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An exploratory study on the use of Nano-science with special emphasis on Nanotechnology in achieving success in cancer treatment: The economic impact of this treatment on the patient

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ABSTRACT

Nanotechnology is widely used in cancer treatment, due to its precision and lack of human error. This is also used for pathological reasons as it is likely to be more accurate. But research has indicated that there could be errors in the use of this AI, ML and Neural technology even in pathology labs. The ideal situation would be a synergy between humans and neural technology to detect the disease as well as help in the treatment. The use of nanotechnology in radiation and chemotherapy has emerged as a major breakthrough for cancer treatment, bringing with it minimal discomfort for the patient.

Key words: Nanotechnology, Cancer Treatment, Artificial Intelligence, Machine Learning, Neural Network, Healthcare, Clinical Diagnosis, Cost-effectiveness, Patient Outcomes, Robotic surgery

Research Question: The paper would research the growth and application of Nanoscience on serious medical ailments. To what extent would Nanotechnology be a breakthrough for cancer remission? Would the treatment be cost effective such that the availability would be to a larger spectrum of patients. With increasing research in AI technology, would the cure for cancer be found? Would there be an increasingly credible literature on the prevention of this disease in the near future globally? Would this technology reduce the pain both mentally and physically on cancer patients? Would this confluence of engineering and designing with medicine help in finding a dependable cure of the disease? How is cancer becoming an infamous disease worldwide? These and other such questions would be attempted to be answered in the course of this paper.

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

1. Introduction

The human brain is an extremely complex and challenging secret due to the intricacy of the circuits involved in its functioning. Scientific technology has advanced to such a large scale that humans are being increasingly equipped to explore how these components interact to produce a vast range of outputs that provides adequate insight into the mechanisms of diseases. The emphasis on nano-materials contributes to novel diagnostic and therapeutic strategies that include drug delivery, neuroprotection, neural regeneration, neuroimaging and neurosurgery. The entrance of nanotechnology is entering into future arenas that include optogenetics, molecular/ ion sensing and monitoring piezoelectric effects.

The brain and the neural system (including neurons) form the basic building block of the nervous system. The nervous system just like any other system in the human body is susceptible to disease and injuries such as cancer, traumatic brain injury and neurodegenerative diseases.

To cure diseases, the cause of the disease needs to be understood, eg- in the case of the nervous system it is important to understand the neuronal circuits and their functioning. Brain circuitry and its function is an area which has eluded scientists for more than a century and represents one of the greatest challenges faced by the scientific community. It is important to understand neural activity, neural circuits, nature of neural function, plasticity of neurons to name a few before the researcher can understand the nature of the disease. Each one of them stated above have intricate interactions in a complex level of organisation.

This is just an instance of one of the parts of the human body, this needs to be replicated to every organ resulting in a complicated and complex system which needs to be demystified before a cure is suggested. Along with this there is the rampant spread of cancer which has struck a large section of people all over the world; there does not seem to be any fixed/ structured pattern in its spread, however due to recent lifestyle changes including rising pollution and increased consumption of processed foods, cancer and other diseases are becoming endemic. With the immense growth of science and technology corresponding to the increase in diseases there has been an equivalent rise in cures. There has been a huge amount of research with respect to pharmaceutical drugs as well as with A.I (artificial intelligence) improving various procedures that can be effectively used to cure the ailment. The use of such treatment tends to be more accurate as well as localised, resulting in less discomfort and pain and reduced side effects for the patient.

2. Definition

To understand the impact of the latest technology in the cure of the ever increasing spread of diseases like cancer, it is important to juxtapose the growth of new technology like nanoscience,

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

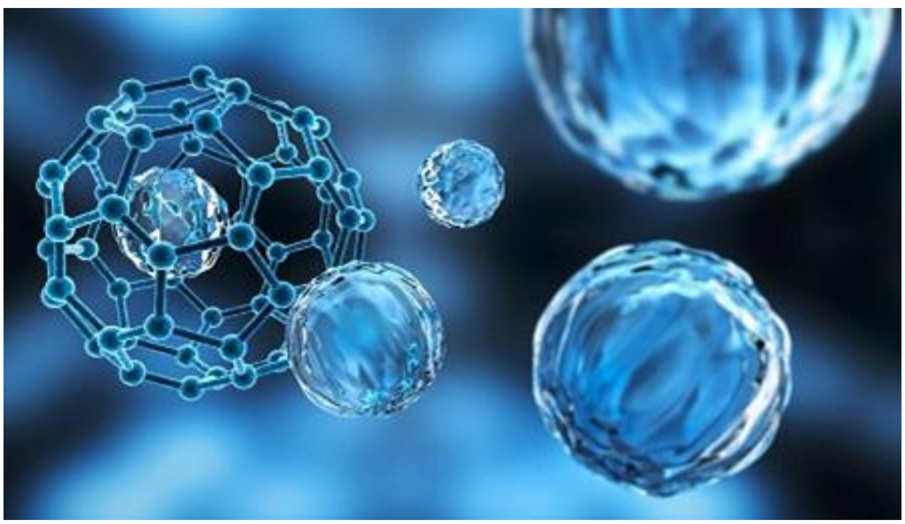
nanotechnology, proton therapy and other such latest and newer findings in treatment of the disease.

2.1 Nanoscience and Nanotechnology:

The word "nano" is a Greek prefix that means dwarf or something extremely small, that is one thousand millionth of a metre () m.

Nanoscience is the study of structures and molecules in the scale of nanometres ranging between 1 and 100 nm, and the technology that utilises it in practical applications such as devices is called nanotechnology (Mansoori. G- An Introduction for the Standards Community). Nanotechnologies in recent years have been applied to human health with promising results especially in the field of cancer treatment. The development of nanoscience can be traced to the 5th century BC when scientists questioned whether matter is continuous and could be infinitely divided into smaller pieces or are they composed of small indivisible and indestructible particles now called atoms.

Figure 1: Image of Nanomaterial



Source: https://biotech-spain.com

Nanotechnology is the most promising technology of the 21st century. The National Nanotechnology Initiative (NNI) in the United States defines nanotechnology as "a science, engineering and technology conducted at the nanoscale (1-100 nm), where unique phenomena enable novel applications in a wide range of fields from chemistry, physics, biology to medicine, engineering and electronics". This definition has two conditions for nanotechnology:

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

a) Issue of scale, here structures can be controlled in shape and size by using the nanometre scale.

b) This technology deals with small things in a way that takes advantage of some properties because of the nanoscale.

Examples of nanotechnology include adhesives made more durable with carbon nanotubes. Cancer treating drugs equipped with nanoparticles and solar panels which become more efficient and are of lighter weight due to nanotechnology.

The applications of this technology is primarily in:

- Electronics
- Energy
- Biomedicine
- Environment
- Food
- Textile

Nanomaterials can be broken down into four types:

- Carbon based material
- Metal based material
- Dendrimers
- Composites

By using nanotechnology, materials can effectively be made stronger, lighter, more durable, more reactive, more sieve-like and better electrical conductors.

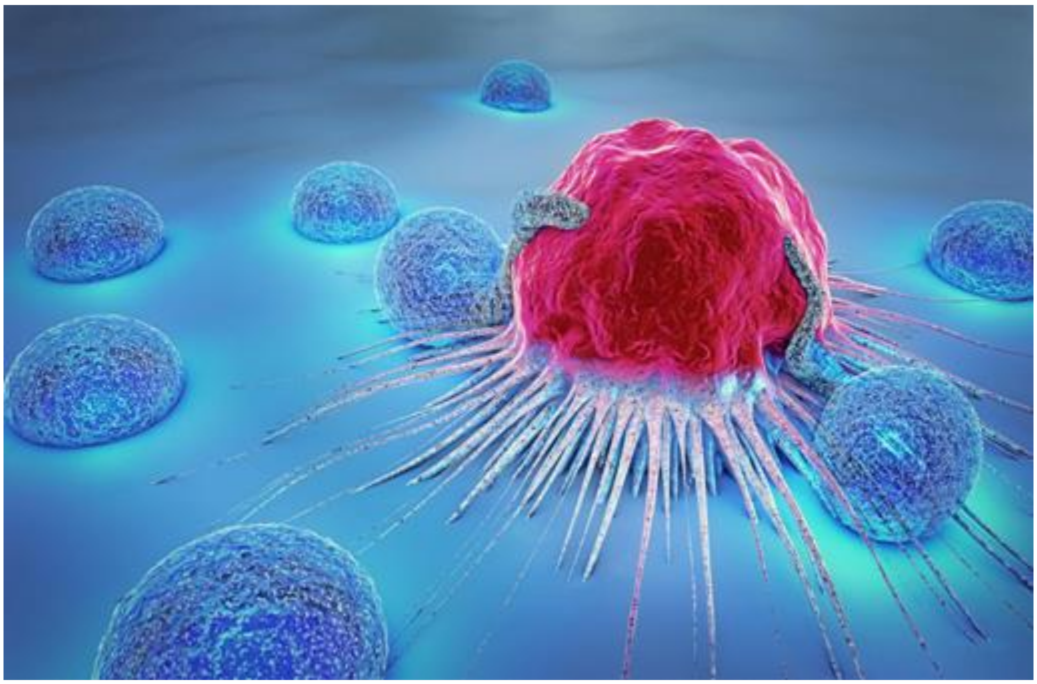
2.2) Cancer:

This is a term for diseases in which abnormal cells divide without control and invade nearby tissues. These cells spread to other parts of the body through the blood and the lymph system. The first definition of cancer is credited to Hibpocrates who named it ‘cancer’ or “Karkinoma

(Carcinoma)". The reason being that the tumour looked like a crab and 'Karkinoma' in Greek means 'crab'. This means that there is a central body to a tumour and the tumour extension appears as the legs of the 'crab'.

It can also be defined as any harmful deviation from the normal structural or functional state of an organism; generally associated with certain signs and symptoms that differ in nature from a physical injury. It is a malignant tumour of potential unlimited growth that expands locally by invasion and systemically by metastasis.

Figure 2: Image of Cancer



Source: https/portfolio-item/the-development-of-cancer/

2.3) A.I in the health sector:

A.I in medicine is the use of machine learning models to help process medical data and give medical professionals important insights, improving health outcomes and patient experience. A.I is becoming an integral part of modern healthcare. A.I algorithms and other applications that are powered by it are being used to support medical professionals in clinical settings and in research. Presently, the most common role in the healthcare sector and *clinical decisions support* and *imaging analysis.* Clinical decision support tools help providers make decisions about treatment, medication, mental health, and other patient needs by providing quick access to information and research that is relevant to the disease and to the patient. In medical science A.I tools are being

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

used to analyse C.T scans, X-rays, MRIs, and other images for lesions or other findings that a human eye might miss.

The healthcare A.I system can analyse patterns in a patient's medical history and current health data to predict potential health risks. This predictive capability helps provide pro-active, preventative care leading to better patient outcomes and also reduced healthcare costs. This concept was first used in the 1970s and today close to 86% of healthcare providers, life science companies and technical vendors use this technology. This technology has the potential to lead to more accurate diagnosis, better care, and less time spent by healthcare professionals on administrative tasks leaving them with more time in interacting and treating payments. The most common type of A.I software in use in healthcare in 2021 was healthcare data integration and natural language processing (statista.com)

Figure 3: A.I the health sector

Source: https://advanced-analytics/the-potential-applications-and-limitations-of-ai-in-healthcare/

3. The growth of confluence of engineering with medicine in recent years

There are a number of research studies that suggest that AI can perform as well or at times better than humans at key healthcare tasks such as diagnosing a disease. Algorithms are already out performing radiologists at spotting malignant tumours and guiding researchers in how to construct cohorts for costly clinical trials.

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

AI is not one technology but a collection of them. Most of these technologies have immediate relevance to the healthcare field but the specific processes and tasks they support very widely. The ones that are very important for healthcare are the following:

1) Machine learning- Neural network and deep learning

Machine learning is a statistical technique for fitting models to data and to learn by training models to data. Deloitte conducted a survey in 2018 and they concluded that 63% of the companies that they surveyed were employing machine learning in their business.

As far as healthcare is concerned the most common application is predicting the treatment protocols that are likely to succeed on a patient which is further based on various patient attributes. A majority of ML and precision making applications require a training data set for which the outcome variable (example- onset of the disease) is known. This is known as supervised learning.

Figure 4: ML in healthcare

Source: https://interesting-applications-of-ml-in-healthcare

2) A more complex form of ML is the neural network. This is used for applications like determining whether a patient will acquire a particular disease. It views problems in terms of input, output and weights of variables of 'features' that associate input with output.

3) Deep learning a neural network model has many levels of features/ variables that predict outcomes. It is possible that there could be numerous hidden features which are uncovered by the faster processing of today's graphics processing units, an important area is the potentially cancerous lesions in radiology images. Deep learning is increasingly being used in imaging data beyond what is perceived by the human eye. This

branch of ML is commonly found in oncology oriented image analysis. It promises greater accuracy in diagnosis than previously attained.

4) Surgical robots provide superpowers to surgeons improving their ability to see, create precise and minimal invasive incisions, stitch wounds, etc. Common surgical procedures using robotic surgery include gynaecologic surgery, prostate surgery, and head and neck surgery.

5) Robotic process automation is used for repetitive tasks like prior authorisation, updating patient records, or billing.

Most AI technology is present in research labs rather than in clinical practice. A number of researchers claimed that they are continuously developing an approach using this technology to diagnose and treat a disease with equal or greater accuracy than human clinicians. They are bringing in an era of evidence and probability based medicine which is regarded as positive but brings with it many challenges in medical ethics and patient clinical relationships.

A large number of firms and startups are building prediction models from big data that are available warning clinicians of high risk conditions such as sepsis and heart failure. There are machines that have been developed that identify patients most at risk as well as those that are likely to respond to treatment protocols.

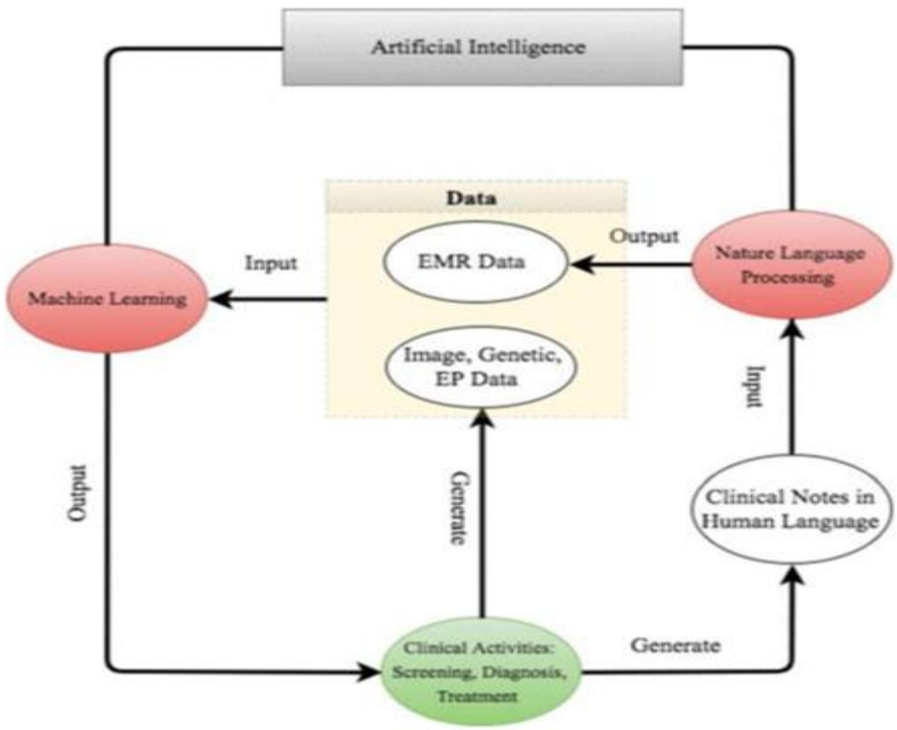
The advantage of the AI system to physicians is that it provides up to date medical information from journals, textbooks, and clinical practices to help in proper patient care. The AI system helps in reduction of diagnostic and therapeutic errors that could occur in human clinical practice. AI systems have the ability to extract useful information from a large database of patient population that helps in making real time inferences for health risk alert and health outcome prediction. At times, many AI algorithms, especially in the case of reading images may not have a full proof interpretation. At times, the radiologists inform the patients that an image which has been discovered with the use of AI technology indicates that there is a huge probability of it being cancerous. The patient in such a state will want to know as to how the doctor has arrived at this diagnosis. At times it may not be possible to give an adequate answer because there have been rare cases where the AI system may not be completely full proof and accountable. The reasons could be that these systems may be subject to algorithmic bias on the basis of gender or race and not hundred percent depending on *causal* factors. For such probable faulty diagnosis it is necessary that regulatory bodies are put in place by the government or any other competent authority so that they establish structures to monitor key issues, react in a responsible manner and reduce negative implications.

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

ML technology analyses structured data such as imaging genetic and electrophysiological (EP) data. The ML procedures attempt to cluster patients' traits and infer the probability of the disease outcome. It also includes natural language processing (NLP) methods that extract information from unstructured data such as clinical notes/ medical journals to supplement and enrich structured medical data.

Figure 5: Overview of the medical artificial intelligence (AI) research



Source: https://svn.bmj.com/

4. Importance of nanotechnology and its mechanisms as a reliable cure for cancer

(Disease focus of AI technology)

In spite of the huge and rich literature on AI in healthcare, research is mainly concentrated around three diseases mainly

- Cancer
- Nervous system
- Cardiovascular

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

The concentration around these three diseases is quite apparent as they are the three main reasons for death, and early diagnosis are crucial in prevention of deterioration of the patients' health status. Also an early diagnosis could be the key factor in prevention of the deterioration of the patient's health.

AI: ML, and NLP

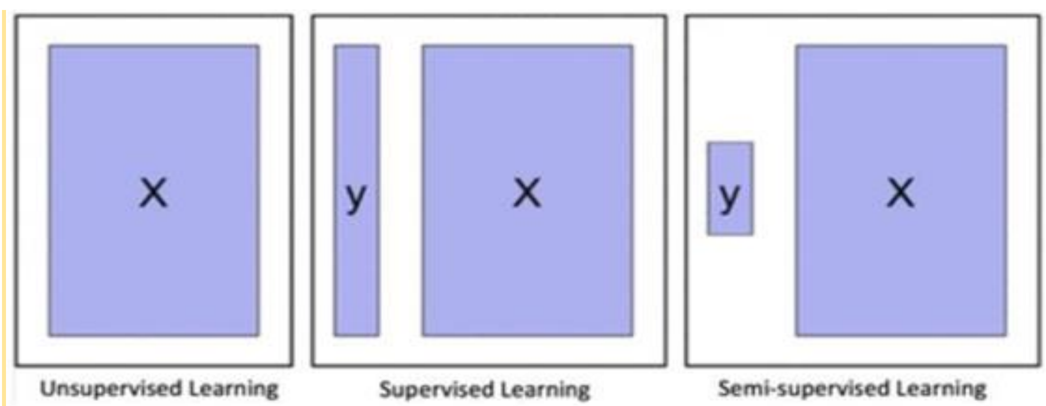
The classical format of AI is the ML which constructs algorithms that extract features from data. The input to ML includes patients' profiles like age, gender, disease history, gene expressions, EP tests, physical examination results, clinical symptoms, medications, etc.

Once this is obtained it is important to decide whether one should incorporate these outcomes. For this, ML algorithms are divided into two major categories:

- Unsupervised learning
- Supervised learning

Unsupervised learning is known for feature extraction, while supervised learning is important for predictive modelling that works on patient traits (input) and outcome of interest (output). Recently, semi- supervised learning is being developed, which is a hybrid between the above two.

Figure 6: Graphical Illustration of unsupervised, supervised and semi-supervised learning



Source: https://svn.bmj.com/

5. The cost- effectiveness of using ML and AI in the healthcare space

Health outcomes and cost by AI methods are extremely important variables to be determined as generalisability across different populations is unclear and it may necessitate reconfiguration of clinical processes. Clinicians productivity may improve when AI is used but if it is poorly implemented it may have an adverse result leading to the clinicians workload to increase. But it is very likely that AI may promote equity by expanding access to medical care leading to unbiased diagnosis and prognosis.

AI can improve decision making and constant monitoring of patients' health and most likely lower healthcare expenditures.

Figure 7: Visualisation of the elements of value

Source: https://www.sciencedirect.com/journal/value-in-health

Blue lines indicate elements of value used in analysis from payer and health land perspectives. Dark blue circles are potentially novel elements of value, green circles are commonly used elements of value, light blue circles are common but inconsistently used elements, red lines elements used from a societal perspective. The main outcome of health technology assessment (HTA) is a cost effectiveness ratio that consists of summed incremental health outcomes, eg: morbidity and mortality reduction outcomes and associated constructive measures like quality adjusted life years. These have to be divided by the incremental costs that are associated with using AI technology. The other factors that have to be taken into account while assisting net costs are the time needed to complete a task rather than just providing an estimate of the clinical impact. Health systems may in fact use AI based on a desire to prepare for the future.

ISSN: 2455-8834

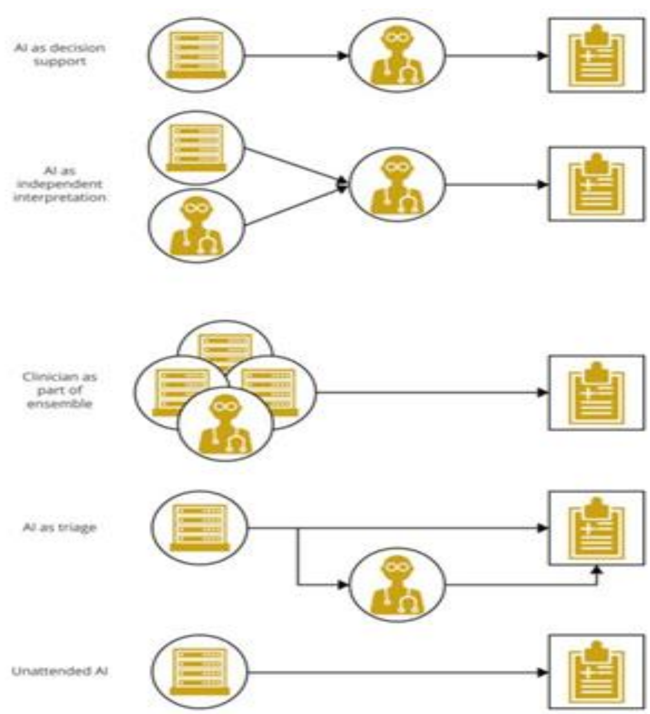
Volume:10, Issue:07 "July 2025"

AI lacks generalizability because at times it is overfitted to a certain population. This lack of generalizability can also be due to when developers train AI on data collected under ideal conditions, eg: optimal lighting. When an algorithm is translated into real clinical settings its performance drops dramatically, for low and middle income countries where chronic healthcare workers shortage exists AI may be extremely appealing but the basic infrastructure in such countries like room lighting, etc is important to capture a clear image.

AI in certain research studies treated cost as a proxy or disease severity indicating gaps between health equity which need to be addressed when expanding AI application. Racial bias is to be completely eliminated when one is using AI technology.

AI equity impacts have to be explicitly specified. The methodology of application of AI should be such that they include the poorest and most marginalised. AI at one end could serve as a decision support for a clinician providing timely information or an independent judgement for the clinician to whey while they are making their decision. This is used as a double reader system for breast cancer screening in Europe.

Figure 8: Clinical diagnosis of manual and AI technology in the detection of breast cancer



Source: https://www.sciencedirect.com/journal/value-in-health

ISSN: 2455-8834

Volume:10, Issue:07 "July 2025"

Ro-bo assisted operations are expensive and unlikely to be used as a common method of surgery till there is a higher demand for it and technology improves bringing the costs to an affordable level.

6. Conclusion and its future prospects

The use of AI technology especially in the diagnosis is an extremely relevant important revelation that has taken place in the world. There are disadvantages in the form of overdependence of only machines in prognosis; there are chances in such cases to lead to wrong results. Hence, it is suggested that AI assists the clinician and or double checks the diagnosis. All biases with respect to race and income should be addressed while using this technology. The widespread use, especially in developing economies can only happen if technology reduces its costs and demand increases. At the present moment all such robotic surgeries are more expensive than the regular ones. For countries like India where there is a lack of healthcare professionals, AI may replace them, but this may lead to further issues with respect to the employment potential of the economy. Efforts should be made to address all of the above, while simultaneously working on correct diagnosis, timely treatment, and continuous follow up.

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