developers as well care providers. Should healthcare organizations choose cheaper technologies or the ones that can be quickly diffused? In this paper, we try to answer this question by reviewing technologies used in the past 10 years across different services in ophthalmology. We generate a framework that bifurcates technologies and provides nomenclature to them based on cost and speed of diffusion. Our work, within its limitations, can provide insights into contemporary technology producers and healthcare organizations.

Keywords: Technology diffusion, Ophthalmology, Health care

INTRODUCTION

Innovation is an idea, object, or practice that is perceived as new by an individual or unit that adopts it.[1] The spread of innovation can happen in two ways, either you let it happen or help it happen. Technology diffusion is a process in which the spread of innovation is helped to happen either by actors in the process, by the structure of the environment, or by the quality of technology itself.[2-7] In the case of health care, technology diffusion refers to the adoption of technology by the larger society of doctors or a group of hospitals.

The healthcare systems have continuously drawn flak for adopting technologies that are not cost-effective and drain out a major chunk of the GDP of a country. A major reason considered has been the adoption of costly technologies with poor outcomes.[8,9] The counterargument based on assumptive theory by Rogers (1995)[1] is that technology generally leads to better outcomes and it is the adoption and diffusion process which is at fault. Furthermore, it is well established that quicker technology adoption has led to the relative advancement of nations and societies, let alone hospitals or healthcare systems.[8] Thus, administration within health care faces a constant scuffle of decision-making between cost and diffusion.

Should healthcare organizations choose cheaper technologies or the ones that have quick diffusion? Unfortunately, technology adoption and diffusion have been poorly studied topics in health care and even more so in the field of ophthalmology. In this paper, we bring forth reasons why some technologies are swift and some are slow in diffusion, associated with their related cost-effectiveness, with a specific focus on technologies used in ophthalmology. For this, we reviewed certain newly introduced technologies from 2007 to 2017 to understand the current forces driving technology diffusion in ophthalmology. The past 5 years were excluded so the process of diffusion could be understood at a time when it had matured enough.

MATERIALS AND METHODS

Faculty members of a leading Indian eye care institute LV Prasad Eye Institute (LVPEI)[1] were consulted to select the ophthalmic technologies in question. These faculties were asked about newly introduced technologies, and the first five technologies they mentioned were considered for the study. Faculty members providing specialty eye care services within LVPEI were questioned to remove inherent individual biases. A technology was considered adopted when it had been purchased by the institute and diffused when it was being used by all faculty members of the service.

Quick diffusion was considered when the technology had been accepted by the individual hospital service within a year. Expensive was defined as a technology costing more to the doctor/hospital, the technologies were arranged in ascending order in terms of cost, and the categorization was done henceforth. The technologies were studied through databases of Google Scholar, PubMed, or Developers website. The research-related information was assessed through PubMed using an expanded version of the technology name along with "ophthalmology" as a keyword. The individual technologies were then grouped as swift or slow diffusers and expensive or economic technologies.

FINDINGS

In [Table 1], we describe in detail 10 technologies that were reviewed. We ensured a fair spread of technologies across departments in ophthalmology. Four of these could be used by the retina service, two by the glaucoma service, three by the cornea service, five by the cataract service, and two by the refractive service. We provide details of technology based on the eye service/s it is used on, year of innovation, value addition it provides, whether it is a software or hardware-based technology, place of origin, and research interest generated in published journals till the time of this review. We also provide specific remarks on the technology based on our personal experience in the last column of the table.[2]

In addition, in [Figure 1], we categorize these technologies in terms of diffusion and expense. To explain this framework, we explain one technology from each of the four categories generated in the two-by-two matrix in the below-mentioned sub-sections.

Case studies

Technologies that are costly and yet swift in diffusion are termed case studies. It is important to study these technologies and actors involved in its diffusion that made the diffusion super quick even when the technology was expensive. One such technology in ophthalmology is 3D display surgery[3]. This surgical technology shifts the previous surgery view from under the microscope to a 3D view on a routine screen, which has other software enhancements to enable fine surgical maneuvers. The main technological advantage is easy surgeon posture, surgery under high magnification, and utility as a creative teaching tool. Thus, it comes as a boon for high-volume academic eye care centers. Its utility across various services has also made it a quick diffuser despite its enormous initial costs making it a productive health economics case study.

In this table, we provide details of technology based on the eye service/s it is used on, year of innovation, value addition it

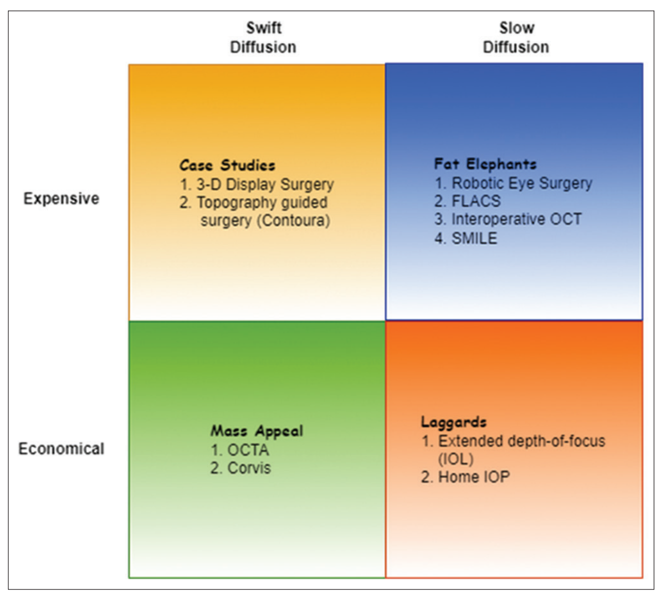

Figure 1: Technology categorization. In this figure, we categorize all the technologies under four categories based on cost and speed of diffusion.

1 Established in 1987, L V Prasad Eye Institute (LVPEI) is a comprehensive eye health facility with 198 vision centers in India. See https://www.lvpei.org

2 In Table A1 we provide information of change in cost with previous comparable technology. Out of the 10 technologies covered by us, only 5 have had predecessors where a useful comparison may be drawn

3 https://www.reviewofophthalmology.com/article/the-pros-and-cons-of-headsup-surgery

Table 1: Details of technologies.

Technology name (eye services)	Year	Value addition	Software/ hardware	Origin	Research interest	Author remarks
OCTA (retina)	2014	Non-invasive, repeatable and quick visualization of abnormal vessels that required resource-consuming invasive procedures before	Hardware	US	10,351	Technology has gone beyond the retina and is being utilized by other specialty services
Robotic eye surgery (retina/cataract)	2016	Higher precision surgery, overcomes surgeon's physiological tremors	Hardware	UK	270	Yet to be adopted and too expensive
Intraoperative OCT (retina/cataract/cornea)	2010	Provides OCT images at the time of surgery, objective knowledge of surgical planes	Hardware	US	599	Yet to be adopted. Most of the time tissue planes can be visualized but in many cases, where a plane determination is difficult it fails
Home IOP (glaucoma)	2017	Overcomes issues of compliance	Hardware	US	137	The useful device that reduces patients visits to physician
3D display surgery (retina/cataract/cornea)	2008	Provides magnification, ergonomically easier for the surgeon, improves teaching a lot	Both	US	39	Can be used by most ophthalmic surgeons
Corvis (cornea/glaucoma)	2013	Non-invasive tonometry in difficult situations and judgment of corneal biomechanics which were oblivious prior	Hardware	Germany	124	Introduced for glaucoma, now getting adopted for cornea
SMILE (refractive surgery)	2011	An alternative form of a non-essential surgery that is better for corneal sensations	Both	US and Germany	481	Less diffusion, technical difficulties as compared to LASIK, non-cost effective
Extended depth of focus IOL (cataract)	2016	An alternative to IOLs that have multiple focuses and can provide spectacle free outcomes	Hardware	US	91	Less diffused. Many companies exist and are yet not cost effective
FLACS (cataract)	2009	Precision partially laser-based cataract surgery	Hardware	US	400	Not cost-effective and diffusion pace is slow
Topography-guided surgery contoura (refractive surgery)	2016	Precision refractive surgery with better postoperative outcomes in terms of aberrations and visual quality	Software	US	156	Diffused in organizations based on profit

FLACS: Femtosecond laser-assisted cataract surgery, IOL: Intraocular lens, OCTA: Optical coherence tomography angiography

provides, whether it is a software- or hardware-based technology, place of origin, and research interest in published journals.

Fat elephants

Technologies under this category have eventually become fat elephants and need either removal of unwanted functionalities that are making it costly or better marketing mechanisms to get diffused quickly. For example, femtosecond laser-assisted cataract surgery (FLACS)[4] utilizes the laser in cataract surgery but can perform only some parts of the surgery

4 https://journals.lww.com/apjoo/Fulltext/2017/07000/Femtosecond Laser Assisted Cataract Surgery .15.aspx [5]https://eyewiki.aao.org/ Optical Coherence Tomography Angiography

Table A1: Change in cost of technology.

In this table, we compare the change in the cost of the studied technology with the existing comparable technology Change in cost is mentioned in terms of percentage		
Technology	**Comparable previous technology**	**Change in cost (%)**
OCTA	OCT	50
SMILE	LASIK	100
EDOF	Monofocal IOLs	150
FLACS	Conventional surgery	100
Topography-guided refractive surgery	Conventional surgery	20

FLACS: Femtosecond laser-assisted cataract surgery, IOL: Intraocular lens, OCTA: Optical coherence tomography angiography, EDOF: Extended depth of focus

using a laser, while most parts of the surgery including intraocular lens (IOL) implantation are done manually like the conventional surgery. This limits its diffusion as value addition is negligible. The technology proves to be very expensive both for the provider and the seeker, thus limiting its utility at any ophthalmologic healthcare center.

Mass appeal

Technologies that are economical and yet swift to diffuse certainly have a mass appeal. A famous example of such technology in ophthalmology is optical coherence tomography angiography (OCTA).[5] OCTA has provided ophthalmologists with a repeatable and non-invasive tool that allows repeated evaluations of blood flow in the eye. The previous technology, OCT, could not provide information on the blood flow but could only provide structure-related information. Before OCTA, dye injection-based fundus angiography was the only tool with a monopoly for this assessment, but it was cumbersomely invasive with morbid side effects, thus precluding frequent usage.

Overall, the technology of OCTA has provided a significant leap in terms of information that improves day-to-day decision-making. This innovation utility combined with a minimum increase in cost to end-user and an average cost hike for the provider is the selling point of OCTA. This has led to multiple research engagements of OCTA, which sets up virtuous diffusion cycles as research leads to more and improved usage, which leads to more research. Further, its usage has expanded beyond the initial usage in retina service. Hence, providing OCTA its mass appeal and quick diffusion.

Laggards

These are the technologies that despite being cheap could not get adopted. Reasons could be that these technologies are either outdated or difficult to use or unattractive to the users. An example of one such technology is EDOF: Extended depth of focus IOL[5]. This technology provides patients with spectacle-free vision after cataract surgery with lesser aberrations, which was impossible with conventional IOLs. Despite this advantage, its diffusion has been less due to the presence of competitor trifocal lenses in the market and "not-so-perfect" acceptance by the end users/seekers. This coupled with the >200% price increase for the seeker has made diffusion of this particular technology slow, despite the no-cost addition to the provider. Thus, it proves to be a laggard.

DISCUSSION

Technology diffusion refers to a macroeconomic event where technology spreads to a larger group of individuals, multiple units of individuals, or the general society. Technology diffusion has been termed as a complex socio-developmental process.[8,9] As per Rogers (1995),[1] there are five stages of technology adoption starting from innovation to early adopters, early majority, late majority, and laggards at the end. This is called Roger's bell curve, which goes in parallel to the "learning curve" associated with technology. In the context of ophthalmology, a contextual example may be the adoption of a newer system of the laser first by the innovator, then by the doctors surrounding and influenced by the innovator and last by the least motivated or least aware ophthalmologist.[10]

There are other factors influencing technology diffusion, namely, cognitive, emotional, and contextual concerns. In the case of an ophthalmologist and the hypothetical new laser system, cognition refers to social learning and social efficacy which drives decisions based on learning about the innovation in a laser from peer ophthalmologists and self-beliefs. Emotional refers to personality traits of a particular ophthalmologist that is inherent and influence decision-making based on past experiences related to laser systems. Finally, contextual refers to the environment for example a non-profit hospital where the laser is to be adopted.

The purpose of this paper is to highlight the reasons why in ophthalmology, some technologies are swift while others are slow to diffuse. Our work is not without limitations. Our viewpoints are limited to those of ophthalmologists working in one organization and are prone to subjectivity bias. Although LVPEI is one of the largest eye care institutes in India, it is non-profit in nature and thus viewpoints of doctors or technicians working there may be prejudiced. We also understand that we have not studied the marketing abilities of the technology-producing firms and heterogeneity existing on these lines could have an impact on its diffusion. Another limitation is the use of subjective methods for defining the technology engagement.

5 https://eyewiki.aao.org/Extended Depth of Focus IOLs

A prior analysis of cataract surgery in India has revealed that while the latest surgery had the highest procedure-related costs to a patient, the oldest surgery had the highest indirect costs.[11] Conversely, a study from our center showed both the direct and indirect costs to be higher with modern equipment in retinal detachment surgery.[12] Thus, with the evolution of technology, the contextual changes are very much applicable to resource-deficient LMICs in ophthalmic care, justifying the need for studies like the current one. Eventually, with changing prices and technological advancements such equations will alter and will both influence and also be influenced by technology diffusion.

CONCLUSION

Irrespective of these limitations, our paper tries to contribute to the literature by providing a framework where we categorize technologies based on cost and speed of diffusion. Technology-producing firms may use our framework to generate technologies that are cost-effective, taking in confidence health-care actors for swift diffusion. Health-care organizations, specifically related to ophthalmology, may use this matrix for the future adoption of technology that helps the patients most efficiently.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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