# From Physician to Technician: The Future of the Healthcare Industry

*An exploration into the relationship between Artificial Intelligence and existing occupations in the Healthcare Industry*

Honors Thesis
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**Abstract:**

This world promises just one thing: continuous change. As humanity has moved through time much has changed in the worlds of science, mathematics, and physics. These shifts in humanity's comprehension often arrive unexpectedly, driven by education, innovation, and experimentation. Such transformative waves resemble a series of technology shocks that are known to cause significant disruptions within an industry and the economy broadly as firms permanently change the ways they produce and distribute goods and services in response to new technologies or information. The recent flurry of innovation and interest in Artificial Intelligence leads us to believe that many industries may be experiencing such a wave of change today.

The healthcare industry currently employs the most workers of any other sector in the United States (outside of the government) and is made up of an unprecedented 77% of female workers making the outcomes of changes in its labor market demands particularly important. In this paper we discuss the current state of Artificial Intelligence adoption within the clinical side of healthcare, what sub sectors and occupations are most exposed, and to what extent the FDA approved AI-enabled clinical healthcare products replace or complement those tasks of existing occupations. We also interviewed a few healthcare professionals with different levels of seniority and exposure to AI-enabled products to develop a holistic understanding of current AI adoption, employee preparation, and potential labor market implications over the short and long term.

We find that AI implementation within clinical healthcare settings is young in its life cycle yet fast growing. Current use cases are mostly in the earlier stages of the patient's care journey assisting workers in various capacities in the processes of patient testing, diagnosis, care planning, and post-treatment monitoring. The tasks associated with patient interaction and care administration do not appear to be threatened by AI automation at this point in time. Additionally, approved Artificial Intelligence products for clinical use are disproportionately concentrated in the subsectors of radiology, neurology, and cardiology. Finally, our interviews revealed a concerning lack of consideration and preparation, among healthcare workers, for the potential automation of their fundamental tasks. Going forward, we believe it wise for healthcare workers to monitor the evolution of clinical AI use cases as well as the FDA approval of AI-enabled products and prepare for potential automation by continuing to learn new skills, take on additional responsibilities, and generally inject themselves into as many stages of the patient's healthcare journey as possible to differentiate among other workers and avoid the coming wave of mass clinical automation.

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**Section #1: Introduction**

This world promises just one thing: continuous change. As humanity has moved through time much has changed in the worlds of science, mathematics, and physics. These changes in humanity's understanding of the world often come in quick unsuspecting waves of education, innovation, and experimentation. Such waves cause significant disruptions in the broad economy as firms change the ways they produce and distribute goods and services in response to new technologies or information.

Despite their importance, these waves of change are extremely difficult to measure and even more difficult to anticipate, making our understanding of their consequences imperfect at best. As a result of our human ignorance, “We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run” according to the popularly accepted Amara’s Law introduced by Roy Amara. This trap has claimed the victims of many of the world’s best and brightest economists, academics, policymakers, and leaders leading to an immeasurable number of mistakes in decision-making throughout history. A great example of this was in 1589 when Queen Elizabeth the First rejected a patent submission from William Lee for a knitting machine which Queen Elizabeth predicted would replace the jobs of many of her citizens (Norman). This temporary rejection of this new technology ultimately only delayed its integration with society and the productivity and output gains that followed all because of fear around change.

Artificial Intelligence, according to Fetzer (1990), is the practice of providing artifacts with intelligence that is artificial to its being (referred to henceforth as AI). This practice has exploded in popularity over the past two decades as technological advancements have unlocked a well of innovative possibilities within the field which remains far from tapped today. As a result, most modern-day industries are currently experiencing high degrees of change as AI-enabled technologies are invented and integrated into historic business processes. One such industry currently grappling with abnormally high levels of innovation and change is healthcare. According to the Bureau of Labor Statistics, the healthcare industry employed a staggering 14.7 million workers which made up for 9% of employment in the United States in 2022, making it the largest industry behind the government (Bureau of Labor Statistics 2023). Healthcare is also unique in the demographics which make up its workforce with women occupying nearly 78% of all healthcare jobs in 2021 (Bureau of Labor Statistics 2022). Given these facts, the outcomes of technology shocks that will affect the productivity, employment, and wages of these workers are of unique importance to not only healthcare workers but investors, workers, and market participants broadly. Within healthcare, Artificial Intelligence has been employed in different capacities and subsectors within the field since the mid-1970s, however only recently has this technology made its way into the clinical setting as innovations like machine learning surrounding artificial intelligence models and their delivery have expanded their use cases. This relative youth within the subsector of clinical healthcare poses an opportunity for us to review the current state of innovative disruption and observe its progression in real time over the coming years.

For these reasons, we will be taking stock of the current state of artificial intelligence integration with clinical work processes to give individuals and decision-makers a better understanding of this current wave of change and provide a floor for future research looking at the ultimate economic implications and labor market outcomes of the AI-enabled technologies being invented and integrated today within clinical healthcare.

To do this we first review popular academic literature on the economics of technology shocks in section two. We then discuss the various decision-makers, customers, and processes that make up the complicated industry of healthcare in section three. In section four, we explain some of the history surrounding Artificial Intelligence in healthcare and dive into examples of popular use cases of AI within the main subsectors it is currently being employed within clinical healthcare. Section five consists of a brief review of the small study we conducted on the relationship between the main occupations within the AI-heavy subsectors of clinical healthcare and the AI-enabled products approved for clinical use by the Food and Drug Administration (FDA) from 1995-2016 and in 2023. Finally, in section six we discuss notable takeaways from the interviews of 3 healthcare professionals who have encountered artificial intelligence or the idea of its looming implementation to different degrees. The result is a general review of technology shocks and their current state within healthcare and more specifically clinical healthcare. Finally, in section seven we conclude our exploration into the impact of AI on the healthcare industry.

## Section #2: The Economics of Technology Shocks

Technological shocks have long intrigued leaders, academics, and economists for their particularly significant implications for society. There are many types of shocks to an economy whose consequences cause temporary changes in peoples' lifestyles such as a fluctuating employment status, varying levels of profit, fluid prices of goods and services, and changing wages. However, the consequences of technological shocks are unique when compared to those of other economic shocks in the permanent nature of the change tech shocks bring about. When firms change how they conduct business to incorporate some more efficient technology or process, they do not often revert to their prior method of doing business. Thus, shifts in employment and capital which are driven by a technological shock are uniquely painful for displaced workers because there is no reversion to "normal" forcing workers to find new employment oftentimes in new industries. In the following section, we will discuss a few of the common consequences of a technology shock on individuals, firms, industries, and the broader economy and where academia falls short in understanding these unique economic shocks.

As with nearly all economic events, there exist winners and losers when there is a technological change. The losers are oftentimes workers within the industry implementing the new technology. More specifically workers whose job functions align with the capabilities of the new technology, also known as competing workers. These workers typically experience mass displacement and a general reduction in their wages as demand for their services is quickly replaced with demand for a new technology. The scale of these effects on the specific position's labor market depends on a variety of factors specific to the new technology adopted like the degree to which the technology performs the various requirements of the displaced job and the accessibility of the technology to firms. In many cases, however, the effects on competing workers are significantly harsh. According to a brief written by Michael Hicks and Srikant Devaraj (2015), the series of technology shocks experienced in the manufacturing sector of the United States between 1999 and 2013 has contributed to nearly 88% of the nearly 10 million job losses seen in that sector over that period (Hicks, Devaraj 2015). To get a sense of the scale of how many jobs this equates to, Hicks and Devaraj (2015) state that, "Had we kept 2000 levels of productivity and applied to 2010 levels of production, we would have required 20.9 million manufacturing workers. Instead, we employed only 12.1 million (Hicks, Devaraj 2015)."

Interestingly, since 1980, the US has operated in a trade deficit of manufactured goods and has been named the culprit of these job losses by much of the public to this day. Hicks and Devaraj (2015) find that in reality this deficit only contributed to roughly 13.4 percent of the jobs lost (Hicks, Devaraj 2015).

Of course, not all workers complete the same tasks. Therefore, there are some workers for whom technology acts as a complement, making responsibilities easier and their work process more productive. Consequently, these now more productive workers oftentimes benefit from growth in wages and demand for their services. By building a model of several fundamental tasks and incorporating different types of labor alongside different types of technology, Stokey (2016) confirmed this theory, finding that employment positions with a low elasticity of substitution to the new technology most times experience growth in output, wages, and productivity. This dichotomy in the effects on workers with different skills after a technological change has been referred to as Skilled Biased Technological Changes. Several economists, like Bound and Johnson (1992) and Katz and Murphy (1992), observed this effect wherein the technological change hurts the labor demand for less educated and less skilled workers by creating a skill bias to service or work alongside the newly developed technology. A great example of this playing out was after the advent of the micro-computer in the early 1970s. Economists in the 1980s noticed a reduction in the real wages of low-skill workers and a significant increase in the wage gap between high-school and college-educated workers (Card, DiNardo 2005). The primary drivers of this widely accepted phenomenon are intuitively quite simple. First and foremost, technological change often makes firms more productive, reducing that firm's need for human labor. It is to be expected that when faced with this reality, firms favor holding on to their top talent and are more willing to sacrifice the lower-skill and less-educated workers who are more replaceable. Additionally, technological change often attempts to automate repetitive tasks which are also the tasks oftentimes assigned to lower-skill workers. Finally, technology shocks almost always require workers' duties, habits, and occupational requirements to adjust; a process easier achieved by higher-educated workers with generally more skills, experience, and knowledge than typical lower-skilled workers. These and other factors likely contribute to the growing skill bias that commonly follows a technology shock like the one seen in the 1980s with the invention of microcomputers.

Outside of those in the labor market, there also exist winners and losers in the general markets. While technological shocks are not necessarily a positive development for lower-skilled workers in the affected industries, they are typically welcomed by consumers and the owners of society's production processes. This is because historically technology shocks have had predominantly positive effects on output and productivity and a negative relationship with prices. Alongside her conclusion that the effects of a technology shock are not the same for all workers within an industry, Stokey (2017) also found that output and productivity almost always increase after a technology shock in the affected industry and in the broader economy (Stokey 2016). She also noticed a notable decrease in the prices of goods or services after the technology shock. All three of these findings are consistent with popular economic thought and historic market data. A great example is the widely acknowledged argument that some of the United States' recovery from the Great Depression was driven by a wave of technology shocks. Using a purified method of measuring Total Factor Productivity (TFP) between 1892 and 1966 Shingo Watanabe, consistent with Alexopoulos (2009) and several others, found that the technology shocks which occurred during and after the Great Depression were critical in the United States' recovery

(Watanabe 2016). This positive relationship between technology shocks, productivity, and output is well documented throughout history.

Despite their importance to the broad economy, policymakers, capitalists, and workers in all industries, much is still unknown about the lifecycle and short-run labor market effects of technology shocks as they move through a firm, industry, and broader economy. The reason for this lies in the notorious challenge of identifying and measuring them. Over the years, economists have tested many methods of quantifying these waves of change including (but not limited to) monitoring book publications, tracking patents, the amount of R&D Expenditure, and changes in Total Factor Productivity (TFP). Yet, each of these comes with its own set of complications. New books do tend to be published around the time of a new technology's relevance, however tracking the number of publications, like Alexopoulos (Alexopoulos, Cohen 2009), fails to consider the popularity of certain books. While patents have good historical data, there are long lags between patent and economic activity and changes in patent law may impact the activity in the data (Schmookler 1966). Similarly, changes in Research and Development Expenditure oftentimes long precede any observable economic changes seen in macro-data (Leonard 2022). Total Factor Productivity is a bit more preferred historically among researchers than the first few methods (Leonard 2022). TFP measured under the Solow Model is the difference between growth in outputs (wealth) and growth in inputs (capital and labor) of production. Total Factor Productivity will rise when there is more production with the same or fewer relative inputs. Unfortunately, like the first two methodologies, there are issues with this form of measurement as well. First, any mismeasurements in the data will appear in the residual (the difference between changes in inputs and outputs) which is what we are attributing to the technology shock. The model also doesn't account for nonconstant returns (different elasticities) of inputs and outputs. Finally, the Solow model fails to consider imperfect competition and distribution of inputs and outputs. So, despite the importance of technology shocks on the progression of economies, distribution of wealth, and evolution of workforces, their measurement throughout history and subsequent understanding remains far from perfect.

As we have documented so far, technology shocks are critical events for the progression of industries, the labor market, and entire economies. However, as we have seen, the measurement and study of technology shocks at the macro and micro levels continue to pose challenges for economists. Luckily, we are likely currently experiencing the early effects of a wave of significant technology shocks stemming from the progression of Artificial Intelligence posing a unique opportunity to better understand these waves of change as they move through an industry. As mentioned earlier, Artificial Intelligence (according to Fetzer (1990)) is the study of providing a thing with intelligence that is not natural to its being. Of course, currently, the most common medium for this practice is machines. Over the past few decades, there has been a flurry of research and invention around ways to provide machines with the attributes of intelligence that used to be unique to beings of natural life. According to Giczy (2021), the common 8 current component technologies that are referred to as AI include, knowledge processing, speech recognition, hardware that implements AI, evolutionary computation, natural language processing, machine learning, computer vision, and planning/control (Giczy, Pairolero 2021). Artificial Intelligence has been selectively implemented for data analysis and decision-making in the healthcare industry since the mid-1970s with Stanford University's program MYCIN used for the diagnosis of bacterial infections and blood clotting diseases (Kulikowski 2019). However, despite its old age, the innovation surrounding, and integration of AI-enabled technologies at scale within healthcare processes has only recently garnered public attention. Given AI's many potential use cases within a data-driven industry like healthcare, its historic existence within that industry relative to others, and the speed and degree to which AI-enabled technologies are being now being invented and integrated into all levels of healthcare, we are choosing to further investigate the early effects of Artificial Intelligence on the wages, employment, productivity, and output of Healthcare Clinics and their workers, contributing to the literature that seeks to understand technology shocks and their economic implications.

**Section #3: The Business of the Healthcare Industry**

Given the complexity of the United States Healthcare System, we will now review a few of its dimensions before discussing how it may be tested by the adoption of Artificial Intelligence. The notable dimensions of the healthcare industry we plan to analyze in the following section include the decision-makers within the industry, the process surrounding setting wages and prices, and the demographic landscape of the healthcare system.

Within the entirety of the healthcare field, two main groups characterize the healthcare sector: providers and payers. A provider in healthcare refers to any individual or entity involved in delivering/providing medical services. This broad category includes professionals such as physicians, dentists, physiotherapists, and nurses. In addition, it includes service beyond just the delivery to attend to patients. Providers also incorporate the physical locations where services are undergone. Hospitals, clinics, and facilities are just a few of these provider locations. The major players, considering overall patients and revenue, within this sub-sector include Tenet Healthcare, McKesson, and Cardinal Health.

The payer sub-group applies to entities that are held responsible for completely financing health services, which most notably include health insurance companies and governmental bodies. These companies' focus originates in taking control of aspects such as “patient eligibility, enrollment, claims processing, and reimbursement procedures (Sub-Sectors in the Health Care Industry). This sector closely analyzes and inspects data on matters related to population health management. The largest players in the payer sub-sector include Optum, Cigna, and Humana. According to a study done by Definitive Healthcare, there is more than just a subjective feel when it comes to the most “dominant” hospital owners. Factors such as the number of hospitals, patient revenue, and bed count are just a few tools used to determine who truly rules the healthcare landscape. The Fortune/PINC AI conducted research in 2023 to find the most populated/utilized health systems in the small, medium, and large landscapes. The most effective large hospital owners are Mayo Clinic and HCA Continental which are located nationwide. As for the small clinics, the CHI Memorial and the Franciscan Sisters of Christian Charity Sponsored Ministries are known for their clinical outcomes and overall operational efficiency/effectiveness.

While a lot goes into determining how wages fluctuate and how hiring/firing procedures are handled, ultimately hospitals and clinics play an instrumental role in determining both wages and staffing levels within their respective organizations. Due to the size of the healthcare industry today, jobs cannot be taken for granted. These organizations consider various factors to make updated and informed decisions. For these owners to ultimately make a change, they consider local market conditions. These conditions can include anything from only including the necessary roles to the direction of wage rates. For example, Adena Health System President and

CEO Jeff Graham announced 69 job cuts with outplacement assistance because they would only be hiring “in strategic areas,” moving forward (Muoio 2023).

When it comes to wage changes and layoffs, finances are always at the forefront. There are instances in which struggling hospitals and clinics have to battle the balance of keeping competitive wages while also maintaining a profitable revenue stream. To put that into perspective, Adventist Health fired 59 administrative employees to reorganize its care networks which saved them $100 million in costs. The leadership said all affected staff were given 60 days written notice and would make “every effort to identify other opportunities for team members impacted (Muoio 2023)” This goes to show that although it is ultimately a tough decision for a hospital or clinic to make, it is a market where profitability and maintenance are key.

Healthcare professionals' wages can fluctuate frequently due to a variety of factors. Organizations do not only take current financial situations into account but also take into consideration performance evaluations and contract renewals. Ultimately, the market sets most of the wage changes within the industry. For example, if a company such as the Mayo Clinic had a demand for a worker with a specific skill, their pay would be reflected by that need. While inflation does play a role in wage shifts over periods, the unadjusted median wage growth was 9.92% for nurses, 5.68% for healthcare practitioners, and 37.6% for physicians from 2001 to 2017 (Barry 2021). In sum, it is very common for pay to shift as providers compete for talent or respond to shifts in the economic landscape.

Even when a healthcare provider experiences success within their operations, wages do not always take a jump. While financial performance does oftentimes play a role in wage changes, they are not strictly tied to an increase in employee wages. On the other hand, there are instances where institutions undergo financial success and decide to raise compensation. As for inflation, it has been recognized that even though compensation may be rising, it is not keeping pace with inflation.

When setting prices in the healthcare industry, it is not all determined in the same manner. Stakeholders, insurers, providers, government agencies, etc., all play a role in the decision-making process when establishing prices. To continue, these prices are not at a set rate for each patient as insurance companies and governmental programs can come into play. Provider companies can oftentimes have flexibility when adjusting prices, however, it ultimately depends on certain constraints within contractual and legal agreements. Now, how do patients know that they are getting the “right price?” Laws and regulations ensure that prices are restricted, and subjective maneuvers are dismissed. Several laws play a part in the industry; however, they are enacted differently in regions where there are set regulations. Laws and regulations such as the Affordable Care Act and the Public Health Service Act enable transparency within pricing and fair treatment of patients. In the healthcare industry, there are a variety of positions that affect the lives of millions daily. These positions are in physical settings which include hospitals, clinics, nursing homes, and private practices. Within the healthcare industry, there are several sub-sectors including “hospitals, ambulatory healthcare services, nursing and residential care facilities, and physician offices (Barry 2021).” These sub-sectors fall under different departments within the physical locations. These departments include nursing, pharmacy, radiology, and laboratory, just to name a few.

Like most of what the healthcare industry entails, the education required for each position varies depending on the role and overall rigor. Entry-level roles such as aides and nursing assistants usually require a high school diploma along with a certain number of hours of on-the-job training. On the other hand, positions like registered nurses and pharmacists require a bachelor's degree, and advanced practice roles like nurse practitioners and physician assistants require master's degrees. Medical school and residency training in addition to these other prerequisites are required for those attempting to become physicians and surgeons. Demographically, the healthcare industry is mostly made up of women. According to the U.S. Bureau of Labor Statistics, "about 8 in 10 workers in all healthcare occupations were women, much higher than for overall employment, where women made up nearly one-half of all employed workers (Blank 2022)." These highly female-concentrated occupations tend to include nurse assistants, dental hygienists, and dental assistants. As for age demographics within the healthcare industry, there are many younger workers in entry-level healthcare roles (Blank 2022). These roles are less demanding when it comes to prerequisites as medical assistants do not need to attend any additional schooling.

As for overall earnings within these roles, the average salary depends on the position and level of the highest education of the employee. To put this in perspective, registered nurses, which are the largest group of healthcare workers, earn a median annual salary of around $81,000 according to data from the Bureau of Labor Statistics (U.S. Bureau of Labor Statistics 2023). Physicians, on the other hand, earn significantly higher salaries, with average annual earnings of over $229,000 (U.S. Bureau of Labor Statistics 2023). Entry-level positions like personal aides and assistants typically have lower salaries, with median annual earnings ranging from $25,000 to $30,000 (U.S. Bureau of Labor Statistics 2023). In sum, the pay in the healthcare industry is extremely competitive, especially for those working in higher-level positions. With that said there appears to be a significant skill gap in the healthcare industry resulting in the more educated individuals earning a large amount more than less educated workers. As we incorporate the integration of new technology in the form of Artificial

Intelligence into this labor market it will be interesting to see which workers' tasks are complementary to the new technologies and which compete to complete the same task. This will ultimately determine whether AI will have a redistributive effect or if it will further broaden the skill discrepancy that is currently visible in the healthcare industry.

**Section #4: Artificial Intelligence in the Healthcare Industry**

The scope of AI applications in healthcare is already wide and likely to grow with functionality enhancements from top to bottom from administrative tasks to laboratory research to clinical care (Bohr, Memarzadeh 2020). According to Davenport & Kalakota (2019), a few notable current uses of Artificial Intelligence in the healthcare sector broadly include: improving early identification and diagnosis, improving speed and efficiency in developing medications, ensuring precision medication delivery, analyzing clinical interactions, preparing notes and research, ensuring rule compliance, improving surgeons' vision, completing administrative duties, and allowing for robotic process automation (Davenport, Kalakota 2019). Lee also pointed out the many opportunities for AI to reduce costs for healthcare clinics and patients alike by improving the efficiency of backend operations (Lee, Yoon 2021). Many clinics that have implemented AI are already seeing tangible results in these areas, specifically improved health outcomes with help in surgery, diagnosis, and evaluation of different treatment options. Some examples of these results that Lee, Habboubn, and Mroz (2020) point out, are substantial in the subsectors of radiology, dermatology, and ophthalmology field where the increased use of predictive modeling and ML algorithms has substantially improved the quality of care provided (Grabowski, Habboub, Lee, Mroz 2020).

The history of the study and implementation of artificial intelligence within the healthcare industry is analogous to a malignant cell. The industry's adoption of artificial intelligence beyond academia was staggered and patchy in its early years. Medical AI research began around the 1950s yet failed to produce a working model until the SUMEX-AIM time-sharing resource initiative was organized at Stanford University in the 1970s (Kulikowski 2019). This quickly produced the MYCIN model, an inference engine that used a knowledge base to diagnose infecting organisms in blood infections (Kulikowski 2019). Adoption of this and following AI models (particularly for research and laboratory use cases in the early years) was eager to the point of being wasteful and inefficient given the resources required to develop and employ such machines at scale. An ensuing "AI Winter" paused widespread research, investment, and implementation into AI models towards the end of the 1980s (Kulikowski 2019). According to Kulikowski (2019), it was around this time that researchers began reexamining the medicinal purposes of "Statistical, and heuristic models for machine learning, pattern recognition, and discovery, also emphasizing models of explanation and description as ways of teaching about the assumptions behind the first-generation knowledge and rule-based system (Kulikowski 2019)." These discoveries unlocked countless possibilities for AI in healthcare, notably machine learning pushed research into clinical applications like radiology. Since then, advancements in technology have enabled greater exploration and innovation of many types of models for thousands of applications within the healthcare industry in nearly all sub-sectors within the clinical, laboratory research, and administrative spaces. These advancements in AI modeling and understanding coupled with the growing ease of implementation and collection of data sparked another "AI Boom" in healthcare around the year 2000, which has grown without a boundary for the past two decades rooting itself in nearly every sub-sector of the healthcare industry (Kulikowski 2019).

As of 2024, the adoption of artificial intelligence within the healthcare industry has skyrocketed as approximately 85% of healthcare executives have utilized AI strategies in some capacity (Horowitz 2022). As mentioned previously, this 85 % widespread application from laboratory research where its utilization in healthcare began to administrative possibilities and now clinical applications like predictive analytics, robotic surgery, and AI-enhanced medical imaging. While growth in the space is seemingly continuing to accelerate, it is worth noting that there exist issues that currently limit its integration within primarily the clinical sector. For example, factors like challenges surrounding data privacy, AI's predictability and control, and the degree of proven accuracy/reliability required by customers and government regulators alike have slowed AI's clinical applications. Furthermore, considering that healthcare is a highly regulated industry, the accuracy of medical data is of the utmost importance due to the implementation of AI, as we are now "in a world where algorithms can make diagnoses, surgical procedures, wearable devices can track vital signs and robots can be remotely controlled to perform surgical procedures (Ganapathy 2018)." Even with some of these limitations, AI implementation is evolving at an exponential rate and the industry is destined to transition continuously. With that being said, by 2030, researchers predict the growth rate of AI in healthcare will increase by 37.5% (Stewart 2022). Challenges or not, AI is a technology that is here to stay and will likely revolutionize healthcare processes and delivery as it slowly seeps its way into all subsectors within each of the sides of healthcare (research, business, and clinical).

We will now discuss a few Artificial Intelligence models and some examples of their application beginning with arguably the most revolutionary model which is taking the clinical side of healthcare by storm: machine learning. Machine learning is a kind of AI that is inherently adaptive and seeks to tailor and even train models to data. Despite its young age, its applications are already wide with the majority (63%) of companies in the United States claiming that they are already employing some form of it (The Impact of Artificial Intelligence on the Future of Workforces 2024). In clinical healthcare, the most common use of this model is in precision medicine—or prediction of treatment success based on the patient and context. This can be broken down further into supervised and unsupervised learning, with the former being more common and requiring a dataset for which the health outcome is already known and the latter processing information that has yet to be classified. A more complex version of this kind of learning can be seen in the AI model of neural networks. Also well established in medicine, it views problems in terms of inputs to be associated with outputs much in the way neurons see signals—with application primarily being for data interpretation and outcome categorization. The most complex version of machine learning is known as deep learning—whose name connotes its use of multiple layers of "thought" to extract a higher level of data and is thus used in higher-level tasks like speech recognition (The Impact of Artificial Intelligence on the Future of Workforces 2024). Distinct from machine learning altogether is natural language processing. This application of artificial intelligence aims to analyze human language, with speech recognition, text analysis, and translation being common uses. Specific to healthcare, this tends to mean the creation and understanding of clinical documentation and published research and can even help with human conversations.

A great example of these machine learning models translating to actual productivity gains and improved quality of care within healthcare is its use in robotic surgery (RS) in pediatric healthcare (Mattioli 2017). An example of one of these products is the Da Vinci Si HD technology. The Da Vinci surgical system is a modern robotic surgical platform created to provide minimally invasive surgical procedures that vary across many different medical fields. The Da Vinci system used high-definition 3D cameras alongside AI to allow surgeons to perform difficult surgical maneuvers while improving precision and accuracy (Mattioli 2017). The Da Vinci Si HD demonstrates a significant change in surgical care as this technological advancement shifts the surgical practices that were previously in place (Mattioli 2017). A study was conducted between February 2015 to April 2016 on the quality of care provided using this new form of surgery enabled by AI and advancements in surgical technology. In the study, there were a total of 77 procedures performed using the Da Vinci system as well as 84 procedures using the conventional minimally invasive surgical techniques (Morgantini 2023). The study produced results that concluded that affirmed the safety and efficacy of the Da Vinci system as the results were very similar to, if not safer and more efficient than conventional practices (Morgantini 2023). Overall, the Da Vinci system is another example of a transformative AI tool that can improve pediatric surgical practices and allow doctors and healthcare professionals to provide superior patient care through the use of advanced technology which emphasizes the importance of the implementation of AI within healthcare (Morgantini 2023).

Another example of the implementation of AI within the healthcare sector fundamentally replacing tasks and changing the process or delivery of a healthcare procedure is the SonoSite Ultrasound with voice automation services. The Assistive Artificial Intelligence on Ultrasound Scanning for Regional Anaesthesia study aimed to compare anesthetists using AI-assisted ultrasounds and anesthetists using conventional methods when they scanned for six peripheral nerve blocks (Bowness 2022). The results of this study were quite complete, putting the AI-assisted ultrasound at a 90.3% accuracy rate compared to those using conventional ultrasound methods achieving 75.1% accuracy (Bowness 2022). Additionally, AI-assisted ultrasound identified 88.8% of sono-anatomical structures compared to a 77.4% identification rate for those using conventional methods (Bowness 2022). The Assistive Artificial Intelligence on Ultrasound Scanning for Regional Anaesthesia study was able to conclude that the potential implementation of AI specifically in the ultrasound industry appeared to be more efficient and significantly more accurate than the current methods being used (Bowness 2022). These findings advocate for the integration of AI solutions in the ultrasound industry and healthcare generally (Bowness 2022).

As mentioned previously, each sub-sector within the healthcare industry has examples of implementing AI on the research side, administrative side, and now the procedural side (Castellino 2005). Given that we have chosen to study the growth in clinical use cases of artificial intelligence for its relative youth in that space currently, we will now review some examples from a few of the primary subsectors/departments within clinical healthcare that these AI-enabled technologies are being implemented into including radiology, pathology, cardiology, and neurology.

A common example on the procedural/clinical side of healthcare is within the subsector of radiology, where we found FDA-approved clinical AI-enabled product growth is highest currently, with innovations like computer-aided diagnosis (CAD). According to Castellino (2005), "The implementation of artificial intelligence is present in radiology in an attempt to decrease oversights and increase detection (Castellino 2005)." In essence, CAD is a technology aimed at getting more accurate results specifically relating to breast cancer but has also recently been actionable in the detection of lung nodules (Castellino 2005). As a result of these implementations, there has been a displacement of tasks as well as a significant change in roles as some healthcare professionals are directly competing with the CAD and image segmentation algorithms (Castellino 2005). The healthcare professionals that are directly competing with the implementation of AI within the radiology sector include radiologic technicians as their regulatory tasks of image interpretation, tumor detection, and anomaly identification are being more efficiently carried out through the CAD and image segmentation algorithms (Castellino 2005). On the other hand, there are also positions such as healthcare data analysts and physicians who work complementarity with current AI-enabled use cases. Positions such as healthcare data analysts are considered complements to the AI because their roles are elevated and their services in greater demand as a result of AI implementation as opposed to the competitors of AI like radiologic technicians who complete the same or similar tasks as AI-enabled technology (Castellino 2005). Overall, the implementation of AI within radiology has just begun to shift some processes and roles within radiology as these technologies are becoming very widely accepted in hospitals and imaging centers within the U.S. and around the world.

Another subsector of healthcare experiencing growth in AI implementation is pathology. These AI-enabled technologies have mostly come in the form/use of digital pathology as well as image analysis software (Bankhead 2022). As with all types of change, the implementation of these AI technologies within pathology is likely to result in some healthcare professionals directly competing with the AI technologies for the task at hand and will ultimately be forced to change occupations or take on new roles in some capacity. Specific to digital pathology and image analysis software in the pathology sector of the healthcare industry, tasks such as microscopic tissue examination, cancer diagnosis, and image analysis are currently being overtaken by AI (Bankhead 2022). Considering that AI is competing with these tasks, there are certain occupations such as histotechnologists whose roles and responsibilities are now unknowingly at risk of change or replacement despite some of these AI-enabled products not even being accepted/implemented into actual healthcare processes yet. On the same note, certain healthcare roles will directly complement these technologies such as medical laboratory technicians and bioinformatics specialists and will continue to do so as the implementation of AI technologies within pathology is continuously emerging and growing.

The field of cardiology is also experiencing abnormally accelerating growth in the number of approved AI-enabled technologies throughout hospitals and cardiology clinics in the U.S (Konstantinos 2021). Within the realm of cardiology, there are generally 2 different AI technologies that are increasingly prevalent in medical research and clinical practices: echocardiography and electrocardiography (ECG) analysis (Konstantinos 2021). Echocardiography and electrocardiography (ECG) analysis are diagnostic tools that have been recently implemented in the cardiology field. Due to the introduction of these advanced technologies, certain tasks and employees have been affected. Tasks such as diagnosing heart disease, arrhythmia detection, and roles like cardiac sonographers and general cardiologists are overlapping with the introduction of AI technologies within the cardiological field. Due to the slow growth of the use of technologies like echocardiography and electrocardiography (ECG) analysis, some roles and responsibilities will directly complement these AI technologies within cardiology such as cardiology nurses and medical assistants due to their improved patient care based on the diagnostic capabilities of the advanced technologies (Konstantinos 2021).

Finally, considering the sectors of healthcare and the recent implementation of AI, recognizing the use of AI within neurology is pivotal. Some of the AI-enabled technologies that have been used widely in certain aspects of neurology are brain imaging analysis as well as EEG interpretation (Koberda, Moses). The implementation of said AI technologies is aimed to improve the diagnostic accuracy of epilepsy, sleep disorders, and brain tumors. Due to the introduction of AI technologies such as brain imaging analysis and EEG interpretation, some professionals within healthcare have experienced a shift in roles and responsibilities. Roles such as neurodiagnostic technicians have been displaced because of the success of AI which is backed up by Patel when he states, “AI not only helps to analyze medical data in disease prevention, diagnosis, patient monitoring, and development of new protocols but can also assist clinicians in dealing with voluminous data more accurately and efficiently (Anwar, Patel, Saleem 2021).” In conclusion, the implementation of AI within the neurological sector of healthcare has been relatively varied as there are no current standards, so some institutions are fully integrated with the newest technologies while some practices have stuck with traditional processes.

## Section #5: The Relationships of current AI-Enabled Clinical Products with existing Occupations in the Healthcare Industry

Now that we better understand the current application of artificial intelligence in the healthcare industry, we can dive deeper into what some of the potential changes the technology shocks from artificial intelligence in clinical healthcare will bring about in the demand for labor.

To do this, we conducted a small study on the relationship between newly approved clinical technology and some previously approved technologies with the fundamental responsibilities of the occupations exposed to these products in the subsectors where they are being implemented. Intuitively, we defined fundamental responsibilities to be those tasks regular enough or worthy of being planned on a worker’s daily calendar. To develop a list of the approved products, we used data from the Food and Drug Administration on the 108 newly 2023 FDA-approved clinical AI-enabled products as well as the first 31 products approved for clinical use between the years of 1995 and 2016 (U.S. Food and Drug Administration 2023). A quick view of the number of products approved during that period and the number of tasks those products automate/contribute to (different product tasks were determined by the FDA's different Primary Product Codes it uses to classify these products) broken down by the subsector they are employed in can be observed in figure 1 below. These products, even if they are not currently being fully used by certain subsectors, can ultimately alter the future of wages within healthcare.

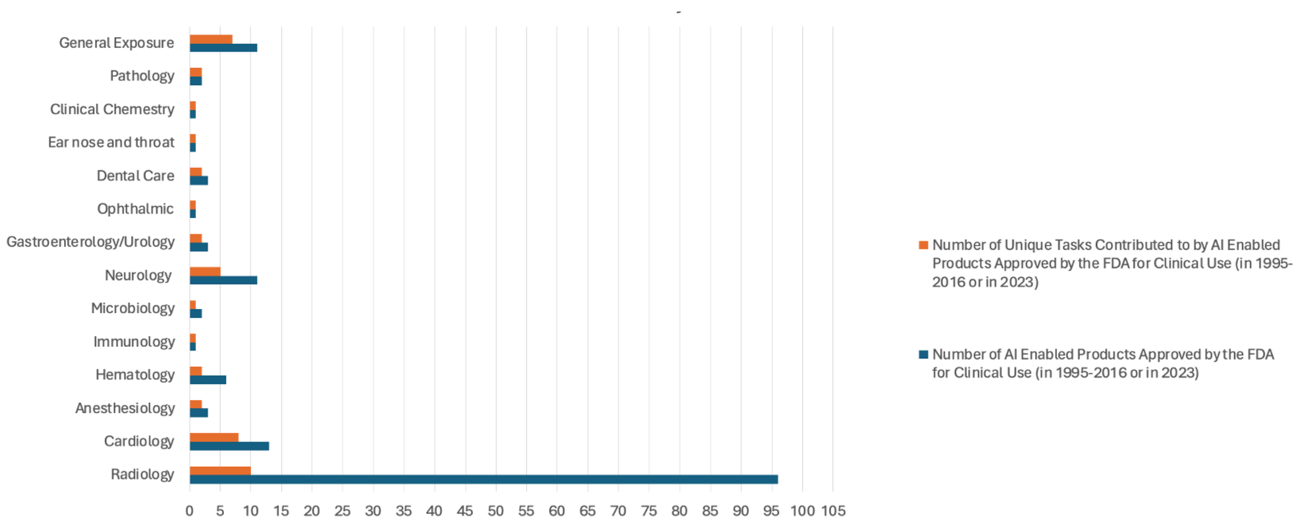


Figure 1: The Number of FDA-approved AI Enabled Products for Clinical Use (approved between 1995-2016 and in 2023) and count of Unique Tasks they contribute to (Source: The US Food and Drug Administration)

In our analysis of the relationship between the roles of these products and the tasks previously completed by workers, we acquired product descriptions of the role or use case of each approved technology using a combination of information in the publicly available FDA classification request for each product and information from the specific company's website. We then developed profiles on the details of the primary occupations we identified as likely to come into contact with the products in the core sub sectors where clinical AI growth is occurring (radiology, cardiology, neurology, gastroenterology, anesthesiology, dental care, and a few generally exposed occupations like nurses and physicians). To get this task level information, we used data from the Bureau of Labor Statistics sourced from the U.S. Department of Labor's ONET database (U.S. Department of Labor 2023). Finally, we employed our newfound understanding of the primary tasks completed by the most exposed occupations to identify whether the role of the newly approved AI-enabled technology was likely to be currently replacing a meaningful previous task of an occupation, potentially replacing an existing responsibility (with some development in the technology, the AI model, or in the way in which the product is employed or trusted/relied upon), or not competing with any current meaningful responsibilities. When it comes to the criteria we used to classify this relationship as "competing", 'potentially", or "not", we engaged in a rudimentary process of reading the product description for each AI-enabled product, reading back over the primary responsibilities of the clinical occupations exposed, and making a final decision as to whether or not this product has or could replace one or more of the tasks currently or in the future with some development. Oftentimes, products would contribute to multiple tasks but to different degrees. For example, an AI model assisting in the diagnosis of radiology imaging also complements the radiologists' post imaging responsibilities like making a plan of treatment by expediting and strengthening the quality of the imaging processes. In this example, we would classify the product as being potentially competing with the radiologist's task of analyzing and diagnosing the images because most models are not currently trusted or capable of completing the entire analysis/diagnosis stage of patient care on their own yet. We would also classify this product as complementary to both the radiologist's task of diagnosing (which would change if the product ever fully took over this role) and complementary to the position's later responsibilities like patient treatment. While there was no quantitative methodology measuring this relationship, our results help us understand the current state of AI adoption within healthcare, which occupations/sectors are most exposed, and where things are headed when it comes to the future of the healthcare industry. Figure 2, shows a summary of the results of this comparison activity on the number of FDA-approved AI-enabled products and the tasks of existing exposed occupations..

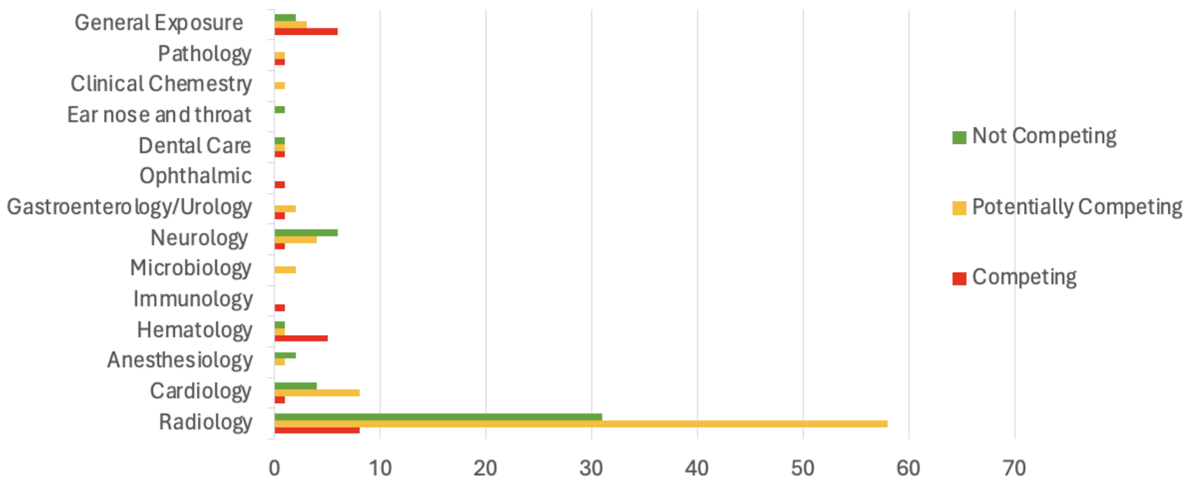


Figure 2: The number of FDA-approved AI-enabled products for clinical medical use (approved between 1995-2016 and in 2023) that are "Currently", "Potentially", or "Not Competing" with the fundamental tasks of existing occupations.

As is to be expected, all the approved products complemented some task or responsibility of at least one of the occupations we analyzed meaning that the implementation of these technologies at scale over the coming years will almost certainly boost productivity in these sectors. Moreover, a staggering two-thirds of AI-enabled products we identified as currently or potentially automating a responsibility fundamental to an occupation(s) within the subsector it is employed. Of course, many of these approved products are developed by competitors in the medical equipment space with similar fundamental understandings of the current possibilities of Artificial Intelligence. That is to say that potentially many of these products complete the same tasks/roles. To investigate this, we used the Primary Product Code as an indicator of the type of task completed by the AI-enabled technology because the FDA tends to use the PPCs as silos that classify similar products[1]. The results of classifying the number of tasks that currently, potentially, or do not compete by the subsector the product is employed in can be reviewed below in Figure 3.

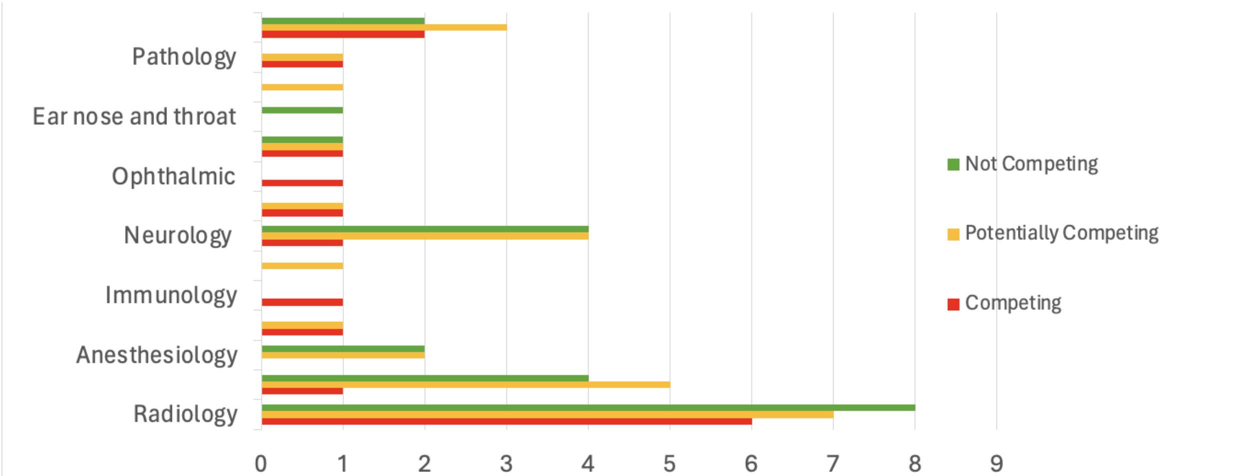


Figure 3: The number of unique tasks (distinguished by unique FDA Primary Product Codes) completed by FDA approved AI-enabled products (approved between 1995-2016 and in 2023) that are "Currently", "Potentially", or "Not Competing" with the fundamental tasks of existing occupations.

Interestingly roughly 60% of tasks completed by the FDA-approved AI technologies were also deemed potentially or actively competing with previous responsibilities. However, the number of tasks whose processes are likely to change as a result of these approvals is far smaller than the number of approvals confirming our suspicion that many of the AI-enabled clinical products are currently similar, a potential indicator of AI's youth and our evolving understanding of its possibilities. This is a positive sign for workers in related occupations as there is still time to acknowledge the reality of the evolving healthcare industry and potentially acquire new skills or knowledge that will aid in a likely necessary long-term career or fundamental responsibility pivot.

An abbreviated summary of the primary occupations which employ roughly 5 and a half million workers whose workplace duties we analyzed alongside some of their defining

[1] While this is not a perfect means of distinguishing similar versus different task contributions, it is acceptable for our purposes.

characteristics can be reviewed for context below in Figure 4. The specific duties, educational requirements, and summary statistics included were collected by the Bureau of Labor Statistics and sourced from the ONET OnLine database (U.S. Department of Labor 2023) and the demographic data sourced from BLS site itself (U.S. Bureau of Labor Statistics 2023). A more comprehensive list of the occupations whose responsibilities we compared can be found in figure 5 in the appendix.

| Occupation | Top 3 Responsibilities | Average Req. Education | Average Income | Number of Employees |
|---|---|---|---|---|
| Radiation Therapists | (1) Administer cancer treatments.<br>(2) Operate diagnostic or therapeutic medical instruments or equipment.<br>(3) Position patients for treatment or examination. | 38% Bachelors degree<br>50% Associates degree | $89,530 | 15,900 |
| Radiologic Technologists | (1) Operate diagnostic imaging equipment.<br>(2) Adjust settings or positions of medical equipment.<br>(3) Prepare medical supplies or equipment for use. | 11% Bachelor's degree<br>73% Associates degree | $65,140 | 222,800 |
| Cardiovascular Technologists | (1) Operate diagnostic or therapeutic medical instruments or equipment.<br>(2) Test patient heart or lung functioning<br>(3) Explain medical procedures or test results to patients or family members. | 13% Post-Sec Certificate<br>63% Associates degree | $63,000 | 58,900 |
| Cardiologists | (1) Test patient heart or lung functioning.<br>(2) Analyze test data or images to inform diagnosis or treatment.<br>(3) Operate diagnostic or therapeutic medical instruments or equipment. | Most require Masters and some require Ph.D/M.D. | $239,200 | 18,000 |
| Anesthesiologist Assistants | (1) Adjust settings or positions of medical equipment.<br>(2) Assist healthcare practitioners during examinations or treatments.<br>(3) Monitor patient conditions during treatments, procedures, or activities. | 42% Bachelors degree<br>22% High School | $126,010 | 148,000 |
| Anesthesiologist | (1) Monitor patient conditions during treatments, procedures, or activities.<br>(2) Implement advanced life support techniques.<br>(3) Prepare patients physically for medical procedures. | 69% Post-Doctoral Training<br>25% Doctoral degree | $239,200 | 40,000 |
| Nurses | (1) Record patient medical histories.<br>(2) Monitor patient conditions during treatments, procedures, or activities.<br>(3) Administer non-intravenous medications. | Bachelors Degree<br>Associates Degree | $81,220 | 3,172,500 |

Figure 4: Summary of High Exposure Occupations within the Clinical Sub Sectors of Healthcare where there have been the most approved AI-enabled products (2022 survey data from ONET OnLine) (a more comprehensive list with all the occupations whose tasks were analyzed can be found in Figure 5 in the Appendix)

A particularly interesting element unique to the current technology shocks we have been discussing on the clinical side of healthcare is the above-average nature of the affected occupations. As can be seen in Figure 5 in the appendix, the average of the median wage of the occupations whose responsibilities we analyzed was $155,955 which is far above the median annual wage of all healthcare practitioners and technical occupations which was $77,760 in 2022 (U.S. Bureau of Labor Statistics 2023). Additionally, the average SVP (Specific Vocational Preparation) range of the studied occupations was between 6.0 and 8.0 implying significant time required to train and learn the duties of these occupations on the job (an SVP of 6.0 is correlated to 1 to 2 years of training and one of 8 requires 4 to 10 years) (U.S. Department of Labor 1991). The prevalence of such positions that require doctor-level education, while some even require postdoctoral training emphasizes the expertise and commitment required for these roles and occupations. As a result of this, the potential impact of AI within the clinical setting could greatly affect these positions.

Another unique element of the series of technology shocks on the clinical side of healthcare is the demographic structure of this labor force. As mentioned earlier, a staggering 8 in 10 workers in healthcare occupations were women in 2022 (U.S. Bureau of Labor Statistics 2023). We conducted a small exercise using data from the IPUMS CPS from 2010-2024 to better understand the demographics of some major healthcare positions that could be exposed to the coming labor market changes (Sarah Flood et al). As can be seen on figure 6 in the appendix, we unsurprisingly found an overwhelmingly large number of women working throughout healthcare. This theme continued in our analysis of the most exposed positions, as can be seen in figure 5. Notably, we observed a relatively smaller share of women occupying higher skill positions that we deemed less at risk of replacement for their importance in multiple stages of the patient's care journey rather than contributing to one or two responsibilities/stages of the care journey. For example, according to the Bureau of Labor Statistics, women occupied 88% of registered nursing positions in 2022 but only 44% of physician positions in the same year (Smith 2023). Going forward, it will be interesting to observe how evolutions in the responsibilities of different occupations change employment levels alongside the education requirements of these positions and ultimately the demographic profiles that subsequently develop.

We will now dive a bit deeper into the main subsectors of clinical healthcare where AI-enabled technologies are being implemented (radiology, pathology, cardiology, and neurology) from an economic perspective, reviewing the occupations and the degree to which the most important roles of the occupations within those divisions compete or are complemented by the AI-enabled technologies that have recently been approved for clinical use by the FDA.

Radiology is the leading subsector that has experienced the most clinical artificial intelligence product developments and FDA approvals that replace or contribute to the most unique tasks of any other clinical subsector. There are significantly several exposed occupations within radiology including radiation therapists, radiologic technologists, and medical sonographers. According to the FDA, 50% of radiation therapists say an associate's degree is required while around 40% claim only a bachelor's degree making this position among the least educated that we analyze. According to ONET data, Radiation therapists' main responsibilities are to administer cancer treatments, operate diagnostic medical instruments, and position patients for treatment or examination all of which are unique tasks that several FDA-approved products currently and potentially could compete with. The Bureau of Labor Statistics estimates this position to experience around 2-4% growth in 2022-2032 which is notably lower than the other positions within radiology (U.S. Bureau of Labor Statistics 2023). As for radiologic technologists, daily tasks include operating diagnostic imaging equipment, adjusting settings/positions of medical equipment, and preparing medical supplies for use; another set of responsibilities that actively competes with recent FDA-approved AI-enabled products. Education for these technologists usually comes in the form of an associate degree (73%) placing this position on the low side of educational requirements for the positions we evaluate similar to radiation therapists. With that said, growth in this profession is expected to increase by 5-8%

within the next 10 years. Finally, positions as medical sonographers are growing at a rapid pace. Sonographers are held responsible for adjusting settings/positions of medical equipment, monitoring video displays of equipment, and operating diagnostic imaging equipment some of which are at risk of potentially competing with approved technologies. On the education front, 19% of sonographers receive their post-sec certificate while 47% have their associate's degree. As mentioned previously, this role within radiology is expected to grow quickly by more than 9% by 2032 (U.S. Bureau of Labor Statistics 2023). Within all of radiology, there are currently eight approved AI tech products that are currently competing out of the total 96 approved products. However, moving forward there is potential for 58 (around 60%) of those products to compete with an existing occupation’s task given there is some relatively insignificant change in the utilization of the technology.

Another sub-sector that is currently making the most of artificial intelligence is cardiology. The most exposed positions to the FDA-approved products that we reviewed within cardiology include cardiologists and cardiovascular technologists. Cardiologists are held responsible for testing patients’ heart or lung functioning, analyzing test data/images to inform diagnosis or treatment, planning a treatment plan, and operating on patients to treat conditions. As of now, most of the AI-enabled innovation within cardiology lies in the testing of patient data and diagnosis of issues. While these do compete with a few of the cardiologist’s primary responsibilities, cardiologists still enjoy a plethora of other responsibilities that have yet to be automated or in competition with approved clinical products. Cardiologists are unsurprisingly on the higher end of the education spectrum with most requiring a master's and some requiring a Ph.D or M.D. This position has an average growth rate from 2022-2032 of 2-4% reflecting middle-of-the-road demand for their services (U.S. Bureau of Labor Statistics 2023).

Cardiovascular technologists' main responsibilities are operating equipment, testing heart/lung function, and explaining medical procedures/results to patients. Unlike cardiologists, many of their primary tasks are already in active contention with approved AI-enabled products. As for education, these technologists are on the lower end with 63% of these technologists stating an associate's degree is required and just 13% advising to pursue a post-sec certificate for this role. Out of the 13 current FDA-approved tech products, one is currently competing with existing occupations and 8 are potentially competing in the future. Artificial intelligence within clinical cardiology is quite new and will look to grow very quickly in the coming years.

Similar to radiology, anesthesiology is a subsector that is particularly at risk as it is the practice of consuming mass amounts of data and making important decisions in real-time, a skill that AI has proven is more efficient and accurate than a human. As a result, this sector is expected to not only continue to utilize artificial intelligence within its landscape but grow to eventually use it to completely automate many of its tasks. The main occupations we review within anesthesiology are anesthesiologist assistants and anesthesiologists. First, anesthesiologist assistants are responsible for adjusting settings/positions of medical equipment, assisting healthcare practitioners during examinations/ treatments, and monitoring patient conditions during treatments. A few of these tasks (like the testing of patients and management of medical equipment) are already competing with newly approved technologies despite the extreme youth of AI implementation within this subsector. As is to be expected, the assistants require little formal education with just 42% of anesthesiologist assistants claiming a bachelor's degree and 22% stating a high school certificate will suffice (U.S. Bureau of Labor Statistics 2023). Interestingly, despite the potential automation of some of these tasks, the role is expected to grow much faster than most positions within healthcare by a rate of around 9% in the next ten years.

This is more likely a factor of heightened demand for healthcare generally which oftentimes requires anesthesiology services. Following this position's employment and wage growth going forward will be particularly interesting. Anesthesiologists, on the other hand, take on much more responsibility than their assistants as they are expected to implement advanced life support techniques, prepare patients physically for medical procedures, and administer anesthetics or sedatives to control pain. With responsibility comes preparation, which is why 69% of anesthesiologists claim post-doctoral training is required and 25% maintain a doctoral degree (U.S. Bureau of Labor Statistics 2023). For this potion, there is an expected average growth of around 2% from 2022-2023. There are currently three FDA-approved AI-enabled tech products within anesthesiology, however, none are currently competing for overall existence. All three artificial intelligence products are being used to assist those in roles, showing the sub-sector's commitment to ease into overall utilization.

The final subsector of clinical healthcare where a large number of AI-enabled technologies are currently being approved and potentially could be implemented is within neurology. The primary occupation within neurology that we evaluated for competing and/or complementary relationships with the approved products was neurologists. Neurologists are primarily responsible for collecting patient information alongside testing patients to identify potential nervous system issues, plan a subsequent path of treatment, and administer said treatment if required. Automation of tasks by AI-enabled products in neurology is primarily fixated on the testing of patients and diagnosis of issues similar to cardiology. As a result, the majority of neurologists' tasks seem to be more complemented by recently approved technologies rather than replaced. Despite this, there is a lot of potential for AI to drive actionable insights and increased productivity within neurology so monitoring new AI-enabled product developments will be key.

Now that we have properly reviewed the main findings of our analysis and what these findings mean for the most affected clinical subsectors, we can discuss some of the interesting takeaways from the several interviews we conducted on healthcare professionals experiencing these changes on a day-to-day basis.

**Section #6: Interview Takeaways**

The course of our investigation, as thorough as it was, proved to be incomplete without the perspectives of those in the medical field. We decided to interview a current resident, a practitioner, and a former practitioner turned public health expert and academic. These voices from the front lines of the industry showed their perspectives to be vital in understanding the developments at the heart of this paper.

As was discovered relatively quickly, for many doctors (even those seasoned by years of practice in their field) the process of mentally accepting the role of AI in the future of healthcare has not always proven to be easy. As one internal medicine practitioner of over a decade at the time within the United States put the feeling of walking out of her first conference on AI, “I definitely felt regret that I had not been more aware of this earlier—the applications, the possibilities, the fact that this was happening now under my nose and not just in a theoretical future. There was some uncertainty as well, with a genuine feeling of not knowing exactly what the future of medicine will look like and some sadness for the younger doctors and especially nonphysician medical professionals who don’t have the opportunities I do to attend these conferences and have these learning experiences, but who will be affected even more by the changes." Another common theme throughout the investigation appeared to be a tendency to relate the impact of AI to past technological shocks that affected the field of healthcare. While there was consensus that these changes were for the better, the physician we spoke with did express that the adoption of something like electronic health records was not always so smooth for several parties, "There was definitely a learning curve that many doctors who were not as used to new technology like I was upon coming to the US were not quite ready for. If you assessed purely the first month plus roughly of the implementation I think you would find a period of even less efficiency than with paper records due to not just an unwillingness to change but the difficulties in the process. On the end of patients, I would say that there were and sometimes still are privacy concerns associated with the electronic nature of records. They are after all more permanent, harder to dispose of, and harder to track possession of—as well as prone to hacks and accidents more so than a single sheet of paper might be to theft. On the labor side, I have had at least one PA (physician's assistant)---an older woman—who was a former transcriptionist specifically in charge of paper records but later went to PA school to gain new and more in-demand skills" (Interview 1). The labor side of this dynamic and how it ties to AI was further echoed by a different interviewee—a public health expert in Germany who, though an MD, has not been a clinical practitioner in over a decade but continues to observe the development of the industry in Berlin, "Most of the AI shock has only reinforced the lack of use of jobs that were already on the way out rather than turned any other jobs obsolete, while of course also improving the work capacity of jobs like mine by leaps and bounds" (Interview 3). It is this angle of healthcare as an administrative and bureaucratic system rather than simply something between doctor and patient that can shed further light on the industry and help us understand the implications of the integration of AI. Our interviewee summed up his realization of the potential during the days of panic in 2019 and 2020, "The first is predictive analytics for seeing the spread of disease and identifying populations at risk and strategies to address these vulnerabilities. I knew about the advances here but I would say it took until Covid when all public health experts got a lot busier that I saw the scale of just how far it had come. Of course, with the way Covid unfolded, politicians ended up taking over a lot of the response and cutting into our responsibilities, but that is a different topic. For the purposes of your subject, AI can do so much by way of analysis compared to that of even a team of experts manually that the time saved is quite significant, especially in times of crisis" (Interview 3). From his input, some interesting new applications of how AI is changing healthcare already in Germany and around the world from the highest level possible were gathered. This was particularly interesting because it is not something visible to patients or observers but affects them profoundly. As he chose to put it, the effects are far-reaching, "On the largest level first I would say the process of drug discovery, development and innovation is being changed by AI and this for obvious reasons affects just about everything else. It's not quite the US, but Germany is a major source of pharmaceutical innovation and at this point the biggest in the EU. The algorithms of artificial intelligence are already at work in identifying candidates faster, cheaper, and more accurately—without the need for so many trials and failures. These clinical trials can be optimized through an AI that can identify the populations most likely to respond to a particular candidate, and thus allow the drugs to hit the market sooner. Good for patients, good for doctors, good for the system as a whole. There is however some labor by way of scientists and data analysts who do a job that the algorithms could do better. For them, reassignment and retraining is normally the go-to as AI generally opens up new jobs as well in analytics, computational chemistry, and bioinformatics but it is not always a smooth process" (Interview 3). The largest scale impact of artificial intelligence comes in the imaging department—an area of medicine already based on technology but facing the prospect of even greater upheaval even if it is for the better. As our interviewee described from simply following developments in healthcare despite imaging not being his regular job, "AI in medical imaging, whether it is a CT scan, MRI, x-ray, whatever. They allow doctors nowadays to read and gain the necessary information so much faster than was ever possible manually. It can help diagnose different types of cancers and also neurological diseases both faster and more accurately" (Interview 3). In his eyes, this level of efficacy is revolutionary in terms of what it means to patient well-being and by extension healthcare as a whole (something he sees as being patient-centered inherently—possibly due to his German background). Nonetheless, when pressed on the possible effects on labor, he did show to have given this quite a bit of thought, "Technicians are still needed because the machine won't operate and run on its own and doctors are needed for making the actual interpretations. I do suppose it's possible that AI could advance to the point of making conclusions on its own; in which case, I imagine radiologists would see a shift in their jobs from a dark room reading images to one where there is more routine interaction with patients which today is more of an oncologist/primary physician/whatever doctor ordered the scan role. I suppose there is a worst-case scenario where radiology could be phased out or become a dead field but we are a long way from that; and even if so, radiologists at the time when this happens would likely just revert to primary care physicians. It would be a bit of a waste for them to get that specialty and maybe a slight step back in salary—though not a big difference in Germany, but not the kind of disaster automation has meant for certain workers in the past" (Interview 3).

It would be tempting to conclude that this period of transition and initial confusion noted by these interviewees is a symptom of an old guard struggling with new technologies more so than a wider reflection on healthcare in the face of artificial intelligence but our third interviewee, an aspirating medical student, shows this trend to be a challenge that even younger generations of doctors face at the outset, with her claiming that it took about 1-2 weeks to get fully comfortable with dictation and charting/orders on the phone. As far as the SonoSite US (an ultrasound technology), it took her about 1 month and the Da Vinci (surgical AI) took about 2 months, but she still has not yet fully mastered each facet of technology that it offers. In her opinion, she argued that the technological implementations have resulted in a net positive benefit. She expanded by saying that the implementation of said technology increased efficiency, quality of work, and time management" (Interview 2).

Despite the apparent differences in the backgrounds of our interviewees, we have discussed a number of common threads that have helped us learn about the experiences and mindsets of healthcare workers around the implementation of clinical Artificial Intelligence. Specifically, though all those interviewed appeared to see AI as being a positive development for the field of medicine (from doctors to patients to really the system as a whole), they did not seem to have much personal enthusiasm for the changes it wrought. This was further cemented by the commentary on prior non-AI technology shocks and how these improved care but were similarly not popular at their outset—even to the point of negatively affecting productivity in the initial stages of their implementation. This reinforces the idea that even with the increasing mechanization and prevalence of technology healthcare is still a human-driven industry and—since humans are not machines—productivity, change, and efficiency are not necessarily linear. In other words, it takes time for waves of change to mature within industries to the point where the technology shocks significantly automate work while increasing productivity. The other key takeaway for this investigation is the fact that preparedness for these changes differs wildly across the medical field with many. This is particularly the case for nondoctors assisting in clinical care. These are the kinds of professions who have the least amount of education relative to other clinical workers and who complete less fundamental tasks as their assistance is typically concentrated in one or two stages of the patient's care cycle (rather than a doctor who is a factor throughout the processes. As a result, these positions are ones we have deemed the most replaceable in our analysis in section 5 and likely to be the most affected. Yet, we discussed how this group does not have the greatest opportunity or motivation to educate themselves on the changes coming in the not so distant future. Even among the doctors we conversated with, there appeared to be a naive lack of urgency around their personal need to re educate, learn new skills, and take on more responsibility in response to the AI wave of change that has only just begun. The overall effect of the interviews is analogous to creating a gray zone by demonstrating the degree of variation that exists in the individuals at the front lines in the healthcare industry and providing an element of variance to the potential human impact that is looming.

## Section #7: Conclusion

In recent times, Artificial Intelligence has enjoyed the public spotlight occupying the newsfeeds and conversations of humans around the world. This popularity is not without warrant as there exist countless exciting possibilities and applications of AI which have already been and remain to be discovered. However, as with all significant waves of change, there exist numerous negative consequences in the short and long run as the new winners and losers of this coming change are defined.

To some degree, it is possible to predict these winners and losers in the labor market that ensue from the incorporation of a change in processes by understanding what changes are made and which workers' responsibilities are ultimately competing with the new technology, and which are complemented by it. With the recent exploding growth of Artificial Intelligence in clinical applications of the healthcare industry, an industry which currently employs the most workers in the U.S. of any other industry, we deemed it valuable to further explore the series of technology shocks in this sector to better which occupations are most at risk or exposed in the short run.

While artificial intelligence is not fully integrated into every level of each subsector of clinical healthcare, the utilization, and overall growth potential are quite apparent. This is reflected in the growing FDA adoption as; between the years 1995 and 2016 only 32 AI-enabled products were approved by the FDA which can be compared to the 135 products approved in 2023 alone. With that said, outside of the subsectors that are already utilizing AI regularly (radiology, cardiology, and anesthesiology, to name a few), further adoption and implementation within the subsectors of clinical healthcare is likely to be a gradual process as there exist regulatory and technological hurdles. That is to say that it is unlikely that AI will completely take over the clinical side of healthcare shortly in a manner similar to previous technology shocks like the automation of 80% of manufacturing jobs over just two decades (Hicks, Devaraj). Michael Bruno, the vice chair for quality and patient safety at Penn State Milton S. Hershey Medical Center, says it perfectly: "Chances are AI is not going to replace us, but instead work with us. We need to see how AI can help radiologists improve their accuracy, efficiency, and overall performance. We have a great mismatch right now between the great resignation, the loss of manpower, and the exploding increase in demand (Fornell 2023)." However, as has been discussed in length, there exist opportunities for significant automation of certain clinical tasks at scale which will ultimately predominantly compete with the responsibilities of existing workers while also complementing some of their other tasks. While this will likely make these clinical subsectors and the healthcare system in general more productive, efficient, and accurate, it will also come at the cost of reduced reliance on human labor. It is wise for workers in the affected occupations to get ahead of this eventuality and prepare by learning new skills or acquiring new knowledge.

In our analysis of the primary occupations within the healthcare subsectors most exposed to Clinical AI products, the reality of the coming automation of many critical tasks was quite apparent. As a whole, the applications of AI within the clinical side of healthcare are currently focused on the automation and betterment of testing. diagnosis, and post-treatment monitoring phases of patient care. As of now, it appears as though responsibilities contributing to the actual administration of treatment and interaction and care for patients continue to be retained by healthcare professionals. Additionally, the tasks in these latter phases of patient care appear to be complimented by the increasingly efficient and accurate diagnosis and planning phases that will likely be realized as a result of the growing approval and implementation of AI-enabled technologies discussed. While all occupations within the clinical subsectors studied were exposed to these processes, these preparation and diagnosis tasks appeared to be overwhelmingly more important to lower-skill positions like nurses, assistants, and technicians consistent with the common economic theory of a growing skill bias that results from a technology shock. For those AI-enabled technologies approved by the FDA between 1995-2016 and in 2023, we also observed a disproportionate concentration of innovation in specific subsectors like radiology, cardiology, anesthesiology, and neurology. Going forward it will be interesting to observe actual adjustments in the labor markets of these subsectors and occupations as well as how clinical Artificial Intelligence applications evolve potentially into the latter phases of patient care.

Our analysis unfortunately entails many shortcomings, particularly surrounding the forecasting of AI-enabled clinical products that are likely to be approved by the FDA in the future and their relationship with current occupations. We only approached the matter from a backward-facing perspective. Additionally, a more standardized approach to measuring the relationship between a particular AI-enabled technology and an employment position would be productive in removing bias. Finally, extending the analysis of the relationship between workers' meaningful tasks and the roles of approved AI-enabled technologies to incorporate all 692 FDA-approved AI-enabled clinical products between 1995 and 2023 would strengthen our general understanding of the current state of AI adoption in healthcare.

## Appendix:

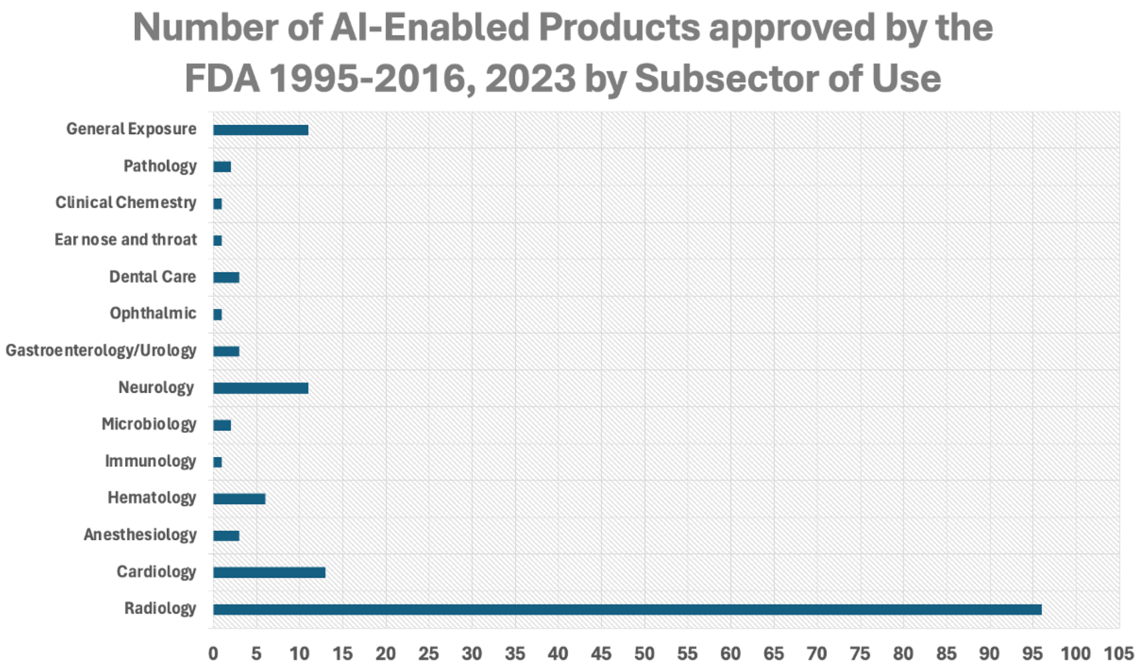


Figure 1B: The Number of FDA-approved AI Enabled Products for Clinical Use (approved between 1995-2016 and in 2023)

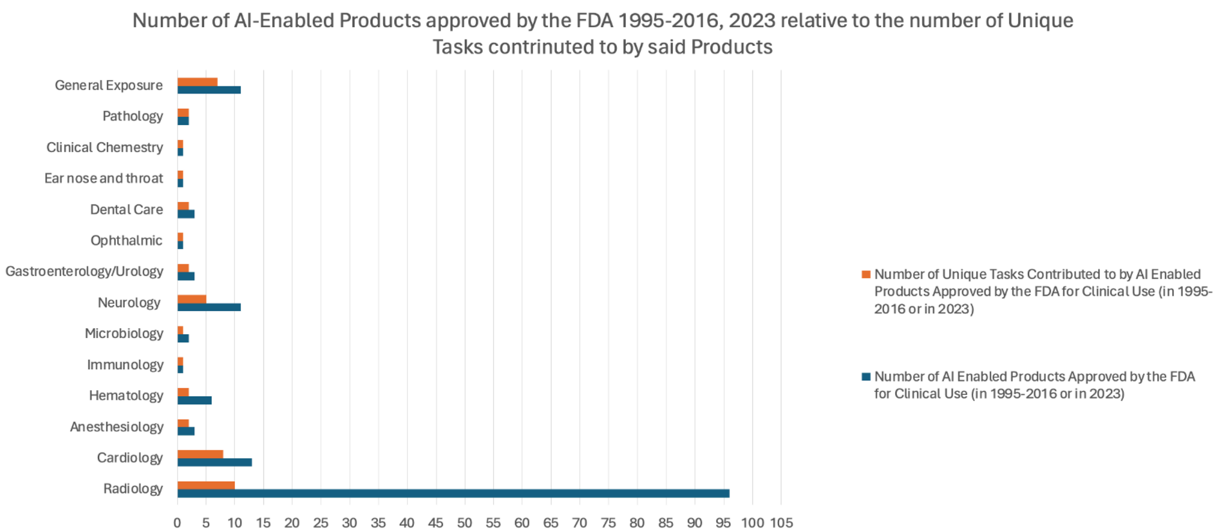


Figure 1: The Number of FDA-approved AI Enabled Products for Clinical Use (approved between 1995-2016 and in 2023) and count of Unique Tasks they Contribute to as defined by the number of unique FDA Primary Product Codes.

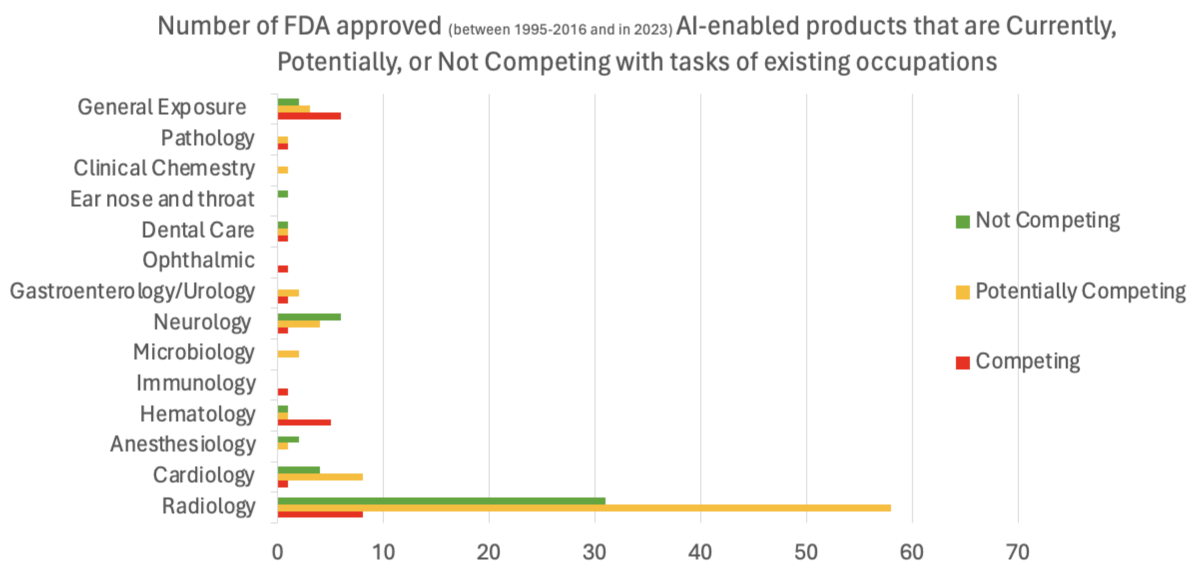


Figure 2: The number of FDA approved AI-enabled products for clinical medical use (approved between 1995-2016 and in 2023) that we deemed "Currently", "Potentially", or "Not Competing" with the fundamental tasks of existing occupations based on a rudimentary comparison of ONET Tasks and FDA.

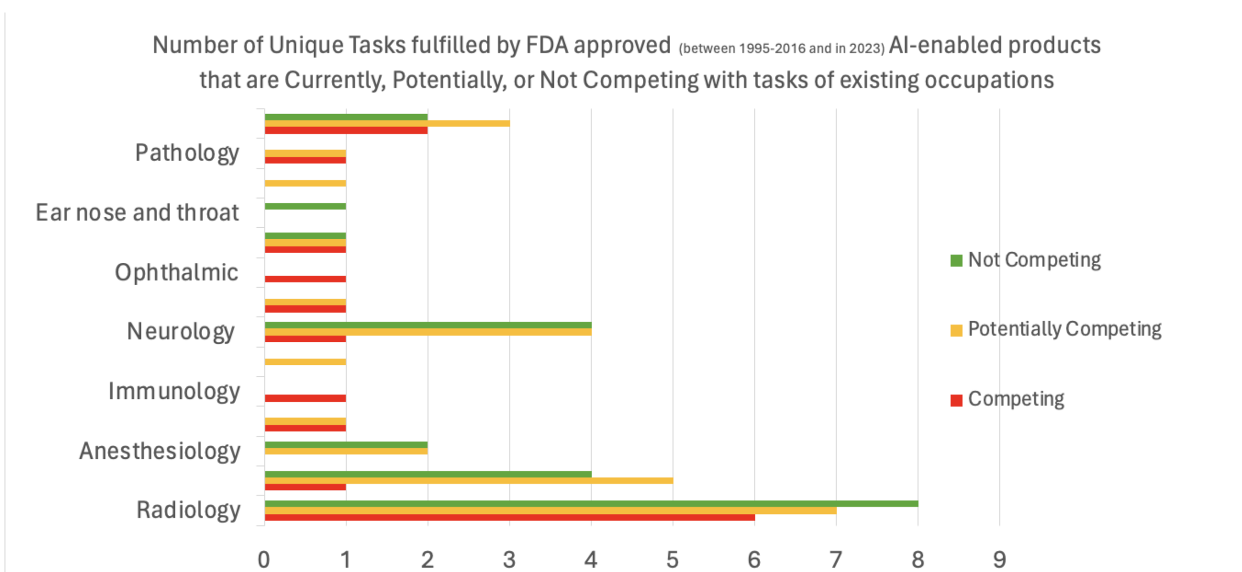


Figure 3: The number of unique tasks (defined by unique FDA Primary Product Codes) completed by FDA approved AI Enabled Products (approved between 1995-2016 and in 2023) that are "Currently", "Potentially", or "Not Competing" with the fundamental tasks of existing occupations.

| Occupation | Top 3 Responsibilities | Average Req. Education | Average Income | Number of Employees |
|---|---|---|---|---|
| Radiation Therapists | (1) Administer cancer treatments.<br>(2) Operate diagnostic or therapeutic medical instruments or equipment.<br>(3) Position patients for treatment or examination. | 38% Bachelors degree<br>50% Associates degree | $89,530 | 15,900 |
| Radiologic Technologists | (1) Operate diagnostic imaging equipment.<br>(2) Adjust settings or positions of medical equipment.<br>(3) Prepare medical supplies or equipment for use. | 11% Bachelor's degree<br>73% Associates degree | $65,140 | 222,800 |
| Cardiovascular Technologists | (1) Operate diagnostic or therapeutic medical instruments or equipment.<br>(2) Test patient heart or lung functioning<br>(3) Explain medical procedures or test results to patients or family members. | 13% Post-Sec Certificate<br>63% Associates degree | $63,000 | 58,900 |
| Cardiologists | (1) Test patient heart or lung functioning.<br>(2) Analyze test data or images to inform diagnosis or treatment.<br>(3) Operate diagnostic or therapeutic medical instruments or equipment. | Most require Masters and some require Ph.D/M.D. | $239,200 | 18,000 |
| Anesthesiologist Assistants | (1) Adjust settings or positions of medical equipment.<br>(2) Assist healthcare practitioners during examinations or treatments.<br>(3) Monitor patient conditions during treatments, procedures, or activities. | 42% Bachelors degree<br>22% High School | $126,010 | 148,000 |
| Anesthesiologist | (1) Monitor patient conditions during treatments, procedures, or activities.<br>(2) Implement advanced life support techniques.<br>(3) Prepare patients physically for medical procedures. | 69% Post-Doctoral Training<br>25% Doctoral degree | $239,200 | 40,000 |
| Nurses | (1) Record patient medical histories.<br>(2) Monitor patient conditions during treatments, procedures, or activities.<br>(3) Administer non-intravenous medications. | Bachelors Degree<br>Associates Degree | $81,220 | 3,172,500 |

Figure 4: Summary of High Exposure Occupations within the Clinical Sub Sectors of Healthcare where there have been the most approved AI-enabled products (2022 data from ONET OnLine) (see figure 5 for complete list)

| Subsector: | Occupation | Projected Growth (2022-2032) (ONET) | Projected Job Openings (2022-2032) (ONET) | Education Required according to Respondents | SVP (Specific Vocational Preparation) Range | Median Wage (2022) | Employment # (2022) | % Women | % White | % Foreign Born |
|---|---|---|---|---|---|---|---|---|---|---|
| Radiology | Radiation Therapists | Average (2-4%) | 700 | (38% Bachelor) (50% Associate's) | 6 to < 7 | $89,530.00 | 15900 | 68% | 89% | 6% |
| Radiology | Radiologic Technologists and Technicians | Faster than average by 5-8% | 13100 | (11% Bachelor) (73% Associate's) | 6 to < 7 | $65,140.00 | 222800 | | 72% | |
| Radiology/Cardiovascular | Diagnostic Medical Sonographers | Much Faster than average by 9%+ | 5700 | (19% post-Sec Certificate) (47% Associate's) | 6 to < 7 | $81,350.00 | 83800 | 79% | 84% | 17% |
| Radiology | Magnetic Resonance Imaging Technologists | Faster then average by 5-8% | 2600 | (13% Post-Sec Certificate) (65% Associate's) | 6 to < 7 | $80,090.00 | 41400 | 62% | 84% | 17% |
| Radiology | Nuclear Medicine Technologists | Little or no change | 800 | (22% Bachelor) (63% Associate's) | 6 to < 7 | $85,300.00 | 18100 | 58% | 80% | 18% |
| | | | | | | | | | | |
| Cardiovascular | Cardiovascular Technologists and Technicians | Average (2-4%) | 3900 | (13% Post-Sec Certificate) (63% Associate's) | 6 to < 7 | $63,000.00 | 58900 | 63% | 84% | 19% |
| Cardiovascular | Cardiologists | Average (2-4%) | 500 | Most require Masters and some require Ph.D/M.D. | 8.0 and above | $239,200.00 | 18000 | | | |
| | | | | | | | | | | |
| Neurology | Neurologists | Average (2-4%) | 400 | (64% post-doctoral) (29% doctoral degree) | 8.0 and above | $224,260.00 | 12200 | | | |
| | | | | | | | | | | |
| Gastroenterology/urology | Urologists | average (2-4%) | 9900 | (64% Post-Doctoral training) (33% Doctoral degree) | 8.0 and above | $223,410.00 | 330900 | | | |
| | | | | | | | | | | |
| Anesthesiology | Anesthesiologist Assistants | Much Faster than average by 9%+ | 12200 (for all physician assistants) | (42% Bachelor) (22% High School) | 8.0 and above | 126010 (for all physician assistants) | 148000 (for all physician assistants) | | | |
| Anesthesiology | Anesthesiologist | Average (2-4%) | 1200 | (69% post-doctoral training) (25% doctoral degree) | 8.0 and above | $239,200.00 | 40000 | | | |
| Anesthesiology | Nurse Anesthesiologists | Much Faster than average by 9%+ | 2500 | (56% Doctoral) (41% Masters) | 8.0 and above | $203,090.00 | 49400 | 55% | 95% | 6% |
| | | | | | | | | | | |
| Ophthalmic | Opthomologists (exclusing pediatric) | average (2-4%) | 300 | . | 8.0 and above | $219,810.00 | 12800 | | | |
| | | | | | | | | | | |
| Dental Care | Oral and Maxillofacial Surgeons | Faster than average (5 to 8%) | 200 | (72% Post doctoral training) (20% Doctoral) | 8.0 and above | $239,200.00 | 4900 | | | |
| Dental Care | Dental Assistants | Faster than average (5 to 8%) | 55100 | (46% post-secondary) (29% High school) | 6.0 to < 7.0 | $44,820.00 | 571000 | 94% | 79% | 20% |
| | | | | | | | | | | |
| Generally exposed Occupations | Registered Nurses | Faster than average by 5-8% | 193100 | (% Bachelor) (% Associate's) | 7.0 to < 8.0 | $81,220.00 | 3172500 | 88% | 66% | 16% |
| Generally exposed Occupations | Physicians | Average (2-4%) | 9900 | Depends on specific occupation | | $223,410.00 | 330,900 | 44% | 65% | 27% |
| Generally exposed Occupations | Emergency Medicine Physicians | Average (2-4%) | 900 | Most require graduate school | 8.0 and above | $239,200.00 | 31300 | - | - | - |
| Generally exposed Occupations | Physician Assistants | Much Faster than average by 9%+ | 12200 | (81% masters) (14% professional degree) | 8.0 and above | $126,010.00 | 148000 | 68% | 78% | 10% |
| Generally exposed Occupations | Nurse Practitioners | Much Faster than average by 9%+ | 26300 | (65% Masters) (24% Doctoral) | 8.0 and above | $121,610.00 | 266300 | 89% | 75% | 12% |
| Generally exposed Occupations | General Internal Medicine Physicians | Average (2-4%) | 2100 | (53% Post-Doctoral training) (41% Doctoral) | 8.0 and above | $214,460.00 | 72600 | | | |
| Generally exposed Occupations | Orthopedic Surgeons (except pediatric) | Average (2-4%) | 500 | . | 8.0 and above | $239,200.00 | 19400 | | | |
| | | | | | | | | | | |
| Average/Total Stats for all clinical positions exposed to AI | | 5.15% | 341200 | | 6 to 8.0 and above | $159,167.14 | 5521100 | | | |

Figure 5: Complete Summary of all High Exposure Clinical Healthcare Occupations that were analyzed for Complementarity with approved AI-enabled clinical products (Demographic data on % women, white, and foreign born was sourced from 2022 BLS summary statistics for the bottom 5 occupations and was calculated using 2010-2024 IPUMS CPS data for all occupations this information is available for above the Dental Care occupations) (ALL other data sourced from 2022 ONET OnLine including the top 10 tasks of each occupation)

*This reveals the demographics of individuals in the healthcare occupations referenced who partook in the CPS survey, not necessarily the demographics of all healthcare workers in those positions. No weights were applied.

*If any of the occupations were missing data, the cell is marked with "-"

## Hospital Summary Demographic Statistics by Occupation (2010-2024) (Source: IPUMS - CPS)

### Clinical Health and Care related Occupations

**Industry Codes Included :** 7970, 7980, 7990, 8070, 8080, 8090, 8170, 8190, 8270

**2010-2024**

| Occ Title | Number of Surveys | Avg Age | % Female | Average Income (2020-2024) | White | Black | White-Black | Asian only | White-Asian |
|---|---|---|---|---|---|---|---|---|---|
| Biomedical engineers | 166 | 42 | 16% | $ 70,000.00 | 78% | 6% | 0% | 7% | 7% |
| Chemical engineers | 13 | 45 | 8% | $ 190,000.00 | 77% | 15% | 0% | 8% | 0% |
| Biological scientists | 474 | 45 | 78% | $ 50,000.00 | 78% | 6% | 0% | 15% | 0% |
| Medical scientists | 2363 | 41 | 60% | $ 154,876.73 | 66% | 5% | 0% | 27% | 1% |
| Biological technicians | 14 | 45 | 64% | - | 71% | 21% | 0% | 7% | 0% |
| Chemical technicians | 11 | 47 | 100% | - | 55% | 0% | 0% | 45% | 0% |
| Radiologists | 0 | - | - | - | - | - | - | - | - |
| Dentists | 12268 | 49 | 29% | $ 185,724.74 | 84% | 2% | 0% | 13% | 0% |
| Optometrists | 2720 | 48 | 41% | $ 110,985.56 | 84% | 3% | 0% | 11% | 1% |
| Physicians and surgeons | 47937 | 47 | 37% | - | 76% | 5% | 0% | 16% | 1% |
| Surgeons | 398 | 54 | 13% | $ 298,370.41 | 91% | 4% | 0% | 5% | 0% |
| Physician assistants | 6456 | 40 | 70% | $ 97,175.16 | 89% | 3% | 0% | 6% | 0% |
| Registered nurses | 15086 | 44 | 91% | - | 82% | 10% | 0% | 7% | 0% |
| Radiation therapists | 707 | 42 | 68% | $ 71,500.00 | 89% | 6% | 0% | 1% | 1% |
| Total | 88613 | 44 | 49% | $ 129,829.07 | 79.34% | 5.47% | 0.20% | 13.45% | 0.50% |

### Hospitals (Tech) - Software Related Occupations

**Industry Codes Included :** 7970, 7980, 7990, 8070, 8080, 8090, 8170, 8190, 8270

**2010-2024**

| Occ Title | Number of Surveys | Avg Age | % Female | Average Income (2020-2024) | White | Black | White-Black | Asian only | White-Asian |
|---|---|---|---|---|---|---|---|---|---|
| Computer programmers | 743 | 45 | 43% | $ 62,476.57 | 78% | 6% | 0% | 14% | 1% |
| Computer scientists and systems analysts | 201 | 41 | 48% | - | 81% | 6% | 0% | 10% | 0% |
| Network and computer systems administrators | 63 | 40 | 22% | - | 86% | 10% | 0% | 0% | 2% |
| Software developers, applications and systems software | 1146 | 43 | 38% | - | 76% | 7% | 0% | 16% | 0% |
| Database administrators | 296 | 45 | 40% | - | 84% | 2% | 0% | 6% | 3% |
| Computer support specialists | 95 | 43 | 55% | - | 79% | 14% | 0% | 7% | 0% |
| Computer support specialists | 1291 | 43 | 37% | $ 86,894.17 | 83% | 10% | 0% | 5% | 0% |
| Computer support specialists COMBINED | 1386 | 43 | 38% | $ 86,894.17 | 82% | 10% | 0% | 5% | 0% |
| Computer systems analysts | 1620 | 44 | 55% | $ 68,428.57 | 75% | 12% | 0% | 10% | 1% |
| Network and computer systems administrators | 653 | 43 | 30% | $ 67,386.82 | 89% | 5% | 0% | 6% | 0% |
| Computer network architects | 134 | 42 | 7% | $ 110,000.00 | 81% | 3% | 0% | 10% | 0% |
| Computer occupations, all other | 1766 | 42 | 33% | - | 82% | 8% | 0% | 7% | 0% |
| Information security analysts | 156 | 44 | 19% | $ 126,000.00 | 83% | 10% | 1% | 2% | 1% |
| Computer and information research scientists | 16 | 47 | 44% | - | 75% | 0% | 0% | 25% | 0% |
| Database administrators and architects | 43 | 43 | 37% | $ 60,000.00 | 47% | 9% | 0% | 44% | 0% |
| Software developers | 149 | 41 | 25% | $ 127,052.63 | 68% | 9% | 0% | 21% | 1% |
| Computer occupations, all other | 314 | 44 | 40% | $ 104,338.85 | 77% | 11% | 0% | 8% | 1% |
| Software quality assurance analysts and testers | 6 | 35 | 83% | - | 17% | 17% | 0% | 67% | 0% |
| Web or digital interface designers | 12 | 41 | 33% | $ 80,500.00 | 100% | 0% | 0% | 0% | 0% |
| Web developers | 6 | 37 | 50% | $ 110,000.00 | 100% | 0% | 0% | 0% | 0% |
| Web developers | 120 | 37 | 73% | - | 77% | 10% | 0% | 11% | 0% |
| Web Developers COMBINED | 0 | 37 | 71% | $ 110,000.00 | 78% | 10% | 0% | 10% | 0% |
| Total | 10216 | 43 | 40% | $ 90,830.98 | 79.98% | 8.68% | 0.14% | 8.85% | 0.58% |

Figure 6: Summary statistics of healthcare worker's demographics by occupation. Data from IPUMS CPS 2010-2024. No weights were applied. (Sarah Flood et al.)

## (Interview Transcript or Summary):

1. Interviewee 1: Dr. Shireen Jindani
    - Internal Medicine Practitioner (Phoenix)

**Me:** Hello Dr. Jindani. Thank you for joining me today.
**Dr. Jindani:** It is no problem, Ari. I am happy to be here.
**Me:** So my first inquiry—seeing as it is the overarching topic of our paper—is on your level of work and familiarity with artificial intelligence in a professional setting.
**Dr. Jindani:** My familiarity with AI started about 6 years ago. I have never been a technologically inclined person and would still hesitate to describe myself in that way, but I do know some technologically inclined people in the IT industry more so than healthcare but still…who brought up repeatedly the rising nature of something straight out of a science fiction movie. It still wasn't until April of 2018 that I decided to attend a conference on the topic, and I have to say it was a real eye opener.
**Me:** Eye opener in what way? Good or bad?
**Dr Jindani:** Well both really—more of an eye opener to reality. I definitely felt regret that I had not been more aware of this earlier—the applications, the possibilities, the fact that this was happening now under my nose and not just in a theoretical future. There was some uncertainty as well, with a genuine feeling of not knowing exactly what the future of medicine will look like and some sadness for the younger doctors and especially non physician medical professionals who don't have the opportunities I do to attend these conferences and have these learning experiences, but who will be affected even more by the changes.
**Me:** So speaking of technological changes in the healthcare field and their effects, do you have examples of prior shocks in the field and what they meant for you and those you observed in the industry?
**Dr Jindani:** I think I am in a bit of a unique place to answer this—at least the part about personal adjustment to technology, because I went to medical school in Pakistan where, especially back then, many of the technologies doctors here consider second nature were a luxury if even available. So in coming to the US, there was an immediate learning curve and as new technology became more widely available here, the learning curve was even steeper for me than it was for doctors who were trained here. I would assume this is something most immigrant doctors have faced but would not describe it as a mountain of a challenge on its own. After all, we are observational learners and can pick up a lot just from seeing those around us use a machine or program. However, I would say it was an additional stressor at a point in life that is already filled with so many stressors and thus certainly more notable that it would have been on its own. Nonetheless, I do think the tolerance to these challenges has built up over the years. Outside of moments like coming out of that first AI conference, I don't see technological changes as threats or worries to the level I once did, having come to understand that they really are just part of our job and something that is inevitable once every few years at least.
**Me:** I appreciate the personal perspective and think the sentiments of those on the front lines of the healthcare industry are an absolutely crucial part of answering the questions we seek to explore. However, I would also like to get some specific technology shocks that you have seen in your time affect the healthcare industry as a whole and the major points of significance of each? This can mean effects on doctors, on patients, on profits, on quality of care, on other healthcare workers, anything that comes to mind.
**Dr. Jindani:** That's an interesting topic. As I said, the longer I have practiced, the more a lot of the technological changes just tend to blur together especially if they occurred at similar times—like within five years of each other. Still, though, there are a few that tend to pop in my memory mostly because of how their effects still endure today in both my work and the industry as a whole. The first one would be electronic health records instead of the paper version. This happened a while ago but was not a widely available thing when I was in Pakistan. Today, however, as I am sure you know, pretty much all first world hospitals and even most in developing countries have some form of computerized record keeping. The other is more recent and probably still developing like with AI, but I think Covid cemented the potential of telemedicine to revolutionize how we consider patient care and has led to most clinics trying to arrange some kind of virtual option for patients coming in for something like a routine checkup and in some cases even for specialist physicians. Something else in this mold would be genomic medicine and its

personalized nature, as the advances made by geneticists can in some cases allow doctors to create customized health plans for patients based on their genomic profiles. I should warn that though the technology here is available, there is even more red tape than for something like AI, making its application in its infancy. For something a bit more established and nowadays perhaps even taken for granted, I would say that wearable health devices with remote monitoring fit the bill. I don't think people nowadays truly understand just what they meant for elderly, for those with high blood pressure, diabetics and many others.

**Me:** So you mentioned quite a few examples of possible tech shocks and I'd like to focus on each one at a time if you are okay with that.

**Dr. Jindani:** Sure. In some of these cases, my perspective may be limited but I'll say what I can attest to.

**Me:** So you mentioned electronic health records first and with the most detail and context. What would you say are the major effects of this change on the industry as a whole for all parties involved?

**Dr. Jindani:** On this change, I feel as though you would struggle to find a single physician who would wish to reverse it—even among the more old fashioned technologically challenged ones. Put simply, electronic records are just better for how they centralize patient information and make it easier to access, for how they can be transcribed easier—whether by voice or a scribe, for how they can be read without being dependent on quality of handwriting, for how they are easier to back up and recover and a plethora of other reasons far too numerous for me to list. The end result is a clear improvement of care as everything is more streamlined and efficient which means better outcomes for patients as well.

**Me:** So in your view, doctors won from this shock, patients won, those on the business side of healthcare won and overcame the costs of the technology through better and more efficient care—and ultimately profits I'd assume, then who exactly suffered from the adoption of EHR? Were there any downsides—whether in the long or short run?

**Dr. Jindani:** Well I very intentionally avoided using words like "win" because I feel they are a little too absolutist. I stand by the fact that very few would seek to reverse the adoption of electronic health records today; but when it first happened, there was definitely a learning curve that many doctors who were not as used to new technology like I was upon coming to the US were not quite ready for. If you assessed purely the first month plus roughly of the implementation I think you would find a period of even less efficiency than with paper records due to not just an unwillingness to change but the difficulties in the process. On the end of patients, I would say that there were and sometimes still are privacy concerns associated with the electronic nature of records. They are after all more permanent, harder to dispose of and harder to track possession of—as well as prone to hacks and accidents more so than a single sheet of paper might be to theft. On the labor side, I have had at least one PA (physician's assistant)---an older woman—who was a former transcriptionist specifically in charge of paper records but later went to PA school to gain new and more in demand skills. Even today, while there are medical transcriptionists, it is a dying field and something more for students to beef up their resumes than to make actual careers as it once was—especially as voice records become more and more prevalent. Despite all of this, I do feel as though the impact on the healthcare industry has been more positive than negative from EHR—but looking beyond just myself, I can't say that it has been all good all the time for everyone.

**Me:** Thank you for that effort to look past your own perspective. It is not always the easiest thing but it really does help establish a clearer picture. I think now we can move on to the impact of telemedicine on the industry as a whole. Similar to how you answered about electronic health records: do you see it as good, bad, to what extent and for which parties involved?

**Dr. Jindani:** This one is a little different because, though it has come a long way in a short period of time, the truth is that it is too early to judge the ultimate effects unlike with electronic records. However, from my personal experiences and observations, I do see it being a slight positive—albeit more for patients and doctors than anyone else. As a doctor, it is convenient and saves time with virtual appointments being shorter and rarely led astray by someone (patient or me) being late. It also allows me to reach more patients that I may be geographically separated from and who may not be able to come in to see me otherwise. For patients, this increased access means more options and, if they seek it out, better care as they are not restricted by location. For rural and elderly patients especially, this is huge as they can choose a different doctor if the only one qualified for their condition in their area happens to be really bad or rude. Costs are also a big deal as for poorer and/or rural patients in particular just getting to the doctor's office can be a major struggle and lead to lower life expectancies and higher rates of diseases not being detected at optimal times. On the other hand, there is a contingent of patients who consider the care received virtually to be inferior and incapable of replacing what they can get in person—whether it is the technological glitches that can strike, the communication errors that can have major implications for health or just the lack of engagement they feel in a conversation on a screen. Higher up than me on the chain, the rise of telemedicine has brought a lot of red tape and regulatory issues which can complicate delivery of care and make it more effort than it

is worth. This can also sometimes make it difficult to integrate a patient's profile between different doctors or specialists and forms another part of the complaints some patients have against telemedicine.
**Me:** What does all of this mean economically in your estimation?
**Dr. Jindani:** I would say that this makes telemedicine very dependent on location and the regulations in place at each one. In its essence, it is clearly something that can cut costs and wasted time without having much impact on any healthcare workers' job prospects while improving choice and access to care. But the quality of that care? And if it is worth offering said services? Those questions can very much be complicated if outside forces wish to.
**Me:** Thanks for your analysis. Now I would like to move on to the advances in genomics. I am guessing this is also an area that is fairly new and unsettled like you described telemedicine to me. From my bioethics type classes I know some of the controversies at least from a philosophical point of view but could fill me in on the level of shock in the clinical and industrial settings?
**Dr. Jindani:** If you know the ethical angle you probably understand at least one component of its implementation: the controversy. It is really really difficult to clear the regulatory and reimbursement hurdles and answer all the privacy concerns related to getting and storing the genetic material needed. Even beyond this though, I think you would find that many doctors are not truly qualified to turn such insights into streamlined, comprehensive action plans. Even among good doctors, it is a challenging skill that takes some level of training regardless of your specialty or experience level. So, in my view, genomic based care represents a hurdle not just to higher ups and patients for ethical reasons but also to doctors for more practical ones—which is perhaps why it has struggled to get off the ground aside from some wealthy individuals and their personal highly qualified physicians.
**Me:** Sorry to interrupt, but just building off your last point on the wealthy individuals…clearly there is some major potential for good when done on a small scale at least right? In terms of outcomes and even economics considering such a shock would be more likely to create new jobs than to destroy them? I realize I am saying this without directly being in the field and having skin in the game like you do but still I am curious.
**Dr. Jindani:** Yes well the potential for good if everything is done right is undeniable. For these individuals, I am guessing it was the precise and customized nature of the care devised for their genetic structures that drew them towards it. If getting really optimistic, the potential of such treatments are truly incredible, with individuals being able to know their dispositions at birth and thus build a lifestyle that ideally avoids them—like say being careful with sugar and fried foods if more prone to type 2 diabetes and heart disease than the average person or raising a child without alcohol if born with a vulnerable liver. They can also allow earlier detection of developing diseases than what we can do today thanks to identifying genes that can mark a certain disposition before something like a mammogram ever could, as well as targeted therapies that target such genes before they ever get a chance to inflict harm on the patient. The effects could very well be drastic to the point of longer life expectancies and a new weapon against diseases like cancer, depression, heart disease and more that have always been regarded as unpreventable. And yes, as you hinted, the labor effects of such a shock would not be negative even for non physician healthcare professionals and may in fact stimulate new industries and research. Now how will the quality of such care be distributed considering how expensive such assessment currently is and all the red tape involved in the industry? That I cannot quite answer and is something that might be a task of your generation to properly assess.
**Me:** Well that is certainly quite the task, Dr. Jindani. I know it seems really problematic today but I do wonder just how many doctors from 40-50 years ago could have seen medicine looking like it currently does so I also believe humans are capable of a lot more than it tends to initially look like. Before I let you go, I want to touch on the last big tech shock you mentioned—the issue of wearable electronic health devices.
**Dr. Jindani:** Of course. I would say the biggest benefit of this "shock" was for patients and specifically how they were empowered to take control of their own health and understand simple metrics like blood pressure, heart rate, sleep cycles and more that we might today consider basic knowledge. As physicians, these devices also helped and continue to help us in seeing abnormalities before they really manifest into major problems—even when they are not in a traditional clinical setting. Also enabled by the devices was the feasibility of data driven insights—insights that have obviously become much more sophisticated in the years since but nonetheless help us see patterns, identify risk factors and if needed develop interventions. This, of course, is something AI promises to help greatly with as well but that's a separate topic.
**Me:** Yeah I can get your thoughts on that at the end as well if you'd like but would like to focus on the personal medical devices at the moment. You showed the clear positives for the industry, for doctors and obviously for patients. Were there any downsides to this change that you observed? Or that you are still observing today?
**Dr. Jindani:** Hmm. That's tricky but I suppose there are a few, especially when they were first introduced, as we have mitigated a lot of this; but at the time, there was a major information overload for providers. Data processing was not as sophisticated as today, and I remember quite a bit of difficulty in interpreting such a vast amount of information and even cases of burnout without the number of cases or patients being increased at all. From the point

of view of patients, I would say the major drawback was in how these devices were initially expensive and in some ways widened health disparities with poorer patients not being able to afford them. It was not like nowadays where there were apps on phones that cover 70% of what those devices could do. Neither really impacted the industry in terms of profits or lost jobs per se aside from maybe an increase in occupational stress as the devices were introduced.
**Me:** So for my final question: how do you see these shocks and their magnitude of impact comparing to what is happening and set to happen with AI? From your experience with the conference I take it you have some thoughts to convey on that topic.
**Dr. Jindani:** I suppose everyone has a bit of a bias when it comes to comparing the present to the past and especially when it involves the dramaticness of a change, but I can objectively say none of these changes compare to the potential of AI. I suppose genomics could if all goes well in the coming years, and of the ones in the past, the transition to electronic health records ticks the box of affecting labor in the healthcare industry, but to me AI is a different matter altogether. It can transform our jobs as doctors, what is asked of patients and the macroeconomic considerations for executives and workers to an extent that none of these changes could single handedly manage to do. I know you have some specifics on that so I won't go too deep into it, but I think the next fifty years of healthcare will see even more change than the last fifty did—which is saying a lot for someone like me who came from medical school in Pakistan.
**Me:** Thank you so much for your time and presence Dr. Jindani. Best of luck in navigating these changes.

2. Interviewee 2: Dr. Brenna McElenney
    - Surgical Resident at Banner Health (Phoenix)

This specific interviewee currently is a Surgical Resident at the University of Arizona College of Medicine. She has just completed a rotation in trauma surgery in Anchorage, Alaska and was kind enough to take the time to sit down and assist us through this interview. Said interviewee has a very strong educational background as she has achieved a medical degree (MD), Master of Public Health (MPH), Bachelor of Science (BS), as well as ACLS and BLS certifications.

According to the interviewee, the day-to-day work of a Surgical Resident from the University of Arizona College of Medicine includes patient care, surgeries and procedures, documentation, dictation, and patient orders. More specifically, tasks such as patient care consist of preoperative, postoperative, and clinic visits and encounters. Similarly, documentation requires charting, daily notes, as well as procedure and operative note taking. Finally, patient orders also encompass electronic ordering of medication, labs, and nursing care. In the interviewee's words, the 5 most crucial tasks she would advise a future Surgical Resident include chart review, orders, documentation, preoperative setup, and basic procedures such as lines and bedside procedures.

In talking to the interviewee, she concluded that the most repetitive tasks and jobs for a Surgical Resident at the University of Arizona College of Medicine consists of documentation, charting, and orders. This is likely due to the fact that the University of Arizona College of Medicine is attempting to develop skills of a competent and reliable healthcare professional within each of their Surgical Residents such as communication, decision making, and precision/ Assiduousness. The interviewee depicts the transformation of her duties over the years beginning with when she was a student to where she is now: a resident. Said transformation includes how she is now responsible for completing documentation, placing patient orders, and being the junior surgeon/ first assistant attending surgeon.

In our discussion of the implementation and introduction of new technologies, the interviewee mentioned the Da Vinci Robot, SonoSite Ultrasound with voice automation, dictation, and charting and orders through new technologies. The Da Vinci Robot is a surgical system often used for prostatectomies, cardiac valve repair, and renal and gynecologic surgical procedures that are often minimally invasive. The SonoSite Ultrasound was first implemented in the late 1990s and was considered a significant advancement in ultrasound technology. Recently, in 2022 SonoSite Ultrasound technologies has made another significant advancement in ultrasound technology with the implementation of voice automation in an effort to improve efficiency and patient care. Furthermore, the interviewee explained advancements in dictation, charting, and orders and encountered said advancements on an everyday basis. According to the interviewee, there was significant education of the Da Vinci Robot, SonoSite Ultrasound with voice automation, dictation, and charting and orders all prior to implementation as well as on the job training.

In our interviewees' experience, becoming comfortable with each of these new technologies took a range of different times. For instance, our interviewee claims that it took about 1-2 weeks to get fully comfortable with dictation and charting/orders on the phone. As far as the SonoSite US, it took her about 1 month and the Da Vinci took about 2 months, but she still has not yet fully mastered each facet of technology that it offers. In her opinion, she argued that the technological implementations have resulted in a net positive benefit. She expanded by saying that the implementation of said technology increased efficiency, quality of work, and time management. Due to the efficiency of the technology being implemented, she and her coworkers have more time to work on other tasks. Overall, she argues that the new technologies are a net benefit because it is more efficient, improves quality but with the increase of efficiency, the workload expectations have also grown. Unfortunately, although the volume of work has increased, the staffing of her specific residency has not changed very much.

3. Interviewee 3: Dr. Nicolai Savaskan
    - Ex MD turned academic Public Health Expert (Berlin, Germany)

**Me:** Hello Dr. Savaskan. Thank you again for agreeing to join me today. It is a big help and I'll try not to take up too much of your time.
**Dr. Savaskan:** Don't mention it, Ari.
**Me:** So I'd like to start off with something that ties your job to the topic of AI that I am interested in. As someone who has been in public health rather than a practicing physician for several years now, how integrated is artificial intelligence in your work and the German healthcare system as a whole?
**Dr. Savaskan:** For the confines of my job, I would say there are two major applications of AI and "major" might be putting it lightly as the effects have been large and grow every year as more money is put into better technology. The first is predictive analytics for seeing the spread of disease and identifying populations at risk and strategies to address these vulnerabilities. I knew about the advances here but I would say it took until Covid when all public health experts got a lot busier that I saw the scale of just how far it had come. Of course, with the way Covid unfolded, politicians ended up taking over a lot of the response and cut into our responsibilities, but that is a different topic. For the purposes of your subject, AI can do so much by way of analysis compared to that of even a team of experts manually that the time saved is quite significant especially in times of crisis. The other is more specialized to the public health infrastructure and its organization for the uninsured which are usually refugees or immigrant arrivals or for checking vaccines in children attending schools—which also falls into the scope of our responsibilities, but can allow us to better streamline administrative tasks.
**Me:** Sorry to interrupt Dr. Savaskan, but just a quick follow up: would efficiency and ability entail the loss of jobs or any economic shocks—whether positive or negative?
**Dr. Savaskan:** Well so far in Germany I would say it has been a lot more positive than negative. Most of the AI shock has only reinforced the lack of use of jobs that were already on the way out rather than turned any other jobs obsolete, while of course also improving the work capacity of jobs like mine by leaps and bounds. Looking a little into the future, I would not say it's unreasonable to conclude that—especially with how much we already have to fight for funding—teams of something like data analysts may be downsized as AI advances even further in both scope and accuracy. However, I do feel as though a core part of public health is not just gathering health information but processing it, weighing the human impact, the political impact, the latest research and more in order to come up with effective recommendations. This is something that neither people nor governments in my time will give control of to an AI in my eyes, especially seeing how polarizing public health directives became during the pandemic—whether for security, privacy, political or just reasons of basic trust. This is true even in Germany and from what I can tell is probably even more relevant in the US.
**Me:** I can't say I disagree personally though I'd add that someone generations ago would have said the same about people trusting computers and now we only trust computers for health records, prescriptions and what not.
**Dr. Savaskan:** You are right though speaking from one of the most bureaucratic healthcare systems in the world, I want to emphasize the difference between storing information and directing policy. They are entirely different functions and the way the public views the tasks are also completely different which I think explains some of the barriers to implementation of AI in healthcare in Germany and in the world.
**Me:** Thank you for that. It was actually the next direction I wanted to take our conversation in because as you mentioned earlier most of the applications are less related to your job specifically and more German medicine as a whole. I'd like to get your thoughts on these even if it's not something you see on a daily basis being in public health or academia rather than in a hospital or office.

**Dr. Savaskan:** Of course. So starting on the largest level first I would say the process of drug discovery, development and innovation is being changed by AI and this for obvious reasons affects just about everything else. It's not quite the US, but Germany is a major source of pharmaceutical innovation and at this point the biggest in the EU. The algorithms of artificial intelligence are already at work in identifying candidates faster, cheaper and more accurately—without the need of so many trials and failures. These clinical trials can be optimized through an AI that can identify the populations most likely to respond to a particular candidate, and thus allow the drugs to hit the market sooner. Good for patients, good for doctors, good for the system as a whole. There is however some labor by way of scientists and data analysts who do a job that the algorithms could do better. For them, reassignment and retraining is normally the go-to as AI generally opens up new jobs as well in analytics, computational chemistry and bioinformatics but it is not always a smooth process. Generally however, the shocks to labor have not yet from my observations been enough to undermine the greater benefits.
**Me:** What about further down the healthcare pyramid? Are the effects there more pronounced in your view?
**Dr. Savaskan:** I would say so. For physicians and healthcare administration as a whole, everything is much more streamlined nowadays when it comes to grunt work tasks like scheduling appointments and managing records. As a whole though, this has meant more that the tasks of receptionists have been changed and more focused in human interaction and working directly with the doctor when needed. Of course, transcriptionists are basically a relic at this point but that was happening even when I was practicing before any AI. Beyond that though, medicine is still an art as much as it is a science and people are just not inputs on a spreadsheet. Your average doctor will be a bit thrown off by an unfamiliar receptionist and nurse practitioner that doesn't fit with his style let alone an AI. This is even more the case with patients, especially older ones.
**Me:** So a couple things…I just want to clarify that when you were still a clinical physician, there was little to no AI involvement in your work?
**Dr. Savaskan:** Oh definitely not. We had electronic health records of course but definitely not the AI German healthcare has today.
**Me:** And my other inquiry: you believe that human interaction and our need for it is what is holding AI back from replacing these jobs?
**Dr. Savaskan:** It is a bit part of it that people tend to overlook—especially people who have not worked in the medical field, but I would not say the only part. There is also the matter of bureaucratic red tape and very valid privacy and data concerns. Even in the other big application of AI in use of chatbots as a part of telemedicine—generally a part of the infrastructure in rural areas, we have had issues spring up with patient data. Something exhaustive enough to replace a receptionist would be an even bigger risk for lawsuits.
**Me:** But despite that, do you see positive effects of AI as a part of telemedicine in Germany—I assume for improving access specifically?
**Dr. Savaskan:** Absolutely though I should say access is a bit different for us as virtually everyone in Germany has access if access is meant to be health insurance but actually seeing a doctor can be more of a pain if you are in a shorter staffed area geographically. And in many cases the condition is just not that bad to the point the visit is merely precautionary. In cases like this, telemedicine really is great for convenience on both ends.
**Me:** Are there any other applications that you have found to be noteworthy?
**Dr. Savaskan:** I would say AI in medical imaging, whether it is a CT scan, MRI, x-ray, whatever. They allow doctors nowadays to read and gain the necessary information so much faster than was ever possible manually. It can help diagnose different types of cancers and also neurological diseases both faster and more accurately and you know how important early diagnosis is.
**Me:** And this has become prevalent without any effects on labor?
**Dr. Savaskan:** In general, from my observations, yes. Remember this is not my day to day work but technicians are still needed because the machine won't operate and run on its own and doctors are needed for making the actual interpretations. I do suppose it's possible that AI could advance to the point of making conclusions on their own; in which case, I imagine radiologists would see a shift in their jobs from a dark room reading images to one where there is more routine interaction with patients which today is more of an oncologist/primary physician/whatever doctor ordered the scan role. I suppose there is a worst case scenario where radiology could be phased out or become a dead field but we are a long way from that; and even if so, radiologists at the time when this happens would likely just revert to primary care physicians. It would be a bit of a waste for them to get that specialty and maybe a slight step back in salary—though not a big difference in Germany, but not the kind of disaster automation has meant for certain workers in the past. And again this is a true worst case scenario.
**Me:** Thank you for your thoughts, Dr. Savaskan, and your time. It is certainly something that promises to reshape medicine in the future and has begun to in Germany as you have laid out.
**Dr. Savaskan:** You're welcome, Ari. I enjoyed thinking through the past and future myself

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