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MEDICAL INFORMATICS

Anusha Reddy and Ajit Reddy

The Academy of Allied Health and Science, Nokia

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***Corresponding author**

ABSTRACT

In this paper, we discuss the relative fields within the domain of Medical Informatics such as Bioinformatics, Public Health Informatics, Imaging Informatics and Clinical Informatics. Within each of these fields the corresponding sub-areas and projects are also discussed. Of the many risks involving Medical Informatics some have been highlighted.

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INTRODUCTION

With the need for the computerization methods for diagnostics and information gathering there is a move to store medical records in secure medical databases and the related diagnostic information pertaining to the individual patient under observation. The field is still evolving and still needs enhancement not only to secure medical databases but also to the medical networks. Improvement is still required in the areas of monitoring, diagnosis and patient care. The emphasis is in improving the clinical making decisions using computing methods to reduce the uncertainty in diagnosis. Complex clinical problems are solved by using advanced techniques in drug design, molecular genetics and cellular genetics. Medical informatics draws upon the techniques employed in the broad range of sciences such as computer science, clinical science, biomedical science, management science and statistics.

BIOINFORMATICS

Bioinformatics is the use of computer technology in the clinical environment. It is used to interpret biological information (hence its name). Bioinformatics is very important because without it, genetic information would be read incorrectly. Bioinformatics is most commonly used to understand and gather information about genes, cell regulation, drug target selection, drug design, and disease.

Human genome mapping

The human genome mapping is a worldwide, collaborative research program which began in 1990 and was completed in 2003. The goal of this project was to completely map and understand all the genes present in human beings. The process of this project can be summarized in six steps (Human Genome Project, 2005).

- The chromosomes were split into smaller pieces of DNA.
- Each single-stranded small piece was used as a template for enzyme DNA polymerase, to create a new, complementary piece of DNA.

- The new strands of DNA were separated from each other based on their size, using gel electrophoresis.
- The DNA was determined by the looking at the sequence of colors that came up on the gel.
- A computer read the colors and determined the sequence. The computer then combined this newly-made sequence with all the other sequences, to come up with and create the whole genome.
- This sequence information is submitted to large public databases, so that other researchers can use this information and/or edit it (https://www.genome.gov/10001772/all-about-the--human-genome-project-hgp/)

The human genome mapping project can aid in the discoveries of genes related to many types of diseases, especially heritable diseases. It can also be used for the cloning of genes, as the process starts to advance more. There are many ethical issues concerning the human genome project. These include privacy issues, high costs, and many different variations of religious reasons. To some people, the human genome project is unnatural and has been deemed as blasphemous. There are others who are concerned that the data gathered about them might be breached and there are those who are dubious of the high costs and are unsure of how this project will be of help in the real world (http://www.yourgenome.org/stories/how-is-the-completed-human- genome -sequence-being-used; http:// healthresearchfunding.org/ human-genome-project-pros-cons/)

Personalized medicine

Personalized medicine is the matching of your ailments with targeted and specialized medical care, such as drugs. Personalized medicine requires four fundamental factors for it to work. These include lots of patient research, and the patient's genetic information, clinical information, and medical history. Personalized medicine basically uses the patient's genome to concoct accurate predictions on the patient's susceptibility of any developing diseases, the path of the disease, and how the patient will respond to the prescribed treatment. In the end, personalized medicine provides the patient with safe treatment and yields effective results. Iressa and Tarceva are examples of personalized medicine. Tarceva is used as the first-line of treatment for some lung cancer patients (http://health.usnews.com/health-conditions/cancer/ personalized-medicine/overview; Ruder, 2008; https://www.drugs.com/tarceva.html)

Rational drug design

Rational drug design is a type of computer-aided drug design that uses past information of biological chemicals to identify the main component and isolate it, for it to develop into a new product that is more effective and beneficial. There are two methods of Rational drug design. The first method, combinatorial library index, screens the index for something specific enough, which will be able to work with the old drug. The second/ other method is by using the actual design to implement chemical groups that will work as a team with the pre-existing drug based off of already gathered information. Rational drug design is better than the normal standards because with this method, scientists can take a more computational approach on research, instead of doing trial and error. Computational approaches will save lots of time, money, and energy (Lloyd, 2017)

Comparative genomics

Comparative genomics is a field in biological research where genomic features (genes, gene order, DNA sequence, regulatory sequences, and other structural landmarks) are compared (hence its name). Comparative genomics can be used to identify evolutionary relationships. To create a genome database, DNA must first be extracted from cells. Next, they must be digested by using a restriction enzyme. A vector must then be inserted. Finally, a comparison must be made of the analysis of the differing species for similarities. By using comparative genomics, scientists have discovered many of the genes involved in human disorders by looking at the distantly related species. Comparative genomics is quite essential when concerning vaccinology. By analyzing the genome of a pathogen, scientists can find antigens for many vaccines (https://en.wikipedia.org/wiki/ Comparative_ genomics)

Protein Folding@home and FoldIt

Protein Folding@home is a computing project that studies the folding of proteins. Protein Folding@home simulates protein folding, computational drug design, and other types of molecular functions. FoldIt is a video game that is based on protein folding. It is like Protein Folding@home. While using FoldIt and the tools provided in the game, the player can fold the structure of a protein. The solutions that have the highest scores are then analyzed by researchers. The researchers determine if those solutions are applicable to the proteins in the real world. Even though there are computers to use, FoldIt is basically based off the idea that humans approach problems differently than computers do. In the end, players can end up designing proteins that could prevent and/or treat many common diseases, such as Alzheimer's, HIV/AIDS, and many of the types of cancer (Foldit, 2017; https://en.wikipedia.org/wiki/Folding@home; http://fold.it/ portal/ info/about). The fact that something as simple as a video game, has the potential to make a great difference (positively) in the world if one of the players designs a protein that can be applicable to real diseases. Basically, this video game can lead the way to the cure for cancer.

PUBLIC HEALTH INFORMATICS

Public health informatics is the protection of the public from diseases and illnesses through the process of tracking, predicting, and analyzing outbreak data (which scientists have been doing over the years). By using these methods, the public can be more informed about how, when, and where disease outbreaks can/will occur.

Geographical Information Systems (GIS)

Geographical Information Systems (GIS) is the application of technology to study geographical relationships. The most important factor in GIS are the maps, which indicate where diseases are centered and how it can be eradicated. GIS studies the effect that a person's environment (physical surrounding) can have on his/her health. Jon Snow's 1854 cholera map is an example of GIS. In 1850, Jon Snow deduced that the ongoing cholera deaths were centered around a water pump. Therefore, Snow mapped 13 of the wells in that area and marked deaths with black bars. GIS can be found today in public health and clinical practice and can be used currently for cancer surveillance programs.

The concept of GIS can be very helpful to many people, especially when a deadly disease outbreak occurs. So, this process will gain more momentum and importance in the future, as technology continues to progress (Briney, 2014)

Surveillance

Surveillance allows for the tracking of disease outbreaks, provides health policies and strategies, and provides alerts for medical-related emergencies. There are two types of surveillance: passive surveillance and active surveillance. Passive surveillance is when an agency receives reports from hospitals, schools, and other local centers. Active surveillance are regular reports generated for the government or for a government agency. The main purpose of active surveillance is to locate outbreaks (http://www.who.int/topics/ public_ health_surveillance/en/; Nsubuga et al., 2006; http://conflict.lshtm.ac.uk/page_75.htm)

Modeling

Modeling is the application of advanced methods to turn an infectious disease into equations, to create an impression of that disease. A public health model consists of a variety of different factors: population, human behavior, interventions, health promotions, disease prevention, and environment and harm. The purpose of modeling is to develop and organize ideas to later give insights on an outbreak. The three major advantages to modelling include: accessibility, balance, and simplicity. To create a public health model, these factors must be considered: number of people who visit their primary care physician (vaccinated or non-vaccinated), approximate amounts of hospitalizations, number of deaths, and total number cases. To create an actual public health model: first, determine the problem, then analyze the possible risks and protective factors, and lastly, complete extensive evaluation. (Meyers, 2016)

Cell phones and public health

The use of cell phones in public health is beginning to rise because this process is quicker, cost effective, easily locates and sorts patterns and data of disease, and is the most widely-used electronic device. Cell phones are being used in the developing countries for educational games on diseases (to educate children in India) and medical tests (to test for HIV and syphilis in the women of Africa) (http://www.freedomhivaids.in/freedomhivaids.htm)

IMAGING INFORMATICS

Imaging informatics is sometimes referred to as radiology informatics and medical imaging Informatics. The goal of imaging informatics is to increase the efficiency, accuracy, and usability of medical imaging services in healthcare fields. Imaging informatics is important because it saves a lot of time and money when it comes to making medical decisions. The field of imaging informatics is growing at a rapid rate (https://en.wikipedia.org/wiki/Imaging_informatics; https:// www.abii.org/About-Imaging-Informatics.aspx)

Teleradiology and nighthawking

Teleradiology is the process of sending patient scans to different locations, for them to be read. It uses the basic network technology and the cloud, along with specialized software, to transmit these images. Teleradiology improves patient care by allowing radiologists who are not with the patient to see the patient's images (Richtel, 2011)

Nighthawking outsources patient images to radiologists in other countries by using teleradiology. The internet and digital images make this process possible. Nighthawking was given its name because it was used during the night. About half of the hospitals in the Unites States use nighthawking. Nighthawking is beneficial to these hospitals because the process is cheaper than hiring a full-time radiologist and it does not disturb radiologists during the night. However, many radiologists feel that nighthawking devalues their line of work. The efficiency of the Nighthawking process through which the radiologists could review patient images without being with the patient is a very valuable tool for hospitals (to use) (DerGurahian, 2007; http://www.barkettlaw.net/ newsletters/ medical-malpractice/radiology-outsourcing/)

Picture Archiving and Communications Systems (PACS) and Digital Imaging and Communications in Medicine (DICOM)

Picture Archiving and Communications Systems (PACS) is a form of medical imaging technology. It is very convenient for hospitals to use because it provides a cheap form of storage, easy access to images, and eliminates the process of manually transmitting images. PACS works with many different types of scans, such as X-rays, CAT scans, and MRIs. PACS also allows images to be transferred across the country. Digital Imaging and Communications in Medicine (DICOM) is the standard for taking care of, storing, printing, and transmitting information. The communication protocol DICOM uses is TCP/IP. DICOM enables the integration of medical imaging devices and PACS. In the end, PACS is the system and DICOM is the protocol (https://en.wikipedia.org/wiki/Picture_archiving_and_communication_system; DICOM, 2017)

Computer Aided Diagnostics (CAD)

Computer Aided Diagnosis (CAD) is a form of technology that combines many elements of artificial intelligence (AI), machine learning, and computer vision along with radiological image processing. CAD can be used in hospitals for detecting tumors and for conducting medical check-ups on cancer patients. CAD systems help san digital images, such as X-rays, MRIs, CAT scans, and Ultrasounds. CAD has been used in the clinical environment for over 40 years. However, it is still not being used as a substitute for a radiologist. CAD methodology is based on very complex recognition patterns. First, the radiologist feeds the system without thousands of different types of patient scans, so that the computer can create an algorithm. Once the algorithm is completed, the radiologist then gives the system a patent scan that it wants it to diagnose. Once the image is scanned, the digital data is then saved and transmitted onto the CAD server in a DICOM-format. Those images are then prepared and analyzed in a very detailed step-by-step process. Lastly, the computer generates markers of possible cancerous sites on the scan, for the radiologist to look at. Enlitic is a company that wants to incorporate CAD into a company of its own. The goal of Enlitic is to just aid radiologists in the process of diagnosing different diseases and disorders in patients.

They do not want to replace the radiologists in hospitals. However, this process still requires a lot of improvement for it to be used in healthcare fields. Dermatologists have incorporated CAD into an app, called SkinVision. You can take pictures of your skin, and the app will then give you feedback on whether that part of your skin has any risks for cancer. SkinVision will also save and track that image overtime, so you can see if that part of your skin will become (more) cancerous overtime. The app has a 90% accuracy rate. Furthermore, there are many problems associated with CAD. many of the times, computers produce incorrect readings, called false positives. Therefore, in the end it is up to the radiologist to come up with the final diagnosis. Most of the time, radiologists just use CAD as a second opinion (https://en.wikipedia.org/wiki/Computer-aided_diagnosis; https://www.technologyreview.com/s/530261/a-startup-hopes-to-teach-computers-to-spot-tumors-in-medical-scans/; Woollaston, 2014; Kolata, 2007).

Human Connectome Project (HCP)

The Human Connectome Project is a type of imaging technology that is non-invasive. It maps the connectomes of the brain by creating a large-scale map of the brain (which is divided into distinct areas). The goal of the Human Connectome Project is the determine the anatomy and function of the human brain and to produce data that will aid in the research on brain disorders. The Human Connectome Project works through the diffusion MRI, mapping the brain by tacking the flow of water, and increasing spatial resolution, quality, and speed. Brain Mapping Projects create new, vivid images of the brain. It aids research in uncovering the paradox behind brain disorders by researching how the brain works. The Brain Mapping Project reconstructs neuron activity by simultaneously sending signals to different parts of the brain. (https://en.wikipedia.org/wiki/Human_Connectome_Project; https://en.wikipedia.org/wiki/BRAIN_Initiative)

Virtual autopsy

Virtual autopsy can also be called Virtopsy. Virtual Autopsy relies on medical imaging machines, such as MRI and CT scan machines, to conduct an invasive surgical procedure and thorough examination on a corpse. Virtual Autopsy is very fast and accurate. It allows for the body to be examined in finer detail. It is being used in the field of forensics by the police investigators. Although the equipment required to conduct a Virtual Autopsy is expensive, the process itself is less expensive and time consuming than an actual autopsy (Virtopsy, 2017; Tejaswi, 2013)

CLINICAL INFORMATICS

Clinical informatics is the practice of an information-based approach to delivering health care. The importance of it in the medical environment is that technology is becoming more advanced, leading to a better experience in the hospitals for patients.

Electronic medical records (EMR) and data mining

Electronic medical records (EMR) are a digital form of a paper chart that contains all of the patient's medical information. Advantages of EMRs include: the reduction of medical errors, safer patient care, saves paper, takes up less space, easily shares medical information with other physicians, and better organization of records. Disadvantages associated with EMRs include: staff training in filing medical records, availability of skilled technicians, frequent system updates, and that it takes about five years for hospitals to switch over to EMRs. EMRs are also associated with privacy and security concerns. These can include: risks of hacking into the system, which can lead to identify theft and lawsuits against hospitals. With the use of EMRs, proper regulations should be put into effect, making systems to always be monitored and for systems to be updated when required (https://www.healthit.gov/providers-professionals/electronic-medical-records-emr; https:/ /www. healt hit.gov/providers-professionals/faqs/what-are-advantages- electronic-health-records; http://health.usne ws.com/health-news/bes t-hospitals/articles/2015/10/1 5/hospitals-are-moving-slowly-to-electronic-medical-records; https://thenextgalaxy.com/the-advantages-and-disadvanta ges-of-electronic-medical-records/). Data mining is the process of finding patterns within large databases of information. EMRs can be used for data mining by providing this process with the information (which can sometimes be patient health/ medical records) it requires.

Medical expert systems

Medical expert systems are computer programs that prompts the judgement and behavior of medical experts by using AI technologies. DXplain is the evidential support for the diagnosis and is a recommended second opinion. DXplain is also a searchable database of diseases. SimulConsult (or Simultaneous Consult) is a type of diagnostic decision support software that aids in the process of thinking in specific cases. With SimulConsult, there is more confidence in recognizing atypical patterns. Watson MD, an AI simulator created by IBM, can collect and translate medical data. Watson can then create a diagnosis based on this information. Through this process, healthcare costs would be cut in half. Currently, IBM is feeding Watson information so that it can learn about medical history and teach students. However, Watson still needs to be further improved upon so that it can be used more dependently in a medical environment (Shortliffe, 1986; DXplain, 2015; http://www.simulconsult.com/ software/ introduction.html; Mole, 2013)

Telemedicine and telesurgery

Telemedicine is the service of telecommunication and information technology to conduct medical care from a distance. Telemedicine saves time, increases doctor-patient communication, and is more convenient for both the physician and patient. However, telemedicine is prone to hacks, requires technical training, contains possible glitches, reduces face-to-face interaction, and physical evaluations and diagnoses are not possible. Types of telemedicine can include: telepsychiatry, teledermatology, teleopthamology, teleobstretrics, teleoncology, and telerehabilitation (https://evisit.com/what-is-telemedicine/). Telesurgery is a type of surgery that is performed by a doctor (from a distance) on a patient, using medical robots and multimedia image communication. The concept of telesurgery is very fascinating by the fact that physicians can use medical robots to perform surgeries on patients from a distance (https://evisit.com/what-is-telemedicine/)

3D printing

3D printing is the process of creating a physical object from a digital model.

3D printing is currently being used to make prosthetics, bones, cartilages, medical equipment, Invisalign, heart valves, and tissues with blood vessels. 3D printing, in the future, can be very valuable in the medical field for creating products, such as pills, stem cells, skull patches, human tissue, and organs (liver, kidneys, and lungs) (https://www.3dhubs.com/what-is-3d-printing; Meskó, 2015; Royte, 2013). Soon 3D printing, will be able to create organs for patients which will become invaluable to people around the world because then patients would no longer have to wait for long periods of time on organ transplant lists; they could just get the necessary organ through the process of 3D printing.

RISKS of MEDICAL INFORMATICS

Risks occur in medical technology throughout the world. Technology will always be susceptible to attacks and errors, no matter how advanced the security for it is advanced. Risks are technology related mistakes that can cause harm to patients.

Operator errors, usability and design problems, bugs, and programming mistakes

Operator errors are errors that are caused by the input of the incorrect patient information into patient files. Usability and design problems can be caused by a lack of instructions on the machine, softwares not being user-friendly, and updates taking place without authorization. Bugs are errors in computer programs which cause the computer to produce an incorrect response. Bugs can be external. Programming mistakes are the incorrect code written for a program. This can cause malfunctions and the most common type of error is a coding error (http://osteopathic.nova.edu/msbi/evolution.html; Richtel, 2011; http://www.telegraph.co.uk/ news/uknews/ 1513550/Baby-died-after-untrained-doctor-took-50-50-gamble-on-pressing-right-button.html)

Security concerns and privacy issues

Security can be a problem when it comes to technology, used especially for medical purposes. Security concerns include the risk of hacking, data management, businesses looking into their employee's personal health records, and medical professionals misusing patients' health information. Medical technology can also be susceptible to malware because many of the times it operates on commonly targeted operating systems, such as Microsoft and Linux. Medical technology also sometimes does not update its operating system's software or its antivirus software. Therefore, the use of technology in healthcare environments can lead to operation mistakes, delayed test results, disturbances in patient care, loss of files, and patient confidentiality being compromised (Nanji, 2009; Harvey, 2013; http://www.ucdmc.ucdavis.edu/welcome/fea tures/2010-2011/08/20100811_cyberterrorism.html). Privacy issues lead to identity theft and expensive lawsuits, which can be caused by a breach in records. Neither paper nor electronic records are safe from privacy issues and can be easily obtained by unauthorized people. Patients health records can be at risk for a variety of reasons. These can include: poor security, lost or stolen records, failure to remove records from systems when they will be no longer used, the unreliability of third-party storage companies, open Wi-Fi, social engineering, rogue employees, and/or the Cloud's unreliability (http://www.ironmountain.com/Knowledge-Center/Reference-Library/View-by-Do cument-Type/General-Articles/E/ Electronic- Health-Records-Security-and-Privacy-Concerns.aspx; Gregg, 2013)

Therac-25

Therac-25 was supposed to monitor the machine's status, accept inputs for treatments, get the machine prepared for treatment, turn on/off the treatment beam, and deliver diagnostic messages when it malfunctions. However, this project completely backfired. Therac-25 burned a patient's arm, gave multiple doses of treatment to another patient, killing her three months later, caused radiation exposure to another, and paralyzed another patient's arms (he died five months later). Therac-25 also gave a patient radiation to the side of his face, causing him to fall into a coma and die three weeks later. Lastly, it overdosed on the treatment of a patient and the patient died three months later. Eleven Therac-25 machines were released in 1987 and then suspended in 1987 after all those fatal incidents. There were two Interface issues that led to the failure of Therac-25. The first issue is called Interface Issue 1. This issue included a bug within the system, the lack of formal instructions and testing procedures, operators making changes to treatment(s), operators not double-checking the treatment plan(s), and the beam being set to photon mode when the turntable is on electron mode. The Interface Issue 2 was the second problem. This issue included the turntable being set in test mode (demo mode) and information being stored in one byte of memory (Porrello, 2017; https://computingcases.org/case_materials/ therac/ case_history/Case/History.html). In the Therac-25 incidents, a machine whose function was to "aid" in the treatment of patients ended up killing or hurting the patients instead. Many of the mistakes that occurred originated from the creation of the machine itself.

Conclusion

Like in every field that is evolving there are pros and cons and medical informatics is one such field that is evolving and needs to be perfected. Security and privacy issues will always be a concern as the hackers have time and again demonstrated that even the most secure sites have been broken into and compromised. Added to this are the bugs and the operator's errors which make this even more vulnerable and further the incidents such as Therac-25 would make the patients even more skeptical about their treatment.

REFERENCES

A History of the Introduction and Shut Down of Therac-25. (n.d.)., https://computingcases.org/case_ materials/ therac/ case_history/Case/History.html

About Imaging Informatics. (n.d.). https://www.abii.org/About-Imaging-Informatics.aspx

All About the Human Genome Project (HGP). (2015, October 1)., https://www.genome.gov/10001772/all-about-the--human-genome-project-hgp/

BRAIN Initiative. (2017, June 7)., https://en.wikipedia.org/ wiki/BRAIN_Initiative

Briney, A. (2014, April 18). Overview of Public Health and GIS., https://www.gislounge.com/overview-public-health-gis/

Britten, N. 2006, March 21. Baby died after untrained doctor took 50-50 gamble on pressing right button., http://www.telegraph.co.uk/news/uknews/1513550/Baby-died-after-untrained-doctor-took-50-50-gamble-on-pressing-right-button.html

Comparative genomics. 2017, May 18. https://en.wikipedia.org/wiki/Comparative_genomics

Computer-aided diagnosis. 2017, May 23, https://e n.wikipedia.org/wiki/Computer-aided_diagnosis

DerGurahian, J. 2007, November 30. Docs talk 'nighthawking' at RSNA., http://www. modernhealthcare. com/article/20071130/INFO/311300005

DICOM. (2017, May 25)., https://en.wikipedia.org/ wiki/ DICOM

DXplain. (2015, August 28)., https://e n.wikipedia.org/ wiki/DXplain

Electronic Health Records Security and Privacy Concerns. (n.d.)., http://www.ironmountain.com/Knowledge-Center/ Reference-Library/View-by-Document-Type/General-Articles/E/Electronic-Health-Records-Security-and-Privacy-Concerns.aspx

Evolution of Medical Informatics. (2017)., http://osteopathic. nova.edu/ msbi/evolution.html

Experts: Cyberattacks threaten hospitals. (2010, August 11)., http://www.ucdmc.ucdavis.edu/welcome/features/2010-2011/08/20100811_cyberterrorism.html

Folding@home. 2017, May 24. https://en.wikipedia.org/ wiki/Folding@home

Foldit. (2017, March 31)., https://en.wikipedia.org/wiki/Foldit

Freedom HIV/AIDS. 2007-2008. http://www. freedomhivaids.in/ freedomhivaids.htm

Garling, C. (2014, August 22). A Startup Hopes to Teach Computers to Spot Tumors in Medical Scans., https://www.technologyreview.com/s/530261/a-startup-hopes-to-teach-computers-to-spot-tumors-in-medical-scans/

Gregg, M. (2013, January 17). Why Your Medical Records Are No Longer Safe., http://www.huffingtonpost.com/ michael-gregg/privacy-medical-records_b_2473458.html

Harvey, R. S., Looney, K. H., & Norwood, E. A. (2013, March 21). Medical Devices and Malware: The Latest Hospital-Acquired 'Infection', https://www.healthcare-informatics.com/article/medical-devices-and-malware-latest-hospital-acquired-infection

How is the completed human genome sequence being used? (2016, June 13)., http://www.yourgenome.org/ stories/how-is-the-completed-human-genome-sequence-being-used

Human Connectome Project. (2017, March 26)., https:// en.wikipedia.org/wiki/Human_Connectome_Project

Human Genome Project. (2005, November 25)., https://www.canada.ca/en/health-canada/services/science-research/emerging-technology/biotechnology/about-biotechnology/human-genome-project.html

Human Genome Project Pros and Cons. (2014, February 17)., http://healthresearchfunding.org/human-genome-project-pros-cons/

Imaging informatics. (2017, February 22)., https:// en.wikipedia.org/wiki/Imaging_informatics

Introduction to the Software. (2016)., http://www. simulconsult.com/ software/introduction.html

Kolata, G. (2007, April 5). Study Questions Exam to Detect Breast Cancer., http://www.nytimes.com/2007/04/05/health/05breast.html

Lloyd, E. (2017, June 1). What is Rational Drug Design? (A. Joseph, Ed.)., http://www.wisegeekhealth.com/what-is-rational-drug-design.htm

Lombardo, C. (n.d.). The Advantages and Disadvantages of Electronic Medical Records., https://thenextgalaxy.com/the-advantages-and-disadvantages-of-electronic-medical-records/

Meskó, B., MD, PhD. (2015, February 26). 12 Things We Can 3D Print in Medicine Right Now. Retrieved June 21, 2017, https://3dprintingindustry.com/news/12-things-we-can-3d-print-in-medicine-right-now-42867/

Meyers, L. A., PhD. (2016, January 19). *Staying Ahead of the Curve: Modeling and Public Health Decision Making*(PDF). Austin: CDC.

Mole, B. M. (2013, February 1). Watson, MD., http://www.the-scientist.com/?articles.view/articleNo/34160/title/Watson--MD/

Nanji, F. (2009, February 19). Security Challenges of Electronic Medical Records., from http://www.computerworld.com/article/2531320/security0/security-challenges-of-electronic-medical-records.html

Nsubuga, P., White, M. E., Thacker, S. B., Anderson, M. A., Blount, S. B., Broome, C. V., . . . Trostle, M. (2006). Chapter 53 Public Health Surveillance: A Tool for Targeting and Monitoring Interventions., https://www.ncbi.nlm.nih.gov/books/NBK11770/

Personalized Medicine. (2011, January 20)., http://health.usnews.com/health-conditions/cancer/personalized-medicine/overview

Picture archiving and communication system. (2017, June 8)., https://en.wikipedia.org/wiki/Picture_archiving_and_communication_system

Porrello, A. M. (n.d.). Death and Denial: The Failure of the THERAC-25, A Medical Linear Accelerator. Retrieved June 21, 2017, from http://users.csc.calpoly.edu/~jdalbey/SWE/Papers/THERAC25.html

Public health surveillance. (2017)., http://www.who.int/ topics/public_health_surveillance/en/

Radiology Outsourcing. (2011)., http://www. barkettlaw.net/ newsletters/medical-malpractice/radiology-outsourcing/

Richtel, M. (2011, December 14). As Doctors Use More Devices, Potential for Distraction Grows., http://www.nytimes.com/2011/12/15/health/as-doctors-use-more-devices-potential-for-distraction-rows.html?pagewanted=allhttp://www.telegraph.co.uk/news/uknews/Baby-died-after-untrained-doctor-took-50-50-gamble-on-pressing-right-button.html

Royte, E. (2013, May). What Lies Ahead for 3-D Printing?, http://www.smithsonianmag.com/science-nature/what-lies-ahead-for-3-d-printing-37498558/?no-ist

Ruder, K. (2004, October 28). Personalized Medicine in Cancer: Matching Patients and Drugs., http://www.genomenewsnetwork.org/articles/2004/10/28/ matchingpatients.php

Schroeder, M. O. (2015, October 15). Hospitals Are Moving (Slowly) to Electronic Medical Records., http://health.usnews.com/health-news/best-hospitals/articles/2015/10/15/hospitals-are-moving-slowly-to-electronic-medical-records

Shortliffe, E. H., MD, PhD. (1986, December). Medical Expert Systems—Knowledge Tools for Physicians., https:// www.ncbi.nlm.nih.gov/pmc/articles/PMC1307157/

Tarceva. (n.d.)., https://www.drugs.com/tarceva.html

Tejaswi, K. B., & Periya, E. A. 2013. Virtopsy (virtual autopsy): A new phase in forensic investigation., https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3826044/

Telemedicine. 2017, May 26. https://en.wikipedia.org/wiki/Telemedicine

TELEMEDICINE GUIDE. (n.d.)., https://evisit.com/what-is-telemedicine/

Teleradiology. 2017, May 18. https://en.wikipedia.org/wiki/Teleradiology

The Science Behind Foldit. (n.d.)., http://fold.it/portal/info/about

Types of surveillance. (2009)., http://conflict.lshtm.ac.uk/page_75.htm

Virtopsy. (2017, May 13)., https://en.wikipedia.org/wiki/Virtopsy

What are the advantages of electronic health records? (2014, September 4)., https://www.healthit.gov/providers-professionals/faqs/what-are-advantages-electronic-health-records

What is 3D Printing? (n.d.)., https://www.3dhubs.com/what-is-3d-printing

What Is an Electronic Medical Record (EMR)? (2016, September 22)., https://www.healthit.gov/providers-professionals/electronic-medical-records-emr

Woollaston, V. (2014, November 12). Should you get that mole checked out? £2.99 dermatologist-designed app scans skin for signs of cancer - and does it with up to 90% accuracy., http://www.dailymail.co.uk/sciencetech/article-2831557/Should-mole-checked-2-99-dermatologist-designed-app-scans-skin-signs-cancer-does-90-accuracy.html?ITO=1490&ns_mchannel=rss&ns_campaign=1490

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