



Cancer and Artificial Intelligence: How can AI assist in diagnosing cancer?

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ABSTRACT

The main objective of this study is to examine the diagnosis of cancer and explore the role of artificial intelligence in the medical field. Cancer is a common disease that can start at any organ in the body when there is abnormal cell growth which will spread throughout the human body. Thus, it is undeniable that this disease will be difficult to detect. However, in a globalized world, artificial intelligence, the field of science and engineering that makes intelligent machines to perform given tasks, is chosen to be used as a tool of cancer detection and treatment. In this paper, we begin with the definition of general cancer before deeply exploring the specific one which is a lung cancer. Then, both causes and symptoms are elaborated before getting into treatment and diagnosis. In addition, the statistics false-positive and false-negative of lung cancer diagnosis are also given for the purpose of comparison. Subsequently, the general meaning and common usage of artificial intelligence are discussed. Nevertheless, the paper will mostly cover the use of artificial intelligence in the medical field, lung cancer diagnosis in particular as well as providing both benefits and risks of using the aforementioned technique. Last but not least, the comparison between human and artificial intelligence is issued. To conclude, we describe how artificial intelligence can take part in the diagnosis of cancer and examine further about the future of artificial intelligence in the medical field.

Keywords: Cancer · Artificial Intelligence · Diagnosis · Narrow AI · Artificial General Intelligence · Statistics

INTRODUCTION

In this day of age, cancer is a major health concern worldwide. Although there is a continuous decline in cancer death rates since 1991, numerous developing countries are experiencing an increasingly disproportionate burden of most preventable cancers (American Cancer Society, 8th January 2019). In fact, these majorities are lacking cancer screening programs that are inevitably paramount in the diagnosis of cancer and, thereby, preventing them before it reaches a severe stage. According to recent ACS Journals in 2018, lung cancer is the most commonly diagnosed cancer and held the highest death rates among both sexes. There are, nevertheless, diagnosis evaluations for patients at risk

of the disease by performing thoracotomy, tissue diagnosis and staging as well as a metastatic evaluation and staging.

The development of technologies, however, can have a huge impact on the diagnosis of cancer. Diagnosis by medical personnel sometimes could be inaccurate due to many factors including human error. In fact, where cancer is left untreated for a certain period of time, the condition can get chronic and incurable. Early and accurate diagnosis is, therefore, crucial for the survival rate of patients. This is where Artificial Intelligence and Algorithms come into play. There are researches that have results illustrating that AI's statistics in the diagnosis of cancer have a

significantly lower false negative and false positive rates. Thus, implementing AI into the diagnosis process of modern healthcare could prevent the death of many. Currently, there are already several uses of AI to assist doctors and nurses in the modern healthcare system. **Review of Literature**

In 2018 the number of deaths related to cancer was approximately 9.6 million people around the world. As the most common form of cancer are lung, breasts, colorectal, prostate, skin, and stomach. According to the World Health Organization, the important factors contributing to these risks are caused by the use and intake of tobacco, alcohol, unhealthy diet, and physical inactivity. (Cancer 2020).

Starting off with the fundamental aspects of cancer, cancer is abnormal activity of the cell by dividing uncontrollably and is mostly to be detrimental to normal cells in our body. This is majorly due to the changes of DNA from mutation, thus initiating an error of instructions for the cell. Furthermore, cancerous cells are not able to detect the mistakes of the mutation and restore the inaccuracy. Gene mutations can exist since birth from inheritance or can be acquired by the person's personal lifestyle. Those mutations inherited from parents account for a small percentage of the population diagnosed with cancer. Thus, gene mutation often occurs from the extrinsic factor, such as smoking, radiation, and chronic inflammation. Therefore, the vulnerability of acquiring this disease is associated with age, habits, family history, personal health condition, and environment. Nevertheless, there are cases in which the actual causes are unknown (Creagan & Giridhar, 2018)

Cancer does not have definite prevention, other than ways to reduce the risk. It has been recommended by the medical profession that those who smoke are advised to stop as it increases the risk of getting cancer. Individuals are also advised to try to avoid being exposed to sunlight, as the ultraviolet being emitted is harmful toward the skin and could possibly increase the risk of skin cancer. Moreover, individuals who feel they have the risk of developing the disease are suggested to receive regular screening as early detection increases the chance of survival. (Creagan & Giridhar, 2018)

Lung Cancer

The following report will be based specifically on lung cancer cases. It is the most prominent type of cancer around the world, as there are estimated to be 1.76 million deaths in 2018 caused by lung cancer. It is considered to be significant due to its effects and how it influences the system of the body. For instance, it will cause complications when breathing as the major airways are blocked, as well as the accumulation of fluid making the lung unable to expand fully during inhalation. This may contribute to the patient coughing up blood as there is extensive bleeding in the airway. Thus, it could lead to the patient experiencing pain in the chest, coughing and trouble breathing. (Creagan & Giridhar, 2018)

The majority of lung cancer patients are either smokers or second-hand smokers as they are both exposed to cancer-causing substances (carcinogens), which deteriorates the cells lining in the lungs. Repeated exposure will eventually lead to an abnormality of the cells and increase the risk of cancer. There are various procedure and tests options in order to detect any possible sign of cancer, such as Chest x-ray, CT scan, PET scan, Biopsy, Bronchoscopy and Blood tests. As lung cancer it can be classified into two distinct types, non-small lung cancer and small lung cancer, therefore the treatment will differ from one another. The non-small lung cancer (NSCLC) are subdivided by *adenocarcinoma* which its initial starting point is within areas secreting mucus, *squamous cell carcinoma* starting at the flat cells lining the inside of the airway path and *large cell carcinoma* fast growing and spread quickly cells. The small cell lung cancer (SCLC) tends to grow and spread more rapidly than NSCLC, thereby those with SCLC undergo chemotherapy and radiation therapy as it tends to respond more effectively. However, NSCLC patient's treatment depends on the stages of their cancer alongside their overall health condition. (Smith, *Small Cell Lung Cancer Guide: Understanding SCLC* 2019)

To elaborate, the stages of cancer is a way to identify the size and how far the cancer has spread throughout the body. This procedure is one of the most important for the best and effective treatment as possible. The system of staging is known as TNM (Tumour, Node, Metastasis), the T refers to the size and the distance it has spread, N determines whether the cancer has been distributed into the lymph nodes and M is whether or not the cancer has spread to other parts of the body.

The number system helps to classify the seriousness and severity of cancer, there are 4 common stages. Firstly at stage 1, the cancer is small and is still contained within the original position. Secondly at stage 2, the size becomes larger, yet still in the original position and has not spreaded. Thirdly at stage 3, the size is larger and has spread to nearby tissue and in nearby lymph nodes. Lastly at stage 4, this has shown to be more serious as it has spread to other organs. As mentioned, cancer at an early stage is less severe than subsequent stages and, therefore, patients whose cancer diagnosis is done before the disease becomes chronic would have a higher chance of survival.

Statistics

However, all diagnoses by medical personnel were not accurate. In fact, according to Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R.L., Torre, L.A. and Jemal, A. (2018), the false-negative rate of lung cancer diagnosis was 56 of 1019 or 5.5%. Furthermore, 32% of the false negatives were due to metastatic disease in lymph nodes. In addition to this error, 1.77% of the diagnosis from PET diagnosis and 1.42% from CT diagnosis were false-positive. More specifically, the normal size of true-positive lung cancer tumor was $n = 28$ while the false-positive ones are $n = 10$ lymph nodes ranging from 10 ± 2 mm and 9 to 16 mm respectively. (Lemaire, Anthony, Nikolic, Ivana, Petersen, Thomas, Haney, Jack C., Toloza, Eric M., Harpole, David H., Amico, Thomas A., Burfeind, William R. 2006)

These findings illustrate that the diagnosis from medical professions could be inaccurate and imprecise. Nonetheless, technologies have evolved to the instance that AI could play a significant role in diagnosing cancer.

Artificial Intelligence

Artificial Intelligence is one branch of computer science that performs “intelligent” tasks such as visual perception, language understanding, and decision making. It consists of two main categories: narrow AI and Artificial General Intelligence. The former is also known as weak AI and it can operate limitedly with a certain condition or can focus only one task. On the other hand, the latter one is a strong AI that can apply intelligence to solve problems similar to a human being. The common examples are

smart assistants (Siri and Alexa), conversational bots for customer services, and song recommendations in Spotify. (Frankenfield, 2020)

More specifically, a multi-agent system or MAS is used in the field of artificial intelligence. The intelligent agents are a model of software applications development which also support the complex interactions between individuals. It is responsible for finding the answers to the questions that are beyond the individual’s capabilities. According to Franklin and Graesser, they divide the autonomous agents into three major groups: biologic, robotic, and computational. In fact, the autonomous agents are intelligent agent operating on an owner's behalf but without any interference of that ownership identity (Franklin and Graesser, 1996) In addition, for the applications of MAS, there are four main fields that MAS has played an important role: industry, commerce, entertainment, and especially medicine. (Rocha, Boavida-Portugal, & Gomes, 2017) Therefore, artificial intelligence is a programmed machine that simulates human intelligence. Its aim is to rationalize and take actions that have the best chance of achieving a specific goal.

Artificial intelligence in medical field

In a globalized world, it is undeniable that computers or artificial intelligence might be the first source that will be sought by patients prior to any physicians. Due to a high performance of artificial intelligence, AI algorithms have to expose to several different sets of data points: both numerical and image-based as an input. Deep into its function, the algorithm is exposed to enough data sets. Each data point has a label or annotation that is recognizable to the algorithm. Thus, those algorithms will definitely know the right answer which will be able to assess the input data for determining the correct answer. Based on *figure x*, the picture shows the anatomy of a hand with both a complete hand and a hand with a missing part. In general, the input is several x-ray hand pictures while the output is a trace where missing parts of a hand should be. Regarding this, the physician would be able to see the proper place for limb reconstruction. Algorithms, actually, learn from data, analyze probability and classify the sources. For example, the collected data of heart rate and blood pressure can lead to further arterial clot analysis. Not only this, but the body tissues can also be determined whether it is

cancerous or not by the means of AI algorithms. (says: et al., 2019

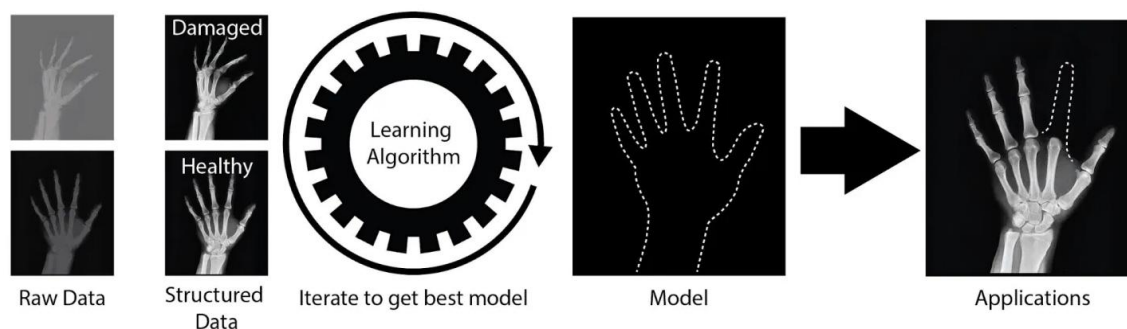


Figure x : AI Algorithm and hand anatomy images

For the field of lung cancer diagnosis, during the 18th World Conference on Lung Cancer or (WCLC), oncologists were at highest risk of burn-out compared to other physicians. More specifically, among physicians who are burn-out, 20 to 35 % of those were reported as mental sufferings. Moreover, there is a higher chance of empathy reduction towards patients' healthcare. Because of this problem, artificial intelligence is one of the solutions used to assist physicians and reduce their burdens. Therefore, a computer-aided detection (CAD) system was first introduced by Niki et al. for analyzing data from CT scans, classifying benign and malignant lung cancer changes, and for the purpose of screening patients using 3D CT scans. Due to the help of the CAD system, the detection of lung nodules with the size of less than 5 mm, generally overlooked, has been enhanced. (El-Baz et al., 2013)

Benefits and Risks

Even though artificial intelligence is still considered a new computer system, its potential can already be proven by numerous benefits it can provide to many fields of the world. Initially, since artificial intelligence can function with high accuracy and consistency, with an effective model, it improves the standardization of the processes that are required to follow the regulation strictly, such as food production, which can attain people's reliability for quality products. With accordance, it is shown that artificial intelligence can aid companies to produce better outcomes and help business to prosper. Furthermore, artificial intelligence is also being used to substitute humans for some duties that might be a

threat to their life. For example, the work that needs to operate underground, one of them is mining, the companies can utilize machines instead of hiring humans and accepting the risk. In addition, with an ability to recognise and process tremendous information within a small amount of time, artificial intelligence allows automations to happen. To illustrate, it can assist logistics by functioning the system that delivers thousands of cargo to their destinations with the lower use of resources. This conveys that most of the process of storage, transportation, and manufacturing have advanced in many aspects by artificial intelligence. (Nadimpalli, 2017)

In spite of the fact that artificial intelligence had provided solutions for many problems, the AI, itself, could be the reason for the new one to appear for humanity to encounter. First of all, as artificial intelligence is capable of a lot of actions that are impossible for humans, people have more effective alternatives to hire rather than humans. Therefore, the rate of unemployment has risen and tends to rise continually in the future. (Nadimpalli, 2017) In conformity with the statistics from ("How robots change the world"), it appears that since 2000 to 2019, people around 1.7 million have lost their jobs to automation. Moreover, the systems are still unstable which means that an accident could sometimes happen causing negative effects to the users. There can be an issue with both the model and its interaction with its users. (Cheatham, Javanmardian, Samandari, 2019) Nevertheless, from the research, it manifests that artificial intelligence

can be very advantageous and practical for humanity, but there are some issues that would probably follow after the coming of artificial intelligence we need to be aware of.

Human intelligence vs Artificial intelligence

Even though artificial intelligence's purpose is to simulate the smartest version of human's brain power, in reality, is it actually better human intelligence? According to figure 1, it manifests that artificial intelligence has poorer performance than human intelligence in some features that are

significant for achieving ultimate intelligence such as logical reasoning, language processing, and auditory and visual processing. On the other hand, artificial intelligence surpasses human intelligence in the features that associated with cognitive ability and consistency such as numerical computation ability, and reaction speed. This suggests that artificial intelligence in present days still can not function effectively in some function; it does not has emotional intelligence as human does, so it is incapable of recognising emotion which negatively affects the processing of data. (Khanam, 2019).

Intelligence Feature	Assessment of features for human beings and machines		
	Human Intelligence	Artificial Intelligence	Remarks
Numerical Computation ability	Less	More	Computers/ machines perform mathematical computations faster because of more hardware processing power.
Logical Reasoning	High	Medium	Human beings find it easy to apply logics and establish correlation between concepts.
Linguistics/ Natural Language Processing	High	Low	Computers understand high level language or machine language but natural language processing seems difficult for them.
Auditory & Visual Processing	High	Medium	Human god gifted senses such as hearing, vision, smell, taste and locomotion outperforms machine intelligence.
Reaction time/speed	Variable	Stable	Under stress condition, sleepy and tired state human beings tend to show slow reactions than otherwise.
Short-term and Long-term memory decision	Unpredictable	Programmed	Human brain phenomenon of keeping information in short-term or long-term memory is still unidentified.
Rational decision making	Medium	High	Human decisions are mostly influenced by external factors.
Multi-issue negotiation	Better individual performance	Fairness in negotiation	Different experiments reveal different results

Creativity	High	Poor	Computers are programmed to behave in certain ways, making use of available information.
Multi-tasking	Medium	High	Better memory and processing power makes it easier for computer systems.
Intuitive behaviour	Yes	No	Interesting behaviour of human brain, not found in machines.
Artistic ability	Good	Poor	Computers lack creativity and thus artistic ability can't be much.
Information retrieval speed and accuracy	Low	High	Data retrieval speed of modern computers is approx. 1000 times faster than human's ability [8]
Memory storage capacity	Medium	High	Computer memory storage is huge and can be further expanded.
Exception handling ability	Good	Poor	Machines can handle exceptions in case they have been coded earlier with the exception scenarios.
Autonomous thinking	Medium	High	Every process executes independently on computers.
Experimental Learning	Medium	Poor	Computers/ robots are unable to do generic experimentations.
Deliberational ability	High	Poor	Computers lack the ability of deriving or correlating concepts.
Emotional Quotient	High	Rare	Non-living things do not have emotions.

Figure 1
(komal, 2014)

and long-term follow-up findi

Introduction of AI into Medical Field

In this day of age, different technologies are being utilized to increase the automation and improve the accuracy and precision of diagnosis in the medical field. According to Abid Haleem, Mohd Javid, and Ibrahim Haleem Khan, AI had assisted the medical field by keeping medical records in digital format and providing targeted treatments. It furthermore, support surgeons during medication, treatment, and operation.

Emphasizing on the use of technology in the field of cancer, it is known that AI had improved the diagnosis of lung cancer, which is the type of cancer causing a large number of deaths in various countries around the world including the United States of America. In treating any cancer, early detection and diagnosis are critical; recently, there is a development in AI systems for pulmonary nodules in pathological diagnosis, probability of malignancy, 3D parameters

Introduction

(Xin Li, Bin Hu, Hui LI, Bin You, 2019). In fact, this development would lead to an early diagnosis and treatment of lung cancer and would also lessen overtreatment due to subjectivities. Furthermore, in AI systems, the three-dimension volume, probability of malignancy of nodules, and visually mirroring the patterns of change would be beneficial to medical personnel as it would make a laborious comparison of CT images less time-consuming and it would also generate visual findings.

Human capabilities versus Artificial Intelligence

As mentioned earlier in the article, a radiologist can produce misleading results. In fact, findings had shown that AI can give results of higher accuracy and precision. According to AJMC, mortality rates have been reduced from 63% to 43% after the use of computed thermography. To be more specific, the model used in this research outperformed radiologists with the reduction in false positives and false negatives, the former of 11% and the latter of 5%.

Furthermore, algorithms that were tested on over 6500 cases were performed with an accuracy of 94%, which is higher than those of medical personnels. (Paul A. Kvale M.D., LTC Frederick R. Bode MC, USAF, Sudha Kini M.D.)

Case Study

There is a case study that has demonstrated that artificial intelligence is more accurate at predicting the development of lung cancer for a patient with 12-year risk. In which, researchers from Harvard Medical School in Boston have constructed a neural network (CXR-LC) that is able to forecast the effects from available resources in the electronic medical records, such as the chest radiographs, age, sex and current smoking status in the terms of CXR-LC risk score. (Michael T. Lu, M.D., M.P.H.). This model has shown that it has a higher sensitivity and is more predictive and beneficial in screening for lung cancer compared to current clinical criteria. Thereby, it provides an example that the CXR-LC model are more eligible for identifying those with high risk of lung cancer than the present centers for medicare and medicaid services (CMS). (Staff, 2020)

Further AI Enhancement

It is generally accepted that artificial intelligence will aid and help physicians from a simple diagnosis to a deliberate treatment. In 2018, there are various opinions towards diagnosis that uses artificial intelligence. According to Forbes, they stated that administrative workflows, image analysis, robotic surgery, virtual assistants, and clinical decision support would be the main areas that are supported by AI. Likewise, Accenture mentioned the same areas in addition to connected machines, dosage error reduction, and cybersecurity.

First of all, in terms of precision medicine, it is expected to provide great benefits to patients. This includes reducing healthcare costs and adverse drug response along with enhancing the effectiveness of drug action. AI plays an important role in three main aspects: complex algorithms, digital health applications, and omic-based tests. Complex algorithm or machine learning algorithm is used with a dataset to provide prediction of prognosis while digital health applications are used to keep record of some patients' information such as food intake and emotion track. This will help giving personal

treatment advice. Lastly, omic-based tests will be used with machine learning algorithms to find correlations and predict treatment responses.

Secondly, in the field of surgery and diagnosis, the main application of AI is to build up some certain features and skills within surgery such as suturing and knot-tying. From the Johns Hopkins University, the smart tissue autonomous robot or STAR demonstrated that it can outperform human surgeons in some surgical procedures such as bowel anastomosis in animals. Basically, the surgery videos are used as training materials to identify the specific interventions performed by surgeons. More specifically, the algorithms will recognize the possibility of the interventions. Therefore, it is extremely important for surgeons to engage in the development of artificial intelligence for facilitating the surgical procedure and minimizing the error.

Lastly, AI allows the physicians to take care of their patients even outside of the hospital and encourage the self-dependencies of patients by providing remote care services type assistance and providing information to the healthcare professionals. There is a concept called Ambient and Active Assisted Living or AAL that talks about living in a technological supported environment; this concept can be implemented in various ways. One of them is a smart house. It is a normal house that occupies a smart, sensor monitor and AI model to assist the residents to live more conveniently. It can also record the personalities and activities of the residents daily and the data can be sent to the physicians and their relatives as an alarm if something wrong happens and as to keep track of their health. Another technology in AAL is assistive robots which is created to assist people with physical limitations such as elders and dysfunctional people in facilitating them in daily tasks. Furthermore, some robots are capable of taking care of their mental and emotional state, such as the MARIO project that has an ability to express real feeling and emotion. Accordingly, AI could play a significant role in the common household needs in the future. (Bohr, Memarzadeh, Bohr, & Memarzadeh, 2020)

Conclusion

In conclusion, it has been supported by a number of studies that even though lung cancer is hard to detect, artificial intelligence can improve the diagnosis of

lung cancer by providing a model that has higher accuracy than the medical personnels. In addition, it can foretell the development of cancer to a person based on his or her medical record. Moreover, it can contribute in various aspects of the medical profession including providing precision medicine, assisting in surgery, creating the opportunities for physicians to take care of the patients at their house and facilitating them. In our opinion, AI will not only develop the medical field, but with regard to its potential, it can pave the way to new discoveries in this field which leads to more possibilities for the physicians to carry out successful treatments. Therefore, despite the unemployment problem that might occur, artificial intelligence will become a significant factor that advances the medical field as well as the diagnosing of lung cancer.

REFERENCES

1. Samantha DiGrande (2019). AI Beats Radiologists in Detecting Lung Cancer, Study Finds. (n.d.). Retrieved December 03, 2020, from <https://www.ajmc.com/view/ai-beats-radiologists-in-detecting-lung-cancer-study-finds>
2. AI Model Using Chest X-Ray May Predict 12-Year Lung Cancer Risk. (2020, August 31). Retrieved December 04, 2020, from <https://www.physiciansweekly.com/ai-model-using-chest-x-ray-may-predict-12-year-lung-cancer-risk/>
3. Bohr, A., & Memarzadeh, K. (2020). The rise of artificial intelligence in healthcare applications (1098378186 831897031 A. Bohr & 1098378187 831897031 K. Memarzadeh, Eds.). Retrieved December 03, 2020, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7325854/>
4. Cancer (n.d.). Retrieved December 03, 2020, from <https://www.nhs.uk/conditions/cancer/>
5. Chronic Inflammation and Cancer. (n.d.). Retrieved December 03, 2020, from <https://www.cancernetwork.com/view/chronic-inflammation-and-cancer>
6. El-Baz, A., Beache, G., Gimel'farb, G., Suzuki, K., Okada, K., Elnakib, A., . . . Abdollahi, B. (2013, January 29). Computer-Aided Diagnosis Systems for Lung Cancer: Challenges and Methodologies. Retrieved December 03, 2020, from <https://www.hindawi.com/journals/ijbi/2013/942353/>
7. Frankenfield, J. (2020, August 29). How Artificial Intelligence Works. Retrieved December 03, 2020, from <https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp>
8. Haleem, A., Javaid, M., & Khan, I. (2019, November 12). Current status and applications of Artificial Intelligence (AI) in medical field: An overview. Retrieved December 03, 2020, from <https://www.sciencedirect.com/science/article/abs/pii/S235208171930193X>
9. Cancer. (2018, December 12). Retrieved December 04, 2020, from <https://www.mayoclinic.org/diseases-conditions/cancer/symptoms-causes/syc-20370588>
10. Lemaire, A., Nikolic, I., Petersen, T., Haney, J., Toloza, E., Harpole, D., . . . Burfeind, W. (2006, September 22). Nine-Year Single Center Experience With Cervical Mediastinoscopy: Complications and False Negative Rate. Retrieved December 03, 2020, from <https://www.sciencedirect.com/science/article/abs/pii/S0003497506009465>
11. Li, X. (2019, November 1). *Application of artificial intelligence in the diagnosis of multiple primary lung cancer*. Wiley Online Library. Retrieved December 04, 2020, from <https://onlinelibrary.wiley.com/doi/full/10.1111/1759-7714.13185>
12. Paul A. Kvale, M.D. LTC Frederick R. Bode, MC, USAF Sudha Kini, M.D. (1976, June 1). *Diagnostic Accuracy in Lung Cancer: Comparison of Techniques Used in Association with Flexible Fiberoptic Bronchoscopy*. ScienceDirect. Retrieved December 04, 2020, from <https://linkinghub.elsevier.com/retrieve/pii/S001236921653270X>

13. Staff, P. (2020, October 29). AI Model Using Chest X-Ray May Predict 12-Year Lung Cancer Risk. Retrieved December 04, 2020, from <https://consumer.healthday.com/hematology-oncology-12/lung-cancer-news-100/ai-model-using-chest-x-ray-may-predict-12-year-lung-cancer-risk-760776.html>
14. Rocha, J., Boavida-Portugal, I., & Gomes, E. (2017, September 13). Introductory Chapter: Multi-Agent Systems. Retrieved December 03, 2020, from <https://www.intechopen.com/books/multi-agent-systems/introductory-chapter-multi-agent-systems>
15. Says:, A., Says:, D., Says:, J., Says:, T., Says:, C., Says:, B., . . . *, N. (2019, June 19). Artificial Intelligence in Medicine: Applications, implications, and limitations. Retrieved December 03, 2020, from <http://sitn.hms.harvard.edu/flash/2019/artificial-intelligence-in-medicine-applications-implications-and-limitations/>
16. Siegel, R. L. (2019, January 1). *Cancer statistics, 2019*. American Cancer Society Journals. Retrieved December 04, 2020, from <https://acsjournals.onlinelibrary.wiley.com/doi/full/10.3322/caac.21551>
17. Staff, S. (2020, September 01). An AI can determine your 12-year lung cancer risk by looking at a chest X-ray. Retrieved December 03, 2020, from <https://medicalxpress.com/news/2020-09-ai-year-lung-cancer-chest.html>
18. Stan Franklin and Art Graesser (1996) Is it an Agent or Just a Program?: A Taxonomy for Autonomous Agents. Retrieved From December 03, 2020, from https://www.researchgate.net/publication/221457111_Is_it_an_Agent_or_Just_a_Program_A_Taxonomy_for_Autonomous_Agents
19. Understanding Advanced and Metastatic Cancer. (n.d.). Retrieved December 03, 2020, from <https://www.cancer.org/treatment/understanding-your-diagnosis/advanced-cancer/what-is.html>
20. Nadimpalli, M. (2017, June 6). Artificial Intelligence Risks and Benefits. Retrieved from https://www.researchgate.net/profile/Meenakshi_Nadimpalli2/publication/319321806_Artificial_Intelligence_Risks_and_Benefits/links/59a47dd20f7e9b4f7df37ab9/Artificial-Intelligence-Risks-and-Benefits.pdf
21. Cheatham, B., Javanmardian, K., & Samandari, H. (2019, April 26). Confronting the risks of artificial intelligence. Retrieved from <https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/confronting-the-risks-of-artificial-intelligence>
22. Khanam, S., Tanweer, S., & Khalid, S. (2019, November 23). Artificial Intelligence Surpassing Human Intelligence: Factual or Hoax. Retrieved December 4, 2020.
23. K. (n.d.). Comparative Assessment of Human Intelligence and Artificial Intelligence. Retrieved December 4, 2020