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The Effects of Emerging Technology on Healthcare and the Difficulties of Integration

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THE EFFECTS OF EMERGING TECHNOLOGY ON HEALTHCARE AND THE DIFFICULTIES OF INTEGRATION

by

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ABSTRACT

Background: Disruptive technology describes technology that is significantly more advanced than previous iterations, such as: 3D printing, genetic manipulation, stem cell research, innovative surgical procedures, and computer-based charting software. These technologies often require extensive overhauls to implement into older systems and must overcome many difficult financial and societal complications before they can be widely used. In a field like healthcare that makes frequent advancements, these difficulties can mean that the technology will not be utilized to its full potential or implemented at all.

Objective: To determine the inhibiting factors that prevent disruptive technology from being implemented in conventional healthcare.

Methods: Peer reviewed articles were gathered from Cumulative Index to Nursing and Allied Health Literature (CINAHL), Educational Resources Information Center (ERIC), Elton B. Stephens Co. Host (Ebsco Host), Medical Literature On-line (Medline), and Psychological Information Database (PsychINFO). Articles were included if written in English and focusing on technology that was or is difficult to implement.

Results: Research suggests that the primary reason disruptive technology is not implemented sooner is the cost versus benefit ratio. Those technologies with extremely high benefits that greatly improve efficiency, safety, or expense are integrated relatively quickly, especially if their cost is reasonable. Secondary reasons for difficulty with integration include ethical dilemmas, extreme complexity, technical limitations, maintenance, security, and fallibility.

Conclusion: Research indicates that a decrease in production cost and selling price along with removing any issues that may depreciate the technology will provide better incentives for healthcare systems to integrate disruptive technologies on a wider scale.

Dedication

For my Family for always telling me I could do anything.

For my mentor, Dr. Leslee D'Amato-Kubiet, for actually making sure I was doing the afore mentioned anything.

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INTRODUCTION

The integration of emerging and potentially disruptive technology into health care is often met with resistance to change and difficulty adapting to new electronic interfaces. Habit and algorithms previously learned by health care providers can hinder progressive technology that can potentially improve health information, documentation, and diagnostics. Technology frameworks change often and vastly; leading to difficulty integrating or updating the latest advancements into systems that are currently in place. An article in the *Harvard Business Journal (1995)* explains that new technology, which is particularly groundbreaking and difficult to accept, is often labeled "disruptive technology". The article describes new technology as often overlooked in its infancy due to customers being hesitant to leave the technology they have become accustomed to; usually after time this technology forges its own market and eventually surpasses its predecessors (Christensen & Bower, 1995). Also mentioned is the detriment of late adoption of new technology which creates a large amount of difficulty when integration into older systems finally becomes necessary or can lead to the generally negative option of simply missing the opportunity entirely and falling to the competition (Christensen & Bower, 1995).

The changing landscape of healthcare is no exception to challenging conditions for the adoption of new technology and is equally vulnerable to difficulty with integrating disruptive technology, often in the form of new diagnostic procedures and equipment, into active use in health care. Resistance to change and educating health care providers about the latest innovations in health care are two of the major burdens to the integration of new and disruptive technologies that can improve health care. Sweeping healthcare changes will be required and, being at the

forefront of technology, will make handling such a change a great deal easier (Pavel, et al., 2013).

Changes in the healthcare system affect all healthcare workers; however, since nurses are most often working with individuals seeking healthcare in a variety of settings, they will be exposed to the integration of new technology in their daily workflow more often. In an article by Carol Houston in *The Online Journal of Issues in Nursing (2013)* several specific aspects of emerging technology are mentioned as being hurdles for nursing care in the near future. The article makes mention of the following: genetics and genetic engineering, stem cells, more advanced diagnostic tools, 3D printing, robotics, Electronic Health Records (EHR's), and computerized order entry. Each of these topics presents unique advantages to the healthcare setting, but is also defined by limiting factors for the integration of new technology noted to be ethical, practical, or financial in nature. Research exploring how new technology and diagnostic testing is integrated into health care is of great value to the people that can have health benefits and improved quality of life from technology innovations.

PROBLEM

Healthcare has greatly evolved and improved in the last few centuries, adding to human life expectance and improving the population's health status. Many of the modern diagnostic and treatment procedures implemented today can result in negative and undesirable side effects leading to dangerous exposure to radiation or harmful drugs, call for excessive testing, or can lead to potentially lethal complications (Pavel, et al., 2013). This review of the literature will examine the challenges of integrating new technology into current health care systems and will examine possible solutions for streamlined integration that fosters early adoption and acceptance by health care providers. It will also determine if and to what extent the lack of integration of new and emerging technologies impede improvements in an individual's healthcare status. Additionally, an assessment of the limiting factors that keep them from reaching mainstream healthcare will be examined.

Overall, by understanding the integration of emerging and disruptive technologies transitioning into the care of the individual can be beneficial and valuable to improving health outcomes.

PURPOSE

This review will examine the current literature on integrating new and emerging technology in health care applications and gain insight into these technologies and the obstacles they encounter during implementation. Multiple aspects of the healthcare system will be analyzed to determine any limiting factors of implementation such as: cost versus benefit ratios, developmental issues halting progress, integration issues and the acceptance by healthcare workers, and standardization of care. A better exploration of barriers to integration of new and emerging technology provides a look at some of the technologies the system currently lacks that could lead to better health status outcomes. A secondary purpose of this review is to compare time to integration of established technology and new technology with the potential to have a human impact. Health care providers with a good understanding of the technology and the hurdles it surpassed to become front line for providing health care will have a better appreciation, respect, and understanding of the technology and be better prepared to utilize it to make the process smoother.

METHOD

Multiple articles related to the issues surrounding new and emerging technology and its acceptance into healthcare was collated to form an extensive literature review. Data bases for the search included: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Educational Resources Information Center (ERIC), Elton B. Stephens Co. Host (Ebsco Host), Medical Literature On-line (Medline), and Psychological Information Database (PsychINFO). Search terms include the following: Disruptive technology*, Emerging technology*, Healthcare*, Hospitals*, Budgets*, 3D Printing*, Limiting Factors*, Improvements*, Technology*, and Advancements*. Inclusion in the review was based on: research published in English, technology that is or was advanced and was difficult to implement initially, economic and business information related to the installment and use of new procedures and products, and information regarding solutions to common implementation issues and financial management of resources. Articles that were excluded consisted of case studies; examining new technologies, but only on a particular patient or smaller sample sizes.

The data was synthesized into an examination of the research problem and limiting factors that kept new technologies from being implemented faster, or at all, along with the possible benefits of implementation. Once this information was established, several possible solutions were suggested. This information may provide businesses and individuals with a greater understanding of the factors preventing new technologies from being brought into our hospitals and other businesses. Subsequently, leaders within healthcare organizations may be willing to adopt new and immerging technologies more readily.

BACKGROUND

Disruptive Technologies Through History and Their Economical and Medical Implications

Disruptive and emerging technology is a term used to describe technology that is significantly more advanced than previous iterations (Christensen & Bower, 1995). This technology is often at the forefront of the field and generally improves on systems or diagnostics already in place. In some instances, disruptive or emerging technology can be an entirely new concept or idea. Often times, the technologies require extensive health care provider training to achieve proficiency and mass overhauls are needed to implement the use of the technology. A great deal of decisive obligations from an organization are essential to make the commitment to adopt new technology. Clayton Christenson, an economist for Harvard Business School, describes the adoption of disruptive and emerging technology into mainstream use difficult because people are habitual and initially unwilling to use a disruptive product in applications already known to them (Christensen & Bower, 1995). After the initial disruption has occurred, newer technology adoption begins to infiltrate outdated systems with older technology eventually becoming obsolete (refer to Figure 1.) This rule has held true many times before within multiple fields and its validity remains consistent in health care as well.

Many older diagnostics and systems began with technology that is now widely accepted and used today. Christenson makes note of several from within the same article such as Sony's first portable radios, which sacrificed sound quality for convenience and the disk drive industry's repeated struggles to deal with new smaller disks (Christensen & Bower, 1995).

A plethora of examples from the health care field exist as well. Another article (Pavel, et al., 2013) mentions that to move toward a universal healthcare system, there must be a great deal

of data input that is shareable and readily available. Data involving individual health components will supposedly come from devices designed to measure a variety of health indicators (Pavel, et al., 2013). These devices could include sensors in the home, continuous monitoring of various bodily systems, multiple new developments in robot-human interaction, and several other emerging technologies. Many of the articles focus on the relatively new emerging technology of 3D printing. A method that involves recreating a three dimensional object that has been scanned or designed in a computer program and is then reconstructed in a variety of materials thus recreating the design layer by layer (Mertz, 2013). Benefits of 3D printing include customization of many healthcare devices like hearing aids, help create more advanced structures therefore expediting manufacturing time, and eventually recreate create organs (Ventola, 2014). Integrating new technologies beneficial for healthcare applications requires acceptance and willingness of health care providers and the general public for implementation, as well as sufficient resources for education and purchasing by the adopting institutions. 3D printing and other emerging healthcare technologies will become more common and useful in health care, but before that can happen, they must overcome some of the more difficult problems associated with adoption of new technology. Once primary reasons for lack of integration of new and emerging technologies are understood, then it is possible to look for attainable processes to decrease the time needed for implementation.

Industry thrives when capitol, materials, and labor are balanced to efficiently create a symbiotic relationship (Christensen & Bower, 1995). These are considerable barriers to entry for new and emerging technologies that dictate a great deal of industrial and corporate decision. Providing healthcare services functions similar to most large business models of operation. The

corporate models of both for-profit and non-for profit acute care and diagnostic testing facilities often have limited resources and readily available funds for new and emerging technology. Christensen mentions budget limitations and restrictions associated with corporate health care models. In his article, Christensen mentions businesses are often less likely to pursue disruptive technology as there is very little certainty when it comes to the technology itself as well as the emerging markets surrounding it (Christensen & Bower, 1995) . Business budgets and priorities determine if the effort needed to develop and manage the new market is worth the risk it would carry. Companies and businesses weigh and assess new technology integration and often find it safer to maintain the markets and products they already know currently work rather than risk the investment needed to implement a sweeping and costly technology change (Christensen & Bower, 1995). There are times however when the allure of extreme profit and large returns on market investment make it irresistible for companies to pass on technologic advancements. An early adoption of technology through a large investment can lead to a market foothold that is equivalent to a much larger gain further in the developmental process when emerging technology has established itself (Christensen & Bower, 1995). For instance, it is often risky to establish and build a new hospital with the latest technologic advancements in diagnostics and imaging for areas with low socio-economic status or affluence due to demand being too low and a new procedure or machine may be underutilized if there are not enough people in need of the technology to rationalize a purchase.

Once a business has decided they want to invest in a new or advanced technology related to healthcare, there is also a great deal of logistics to consider. The business is now responsible for researching the technology to determine how it will be implemented and whether it is a

sustainable investment (Christensen & Bower, 1995). Consideration must also be allotted to determining how influential the technology is likely to be convincing investors and board of trustees that the technology is necessary for health care advancements in saving lives.

Other factors influencing technological advancements consist of: the economic ability of individuals and healthcare facilities to maintain and obtain the equipment; scalability ensuring that the technology can be widened to incorporate more people and systems; invasiveness of the technology to ensure it impedes activities of daily living as little as possible; usability and adaptability that allows the software or procedure to be installed with ease and remain up to date and provide quality care as healthcare changes; accuracy and infallibility of the technology should be high to ensure trustworthy results; security of the system should be high to maintain privacy; and the technology can be easily integrated into the workflow to ensure there are no additional difficulties associated with integration of the technology (Pavel, et al., 2013). Adoption barriers and access are the primary issues holding back innovative technology in health care integration and the possible solutions to improved and streamlined integration remain elusive.

3D Printing Technologies

Since the advent of the technology in the 1980s it has made a great deal of progress. In the nearly 40 years since its invention it is still a fairly expensive technique for prototyping and has only recently joined the domestic market. In essence 3D Printing is a technology utilized to create three dimensional (3D) objects out of various materials with the assistance of a computer program and specialized machines that deposit materials one layer at a time until they form a three dimensional object (Mertz, 2013). There are multiple methods of this execution with media

ranging from plastics to metals; however, as technology advances living cells are quickly becoming integrated. There is variation among the speed, amount of layers, and size of the printing capabilities of the machines, but they all create 3D objects by printing small layers one at a time and fusing them together (Mertz, 2013).

3D technology in its infancy was mainly used by large scale companies for rapid prototyping of products. Specially calibrated 3D machines would cost thousands of dollars and were almost unheard of within the private sector; however, in 2006 several small kits were released that allowed any interested person to construct their own. These kits would cost around $1000 and were still fairly limiting, but were cheap enough to bring the technology more prominently into the foreground (Mertz, 2013). With the advent of 3D technology kits the barrier to entry was lowered significantly. Since then, many private citizens have created new techniques and machinery that has allowed the price of 3D printing to drop even further.

Several innovative new techniques and materials have led to advancements in 3D printing that relate to its use in health care. To date, 3D technology has been exclusively used for skeletal support and replacement, such as 3D printed knee and hip replacements, 3D printed teeth fillings, and even so far as replacing skull portions (Gross, et. Al, 2014). 3D printing is an ideal technology for joint and bone replacements since the model that is printed can have natural bone porosity integrated into the design. Additionally, each piece can be specialized and individualized (Xiao, et al., 2017)(Gross, et al., 2014).

Individually tailored care is one of the major allures of 3D printing and has also led to the use of 3D printing in surgical planning. Diagnostic scans of the individual, such as CT scans or even serial x-rays can be used to create a 3D model of a person's body part. There have been

instances where physicians have constructed 3D models of a person's tumor and surrounding tissue so simulated practice surgeries can be performed on the plastic stand-in without endangering the individual's life (Gross et al., 2014)(Irwansayah et al., 2017)(Ventola, 2014).

Bioprinting has also become a recent development in 3D printing technology. This technology involves printing using cells and biomatter instead of plastics or metals. Thin layers of cells are built up to form new cell structures such as ears or organs. Bioprinting technologies are still in their infancy and have had many technological setbacks involving vasculature formation and other difficulties involving the nutrition of the cells after they are layered. (Gross et al., 2014)(Ozbolat, & Yu, 2013)(Ventola, 2014)

Difficulties in implementation of new technology are not exclusive to bioprinting. All forms of 3D printing continue to struggle to meet the accuracy and resolution demands of the health care setting as well as the expense of development in the field.

Electronic Health Records

The implementation of the EHR has been easier than the implementation of 3D printing. The use of EHR's is considered a precise method for reducing accidents in drug therapy administration and improving overall care for people. As such, there is likely to be little resistance from providers in integration. (Boswell, 2013) EHR's have not been integrated on an international level, with multiple countries requiring extra time for integration and recognizing hospitals need different amounts of time to provide education and training for staff. The U.S. plan for integration of EHR's by the year 2014 has been unsuccessful to a degree. There are still many hospitals or specific hospital staff members that have difficulty integrating the EHR into their workflow due to a number of reasons, such as patient confidentiality, aversion to

technology, lack of resources, and other factors (Odom, 2016). The Institute of Medicine (IOM) asserted in 1991 there should be an EHR to improve medical record accuracy better than is currently available. Reasons noted included increased legibility of orders, better communication between caregivers, improved portability, better security features, sharing of medical information and many other factors. (Odom, 2016) By 1996 the use of the EHR was mandated by the Health Insurance Portability and Accountability Act (HIPAA). There has still been resistance to integration by certain caregivers or even entire clinical settings. However, there are also successful stories of integration that have typically taken place within the healthcare system where use of the EHR is mandated, such as the Veteran's Administration (VA) hospitals. There are still several small scale or individual practices that have yet to integrate the EHR into their practices and do not see the benefits of implementation. (Odom, 2013)

There are still plenty of individuals and healthcare facilities that do utilize electronic health systems for data about an individual's health. It was found there was a high correlation with the EHR and the use of a better quality system which increased use by the staff, and the users were more likely to access the system when the quality of the system data also highly correlated to individual data. It was also found that in order to improve a system's data overall, more quality education about using an EHR is required. There are many factors that depend heavily on each other when it comes to EHR integration in health care: self-efficacy depends on training, quality data depends on efficacy, system data depends on individual data, and so on (Yu, Qian, 2018).

This brings forth the issue of education and acclimating staff to the system. The electronic health record has been fairly well integrated into healthcare in part due to its mandate

by HIPAA; however, there was a great deal of kickback initially and still remains today (Senior, 2006). There were multiple clinicians and nursing staff workers throughout the country that had difficulty adjusting to the technological curve. Many of these caregivers had decades of experience in paper records leading to a very hard set of training to overcome. In fact, it was found through several studies that over 70% of physicians had never had any formal computer training. Also, several large health care systems realized they would need to hire up to 50,000 additional IT professionals to cope with the induction of the EHR. Many caregivers had never even used a mouse in their previous healthcare setting due to a smaller sized facility or lack of exposure to a computer system. Health care executives introduced seminars throughout their healthcare system to teach staff and providers specifically about EHR technology, such as using a word processor, using a monitor, and other seemingly basic conditions (Huang, 2013)

Stem Cells, Bioprinting, and Other Questionable Methods

The technologies discussed this far have been technologies that are widely used in the current healthcare environment or technologies that have been in use for more than 10 years. Stem cells and bioprinting are still technologies that have yet to be integrated in the healthcare setting in a widespread manner. These technologies are extremely new and laws and regulations are still in early stages of licensing and integration. Newer, innovative, technologies are also imposing the unique challenge of moral and ethical complications. Bioprinting is similar in method to 3D printing, with layers of material being deposited to form a 3D shape, though in this case the material being deposited is a layer of cells. As these cells are deposited they can be designed to form the shape of a skin graft or a replacement nose and perhaps in the future even entre organs. Bioprinting technology has actually existed for some time with an initial method of

a single 2D layer of cells being deposited by laser in 1999. (Ozbolat, YU, 2013) There were even exploratory trials into the idea of bioprinting previous to the current level of printing ability using biologic materials. The technology is still having trouble advancing and, in comparison to its solid plastic or steel counterpart, 3D printing is still relatively in its infancy. The problem for bioprinting at the moment is creating a sufficient network of blood vessels to deliver nutrients to the printed cell structures (Ozbolat, YU, 2013) (Kirkpatrick, 2017). The technology also often utilizes embryonic stem cells and other types of stem cells which introduce a moral element of difficulty or barriers to harvesting respectively. Similar issues and others like cellular maturation, difficulties in specialization of the cells, and changes in cell behavior during the printing process are impeding advancements (Ozbolat, YU, 2013).

Embryonic stem cells are becoming increasingly important to research due to their genetic uniqueness making them perfect subjects for DNA testing. DNA testing and DNA modification is also becoming an emerging field in healthcare and science. Genetic manipulation and modification involves the changing of the DNA in a cell. The instructions that cells depends on are altered and the cells function can be potentially changed. Recently several new methods of genetic manipulation have been created. Some of the most ambitious and influential are those of CRISPR and CAS-9. CRISPR and CAS-9 are enzymes that have been recently engineered in laboratories to be used for gene editing. CRISPR and Cas-9 are unique in that they are extremely affordable, with the use of CRISPR costing about $30 per use as opposed to thousands of dollars for previous techniques (Smolenski, 2015) New gene modification tools can help damaged areas and specific portions of DNA to deactivate poorly coded strands, so they no longer function. This is helpful if there is a particular mutation that will affect the body negatively. DNA

modifying technology is being discussed and questioned by health care scientists and provider because of its potential to create “designer babies” or babies whose attributes have been carefully selected or corrected (Sheppard et al., 2016). Genome editing has also been called a “weapon of mass destruction and proliferation,” by previous government agency officials (Boston College Law Review Staff, 2018). Many issues with moral and ethical concern will present further difficulties with integration of new biotechnology in the health care setting. Other morally questionable technologies will, in all likelihood, continue to be created, so advances in biotechnology and other innovative technologies that involve health outcomes will continue to impede integration well into the future.

RESULTS

Of the thirty one articles reviewed, twenty articles directly referenced reasons behind a lack of integration into widespread healthcare. Additional articles were included to supplement information and provide a background on histories and the current level of integration. Of the thirty one articles, nine covered the topic of 3D Printing, twelve covered the topic of Electronic Health Records, six covered moral topics, and four additional sources spoke on overall and generic topics covering economics and technological integration.

Table 1: Summary of Articles Focused on the Impeding Factors of Emerging Technology Integration

Technologic Focus	**Supportive articles for Risk Factor**	**Total Articles**
3D Printing	Gross, B. C., Erkal, J. L., Lockwood, S. Y., Chen, C., & Spence, D. M. (2014). Hoy, M. B. (2013), Hurst, E. J. (2016), I., Redyarsa, D., Lai, J., Essomba, T., & Lee, P. (2017), Mertz, L. (n.d.), Ventola, C. L. (2014), Sparrow, N. (2015, December 17), Xiao, Y., Sun, X., Wang, L., Zhang, Y., Chen, K., & Wu, G. (2017),	**7**
Electronic Health Record	Boswell, R. A. (2013), Odom, S. A. (2017),	**7**

	Senior, T. (n.d.), Yu, P., & Qian, S. (2018), Sheppard, M., Spencer, R. N., Ashcroft, R., & David, A. L. (2016), Suominen, H., Lehtikunnas, T., Back, B., Karsten, H., Salakoski, T., & Salanterä, S. (2007), Ventura, M. L., Battan, A. M., Zorloni, C., Abbiati, L., Colombo, M., Farina, S., & Tagliabue, P. (2011)	
Morals and Ethics	Boston College Law Review Staff. (n.d.), Green, E. D., & Guyer, M. S. (2011), Kirkpatrick, K. (2017), Ozbolat, I. T., & Yu, Y. (2013), Potter, L. M., Bissonnette, S. A., Knight, J. D., & Tanner, K. D. (2017) Smolenski, J. (2015),	**5**
Other (economic, systemic healthcare, etc.)	Christensen, C. M., & Bower, J. L. (1995), Pavel, M., Jimison, H. B., Wactlar, H. D., Hayes, T. L., Barkis, W., Skapik, J., & Kaye, J. (2013)	**2**

Impeding Factors

3D Printing

The cited articles mentioned in table 1, in regards to 3D printing, describe many impeding issues surrounding cost as a barrier to entry, technical limitations, personalization, and software problems. The cited articles describe an increase in 3D printing usage in the hospital, but also a great deal of hesitancy when it comes to further usage. Multiple studies showed that not only was the usage of 3D printing in the healthcare setting incredibly expensive, but also simply technically impossible with the current technology available.

Ventola, C. L. (2014), cites that during the time of their publishing that only 1.6% of 3D printing funding is going to medical applications. All of the articles focused on 3D printing recommended that the technology be used more often and that more research should be put into perfecting the technology. Gross, B. C., Erkal, J. L., Lockwood, S. Y., Chen, C., & Spence, D. M. (2014) cited that the industrial level printers can cost upwards of $250,000. All of the studies also felt that it could have a bright future in the clinical setting and that the technology could likely revolutionize healthcare. Ventola, C. L. (2014) also lists several different ways that 3D printing could be used in the future. Four of the articles on 3D printing mentioned that the technology could be improved to make its usage in the hospital more popular. One article quoted a surgeon saying that the change from the preoperative plan to the real surgery was markedly different due to imperfections in the scanning software and inability of the printer to make accurate edges. 50% of the articles on 3D printing mentioned the usage of the technology to create new prescription medications in the future when the accuracy and fidelity have improved enough (Xiao, Y., Sun, X., Wang, L., Zhang, Y., Chen, K., & Wu, G., 2017). All of the articles

mentioned the possibility of personalization of care as an enticing factor of 3D printing. Although Ventola, C. L. (2014) also mentions that there are still issues with copyright and getting approval from government departments to ensure that care and prosthetics are well maintained and the quality of custom replacements are secure.

Electronic Health Records

The electronic health record articles mentioned in Table 1 describe a system that is working relatively effectively, yet requires more proper training and incentivizing before it will be 100% integrated into the healthcare system. Five of the articles on the subject of Electronic Health records heavily recommend the usage of further training for healthcare professionals in order to ensure better EHR usage.

Moral and Future Breakthroughs

The articles on bioprinting and stem cells and the like show a definitively undeveloped area of healthcare. All of the articles on these subjects mentioned that the technology was in some way not complete enough for usage in the healthcare setting in a wide setting. All of the articles on bioprinting mentioned that the technology has a great deal of technical aspects to overcome before it is able to be utilized fully. Multiple articles not only mention a technical limitation, but also a mental limitation. (Kirkpatrick, 2017) mentions that the pure knowledge of how the cells will interact and join over extended periods is not understood at all. All of the articles on bioprinting also mention that more funding is required if any progress is to be made. (Kirkpatrick, 2017) also mentions that even though the technology was initially developed over 20 years ago the technology is at least 3 to 5 years away from a breakthrough in their process and

will likely need several years beyond that before it is a process ready for the healthcare field. It is also mentioned that the current model that is capable of bioprinting is roughly $2000.

As for the issues in genetic testing and gene therapy all of the articles examined mentioned their current or past difficulties overcoming the social difficulties associated with manipulating genetic material. Several articles also mentioned that difficulties in accruing genetic material that was worth testing on. (Smolenski, J. 2015) mentions the difficulty in initially sourcing embryonic stem cells, and now the difficulty in affording the expensive procedures necessary to create induced pluripotent stem cells which do not carry as much social stigma.

Other

There are some articles that are more general and cover a more systematic approach to the integration of technology into healthcare. (Christensen, C. M., & Bower, J. L. 1995) mentions a great deal about the importance of analyzing the market and understanding at what point the cost versus the benefit is worth the investment. The article describes in detail the importance of new technologies integration into systemic industries by outweighing the previous iteration in fidelity and accuracy, efficiency, saved cost versus spent cost, and other more economic aspects of integration. One article specifically mentions the importance of integrating more healthcare technology into everyday life in order to better form a picture of the health of the clients once they leave the healthcare system (Pavel, M., Jimison, H. B., Wactlar, H. D., Hayes, T. L., Barkis, W., Skapik, J., & Kaye, J. 2013).

Overall

Out of all of the articles found in the Table of Evidence, 13 of them mentioned cost as a limiting factor in the integration of their respective technologies. Costs varied by technology, but many of them mentioned the need for further research and development in order to get the respective technologies to a level that would be acceptable and easier to justify. Most articles often stated that further research would lead to scientific breakthroughs that would subsequently lead to a reduction in overall cost of the use of the technology. Many of these articles also mentioned the importance of further education of staff in the usage of the technology as mentioned above. Along with cost the most discussed limiting factors were technical limitations. Of the article in the Table of Evidence, 15 of them mention a current technical limitation of the technology in one way or another. Technical limitations were the most frequently mentioned reason behind the lack of integration. The mention of technical limitations is often correlated with or followed by another mention of further development and research. Cost and technical limitations were by far the most prevalent limiting factors to integration of new and innovative technology in health care; however, education, training, and ethical bias were still mentioned fairly regularly. Moral reasons for difficulty in integration were mentioned in approximately 25% of the articles, with further staff education receiving the same number. Other reasons such as personalization and regulatory issues, further biological study, and copyright infringements were a smaller fraction of issues facing integration.

DISCUSSION

The studies examined provide insight into the larger healthcare system and the gap between research and the hospital setting. The data consistently demonstrates the many problems new technology faces for integration and must overcome such as financial, technical, or moral and ethical barriers to integration. This review of the literature has examined the use of 3D printing, the EHR, bioprinting, and related new technologies and the difficulties faced with use in health care and improving health outcomes. They describe technology currently being integrated, technology that was previously integrated and the difficulties involved with integration, and what technology currently awaits integration. The examples provide the framework for a common set of factors that impede integration. The factors impeding integration of new and innovative technology in the present can be applied to current models of education and training that advances future technology in the health care setting.

Based on the results there are several deductions that can be made. One such deduction is the importance of funding research on sociologic adaptation of new skills and tasks related to the adoption of new technology. The results show a series of technologies that have existed for well over 20 years, but are only truly starting to be integrated now. High cost barriers to entry keep a great deal of people out of the industries and leads to a select few being knowledgeable on the subject. This esoteric group is far less likely to innovate and thus bring about higher efficiency, lower cost of entry, and integration (Refer to Figure 1.). The results show a lack of technical ability in some regards as well, along with multiple different moral fronts on which to contest. The limiting factors of technical, financial, and moral grounds will continue to impede not only

new and emerging technologies, but those of the future as well if they are not addressed individually and addressed at a system wide level.

Recommendations for Further Integration of Technology

Education

Technology integration is always difficult to do. The initial cost of changing out the old system along with the retraining and replacement of the old system is often more than enough for investors and healthcare executives to overlook the idea. (Christensen, C. M., & Bower, J. L., 1995) If the executives are more aware of the benefits of the technology then there is a higher likelihood that they may integrate it more into the system. (Xiao, Y., Sun, X., Wang, L., Zhang, Y., Chen, K., & Wu, G., 2017). Further education of all staff is also beneficial. Education of staff in EHR training led to a marked increase in usage among all hospital staff. (Senior, T. , n.d.) This education leads to higher familiarity with the technology and less likelihood to disagree with its integration and usage.

This education will also lead to a higher degree of people interested in the technology and the heightened level of interest can often lead to more people working with the technology and a higher likelihood of innovation amongst this population. (Mertz, L., n.d.).

Research

A higher level of research is also required if there is to be any progress. The necessity of funding cannot be understated and a great deal of the advancements that these technologies have made thus far are due to funding. Many of the bioprinting and gene therapy technologies are understood on a basic level and there is a relatively high level of interest, but more research is necessary (Ventola, C. L., 2014). A great deal of the articles mentioned cite technical problems, but also cite exactly what needs to be done or researched to correct them only sentences later. This shows a large amount of understanding of the problem, but a lack of research and funding.

Many of these technologies have already overcome some significant other impeding factors due to research. Gene therapy has developed CRISPR, which reduces the cost of genetic manipulation drastically and Induced Pluripotent stem cells were developed as an alternative to the more socially guarded embryonic stem cells. These changes came about due to further research and they have allowed great strides in innovation since their inception. With even further funding and research there will surely be more developments that allow the technologies to circumvent their problems.

CONCLUSION

These technologies have been shown to make great medical advancements, but have also been shown to be an incredibly small portion of the financial budget. (Ventola, C. L., 2014) These technologies are at the hands of technical, financial, industrial, and moral requirements, and the literature shows that there is a good chance they could overcome them. The nurses and hospitals that will be using this technology someday need to take greater action in educating themselves and their staff so that they may better understand that the benefits do outweigh the costs. (Christensen, C. M., & Bower, J. L., 1995) These technologies show that technology takes a great deal of time to integrate. It has in the past, it does now, and it will in the future. These technologies also show that there are many different things that people do to hold them back and that with the right funding, enough research, and some innovation all technologies can be made efficient, cost effective, and more than ready to be integrated into the healthcare system.

APPENDIX A: FIGURES

Figure 1: Model of Technological Development and Innovation Cycle

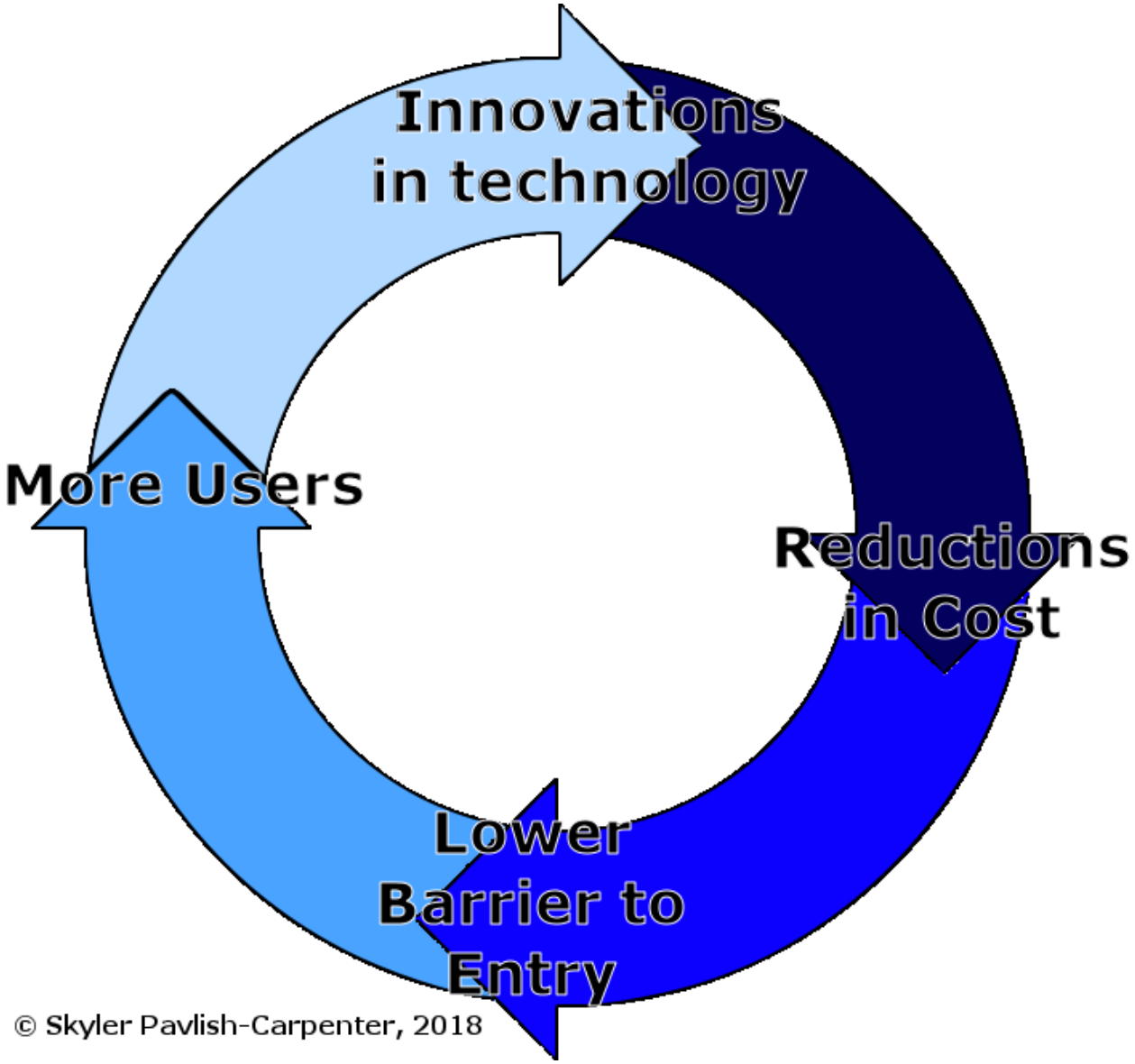
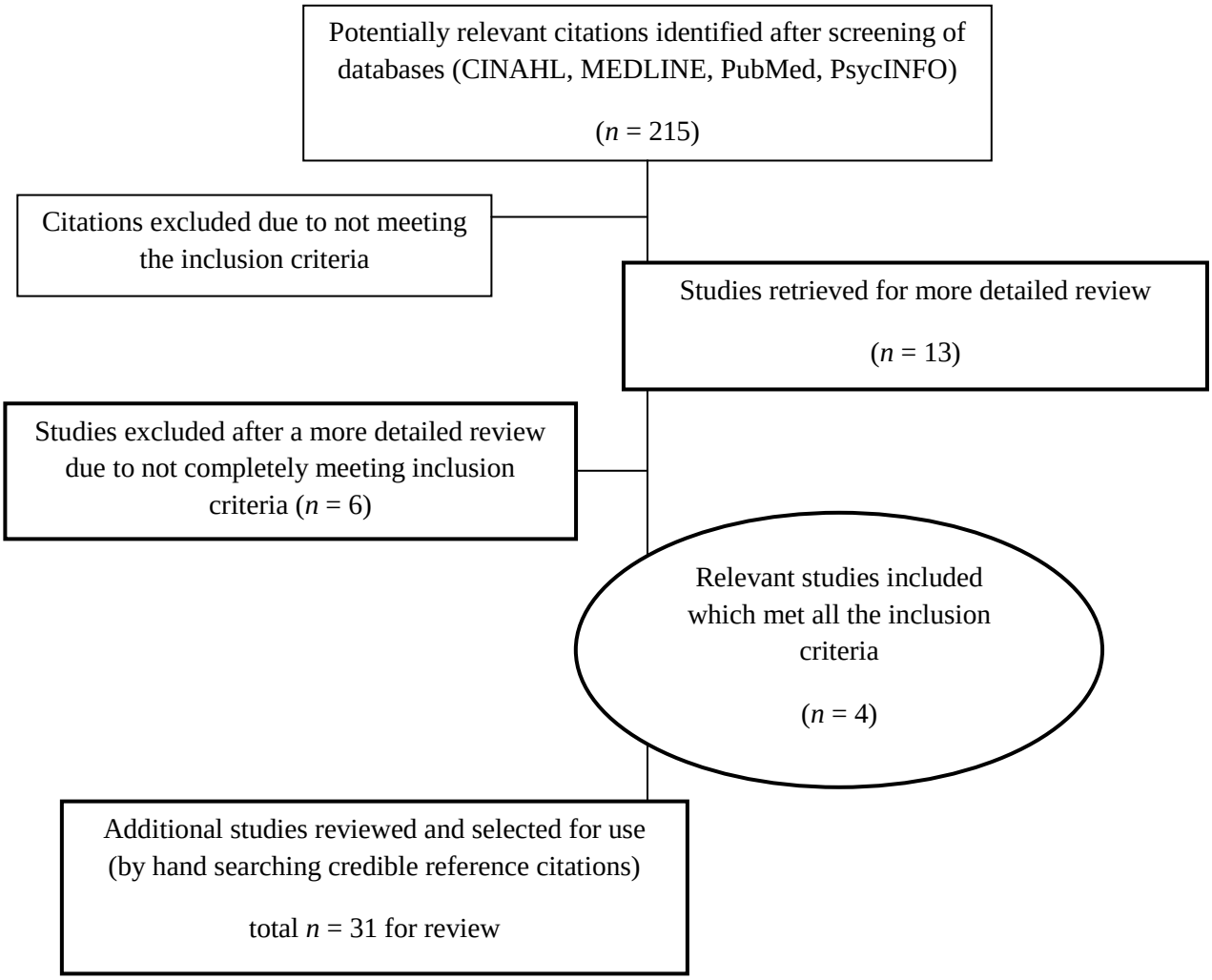

Innovations in technology
Reductions in Cost
Lower Barrier to Entry
More Users
© Skyler Pavlish-Carpenter, 2018

Figure 2: Consort Diagram of Thesis Methodology

Flow Diagram of Study Selection Process

Key Search Terms = 3D Printing, Electronic Health Record, Bioprinting, Stem Cells, Emerging Technology, Disruptive Technology, New Technologies, Healthcare systems, Industrial history, Healthcare industry, Technological integration, and Cost versus benefit analysis.

Limiters = English language, peer-reviewed, Literature is not a case-study.



APPENDIX B: TABLE OF EVIDENCE

Table 2: Table of Evidence of Reviewed Literature

Article	Article's influence on thesis	Key Findings and Limitations	Key words	Technology discussed	Other Limitations discussed
Boston College Law Review Staff. (n.d.). The Price Tag on Designer Babies: Market Share Liability. BCLR,59(1). Retrieved from http://lawdigitalcommons.bc.edu/bclr/vol59/iss1/8	Integral. Many technical limitations mentioned.	A very technical view at the current technology in place for genetic manipulation. Many limitations presented and an in depth look into the exact science behind the technology; however, very complex and often more detailed than is needed for this instance.	Genetic Manipulation, Gene Therapy, Gene editing.	Genetic manipulation	Mentions the limitations of the technology surrounding the difficulty using the enzymes. Biological limits are also mentioned as well as cost and moral opposition.
Boswell, R. A. (2013). Implementing electronic health records: Implications for HR professionals. Strategic HR Review,12(5), 262-268. doi:10.1108/shr-08-2012-0010	Integral. Mentions of historical facts are utilized.	An article more focused on the training of the staff as well as the healthcare implications of the HER. The article does focus on its usage in Human Resources, which is not ideal for this review, but still useful.	Electronic health record.	Electronic Health record.	Cost as well as further education of staff are listed as limiting the integration of the EHR.
Christensen, C. M., & Bower, J. L. (1995). Disruptive technologies: catching the wave. *Long Range*	Integral. Discussion of overarching reasoning behind economical hesitancy.	Discusses at length the issues presented with new technologies from a mostly business stand point. Provides great insight into several economic	Economics, fiscal, innovation, development, purch	Radios, cassette tapes, other more industrial innovations.	Ideas influencing decisions by companies and company heads to move into certain markets, as well as several other purely economical

Planning,28(2), 155. doi:10.1016/0024-6301(95)91075-1		foundations that influence the purchasing and developing of new technology. Does not discuss medical advances, but utilizes other technological innovations instead.	asing, disruptive.		issues.
Green, E. D., Guyer, M. S., Manolio, T. A., & Peterson, J. L. (2011). Charting a course for genomic medicine from base pairs to bedside. Nature,470(7333), 204-213. doi:10.1038/nature09764	Exemplar, small references to moral issues.	Outlines advances made and to be made in genetics. Is fairly outdated with the final view being of the world in 2011.	Genetics, morality, diseases, design.	Genetic manipulation	Limitations of moral obstacles to genetic manipulation in medicine is mentioned throughout.
Hoy, M. B. (2013). 3D Printing: Making Things at the Library. Medical Reference Services Quarterly,32(1), 93-99. doi:10.1080/02763869.2013.749139	Exemplar	Gives a good overview of the 3D Printing technology. Examines the limitations of the technology and gives possible solutions. Mentions instances of low barriers to entry.	3D Printing technologies and their use by hobbyists	3D printing	Limitations of consumable resources and the overall need for improvement.
Hurst, E. J. (2016). 3D Printing in Healthcare: Emerging Applications.	Exemplar, discussion of a specific and cutting technology with a	Outlines history of 3d printing in detail as well as offering several instances where it is being used today. Fails to	3D Printing, Tissues, emer	3d printing, prosthetics, drugs, tissue replaceme	Library use of 3d printers.

Journal of Hospital Librarianship,16(3), 255-267. doi:10.1080/15323269.2016.1188042	myriad of untapped uses.	have a vast array of innovations possible in the future.	ging, Developing, Current.	nt.	
I., Redyarsa, D., Lai, J., Essomba, T., & Lee, P. (2017). Integration of computer-aided pre-operative planning and 3D printing technology for comminuted fracture bone surgery. 2017 International Conference on Applied System Innovation (ICASI). doi:10.1109/icasi.2017.7988116	Exemplar and statistics	A detailed report on the usage of 3D printing in a current healthcare setting. The Article describes several limitations of 3D printing and it's usage; however, the article only references a few individual cases and is unable to make any analysis of the technology's usage on a wider scale.	3D printing, Orthopedic	3D printing, Orthopedic replacements, x-rays, Computer topography	Limitations of 3D printing technology discussed and evaluated. Accuracy of 3D prints questioned.
Kirkpatrick, K. (2017). 3D-printing human body parts. Communications of the ACM,60(10), 15-17. doi:10.1145/3131068	Integral	Detailed article on the history, technology, and limitations of Bioprinting and replacement of human body parts.	Bioprnting, Organ replacement.	Bioprinting, 3D printing, Organ replacement.	Cost of the printers themselves as well as the materials needed to recreate the body parts were mentioned. There was mention of many technical and biological limitations related to the

					ability to construct living tissues with 3d Printing.
Mertz, L. (n.d.). New world of 3-D printing offers "completely new ways of thinking": Q&A with author, engineer, and 3-D printing expert Hod Lipson. Retrieved April 05, 2018, from https://www.ncbi.nlm.nih.gov/pubmed/24215725	Integral. Many facts and statistics utilized.	An in depth look into the industry from a professional. Many facts about the history and early years of 3D printing. Less focused on the Healthcare aspect.	3D Printing	3D Printing, 3D scanning.	Technical limitations of printer mentioned including speed and limited materials.
Odom, S. A. (2017). ELECTRONIC HEALTH RECORDS: OVERCOMING OBSTACLES TO IMPROVE ACCEPTANCE AND UTILIZATION FOR MENTAL HEALTH CLINICIANS	Integral. Many Statics and historical facts.	A detailed view of the history of the Electronic Health Record and aspects of its initiation and integration into the American healthcare system. An extremely useful article with a great deal of statistics about initial plans and usage. Article is very exhaustive and can be difficult to understand in portions.	Electronic health record.	Electronic Health record.	Further education of staff is mentioned throughout the document.
Ozbolat, I. T., & Yu, Y. (2013).	Integral. Many	Detailed history and current trend	3D Printi	3d Printing,	Limitations of the current

Bioprinting Toward Organ Fabrication: Challenges and Future Trends. IEEE Transactions on Biomedical Engineering,60(3), 691-699. doi:10.1109/tbme.2013.2243912	limitations mentioned and what can be done to correct them.	of 3D printing as well as the idea of bioprinting and the limitations and challenges therein. Article is fairly technical and can be difficult to summarize and utilize in the review.	ng, Bioprinting, Organ replacement.	Bioprinting.	technology are mentioned including lack of tissue regeneration and fidelity of the printer.
Pavel, M., Jimison, H. B., Wactlar, H. D., Hayes, T. L., Barkis, W., Skapik, J., & Kaye, J. (2013). The Role of Technology and Engineering Models in Transforming Healthcare. IEEE Reviews in Biomedical Engineering,6, 156-177. doi:10.1109/rbme.2012.2222636	Integral.	Provides a much more in-depth look into technology and how it becomes integrated into healthcare. Focuses on statistical analysis and can be verbose at times.	Long term, healthcare systems.	Sensors, monitoring, computers, cameras, integrated record sharing.	Policy making, payments, and policing.
Potter, L. M., Bissonnette, S. A., Knight, J. D., & Tanner, K. D. (2017). Investigating Novice and Expert Conceptions of	Integral. Many insights into public thought on genetic manipulation.	A study into the preconceived or educated notions of the public and the experts on the idea and future of genetically Modified organisms.	Genetic manipulation, gene therapy.	Genetically Modified Organisms.	Moral limitations were mentioned throughout the article as a contributing factor to the limited usage and acceptance

Genetically Modified Organisms. Cell Biology Education,16(3). doi:10.1187/cbe.16-11-0333					of Genetically Modified Organisms.
Senior, T. (n.d.). Paper to EMR: A Successful Transition For Children's Healthcare of Atlanta, involving users in a robust selection process and gaining user buy-in was key to a successful implementation. POC/Mobile Computing	Integral. Statistics and explanations behind some of the difficulties of using the Electronic health record.	A study of a small hospitals transition to the use of the Electronic Healht record from the use of paper charting. Gives many reasons why the transition is difficult as well as solutions. Article is very short and is not about the healthcare system as a whole.	Electronic health record.	Electronic Health record.	Education of workers was the most prevalently mentioned limiting factor for this article.
Sheppard, M., Spencer, R. N., Ashcroft, R., & David, A. L. (2016). Ethics and social acceptability of a proposed clinical trial using maternal gene therapy to treat severe early-onset fetal growth restriction. Ultra sound in Obstetrics & Gynecology,47(4	Exemplar.	A look into some of the possible moral limitations that could be imposed on bioprinting and genetic manipulation in the near future.	Ethics, Gene Therapy.	Gene therapy.	Cost of the procedure and further development as well as oral obstacles was mentioned.

), 484-491. doi:10.1002/uog.15880					
Smolenski, J. (2015). CRISPR/Cas9 and Germline Modification: New Difficulties in Obtaining Informed Consent. The American Journal of Bioethics,15(12), 35-37. doi:10.1080/15265161.2015.1103816	Exemplar	A look into some of the moral questions that are presented when utilizing gene modification technologies.	Ethics, Gene Therapy.	Gene therapy.	Cost of the procedure and moral difficulties to overcome are mentioned as well as technical and developmental limitations.
Sparrow, N. (2015, December 17). FDA tackles opportunities, challenges of 3D-printed medical devices. Retrieved April 05, 2018, from https://www.plasticstoday.com/content/fda-tackles-opportunities-challenges-3d-printed-medical-devices/13081585320639	Exemplar. Cautionary.	Makes mention of some of the implications of the usage of 3D printing and other emerging technologies along with their respective difficulties of regulation. Short article. Limited information.	3D Printing	3D printing, Medication, Medical Procedures	Personalization of Healthcare becomes a problem as FDA regulation becomes difficult.
Ventola, C. L. (2014). Medical	Integral. Insight into	Discusses the history of 3D	3D Printi	3d Printing,	More biological research is

Applications for 3D Printing: Current and Projected Uses. P&T,39(10).	the cutting edge technology and its limitations	printing and Bioprinting and their current usage in the healthcare field. Is very technically written and dense.	ng, Bioprinting, Organ replacement.	Bioprinting.	noted as a factor that is limiting bioprinting currently.
Ventura, M. L., Battan, A. M., Zorloni, C., Abbiati, L., Colombo, M., Farina, S., & Tagliabue, P. (2011). The electronic medical record: Pros and cons. The Journal of Maternal-Fetal & Neonatal Medicine,24(Sup 1), 163-166. doi:10.3109/14767058.2011.607582	Integral.	Another look into the transition to the HER in a relatively small hospital. This article makes mention of some of the history as well as more of the entire healthcare teams usage of the EHR.	Electronic health record.	Electronic Health record.	Education of workers was mentioned as a limiting cause as well as cost and technical limitations of the computers.
Xiao, Y., Sun, X., Wang, L., Zhang, Y., Chen, K., & Wu, G. (2017). The Application of 3D Printing Technology for Simultaneous Orthognathic Surgery and Mandibular Contour Osteoplasty in the Treatment of Craniofacial	Exemplar and statistics	A detailed report on the use of 3D printing in corrective and personalized surgery. The article focuses more on the procedure and less on the 3D printing aspect.	3D printing, Corrective surgery	3D printing, orthopedic replacement, Computer topography.	Acceptance by the body mentioned. Appreciates the accuracy.

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Yu, P., & Qian, S. (2018) Developing a theoretical model and questionnaire survey instrument to measure the success of electronic health records in residential aged care. Plos One,13(1). doi:10.1371/journal.pone.0190749	Exemplar.	Examines more overarching models of healthcare and how engineers can influence the changes. Focuses on some examples of current technology being integrated, but also veers into less healthcare oriented portions.	Models, healthcare, Systems.	Imaging, analysis, online and shared files.	Handling of large scale systems regardless of basis in healthcare.

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