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Advancements of the 21st century and Their Implications on Medical Research and Diagnosis

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Abstract

Throughout the 20th century, new research and new demands have led to an increased amount of technology used in medicine. These methods have led to early detection, better context of conditions, increased efficiency, and brighter prospects for the future of medical diagnosis. However, the increasing use of AI and genetics in medicine has called for checks and further clinical trials to determine how ethical these practices might be. The debate surrounding the integration of Artificial Intelligence has created further controversy—that is, what technologies should be used and what technologies should not be used. To determine a solution, certain factors should be considered including the comfort of patients during treatments including advanced technology, the risk factor of integrating AI into procedures, and the efficiency of technology compared to traditional medical practices. For example, imaging technologies such as X-ray and sonography are found to be more comfortable for patients due to their long-standing familiarity, yet their precision and accuracy fall short in comparison to advanced Imaging technologies such as CT, MRI, and PET scans. There has also been discussion of the use of genetic testing such as chromosomal microarrays. Advances in genetic testing have led to the ability to detect conditions in embryos which can be beneficial, but the manipulation of the embryos could raise ethical concerns. Past ethical grey areas, there have been amazing prospects for the future of medicine and these innovations, such as the use of non-invasive testing which is an emerging alternative to traditional surgical methods. Through extensive literary research, this paper considers the multiple aspects that should contribute to deciding to implement technological advancements brought in the 21st Century. By investigating previous integrations of innovations within medicine, this research could envision a risk-free and more ethical approach to advancing medicine with technology.

Keywords: Genetics, Imaging, Medicine, Ethics, AI and Robots

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Implications of Innovative Imaging Technologies

Methods of medical imaging such as X-rays/plain films and sonography are found to be more comfortable among patients due to their long-standing familiarity with them and their low cost. However, the image outcome of those assessments do not give physicians a clear answer, leading them to order more advanced imaging tests. Imaging technologies have been playing an essential part in finding diseases during early stages, accurate diagnosis, and more accurate staging of the severity of the disease. Some prominent examples of such technologies include CT scans, MRI scans and PET scans. All which serve the purpose to give medical experts a better understanding of the inner workings of the patient's body.

Computed Tomography (CT scan) uses radiation to generate detailed 3D images. This form of scan is posed at a relatively inexpensive price (compared to other advanced imaging) with results that come out relatively quickly. Even with its attractive qualities, its heavy usage of radiation cannot be ignored. Because radiation is harmful to humans—especially children and pregnant women–-doctors try to not order CT tests unless absolutely necessary. A cross-sectional survey done across doctors in Germany about pediatric CT scan usage suggests that of the 295 (36.4%) doctors that responded, 59% had not referred pediatric patients to CT scans in the past year. 30% of the doctors who responded to “yes” said that they referred 1-5 patients annually and that they were majorly trauma or suspected cancer related scans. This has been a big limitation for CT scans as it was too dangerous for some patients. As a result, numerous advancements have been made towards the reduction of radiation usage.

One example would be Photon-Counting Computed Tomography (PCCT). PCCT is presumed to be a revolutionary advancement in CT as it allows for production of high spatial resolution images while using low radiation dosage. It outcompetes the conventional CT in both its quantitative and qualitative aspects. In terms of quantitative ability, PCCT has better spatial and spectral resolution as well as the ability to minimize the distortion caused to image by metal artifacts by using virtual monoenergetic image reconstruction. As for qualitative ability, PCCT shows its excellence through images of bone and joint. Not only is it able to capture fine structure of the bone, it is also able to calculate bone mineral density (BMD), bone microstructural analyses, and evaluate cartilage quality with precision. All of which are crucial to understanding and assessing bone health *(Jilmen Quinties et al, 2024)*. Another example would be Advanced Modeled Iterative Reconstruction Algorithm (ADMIRE). A task-based image quality assessment was done to measure the impact of radiation reduction and the use of ADMIRE on image quality on a dual-source CT system *(Jöel Greffier et al. 2021*) The result of the assessment suggests that ADMIRE had significantly reduced the noise magnitude as the energy level increased, improved spatial resolution and improved the detectability of enhanced iodine lesions. This assessment implies that adopting ADMIRE with the aim of reducing radiation dosage will lead to enhanced resolution and patient safety.

Magnetic Resonance Imaging (MRI) uses magnetic fields to generate 3D images that are clear, detailed and show significant contrast between the soft tissues. MRI scans are expensive and take much longer for imaging results to come out. Although MRI reduces the risk of radiation exposure, because it is powered by magnetic fields, it reacts strongly with metal. As a result, MRI is not opted for, for patients who have metal implants as it leads to distortion of image. Luckily, recent advancements show that there is a solution.

A new MRI called High-V MRI with .55T field strength is said to be greater than the conventional MRI *(Bradfield, "What's New in MRI Technology — 2024 Edition")* This new version promises much more clear and detailed images of areas which, previously, were difficult to scan, an example being metal implants and blurry areas such as the sinus. Additionally, it promises to enhance pulmonary imaging, something that the conventional MRI lacks due to air-tissue interfaces on the lungs which ultimately leads to blurry images.

Positron emission tomography (PET scan) shows the severity or activeness through brightness instead of showing location and size. This gives radiologists an idea of the disease progression or of its presence. According to *Stanford Health Care*, Radiologists start by injecting a substance attached to a radioactive tracer or probe into the vein. For example, if the scan is being done to show the intensity of cancer, fluorodeoxyglucose (FDG), which is glucose sugar, will be injected into that area. Places where the FDG is accumulated signifies high metabolic activity which correlates with high numbers of cancerous cells. The denser the amount of FDG accumulated, the brighter the FDG will show up in the images—indicating a malignant tumor or cancer. However the substance used differs by the reason of the scan. From these scans, finite details about the molecules are captured.

An advancement of PET scan is improving the sensitivity which will further enhance image quality and reduce the dosage of radiation through molecular imaging. Molecular imaging has allowed Positron Emission Tomography to further develop a molecular level of data that is crucial for diagnosing. With this advancement, PET scans are able to detect functional and molecular information such as metabolic activity, molecular pathways, receptor status which all help with early detection and staging of diseases (*Steven P Rowe et al, 2022*).

Medical imaging technology has allowed for disease to be diagnosed at earlier stages. This opens up the opportunity for patients to receive better treatment and experience better outcomes after the treatment. CT scanner was introduced in 1972; however, it was not until 2015 that the prototype for ultra-high resolution CT improved on the spatial resolution. The new Ultra-high resolution, also known as high-spatial resolution CT (HSR CT), has 0.25mm detector elements whereas the conventional CT had only 0.5mm detector elements. With the HSR CT, structures that were easily missed due to their small size, became much more clear. For example, it would be difficult to recognize the start of lung cancer as the resolution was only able to show nodules that were bigger. However, due to better spatial resolution of HSR CT, the small lung nodules can now be identified at the beginning stages.

In a study titled *"High-Spatial-Resolution CT Offers New Opportunities for*

Discovery in the Lung", *Yanagwa et al*. observed 89 patients who were in different stages of invasiveness of lung adenocarcinoma: minimally invasive and invasive. She found that if air bronchogram was disrupted, then that would be a strong indicator towards the invasiveness of lung adenocarcinoma. The results showed that disruption of air bronchogram was noted for 100% of minimally invasive and 96% of invasive lung adenocarcinoma whereas only 14% of early stage lesions showed signs of invasiveness. Through this study, HSR CT capability of diagnostic accuracy, enhanced sensitivity and specificity was clearly present.

PET scan and molecular imaging are also capable of diagnosing during early stages. This is because PET scan is able to show the changes happening within a cell or tissue. The first hint

of the possible presence of disease is during biochemical changes, something that can be easily discovered through PET scan and molecular imaging. CT and MRI scan will discover this in the latter change which is the anatomical changes. Although both are still excelling in identifying early on, with the findings of PET scan initialized first, higher chance of patient outcome is guaranteed.

Medical Imaging technology leads to more accurate diagnosis. As discussed above, both CT and MRI scans have taken steps towards ensuring that its scans are accurate, detailed and overall diagnostically beneficial. These advancements have led to accurate diagnosis which led patients

to receive the proper treatment for their condition. In the case of diagnosing patients with acute appendicitis, inflammation of the appendix, the benefit of using CT and MRI is also present. Traditionally, acute appendicitis would be diagnosed through physical examination, family history and laboratory tests to check for possible inflammation (*Jerry L et al*, 2005) explains that although the accuracy of using this method was 80%, numerous cases of false-positives arose. In 1997, 261,134 patients suspected of appendicitis underwent appendectomy in the United States. However, of the patients who underwent the procedure, 39,901 (15.3%) showed no pathological features of appendicitis. Going through unnecessary surgery costs patients increased risk, morbidity and hospital expenses. Luckily, with the advancements of modern imaging technologies such CT and MRI, the percent of diagnostic accuracy of appendicitis increased from 80% to 93-98%. In both of these examples, MRI and CT capability in accurate diagnosing is prevalent, thus leading to better patient outcomes.

Medical Imaging technology leads to more accurate staging of the severity of the disease. As mentioned earlier, PET scan shows the progression of a disease through substances injected through radioactive tracers who;s brightness indicates the severity of the condition. Through this measure, it makes staging easier as well as make the process of personalized treatment plans much simpler to create.

Cancer or tumor that is in its initial stage is usually much smaller and is in one place. However, cancer or tumor that is in its later stages, spreads to other parts of the body forming metastases. Although both are dangerous to the body, the way to ensure proper treatment of removal differs. When one is in the initial stage of the cancer/tumor developing, surgery is usually opted for. However, when the cancer/tumor enters the later stage, it becomes too big and dangerous to be removed by surgery so those patients are usually referred to chemotherapy. Without proper advancements such as full body scan or sensitivity and specificity, sending stage 3 or stage 4 patients for surgery would be common. This would ultimately increase risk for the patient because the remaining bits of cancer that were not detected earlier, would still remain.

A clinical study published titled *"Metastases from Non-Small Cell Lung Cancer: Mediastinal Staging in the 1990s—Meta-Analytic Comparison of PET and CT." (Dwamena, Ben A. et al, 1999).*CT scan and PET-CT scan in accurately staging mediastinal non-small lung cancer in its initial stage. 23 patients who were recently diagnosed or suspected of such a condition participated in this study and of the 23, 19 patients were diagnosed with non-small cell lung cancer. The study found that the cancer had spread to the mediastinal lymph node which the CT accurately detected cancer for only 64% of the cases whereas PET and PET-CT fusion

detected cancer for 82% of patients. This study shows that PET scans are excellent at accurately staging the disease as it was able to detect other areas in which the cancer spread to.

With all being considered, advancements in imaging technology have shown to cast a positive impact in the medical field. It has increased patient survival rate and has allowed doctors the opportunity to intercept, if not prevent, a dangerous disease from taking control of the patient's body. Imaging technology is truly a miraculous invention that gives patients hope for renewal and doctors hope for their patients safety. It is not only important to have safe imaging technologies, but also a plethora of testing opportunities. This creates the need for new non-invasive testing which can help gather detailed information in high risk opportunities, when typical testing is too dangerous.

Advancements in Non-invasive Technologies

The rise of noninvasive testing has brought greater ease, efficiency, re-testability and also has lessened the effect of the test on the patient. Three main methods have emerged due to the demand for more noninvasive tests, namely saliva testing, breath tests and liquid biopsies.

Foremost, Liquid biopsies are typically accessed through the patient's blood, contrasting to regular biopsies taking specimens of the patient's tissue, both methods are used to determine if he has developed cancer. Liquid biopsies work by evaluating circulating DNA in the bloodstream, also known as cell-free DNA, which can symbolize a tumor-creating environment. Liquid biopsies stand as an effective method of testing because of their re-testability. As opposed to tissue biopsies, liquid biopsies can be taken multiple times, it is more affordable, it is less risky, and the procedure is shorter and it doesn't require a large amount of blood. In addition, this way of testing has also improved patient comfortability. Traditional tissue biopsies may result in surgical intervention which can cause bleeding, pain, and infection leading to longer recovery times. Thus liquid biopsies limit the complications and risk that come with tissue biopsies. Additionally, in a survey of 413 patients 90% expressed a preference for liquid over tissue biopsies for analyzing biomarkers (Min Joon Lee et al., 2020). Therefore liquid biopsies provide improved experiences for patients in alternative to tissue biopsies, but there is even more to their existence.

Liquid biopsies aside from being known for their efficiency and relative ease have also been used for early detection and monitoring of cancer and cardiovascular diseases.

One case study highlights the advantage that liquid biopsies show promise for. Outlined in case study a healthy 3 year and 10 month old female was raising concern through squinting and difficulty to urinate (Arthur, 2024). After a CT and MRI scan a tumor in the medulla oblongata was revealed, leading to a discussion of treatments or tests to assess the patient's condition. A tissue biopsy was ultimately out of question as the tumor was inoperable and not safe for the patient, so instead the patient underwent radiotherapy. The scans showed an increased hydrocephalus, from which they decided to undergo a VPS (Ventriculo-Peritoneal Shunt) collecting cerebrospinal fluid and blood samples. Using a BRAF V600 testing kit, the CSF sample was positive for tumor DNA and BRAF V600 mutations. Using the outcome of the liquid biopsies to guide their treatment, they administered the FDA approved dabrafenib,

and presently the child has no symptoms, deeming the treatment successful. In this case, liquid biopsies were a great advantage especially with the inability to collect a tissue sample from the tumor. The liquid biopsy confirmed the type of mutation, site of the tumor and defined clearly the steps to recovery.

One last thing to mention is NIPT or noninvasive prenatal testing, which is a form of liquid biopsy performed on the amniotic fluid of a pregnant patient's uterus. This is an important talking point as NIPT can be used to determine the risk for genetic abnormalities. On one hand this can be great for providing care to ensure the proper growth of the child, and so that doctors more closely can observe the growth of the child in case of emergency. However as we will discuss in the moral implications section, this can lead to parents being selective.

Saliva testing, like liquid biopsies, has started to replace more traditional testing methods. Saliva testing is testing that assesses the patient's saliva, measuring hormone levels and identifying any infectious agents and it has been useful in determining HIV, the various types of hepatitis, and substance use.

The advantages to using saliva testing in comparison to traditional testing methods is abundant. Primarily is the affordability of saliva testing in respect to the intensive swab based testing which saves a little over $600,000 (Tan et al., 2022). Additionally the test is very efficient. The time taken to take the tests is very minimal as doctors can conduct multiple tests within a single day without any major complications, and determining the test results also takes a limited amount of time. What accentuates the speed and retestibility of the tests in their accuracy. Saliva is made up of secretions from various sources resulting in a large pool of biomarkers, which lead to a heightened probability that a virus will be detected (Ghosh et al., 2022). This method is so reliable that the RT-PCR saliva tests have been used by researchers to find the contamination of COVID-19. This new method of testing boasts higher comfortability which further can increase the accuracy of the tests. In comparison to the pain associated with venipuncture, a traditional testing method, saliva tests are fully painless. It is useful to note that some hormone levels can change due to stress, and this may impact the reading of the tests. Saliva tests maximize the accuracy and lessen the margin for fluctuation because of the comfortability it provides.

The case of COVID-19 proved the competence of saliva testing versus traditional testing. During the pandemic a mass testing process was approved for addressing the high transmission risk contexts, and for this to be possible the form of testing has to be simple, cheap and available, and saliva testing has proved to aid in the mass testing campaign. The whole nation had fallen under the pandemic and the economy was failing, so it was not feasible to employ large expensive testing upon the already distressed country. In this time the convenient nature of saliva testing was useful in particular. With the ability to take these tests at home, the population did not have to worry about getting COVID-19 when traveling to the hospital which already had many sick individuals with the virus.The public opinion shows support for this method of testing, 96.9% voting it very favorable in nursing homes, and 100% in schools (Petre, 2022). The instance of COVID-19 has also shown the accuracy of saliva testing rather than traditional procedures. In addition, saliva testing recognises the SARS-Co-V-2 virus quicker than nose swabs (American Society for Microbiology, 2022).

Lastly, breath tests have been further utilized in healthcare following the growth in noninvasive testing. Breath tests evaluate the levels of chemicals using someone's exhaled air. One main form of breath testing, hydrogen breath tests, evaluates the levels of hydrogen gas and can be used to determine a myriad of digestive issues.

Breath tests are similar to saliva testing in that they are simple and easy to perform, but most important is their role in helping spot gastroenterology diseases. In fact, basal breath hydrogen is greater in those with IBS, and those who have constipation have greater methane (Ghoshal, 2011). With these biomarkers having relationships with both Hydrogen and Methane, through breath tests scientists can evaluate a patient's condition through the use of breath tests such as IBS and constipation. These Hydrogen Breath Tests (HBT) are known as easy, cheap and noninvasive tests, and some breath tests can even be performed in one's home. The uses of breath tests go beyond examining gastrointestinal diseases and conditions, there is also some potential in it being able to detect diabetes. Wang et al. described their reports similarly, stating "breath test is a promising approach to non-invasive diagnosis of diabetes mellitus and is especially appropriate for large-scale preliminary screening" (Wang et al., 2021).

Though breath tests are becoming increasingly incorporated in diabetes testing, breath testing has already been shown to have successful times in which breath tests have been able to successfully detect liver cancer in individuals, even when traditional methods had failed.

The progression of hydrogen tests can be seen through the development of early liver disease detection. Liver disease is really hard to diagnose because of its lack of symptoms, so although 90% of liver diseases may be preventable by the time the patient is informed of their condition, their liver cancer has developed to extreme levels. This can be seen as *Owl Stone Medical* reported that "75% of patients receiving a diagnosis of cirrhosis (scarring of the liver) only upon liver failure". So basically a majority of liver disease patients receive a diagnosis of cirrhosis, the last stage before liver failure before shortly going through liver cancer. So had these patients undergone early testing for early detection their outcomes would have been way different. The need for quick testing rather than tissue biopsy led to a breakthrough with limonene. Scientists have found that limonene is a biomarker that can be used to accurately detect and show the progression of liver disease. Even more so *OwlStone Medical* found that " 29 volatile compounds were significantly different between people with cirrhosis vs controls' ' leaving great promise for breath tests in monitoring liver disease. Breath testing as of recently has been taking great leaps for early detection of liver disease, and a recent trial shows that it has overrun recent testing methods by proving the presence of cancer in a patient who was previously cleared for liver disease. *OwlStone Medical* reported this case stating " a subsequent liver disease trial showed that the breath test was incredibly accurate, even to the point of detecting the presence of liver damage in someone who had a liver disease but was misassigned to the healthy control cohort"(OwlStone Medical, 2023) .With the accuracy of breath tests, the future of early diagnosis is looking positive.

In conclusion, these emerging noninvasive technologies create a brighter future and a higher quality of life for patients. Noninvasive testing methods such as liquid biopsies, saliva testing and breath tests have been utilized to create cheaper, more comfortable, and more effective testing in comparison to traditional methods, and it has been shown that these testing methods

can be relied upon in situations where invasive testing is either not practical or safe for the patient.

New Generation Genetics and Personalized Medicine

Our DNA sequencing governs the way we look, act, feel, and most importantly the health conditions that we can develop. Through pairs of adenine, thymine, cytosine, and guanine all of our defining qualities were carefully curated from the lengthy instructions that our double helixes provide. As of late, we have understood the true importance of these configurations as mutations in our DNA and other genetic disorders have led to rare diseases that have resulted in lowered quality of life. In the age of our technology through advancements in genetics, we have been able to use methods of testing to highlight the error in our genetic background to find a personalized path for treating these rare disorders and conditions, with increased knowledge and more insight into individual problems we have paved a path for better, safer, risk-free care.

Chromosomal microarrays are one way that we have utilized technology to reveal genetic secrets, this method has proved valuable for insight into certain conditions such as autism and differing disabilities. CMA shows the changes within a gene or karyotype, showing added DNA or deleted DNA. CMA is often used for pregnant women to assess the health of their prenatal child, allowing them to make decisions for the best interest of both the mother and the child. In the Journal of National Library of Medicine the article *Karyotype versus Microarray Testing for Genetic Abnormalities after Stillbirth by* Reddy et. al stated that in a study of 532 stillbirths, CMA provided more results (87.4%) in regards to karyotyping (70.5%) and was more accurate in detecting mutations, meaning it is more reliable in giving a diagnosis because of its ability in using nonliving (nonviable) tissue (Reddy et al., 2012). The most outstanding quality of CMA is its ability to detect copy-number variants. A study by Wapner et. al proceeds to explain "The development of array-based molecular cytogenetic techniques has improved the detection of small genomic deletions and duplications (called copy-number variants) that are not routinely seen on karyotyping, the standard cytogenetic analysis performed." (Reddy et al., 2012). Sticking to the common practice of using karyotyping could lead to missing out on identifying these copy-number variants, and this is important because CNVs are characteristic of cancer as genetic deletions are common in tumors. So CMA as an emerging discovery in genetics has helped guide treatment and personalized medicine, as upon discovering CNVs and mutations, doctors and physicians can tailor their treatment.

The true usefulness of CMA genetic testing can be seen through the case study of a 49-year-old woman. In the case of the 49-year-old woman, CMA testing provided valuable context for her condition. Dr. Sukhanova of *Northwestern Feinberg School of Medicine* in the journal *Solving Oncology Cases With Chromosomal Microarrays* reports that after a karyotyping test, the patient's cancer was discovered to be hyperdiploid, which has a high recovery rate (Thermo Fisher Scientific, 2022). However, upon CMA testing, it was revealed that the hyperdiploid tumor was caused by a hypodiploid tumor, which complicates things as while hyperdiploid tumors generally have a high recovery rate, hypodiploid tumors are more strenuous to treat. As well as that, the 49-year-old women had genetic characteristics more

resembling the hypodiploid tumor rather than the hyperdiploid tumor, so as a result of the CMA testing the doctors decided to lead the patient into more intensive treatment because of the higher risk of the hypodiploid tumor. So while using the initial karyotyping results lacked sufficient insight into the patient's condition, the CMA testing showed the higher risk that the patient had which allowed the doctors to redirect their treatment.

Another development important for genetics is single gene testing. Single gene testing is often used to confirm a certain diagnosis, thus the doctor wants to zoom in on a single gene to make sure that the gene is the cause of the symptoms and not another case. Single gene testing is efficient and affordable, *National Genomics Education Program* reports that single gene testing "can provide rapid cost-effective genetic confirmation of a diagnosis"(Frost et al., 2024). This paired with single gene testing being 100% accurate makes for great early detection purposes, positively affecting the patients future outcomes. This can be shown by the NPV value. The NPV (negative predictive value) or probability that those who received a negative result on a test for a condition or disease in reality does not have the condition was very high, a percentage of 99.8%, meaning that the test results properly represented the condition of the patient accurately. Thus single gene testing is an effective method of testing for early diagnosis of passed down diseases, and also for predicting if the mother will pass down any traits to her child.

Gene panel testing is another new method that scientists use to assess a patient's genetic makeup, how it will affect them or their offspring, and depending on the condition how the doctor will treat them. Gene panel testing is different from single gene testing because instead of trying to find a mutation in one gene, gene panel testing searches in many genes for any variants. The ability to test many genes and thus rule out which ones are affecting the patient's condition is among the many strengths of panel testing. A journal in *JNCCN* shows an example of this strength in the application of cancer, because ovarian cancer can be both a mutation in the BRCA1/2 genes of hereditary breastovarian syndrome and the mismatch repair genes of Lynch Syndrome gene panel testing is valuable in that it can assess both of the genes to see if either or both of the mutations that caused those syndromes occurred (D. Angeli, 2020). Panel testing also opens doors for improved efficiency and comfortability with the patients, as where before multiple tests were needed to highlight the specific cause of a tumor with multiple associations, now we only have to use one test to find the determinant. This alleviates the initial burden of having to take multiple tests which is common with patients who have tough to diagnose diseases. It is not just the efficiency of the testing that makes panel testing worthwhile to look into, but also the accuracy of the testing in comparison to other testing methods. A journal in the *National Library of Medicine* by Fedrico Anaclerio et al. demonstrates the importance in utilizing panel testing in hereditary cancer patients, stating, “the panel testing approach increased the mutation detection rate of 15% in PC, 8% in BC and 5% in OC cases“(F Anaclerio, 2024). However there are also some downsides to panel testing and new issues that need to be looked into, such as that sometimes mutations that are detected using single gene testing can be missed with panel testing. As well as that there has been an increased occurrence for detecting VUS, which is a variant of unknown significance, which means that we aren't sure if the mutations are benign or malignant, because of lack of information and verifying research.Though there are many pros

and cons of this testing, further research and improvements on panel testing will prove valuable for NGS in medicine.

Lastly, large scale genetic testing is the largest form of genetic testing, looking from all the genes in a DNA helix, to all the DNAs in a whole genome (Medline Plus, 2021). There are two main types of large scale genetic testing, exome and whole genome testing. Exome testing is a less big evaluation, as it focuses on the exon which is all the protein coding elements of the genome, meaning that it is valuable for testing for mutations which may cause conditions or diseases. Whole genome testing is testing all of the genetic material within a sample of a patient. Whole genome testing can be useful when one wants to see any changes within the genetic information than usual, such as additions, subtractions and multiplications of certain genetic code, and it can also be useful for detecting large structural changes. Exome testing, however, is more focused on finding changes in protein creating elements, and when trying to specifically determine if a patient has changes in a protein creating element that cause a certain disease or dysfunction, then that type of testing is clinical exome testing. These collectively are used when a patient either has a rare or difficult to diagnose disorder, as well as if other genetic tests have given no insight into diseases or conditions that have similar symptoms to the ones that the patient is showing. WGS testing ushered in a new age of our technologies capabilities in 2018, as prior according to the *CDC*, we had only been able to assess 1% of the genome, and after 2018 we are able to assess over 90% of the genome (CDC, 2024).

All of these methods of finding out genetic disorders pays out in our ability to change and manipulate genes. Advancements into proteomics such as the crispr treatment has led to greater treatment of once untouchable genetic conditions. This process and evaluation of being able to change genes has been an ever evolving task. In the 1960s researcher Werner Arber discovered a microscopic process that changed our perspective on genes and genetics entirely. Arber was researching bacteriophages, viruses that infect a bacteria, and he found that these bacteriophages inject virus DNA into the bacteria to kill the target bacteria, however the main breakthrough was the method that the bacteria use to protect themself from the viral DNA. What Arber discovered was the use of restriction enzymes to protect the bacteria from the lethal bacteriophage viral DNA. Smith further discovered that these enzymes can find DA sequences and cut the DNA at those specific sites. This finding prompted Dan Nathans to apply this knowledge to genetics, as if bacteria could use enzymes to cut out unwanted segments from viral DNA, humans too could use enzymes to cut out genes that contributed to the development of genetic conditions. Together these three were granted the Nobel Peace Prize in 1978 and these discoveries opened a gate for personalized medicine to shine (The Nobel Prize, 2024). This discovery of manipulating genes led to the CRISPR technology.

CRISPR has already been implemented in the clinic, providing a bright future for medicine. There have already been trials after using an ex vito CRISPR based technology, which takes a patient's cells outside of their body and uses CRISPR to manipulate those cells to eliminate the disease. The patients who once had either SCD or beta thalassemia, which are critical blood diseases, were assessed and the findings were posted in a journal by *Innovative Genomics Institute*. Hope Henderson the publisher reported that those who were treated using the ex vito CRISPR technology who had SCD or beta thalassemia had now had "normal to

near normal" hemoglobin levels, patients with both conditions were free from blood transfusion and those with SCD didn't have struggles with pain crises anymore (Henderson, 2021). Additionally tests that analyzed the blood marrow of patients a year later showed thHope Henderson the publisher reported that those who were treated using the ex vito CRISPR technology who had SCD or beta thalassemia had now had "normal to near normal" at the ex vito cells were still prominent. Even though there was one case in which a patient with beta thalassemia had "serious immune reactions", the majority of the treatments were successful including the story of Victoria Gray. On *NPR* Victoria Gray, gave details on her recent health condition. After having sickle cell since she was a child, upon CRISPR treatment the pains she previously endured were gone, no "attacks of horrible pain", "devastating fatigue", and no longer would she consistently need blood transfusions (Stein, 2023). Even after a year later, the effects of the treatment have not worn off and her modified stem cells still continue to work, she even adds "I haven't any problems with sickle cell at all". CRISPR technologies also help those who don't have any other choice, any other method to fix or make their condition more livable, such is the case of a teenager named Alyssa who underwent treatment for leukemia. *MIT Technology Review* reported that after failed attempts of chemotherapy and bone marrow transplants to cure Alyssa's leukemia, the physicians led a treatment using CRISPR technologies (Hamzelon, 2023). Upon receiving T cells from a donor, scientists manipulated the cells using CRISPR to make sure that her immune system would not attack the cells and get rid of any mutated T cells, and after a while the cancer was "undetectable". While a majority of the treatments including Victoria, and Alyssas were successful, there have been some failed attempts at applying the CRISPR technology, and Terry Horgans case reflects those failures. Terry Horgan who had Duchenne Muscle Dystrophy had attempted to use CRISPR to help cure his disease. After treatment Terry passed, yet the cause of his death is still unknown (Hamzelon, 2023). Terry is a reminder that there is still much to come to CRISPR, and that we still need to be changing, tweaking and fixing CRISPR to make it less risky and more reliable.

Genetic testing can give us unique insight into an individual's inner workings, and what specifically is causing disorder or symptom. In this way Genetic testing is imperative to unique and personalized care for patients, as healthcare providers can craft exclusive treatments for that patients condition. All of the above developments have led to a greater understanding of genetics and this has subsequently resulted in changes in personalized medicine and how doctors are able to utilize genetics to ensure better patient outcomes.

Through the 21st century genetics and personalized medicine has emerged, bringing us new testing methods such as single gene, panel and large scale genetic testing, but it has also brought new innovative technologies which can help combat conditions caused by genetic mutations, such as crispr. The future of genetics and personalized medicine will be carried out by more extensive use of WES and WGS testing, clinical trials and more funding to create a larger pool of data. The further use of genetics and personalized medicine depends on the implications of it on our population, its success and the ethics of it, the question of if it should truly be implemented in the future.

The Advent of Robotics and AI in Medicine

Artificial Intelligence (AI) is undoubtedly becoming a part of life whether it be in a personal setting or healthcare setting. It is debated on whether AI is saving lives or causing harm to it. Although automation may seem to overpower some aspects of life, it truly is doing life changing work within the medical field. It has allowed for increased diagnostic accuracy and doing so while making work a bit less stressful for all doctors. Robotics is also a crucial part of today's medical field as it has allowed for increased precision during surgery. It is continuously saving lives and becoming a useful tool to professionals.

AI is being used as a tool for accurate interpretation of images from imaging technology and also aiding Radiologists in their analysis. A study published regarding AI capability of interpreting a Breast MRI and coming up with a diagnosis was compared with the conventional computer aided software to see which would help Radiologists more (*Yulei Jiang et al. 2020*). 19 Radiologists were gathered to examine 111 Dynamic Contrast Material Enhanced (DCE) MRI two times. First read was done through utilizing a conventional available software for assistance such as kinetic maps and the second read was aided by AI analytics through computer aided diagnosing software. The AI showed an increase from 0.71 to 0.76 increase in the Area Under the ROC curve (AUC) for all readers and a 90% to 94% increase in the sensitivity when using Breast Imaging Reporting and Data System (BI-RAD 3) as the cut off point. As AUC is a measure of the overall accuracy of a diagnostic assessment, the increase in value indicates that AI has the ability to differentiate between malignant and benign tumors. The increase in sensitivity suggests that AI was able to assist radiologists in identifying the true positive cases. Furthermore, what makes AI more efficient is its ability to reduce variability in decision making. As another study showed, AI caused an improvement in mitigation of decision making and an increase in time efficiency which caused 71% of cases to not require double reading. With its ability to show accurate diagnosis and also reduce workload of radiologists, AI integration in healthcare is a definite improvement in the healthcare field and for the patients.

AI as a second reader (AISR) is continuously growing due to the positive impact it has made towards the radiology field *(Amanda R et al. 2018)* It has allowed the reduction of workload, consistency among radiologists while still maintaining high accuracy and sensitivity. In a study done to compare the benefit of double reading versus AISR to see if AI is able to maintain high accuracy while reducing the burden on the healthcare system, the results were in favor of AISR.

Another way that technology aids healthcare is through the use of robotics. Modern research shows that robotic devices lower the risk of complications and improve overall patient recovery. In the article, called "*Clinical Outcomes of Robotic Surgery Compared to Conventional Surgical Approaches (Laparoscopic or Open)*" *Patel et al.* (2018) provides an example of robotic surgery. This study demonstrated the clinical outcomes of surgeries conducted with robotic systems such as the da Vinci Surgical System. The study's main goal was to experiment with an analysis of clinical outcomes in patients who underwent robotic-assisted operations vs traditional surgical procedures. The study discovered that robotic-assisted surgeries provide more precision and accuracy, which is important in difficult procedures such as prostatectomies and hysterectomies.

Robotics have the ability to assist in surgery with great precision and efficiency. A study conducted for the purpose of evaluating the accuracy and precision of remote-controlled robotic computed tomography (CT)-guided needle insertion in phantom and animal experiments *(Takao Hiraki et al. 2017*).In phantom experiments, the robotic system showed equivalent accuracy to the conventional manual insertion methods. Robotic mean accuracy was 1.6 mm and manual insertion accuracy was 1.4 mm. As the difference between accuracy levels are similar, it does not count as a significant finding;however, it indicates the robotic system is able to perform precise surgical tasks and doing so with reduced human error. Additionally, the robotic system was able to reduce radiation exposure to physicians from 5.7μSv to 0μSv. In animal experiments, the robotic system was able to adapt to different surgical environments as its overall mean accuracy was 3.2 mm, however 3 minor complications were reported. This shows that the robotic system was successful in completing tasks with great precision and accuracy, something that is crucial in surgery.

Transoral Robotic Surgery (TORS) is used for treatment of head and neck cancers (*Lauri A et.al, 2013*) It reduces the need for open surgery which involves an external incision, which is much more dangerous for the patient. TORS allows for improved surgical precision as it provides wide-view, high resolution, magnified three-dimensional features that help visualize the mucosal surfaces of the head and neck. This enhancement in visual quality makes it easier for surgeons to perform delicate surgical movement more precisely. Additionally, TORS maintain patient safety by lowering anesthesia intake and hospital stays. If everything goes correctly in the operating room, patients can expect to stay at the Intensive Care Unit (ICU) for a shorter amount of time. All of this together, builds the great nature of TORS with its ability to properly assist with surgical procedures and doing so while maintaining efficiency.

Ethical and Legal Discussion

With so many medical advances forever altering the way we perform and diagnose in the medical field some certain considerations and implications may not be beneficial to take into this new age of medicine. In the same way there should be ethical and legal deep dives to assess the overall effects of new generational medicine. Thus we will take time to discuss the potential problems and hazards for new-age technology and review the checks and balances that need to be put into place. One of the most controversial topics around new generational genetic testing is the question of what will happen after the parents find out their child has genetic conditions and dysfunctions. There is a lot of stigma around diseases such as Down Syndrome and Trisomy, which could lead to the parents purposefully trying to change/alter and even abort the child. This raises concern for selectivity among expecting couples. I don't think it is particularly ethical to try to selectively pick and choose based on genes and because of this ethical concern there, there is a need for some legal roadblocks. Such as that, before screening for genetic tests for your child, you must claim the status of the child beforehand, meaning you have to decide before testing if you intend to be their legal guardian/parent, are giving the child away to another facility upon birth, or if you are planning to abort beforehand. After the testing, however, you can;t change the status of the child in extremes, meaning you can't decide to abort after learning of any potential genetic disorders, however, if it is in the best nature for the child to be in the hands of another facility that can better take

care of the child, that should always remain an option. Another concern is the effects of genetic sequence altering on humans. In most cases, genetic altering doesn't work out perfectly, meaning the procedure might have been done wrong and could lead to death, or it can lead to physical change or disfigurement overtime. Because there have been few or not enough case studies demonstrating the effects of most gene editing programs, it is hard to determine what exactly to do, for failed genetic editing. However, one thing is for certain, the member getting genetic editing must give consent and have full responsibility for the outcome of the genetic editing. Even fewer case studies have been done on gene editing in embryos or fetuses, which can get even more complex. There should also be a law stating that only certified clinics can initiate gene care, and there should be heavy inspection into the processes that were done to ensure no malpractices. What is essential for the study and health growth of genetic editing and use of it in clinics worldwide is case studies. The more testing and trials we have, the more policy we know to implement. While genetic technologies can be life saving and have a bright future, going forward as we have more case studies we need to make sure that we ensure a safe practice of medicine, ensuring integrity.

Even with new advancements to imaging technology, the overuse of radiation remains an ethical problem in radiology. Although advancements such as the HSR-CT have introduced a new generation of high-resolution CT which came with the benefit of early detection of tumors, it came at the cost of exposing patients to more radiation.. However, newer models of CT scan show that efforts are being made towards the reduction of radiation such as the creation of photon-counting CT (PCCT). Similarly, the increased integration of robotics and AI into healthcare and scientific settings raise concerns for patient comfort and job security. With the rise of the digital age and its obsessive use of AI, concerns for job security have risen in almost every career field. Integration of AI in the radiology field specifically shows that it is capable of doing their job but more efficiently and accurately. Similar to radiology, the surgical field has also faced the same issue. Robots have become an essential part at the operating table due to its precision and minimally invasive nature. Even though robotics and AI has allowed efficiency and accuracy of diagnosis and procedure, it remains as a threat to doctors who’s jobs can be replicated by automation. The integration of automation in the medical field may not just be a threat to those working under it, but the patient as well. As mentioned before, robots can perform surgery or surgical procedures with excellent precision. However, will patients feel comfortable being operated by robots? Because with the current trend with automation, this reality does not seem distant. If this trend does continue, free training on ways to adapt to the changing practice of medicine caused by automation, should be offered to new and existing doctors.

References

Anaclerio, F., Lucrezia Pilenzi, Dell'Elice, A., Ferrante, R., Grossi, S., Luca Maria Ferlito, Marinelli, C., Gildetti, S., Calabrese, G., Liborio Stuppia, & Antonucci, I. (2023). Clinical usefulness of NGS multi-gene panel testing in hereditary cancer analysis. *Frontiers in Genetics*, *14*. https://doi.org/10.3389/fgene.2023.1060504

Angeli, D., Salvi, S., & Tedaldi, G. (2020). Genetic Predisposition to Breast and Ovarian Cancers: How Many and Which Genes to Test? *International Journal of Molecular Sciences*, *21*(3). https://doi.org/10.3390/ijms21031128

Arthur, C., Carlson, L.-M., Svoboda, J., Sandvik, U., Jylhä, C., Magnus Nordenskjöld, Holm, S., & Tham, E. (2024). Liquid biopsy guides successful molecular targeted therapy of an inoperable pediatric brainstem neoplasm. *Npj Precision Oncology*, *8*(1). https://doi.org/10.1038/s41698-024-00535-8

Bradfield, B. (2023, November 17). What's New in MRI Technology — 2024 Edition. Www.cassling.com. https://www.cassling.com/blog/whats-new-in-mri-technology-2024-edition

CDC. (2024). *Tuberculosis Whole-Genome Sequencing*. Tuberculosis (TB). https://www.cdc.gov/tb/php/genotyping/whole-genome-sequencing.html

Deo, N., & Anjankar, A. (2023). Artificial Intelligence With Robotics in Healthcare: A Narrative Review of Its Viability in India. *Artificial Intelligence with Robotics in Healthcare: A Narrative Review of Its Viability in India*, *15*(5). https://doi.org/10.7759/cureus.39416

Dwamena, B. A., Sonnad, S. S., Angobaldo, J. O., & Wahl, R. L. (1999). Metastases from Non-Small Cell Lung Cancer: Mediastinal Staging in the 1990s—Meta-analytic Comparison Of PET and CT. Radiology, 213(2), 530–536. https://doi.org/10.1148/radiology.213.2.r99nv46530

Frost, A. (2015). *Single gene sequencing — Knowledge Hub*. GeNotes. https://www.genomicseducation.hee.nhs.uk/genotes/knowledge-hub/single-gene-sequencing/#:~:text=If%20the%20 patient

Ghosh, S., Dhobley, A., Avula, K. K., Joseph, S., Gavali, N., & Sinha, S. (2022). Role of Saliva as a Non-Invasive Diagnostic Method for Detection of COVID-19. *Cureus*. https://doi.org/10.7759/cureus.27471

Ghoshal, U. C. (2011). How to Interpret Hydrogen Breath Tests. *Journal of Neurogastroenterology and Motility*, *17*(3), 312–317. https://doi.org/10.5056/jnm.2011.17.3.312

Greffier, J., Dabli, D., Hamard, A., Akessoul, P., Belaouni, A., Beregi, J.-P., & Frandon, J. (2021). Impact of dose reduction and the use of an advanced model-based iterative reconstruction algorithm on spectral performance of a dual-source CT system: A task-based image quality assessment. Diagnostic and Interventional Imaging, 102(7-8), 405–412. https://doi.org/10.1016/j.diii.2021.03.002

Hamzelou, J. (2023, March 10). *More than 200 people have been treated with experimental CRISPR therapies*. MIT Technology Review. https://www.technologyreview.com/2023/03/10/1069619/more-than-200-people-treated-with-experimental-crispr-therapies/

Henderson, H. (2021, March 3). *CRISPR Clinical Trials: A 2021 Update*. Innovative Genomics Institute (IGI). https://innovativegenomics.org/news/crispr-clinical-trials-2021/

Hiraki, T., Tetsushi Kamegawa, Matsuno, T., Sakurai, J., Yasuzo Kirita, Matsuura, R., Yamaguchi, T., Sasaki, T., Toshiharu Mitsuhashi, Toshiyuki Komaki, Yoshihisa Masaoka, Matsui, Y., Fujiwara, H., Iguchi, T., Hideo Gobara, & Kanazawa, S. (2017). Robotically Driven CT-guided Needle Insertion: Preliminary Results in Phantom and Animal Experiments. Radiology, 285(2), 454–461. https://doi.org/10.1148/radiol.2017162856

Jiang, Y., Edwards, A. V., & Newstead, G. M. (2021). Artificial Intelligence Applied to Breast MRI for Improved Diagnosis. *Radiology*, 298(1), 38–46. https://doi.org/10.1148/radiol.2020200292

Quintiens, J., & van Lenthe, G. H. (2024). Photon-Counting Computed Tomography for Microstructural Imaging of Bone and Joints. *Current osteoporosis reports*, 22(4), 387–395. https://doi.org/10.1007/s11914-024-00876-0

Kreel, L. (1991). Medical imaging. *Postgraduate Medical Journal*, 67(786), 334–346. https://doi.org/10.1136/pgmj.67.786.334

Lee, M. J., Hueniken, K., Kuehne, N., Lu, L., Jiang, S. X., Id Said, B., McCartney, A., Gao, Y., Liang, M., Obuobi, T., Sorotsky, H., Eng, L., Brown, M. C., Xu, W., & Liu, G. (2020). Cancer Patient-Reported Preferences and Knowledge for Liquid Biopsies and Blood Biomarkers at a Comprehensive Cancer Center. *Cancer Management and Research*, *Volume 12*, 1163–1173. https://doi.org/10.2147/cmar.s235777

Loevner, L. A., Learned, K. O., Mohan, S., O'Malley, B. W., Scanlon, M. H., Rassekh, C. H., & Weinstein, G. S. (2013). Transoral robotic surgery in head and neck cancer: What radiologists need to know about the cutting edge. *RadioGraphics*, 33(6), 1759–1779. https://doi.org/10.1148/rg.336135518

Lynch, D. A., & Oh, A. S. (2020). High-Spatial-Resolution CT Offers New Opportunities for Discovery in the Lung. *Radiology*, 297(2), 472–473. https://doi.org/10.1148/radiol.2020203473

Medline Plus. (2021, July 28). *What are whole exome sequencing and whole genome sequencing?: MedlinePlus Genetics*. Medlineplus.gov. https://medlineplus.gov/genetics/understanding/testing/sequencing/

Merzenich, H., Krille, L., Hammer, G., Kaiser, M., Yamashita, S., & Zeeb, H. (2012). Paediatric CT scan usage and referrals of children to computed tomography in Germany-a cross-sectional survey of medical practice and awareness of radiation related health risks among physicians. *BMC Health Services Research*, 12(1). https://doi.org/10.1186/1472-6963-12-47

Muaddi, H., Hafid, M. E., Choi, W. J., Lillie, E., de Mestral, C., Nathens, A., Stukel, T. A., & Karanicolas, P. J. (2020). Clinical Outcomes of Robotic Surgery Compared to Conventional Surgical Approaches (Laparoscopic or Open). Annals of Surgery, 273(3), 467–473. https://doi.org/10.1097/sla.0000000000003915

OLD, J. L., DUSING, R. W., YAP, W., & DIRKS, J. (2005, January 1). *Imaging for Suspected Appendicitis*. AAFP. *https://www.aafp.org/pubs/afp/issues/2005/0101/p71.pdf*

Pétré, B., Paridans, M., Gillain, N., Husson, E., Donneau, A.-F., Dardenne, N., Breuer, C., Michel, F., Dandoy, M., Bureau, F., Gillet, L., Leclercq, D., & Guillaume, M. (2022). Acceptability of Community Saliva Testing in Controlling the COVID-19 Pandemic: Lessons Learned from Two Case Studies in Nursing Homes and Schools. *Patient Preference and Adherence*, *Volume 16*, 625–631. https://doi.org/10.2147/ppa.s349742

Reddy, U. M., Page, G. P., Saade, G. R., Silver, R. M., Thorsten, V. R., Parker, C. B., Pinar, H., Willinger, M., Stoll, B. J., Heim-Hall, J., Varner, M. W., Goldenberg, R. L., Bukowski, R., Wapner, R. J., Drews-Botsch, C. D., O'Brien, B. M., Dudley, D. J., & Levy, B. (2012). Karyotype versus Microarray Testing for Genetic Abnormalities after Stillbirth. *New England Journal of Medicine*, *367*(23), 2185–2193. https://doi.org/10.1056/nejmoa1201569

Rowe, S. P., & Pomper, M. G. (2021). Molecular imaging in oncology: Current impact and future directions. *CA*: *A Cancer Journal for Clinicians*, 72(4), 333–352. https://doi.org/10.3322/caac.21713

Saliva Testing for COVID-19 Quicker, Safer Than Nasal Swabs. (2022, March 21). ASM; American Society for Microbiology. https://asm.org/press-releases/2022/march-2022/saliva-testing-for-covid-19-quicker,-safer-than-na#:~:text=Washington%2C%20D.C.%20%E2%80%93%20 Genetic%20testing%20of,the%20American%20Society%20 for%20 Microbiology.

Smolock, Amanda R., et al. "Robotically Assisted Sonic Therapy as a Noninvasive Nonthermal Ablation Modality: Proof of Concept in a Porcine Liver Model." Radiology, vol. 287, no. 2, May 2018, pp. 485–493, https://doi.org/10.1148/radiol.2018171544.

Stein, R. (2023, December 25). *Sickle cell patient's journey leads to landmark approval of gene-editing treatment*. NPR. https://www.npr.org/sections/health-shots/2023/12/25/1219342935/sickle-cell-patients-journey-leads-to-landmark-approval-of-gene-editing-treatmen

Tan, S., Allicock, O., Katamba, A., Carrington, C., Wyllie, A., & Armstrong-Hough, M. (2022). Saliva-based methods for SARS-CoV-2 testing in low- and middle-income countries. *Bulletin of the World Health Organization*, *100*(12), 808–814. https://doi.org/10.2471/blt.22.288526

The Nobel Prize in Physiology or Medicine 1978. (n.d.). NobelPrize.org. https://www.nobelprize.org/prizes/medicine/1978/summary/

The, B. (2022, August 30). *Solving Oncology Cases With Chromosomal Microarrays*. Behind the Bench; Thermo Fisher Scientific. https://www.thermofisher.com/blog/behindthebench/solving-oncology-cases-with-chromosomal-microarrays/#:~:text=CMA%20is%20a%20 powerful%20tool

What to expect. Stanford Health Care. (2017a, September 12). https://stanfordhealthcare.org/medical-tests/p/pet-scan/what-to-expect.html#:~:text=A%20PET%20scan%20can%20be,being%20used%20in%20the%20 brain