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An overview of artificial intelligence use in diabetic retinopathy treatment: a narrative review

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Abstract

Background: Artificial intelligence (AI), usually called machine intelligence, is a scientific field that allows robots thinking like people. The most common diseases that cause visual impairment and blindness, such as age-related macular degeneration (ARMD), cataract, glaucoma, and diabetic retinopathy (DR), have recently been subject to deep learning-based on AI screening and prediction models.

Aim: to discuss the core ideas of AI and its apply to DR, as well as to evaluate the currently faced issues and the future of ophthalmology.

Methods: In this review, English studies from common databases such as Pubmed/MEDLINE, Google Scholar, Web of Science, Scopus, and the Cochrane Library with the keywords "Machine Learning," "Artificial Intelligence," "Deep Learning," combined with keywords, involving "diabetic retinopathy" were involved. The end date for this review is April 2022.

Scientific novelty: This paper illustrates the core AI concepts and their application in diabetic retinopathy. The current ophthalmology issues and future opportunities, offering undiscovered knowledge in this field are also analysed. It will raise community knowledge of employing AI and reveal new capabilities in the analysis of ocular disorders to present the fundamental idea of AI regarding its therapeutic applications.

Conclusion: Medical professionals can make quick and precise decisions using AI technologies in orded to analyse massive volumes of data, such as physiological imaging and clinical presentations. It is believed that over time, AI systems will become more precise and successful at predicting the onset and course of DR.

Keywords: diabetic retinopathy, artificial intelligence, diabetes Mellitus, machine learning.

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Introduction

A large field of computer science called artificial intelligence (AI) explores theories, techniques, tools, and software to replicate, enhance, and grow machine intelligence [1]. Machine learning (ML) [2] is an AI branch that creates intelligent systems using statistical methods. Without being specifically designed, the intelligent system can automatically learn and improve its performance, such as precision, using either an unsupervised or supervised approach. Deep learning (DL) [3], a method for ML that takes advantage of cutting-edge approaches, has been very successful in computer vision and NLP tasks. Thus, the input is associated with a diagnostic output. As a result of this extraordinary accomplishment, numerous researchers have used DL for healthcare-related and medical tasks and DL has lately developed into a potent tool for intelligent diagnosis, treatment, and screening of different diseases.

Thyroid classification from ultrasound imaging, COVID-19 identification from chest X-rays, thyroid classification from computed tomography (CT) images, lung nodule staging, and detection from CT images have all been accomplished with the use of DL [4,5]. The foundation of evidence-based medicine is the development of relationships and patterns from the already-existing collection of data in order to produce clinical correlations and insights. In the past, one has relied on statistical techniques to identify these patterns and relationships. Using flowcharts and database approaches, computers can learn how to diagnose patients. The history-taking process, in which a doctor asks a series of questions and then combines the reported symptom complex to get a probable diagnosis, is translated using the flowchart-based technique.

By learning from examination images, AI assures the diagnostic of medical images at a radiologist's level, greatly enhancing clinical workflows. AI for medical image analysis is widely used to maximise productivity and improve doctors' treatment and diagnosis precision. The application of AI also significantly contributes to solving current logistical and financial problems. Four essential eye diseases that cause blindness have been treated using DL in the field of ophthalmology: diabetic retinopathy (DR), glaucoma, cataracts, and age-related macular degeneration (ARMD) [6–12]. Optic coherence tomography (OCT) and fundus photographs are the foundation for DL [13]. The potential for using AI for the auxiliary diagnosis of retinopathy of prematurity (14), refractive error (15), ocular cancers [16], choroidal disease [17], and retinal detachment [18] has been quite promising [19]. Current research focuses on image-based AI-assisted medical diagnosis and screening. Currently, the use of this technology in ophthalmology is primarily concentrated on conditions with a high incidence, such as DR, age-related macular degeneration (ARMD), age-related or congenital cataract, glaucoma, retinal vein occlusion (RVO), and retinopathy of prematurity (ROP).

In order to prevent treatment delays and visual loss, it is especially crucial to get an early diagnosis. Patients with prostate, lung, and other malignancies can benefit from the diagnostic and therapeutic approaches offered by the IBM Watson System, a question-and-answer platform. This system's development was effective because it incorporated lessons from empirically supported publications, medical articles, treatment regimens, experiment reports, and clinical data. All people with diabetes, regardless of the type, require routine annual retinal screenings for the prompt detection and appropriate management of DR. Traditionally, ophthalmologists accomplish fundus examinations to check for retinopathy, or trained eye technicians or optometrists use conventional fundus cameras (mydriatic or non-mydriatic) to take color fundus images. The main problem is the lack of retina specialists—ophthalmologists—to grade the retinal scans, as there are far fewer of them than people who need to be screened. AI is expanding into the public health field and will significantly impact all areas of primary care. Primary care providers will be better able to recognise patients who need extra attention and deliver individualised regimens for each individual with the aid of AI-enabled computer programs. Primary care doctors can use AI to take notes, evaluate patient conversations, and upload necessary data into EHR systems. These programs will gather and examine patient information and give primary care doctors knowledge of the patients' medical requirements. Ophthalmologists can expect new automated tools from the back to the front of the eye, thanks to AI that can help identify and cure ocular illnesses. Big players in the digital world, including Google and IBM, have recently shown a lot of interest in the use of AI in medicine. As a result, it is anticipated that research and development for identifying and managing diseases will increase. Compared to current methods of eye care, researchers in the field of AI ophthalmology consider that computerised analytics will lead to more effective and objective image interpretation methods.

Research focus

This paper illustrates the core AI concepts and their application in diabetic retinopathy. The current ophthalmology issues and future opportunities, offering undiscovered knowledge in this field were analysed. It will raise community knowledge of employing AI and reveal new capabilities in the analysis of ocular disorders to present the fundamental idea of AI regarding its therapeutic applications.

Research problem

Late detection and DR diagnosis will lead to many complications, up to the visual loss. Many challenges prevent the early DR diagnosis. AI utilisation for the management of DR is still under development and needs more research to help this development.

Research questions

1. What are the causes of DR?
2. What is the role of AI in the management of DR?
3. What are the challenges of utilising AI for DR?
4. How to develop AI in order to make it more effective in the management of DR?

Research aim

In this study, the core ideas of AI and its apply to DR are discussed, the currently faced issues and the future of ophthalmology are discussed.

Research Methodology

General background

Smart home technology and future wearables will be able to dynamically monitor personal health data, providing a plethora of information for medical diagnosis. Using this personal health data in modeling will make it possible to accurately and consistently predict the illness risk. AI provides the general public with comprehensive, full-cycle health services daily in a high-quality manner, and the artificial intelligence makes the proper recommendations for controlling blood glucose and blood pressure levels as well as serves as a monitor for various aspects of health and a medication reminder system.

Unprecedented chances to solve some of the most pressing issues in DR and other ocular illnesses are made possible by the recent advancements in AI algorithms. For example, after being trained with labeled fundus images, the Inceptionv3 system can attain diagnosis performance comparable to human experts. Although the community has published several evaluations on connected topics, the technical basis has sadly not received sufficient attention.

In this review, English studies from common databases such as Pubmed/MEDLINE, Google Scholar, Web of Science, Scopus, and the Cochrane Library with the keywords "Machine Learning," "Artificial Intelligence," "Deep Learning," combined with keywords, involving "diabetic retinopathy" were involved. The end date for this review is April 2022. The studies using each set of keyword combinations were then pooled to create an impartial collection of publications. Studies and/or articles that weren't subjected to peer review, as well as proposals, procedures, letters, and opinions, were eliminated. The references include publications that were chosen as they are related to our topic. In this paper, one concentrated on providing an overview of AI's use in DR. As a result, we try to choose appropriate AI methods for DR.

Research Results | Literature review

The result of the search using the chosen search strategy was 2825 articles. These papers were screened in order to choose the articles related to the topic. A full-text screening of 237 articles after excluding the remaining article by title and abstract screening was evaluated. Finally, 50 articles to gather information about our topic and write this review were used (Figure 1).

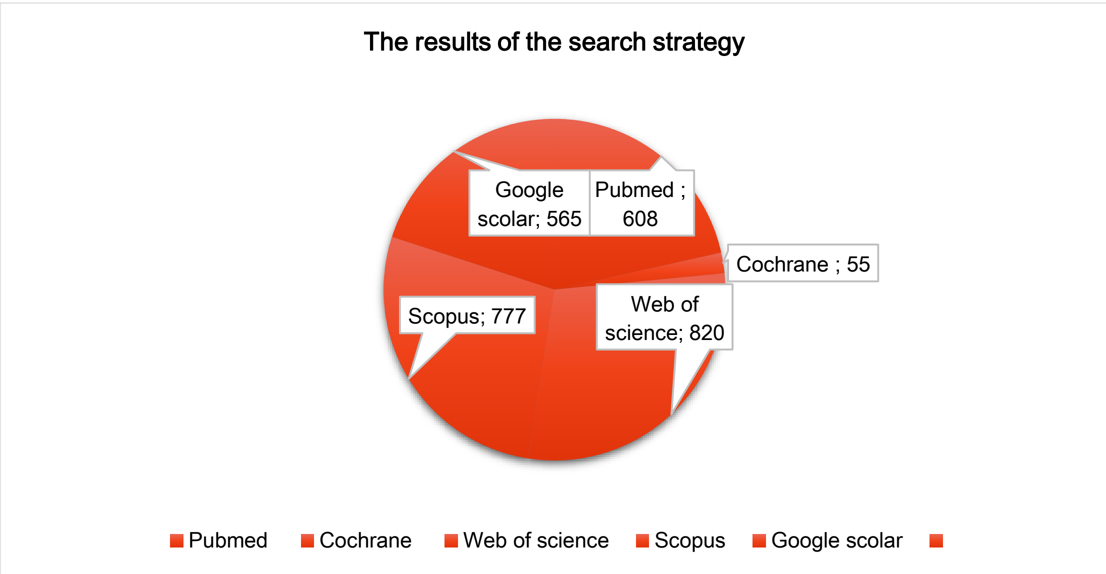

Figure 1. Research results

Artificial intelligence (AI), usually called machine intelligence, is a scientific field that allows robots to think like people. AI is a term used to describe a system that simulates human intelligence using computer programs. AI is quickly advancing in many interdisciplinary domains, including ophthalmology, healthcare, and diagnosing, managing, and preventing illnesses [20,21]. The most common diseases that cause visual impairment and blindness, such as age-related macular degeneration (ARMD), cataract, glaucoma, and diabetic retinopathy (DR), have recently been subject to deep learning-based AI screening and prediction models. Smart home technology and future wearable will dynamically monitor personal health data, providing a plethora of information for medical diagnosis

[22,23]. Using this personal health data in modeling will make it possible to accurately and consistently predict the illness risk [24]. The used dataset should be split into validation, training, and test sets, with no overlap, while creating AI-based diagnostic systems for DR. The algorithm is trained using the training set. For parameter tuning and selection, the validation set is utilised. The testing set is used to assess the AI system's actual performance in clinical settings. The testing set must be separate from the validation and training sets and cannot be reused since otherwise it may cause errors when the algorithm is being evaluated for performance. Both the validation and training sets are used to create and optimise the algorithm. AI provides the general public with comprehensive, full-cycle health services on a daily basis in a high-quality manner, and intelligence makes the proper recommendations for controlling blood glucose and blood pressure levels as well as serving as a monitor for various aspects of health and a medication reminder system.

Diabetic retinopathy

The primary factor in working-age persons becoming blind in both developing and developed nations is diabetic retinopathy (DR), which is the most severe diabetes mellitus (DM) ocular complication. The International Diabetes Federation projects that there will be 600 million diabetics worldwide by 2040, of whom 30% will eventually suffer kidney illness associated with diabetes. Based on a meta-analysis of 35 cohort articles involving 22,869 patients, the DR prevalence worldwide is 34.6%, and vision-threatening DR accounts for 10.2% of instances of blindness globally or 51% of all occurrences of blindness [19]. One of the main neurovascular consequences of diabetes is diabetic retinopathy, which is also the main factor in adulthood-related blindness. The main pathogenic factor in DR is regarded to be chronic hyperglycemia. The polyol pathway and other alternative glucose metabolism routes are activated by hyperglycemia. Advanced glycation end products are produced as a result of oxidative stress, non-enzymatic protein glycation (AGEs), and protein kinase C activation. The activation of cytokines, growth factors, and vascular endothelial dysfunction that results from these alternate pathways finally causes an increase in microvascular occlusion and vascular permeability. Microvascular blockage causes retinal ischemia, which results in the development of neovascularisation and IRMA (intraretinal microvascular abnormalities). The timely prevention and treatment of vision loss depend on routine DR screening [25]. For both endocrinologists and ophthalmologists, time and cost restrictions are significant problems. The insufficient number of registered ophthalmologists, especially retinal specialists, has a considerable negative impact on the efficacy of fundus photograph-based screening. The most typical fundus features of DR include microaneurysms, hemorrhages, exudates, and neovascularization. DR is the most prevalent retinal vascular illness. These lesions should be manually tagged on fundus pictures for automatic disease screening before establishing a tentative diagnosis using ML Figure 2 [26, 27].

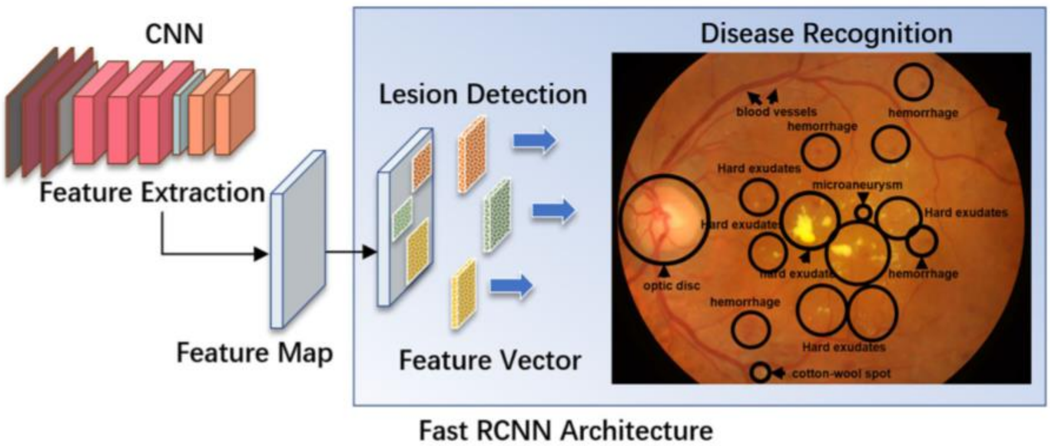

Figure 1 **A diagram demonstrating a fast R-CNN algorithm for automatic lesion detection and disease detection from fundus images (28)**

Artificial intelligence and diabetic retinopathy

ML detects quicker and more accurately DR than humans [29]. Deep neural networks also provide better DR screening utilising retinal image prediction capabilities [30,31]. Patients in endocrinology outpatient clinics can use and accept the AI-based DR screening tool [32]. Enough training datasets are crucial for DL models to function well. However, getting enough data in the actual world is difficult due to convoluted data-collecting processes and ethical limitations. Researchers have used migration learning to create a neural network with minimal data and incorporated features from conventional approaches to get over this restriction. In categorising diabetic macular edema (DME) and ARMD, this technique performs as well as human specialists [33,34].

Diabetic choroidal vasculopathy (DCV) has recently gained popularity as a study topic. Patients with DR may receive information regarding their risk of developing DR through early DCV detection. Due to the weak contrast, variable intensity, irregular texture, and unclear borders between the choroid and sclera in the OCT images, automatic segmentation of the choroidal layer are still difficult. Regions of interest are still segmented either semi-automatically or manually in current methodologies. Researchers proposed DL segmentation of the choroidal layer and morphological segmentation of Bruch's membrane (BM) in OCT images [26,27]. Additionally, a segmentation technique was created to divide the retinal layers based on the prior shape and adaptive appearance information [35].

With various potential future directions, AI has huge potential for DR diagnosis and screening. More AI systems based on portable devices like smartphones will be developed, allowing patients to complete DR screening on their own devices at home without the assistance of medical staff. This greatly reduces the need for trained medical staff and medical equipment and increases the accessibility of DR screening. Such telemedicine is becoming increasingly important during the coronavirus disease pandemic of 2019 (COVID-19) and would benefit patients and medical professionals in many ways. Presently, classical fundus imaging is the foundation of the majority of AI-assisted DR screening methods. As innovative examination procedures are developed, AI-based systems may be able to do more types of assessments, such as multispectral fundus imaging and OCT. The accuracy may also be increased by combining several examinations. This technology will play a crucial role in diagnosing DR in addition to the current AI-assisted screening tools. In recent studies, AI-based systems outperform ophthalmologists in sensitivity and have the potential to outperform ophthalmologists in accuracy. As a result, the AI-assisted diagnosis tools can help ophthalmologists diagnose patients more effectively and accurately.

The diagnostic performance of middle- and late-stage PDR and non-proliferative DR (NPDR) has recently improved thanks to the rapid development of DL methods for detecting DR significantly [8,9,27,36]. Researchers have also looked into how to grade and predict DR based on the presence of lesions. DR is classified as moderate, PDR, severe NPDR, or/and macular edema (ME) by the International Clinical Classification of Referable DR (rDR). According to Abràmoff et al., VGG and AlexNet each achieved 98% area under the curve (AUC), 96.8% sensitivity, and 87% specificity [6]. This AI system's sensitivity, specificity, and imageability were each 87.2%, 90.7%, and 96.1% [36]. Gulshan et al. identified the referable DR using CNN and achieved 93.4% specificity, 97.05% sensitivity, and 99.1% AUC. They also classified the referable DR as referable DME, moderate or worse DR, or both [8,9].

Researchers from Aalto University discovered that DL could precisely distinguish macular edema and DR in a different investigation by training a model based on Inception-v3 [37]. By combining a multiple-improvement depth to refine the Inception-v4 algorithm, Feng Li et al. could detect DMO and DR with an AUC, specificity, and sensitivity of 99.2%, 96.1%, and 92.5%, respectively [38]. For DR categorisation, Inception-v3, Xception, recognising deep residual learning (ResNet) 50, and InceptionresNet50 all achieved accuracy levels of 89–95% with corresponding specificities, AUCs, and sensitivity 93–97%, 95–98%, and 74–86%, respectively. Reguant et al. evaluated image features and illustrated the neural network decision process [39]. Based on optical coherence tomography angiography (OCTA) pictures, Ryu et al. suggested a convolutional neural network (CNN) model for DR diagnosis that has 91-98% accuracy, 91.9-97.6% AUC, 94-99% specificity, and 86-97% sensitivity [40].

Discussion

The deep neural network-based artificial intelligence (AI) a system developed by researchers at Shanghai Jiao Tong University has significantly increased the accuracy of the automatic identification of early STDR and DR, especially proliferative DME and DR [41]. The captured fundus images can be sent to a server for diagnostic analysis, such as the localisation of the optic disc and macular, the segmentation of the vascular network, the identification of lesions, and the classification of lesions. When this system's diagnostic outcomes were compared to those of ophthalmologists, it had an 85% accuracy rate [12]. The researchers also suggested a kernel least squares classifier-based technique for detecting the optic disc and macular area. The field of deep learning DR diagnostic software is currently undergoing rapid development. The ideas underlying automatic DR screening have changed over the past ten years, going from a few expert-designed algorithms with various degrees of accuracy to a wide variety of methods utilising the most recent advancements in deep learning and other areas. As studies have become more thorough, they have demonstrated the accuracy and dependability of diagnostic or decision-support algorithms. Some studies used millions of images, while others rigorously set their gold standard. Many software systems have received approval from regulatory agencies during the past two years and are almost ready to be incorporated into widespread screening in the different nations. Following the overall global trend, mobile solutions are receiving more attention, which may make them a better fit for areas with limited resources.

This approach establishes an accurate mapping from the image to the region by using numerous images of the macular and optic discs that have already been tagged. Using a kernel least-squares classifier to determine the optic disc area, the researchers developed a method to identify the optic disc region and pinpoint its location for retinal color pictures [42].

The approach then uses multimodal data to locate the vascular aggregation and pinpoint the optic disc's center more precisely. This method detected 332 out of 340 test images concerning optic disc localization, yielding a detection success percentage of 97.65%. On 112 out of the 340 test photos, the approach correctly located the borders of the optic disc, yielding a detection of 94.54% success rate for the optic disc boundary and 97.06% for the macular region [43,44].

Additionally, to diagnose related illnesses, it is crucial to locate and inspect blood vessels in fundus images [45]. Researchers have suggested a method for automatically extracting blood vessels from fundus images. It provides an orientation-aware detector based on direction-aware detectors capable of successfully extracting blood vessels from fundus images. This technique teaches the detector the orientation and distribution characteristics of blood vessels using the Fourier transform's energy distribution [46]. On the global public dataset DRIVE and the STARE dataset, the algorithm attained an accuracy of 80.82% and 68.94%, respectively, as measured by the reliable connectivity, length (CAL), and area provided by Gegndez-Arias. According to experimental findings, the suggested method outperforms the already-used segmentation techniques and has high accuracy and robustness [47]. To overcome the localisation difficulty, researchers created a CNN-WSSH model by fusing a weakly supervised localisation technique with automatic DR category identification. In addition, they incorporated a weakly supervised sensitive heat map (WSSH) into the CNN [48]. Small retinal arteries in DR exhibit morphological changes such as early pericyte loss, basement membrane thickening, increased vascular permeability, loss of endothelial cells, leukostasis, platelet aggregation, and capillary dropout. The major glial cells of the retina, the Müller cells, are also impacted by diabetic retinopathy in addition to the microvessels. The maintenance of the retina's structural integrity, control over the retinal blood flow and blood-retinal barrier, retinoic acid compounds, uptake and recycling of various neurotransmitters, and ions (such as potassium), control over metabolism, and provision of nutrients to the retina are all responsibilities of Müller cells.

DL methods enable routine screening, especially in rural areas, which allows the earlier detection of common chronic illnesses [49]. Self-filming fundus imaging (SFI) allows patients to take fundus images similar to those of skilled professionals [50]. The researchers came to the conclusion that DL models are helpful in predicting disease development in a longitudinal population through a prospective investigation of fundus photos captured with mobile phones and chronic kidney disease and type 2 diabetes [51]. Modern machine learning (ML) techniques like deep learning have demonstrated promising diagnostic results in the areas of speech recognition, picture recognition, and natural language processing. It has been broadly accepted in various fields, such as social media, telephones, cybersecurity, and health. DL continues the long tradition of autonomous and helped analyse retinal images, which has appeared in ophthalmology since the 1990s and before. Medical imaging analysis, in general, has achieved robust results in various medical specialties such as dermatology and radiology.

Although the use of AI technology in the healthcare profession, especially in ophthalmology, is growing, numerous issues still need to be handled before they can be effectively integrated into clinical practice. OCT is a crucial part of ophthalmology care and is crucial for diagnosing, grading, and evaluating treatment outcomes in DR. The success of the model is directly determined by the labels and data quality because the usage of AI technology is based on a substantial amount of treatment data. The following issues with data quality are possible:

1. Poor quality of the data itself includes blurry images and other artifacts
2. Poor quality of the data labels, including inaccurate labels.
3. Only a tiny percentage of the data has been labeled, indicating inadequate data.

The development of DL, which carried the robustness findings on diagnostic accuracy from in silico evaluation to offline validation on multiple datasets from different populations, led to the breakthrough in AI for DR screening on color retinal images. Even though many prospective validation studies were conducted in the evaluation's latter stages to support the diagnostic accuracy, the overall results were still appropriate for use in clinical settings. Several practical concerns must be considered seriously in deciding to use AI for screening in the real world. These concerns are at least as significant as diagnostic accuracy. They include mydriasis, integration with existing camera systems, integration into electronic health record systems, and patient and provider acceptability. To promote fairness, transparency, trustworthiness, and responsibility for all stakeholders, including policymakers, healthcare providers, AI developers, and patients, AI for DR screening should adhere to the governance of AI in healthcare.

Conclusion

1. Medical professionals can make quick and precise decisions using AI technologies to analyse massive volumes of data, such as physiological imaging and clinical presentations.

2. The desire to increase the effectiveness and efficiency of health care continues to inspire a wide range of innovations, including AI.

3. Computer-assisted diagnosis will aid in detecting early lesions and improving patients' prognoses. Although much work remains to be done, the use of AI in DR has a promising future due to a lack of common databases, standardised guidelines created by various institutes, and relevant national policies and regulations. More precise and sensitive algorithms or machines are required to reach the goal of individual treatment.

4. One believes that over time, AI systems will become more precise and successful at predicting the onset and course of DR.

5. All people with diabetes, regardless of the type, require routine annual retinal screenings for the prompt detection and appropriate management of DR.

6. AI mimics medical professionals' diagnostic and thinking abilities by absorbing their knowledge and medical information to quickly and accurately diagnose patients and provide individualised treatment plans utilising medical imaging and other pertinent data.

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Change in physical and mental health due to aging: future perspective

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Abstract

Aims: By addressing these research issues and examining the findings of the pertinent studies, this systematic review aims to provide a thorough understanding of the changes in physical and mental health that are related with aging as well as the significant factors that contribute to these changes. This evaluation will also look into potential new treatments and technological advancements that could improve elderly people's health. The results of this work will offer crucial new perspectives on aging research and therapeutic practice in the future.

Methodology: "Aging", "physical health", "mental health", "wellbeing", "lifestyle interventions", "age-related health problems", "literature evaluation", "future perspectives", "key factors", "potential new interventions", and "health outcomes" were used to search Medline, pubmed, and Google Scholar. Successful search. Data analysis began with selecting relevant details. Second, the data was compiled into a table, followed by study conclusions. After reviewing each article, the overarching idea that best proves the study issue's relevance was chosen.

Results: The literature display includes several physiological and physical effects of aging and research and reference information. Aging affects skin, hair, nails, vision, digestion, bone density, muscle flexibility, and heart disease risk. Aging causes anxiety, memory loss, and executive dysfunction

Scientific Novelty: Potentially effective innovative measures to enhance senior citizens' health a study of the key elements influencing how physical and mental health vary as people age

Conclusion: The systematic review gave a thorough grasp of the alterations in physical and mental health brought on by aging, as well as the main causes of these alterations. The review also uncovered potential novel therapeutic approaches and scientific developments that might enhance the health of senior citizens. This work emphasizes the necessity of ongoing study and therapeutic application to improve older individuals' quality of life.

Keywords: Elder people; life style intervention; health problems; psychological issues.

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Introduction

The process of aging is characterized by slowness and continuity, and it begins in the early years of maturity. Many of the body's functions start to gradually decline when people are in their early to middle 40s. There is no one age at which a person automatically enters their senior years. Historically, the onset of old age has been considered to commence at the age of 65. However, the reason was not rooted in biology but rather in history. In Germany, the country that pioneered the concept of a national retirement system, the age of 65 was selected as the point at which one may officially retire [1]. In the year 1965, the United States government established the minimum age of eligibility for Medicare health insurance at 65 years old. This age is quite close to the real retirement age that the majority of individuals in economically developed cultures reach.

The question of how old a person is can be addressed in a few different ways: The only factor that affects one's chronological age is the passage of time. The number of years that a person has been alive. In terms of one's health, chronological age is of only little consequence. However, as people get older, their risk of developing a health condition rises. Contrary to popular belief, it is not the natural process of aging that leads to a decline in functional capacity in old age; rather, it is the health conditions that people experience. There are certain legal and financial applications for chronologic age due to the fact that it can forecast a variety of health concerns. The term "biologic age" refers to the changes that take place in the body as a natural consequence of aging [2]. Some people are biologically old at the age of 65, while others will not be of that age until at least ten years later. This is because these changes impact some people quicker than others. However, the majority of noticeable disparities in apparent age between people of equivalent chronologic age are triggered by lifestyle, tradition, and the subtle effects of disease rather than differences in actual aging. This is the case even among people with the same chronological age. The way a person behaves and how they feel might help determine their psychological age [3]. For instance, a person who is 80 years old but continues to work, make plans, anticipate what the future holds, and take part in a variety of activities is regarded to be mentally younger. The majority of healthy and active individuals do not require the services of a geriatrician (a medical practitioner who specializes in the treatment of older people) until they reach the age of seventy, seventy-five, or even eighty years old. However, due to their medical conditions, some individuals require the services of a geriatrician at an earlier chronological age than is typical [4].

Age and health concerns are discussed in terms of chronological age, but other elements like heredity, way of life, and environment are not included. When determining how old a person is, these elements should be taken into account as they can also affect how they age. Frequent root causes of differences in perceived ages between individuals of equal chronological ages. It would be beneficial to give illustrations of these elements and how they could impact aging. the social and cultural aspects of aging, including ageism and age-related prejudices. As people age, these problems may have a big impact on how they see themselves and how others see them.

Literature Review

People frequently question whether or not the changes they're observing in their bodies as they become older are natural or aberrant. Despite the fact that people age in slightly unique ways, there are some changes that come about as a result of the process of aging itself. As a result, these shifts, despite the fact that they are undesirable, are seen as natural and are sometimes referred to as "pure aging." [5] These shifts take place in every person who lives a full life, and the fact that they are universal is a component of the notion of pure aging. Changes of this nature are to be anticipated and, in most cases, cannot be avoided. For instance, as individuals become older, the lens of the eye grows thicker, more rigid, and less able to concentrate on close objects, including reading material (this condition is known as presbyopia). Almost all elderly persons experience this transformation as they get older. Therefore, presbyopia is considered to be a natural part of aging. The words "normal aging" and "senescence" are also used interchangeably to refer to similar processes [6-9]. In addition to these differences, dementias such as Alzheimer's disease stand out from the natural process of aging in a number of other respects. For instance, brain tissue from persons who have Alzheimer disease (obtained during autopsies) appears differently from brain tissue from elderly people who do not have Alzheimer disease. Therefore, there is a clear distinction to be made between typical aging and dementia [10, 11].

These alterations are prevalent and, for the most part, inevitable. Presbyopia, which is seen as a natural component of aging, is caused by the lens of the eye thickening and losing flexibility. These organic processes are also referred to as "normal aging" and "senescence." Dementia, such as Alzheimer's disease, has been found to be unique from normal aging. Alzheimer's disease brain tissue differs from that of healthy older adults in appearance, demonstrating a substantial difference between normal aging and dementia.

Physical based aging effects

Bone and Muscle funcionality: Bone and muscle are necessary for mobility, but in addition to this, they play an important role in the endocrine and metabolic systems. Both osteoporosis as well as sarcopenia can develop in conjunction with one another when bone loss and weakness of muscles happen at the same time, as can happen with aging and in many chronic conditions. This affects people of both sexes, but postmenopausal women appear to be more vulnerable to age-related bone and muscle loss, whilst males appeared to have greater safeguards against this [12]. Musculoskeletal gender dimorphism is largely caused by the presence of steroid hormones, particularly androgens such as testosterone and oestrogens such as estradiol. They promote mass in bones and muscles accretion between adolescence and midlife, and they minimize future loss in males as they age, but not in women who have gone through menopause. [13]. The existing evidence indicates that the clinical diagnose and therapeutic method for treating male osteoporosis is substantially comparable to that in postmenopausal women. This is the case despite the fact that randomized clinical research studies in male osteoporosis are fewer than those in postmenopausal women and, as a result, inadequate for some outcomes such as hip fractures [14].

Risk of cardiovasular disease: People who are getting older and are already elderly are at an increased risk of developing cardiovascular disease. Age is a risk factor in and of itself for cardiovascular disease, or CVD, in adults; however, the risks posed by age are increased by additional factors such as frailty, being obese, and diabetes [15]. It is well established that the presence of these factors both complicates and exacerbates the cardiac cardiovascular risk factors that are typically linked with the beginning of old age. Given that older women are said to be at a larger risk for cardiovascular disease than age-matched men, sexual orientation is an additional risk indicator in persons who are getting older. However, the risks associated with cardiovascular disease (CVD) increase with age in both men and women, and these link to a general decrease in sex hormones, primarily both testosterone and estrogen. This is applicable to both men and women [16].

Gut Health: From infancy into old age, the microbiome plays an essential part in the development, function, and control of the host immune system. This is true over the whole lifespan. In exchange, the body's immune system has co-evolved a symbiotic relationship with the trillions of helpful bacteria that reside within our bodies, allowing it to mount effective responses to the invasion of pathogens. Both the body's immune system and the microbiome of the gut go through major changes in constitution and function as we become older. These changes are directly related to an increased risk of contracting infectious diseases and a diminished response to vaccinations. Emerging research suggests that addressing age-related dysbiosis might extend both health and lifespan. This may be accomplished, in part, by reducing systemically moderate inflammation and immunosenescence, which are two characteristics that are associated with the aging process. However, a cause-and-effect relationship between age-related dysbiosis along with functional reductions in immune cell functioning has not yet been demonstrated in clinical settings. This is despite the fact that age-related dysbiosis is associated with aging [17].

Changes in skin, hair, and nails: The aging process affects many aspects of an individual's appearance, including their hair, nails, and skin. Alterations in the color, growth, and arrangement of the nails and hair are typical as a result of advancing age. In contrast to the process of aging that occurs in the layer of skin, the gerontobiological process of what happens to hair and nails through time has not been thoroughly researched [18-20]. Today's understanding of the processes that are involved in the graying of hair is improved by research on signaling pathways that are crucial for melanogenesis in the hair follicle. Variations in the lipid content of the nail plates that are age-dependent are the primary factor responsible for the differences in structure as well as overall performance of the nails that occur with advanced age. On the other hand, it is essential to acknowledge the age-dependent processes that occur in the shafts of hair and nails and to differentiate between the natural process of aging and alterations that are caused by disease [18].

Vision due to aging: At around forty years of age, structural changes in the eye cause an impairment of near vision. Later in life, these same changes cause an impairment in visual acuity due to changes in the lenticular and retinal structures. "Visual acuity, contrast sensitivity, scotopic vision, visual field, and visual processing speed" are some of the visual qualities that might alter with age. Alterations to any of these aspects of vision can have a substantial bearing on one's overall quality of life. The central vision is impacted by age-related macular degeneration (AMD), which also has a significant negative effect on quality of life as a result of vision impairment. Deficits in visual field caused by cerebral causes also have a negative impact on both the patient's quality of life and the outcomes of rehabilitation for neurological disorders in patients who have numerous deficits [21].

Physiological based aging effects

Decreased executive functioning: Executive functions, often known as EFs, are high-order cognitive abilities that encompass things like memory retention, inhibitory based control, flexibility in thinking, organizing, deductive thinking, and solving problems. Humans are able to accomplish goals, adjust to novel situations that arise in everyday life, and successfully navigate social relationships because to EFs. Traditionally speaking, EFs have been linked to the functioning of the frontal brain. More recent research has shown that the posterior and subcortical regions of the brain also play an important part in the processing of EF, particularly in the incorporation of sensory information as well as emotional experience [22]. The executive functions show a variable development and aging profile, with prolonged growth into early adolescence and reductions in later life. This pattern occurs in both children and adults. However, only a relatively small number of studies have chosen to include adults in the middle years of their lives when investigating age-related variations in executive functions [23, 24].

Memory changes: "The Spanish and English Neuropsychological Assessment Scales (SENAS) " were used to test executive function, spatial ability, episodic memory, semantic memory, and executive function. The amount of gray matter change and, more specifically, temporal lobe alteration, had a significant impact on cognitive deterioration. The significant relationship between the temporal lobe- gray matter changes and cognitive loss may be due to the contribution of temporal lobe structures, which are important for maintaining cognitive health in old age but are also susceptible to aging-related disorders [25].

Anxiety: It is believed that generalized anxiety disorder, also known as GAD, is the most frequent kind of anxiety illness found in older persons. This form of anxiety is characterized by racing thoughts, persistent worry, and a sense that there is no way out of the situation. It's not uncommon for older folks to struggle with anxiety, yet most of the time their issues go undiagnosed. Problems with anxiety can be brought on by either stressful or traumatic experiences. coffee, alcohol, and several drugs are all included. People who suffer from generalized anxiety disorder tend to worry incessantly about a variety of different things. They expect the worst from every circumstance, even when there is no basis for such expectations [26].

Although the study shows that working memory capacity keeps growing throughout adolescence and the first few years of adulthood, it also shows that functioning memory and inhibiting control start to decline as early as 30 to 40 years of age and continue into later life. The study also highlights a strong link between cognitive decline and alterations in the gray matter of the temporal lobe. The results indicate that although the temporal lobe structures are vulnerable to aging-related diseases, they are crucial for preserving cognitive health in old life. The book also emphasizes how common anxiety problems are in older persons, with generalized anxiety disorder being the most common type.

Research Problem

There is a dearth of full knowledge of the most effective ways for sustaining well-being and health in older persons, despite the fact that the process of aging is recognized to have an influence on both physical and mental health. The focus of this research should be on meeting the specific physical, mental, and social requirements of older persons in the future.

Research Focus

The purpose of this research is to conduct a thorough analysis of the previous research on the effects of aging on one's physical and mental health, with a particular emphasis on determining the most important elements that are responsible for these effects. This review will give significant insights into the potential future paths of research in aging and guide clinical practice in the treatment of both mental and physical wellness in older persons. This will be accomplished by synthesizing the present body of information on the subject at hand.

Research Aim and Research Questions

1. What are the primary variables that lead to changes in one's physical health that are associated with age, and what are the most typical alterations that accompany this aging process?

2. What are some of the most prevalent shifts in mental health that are associated with age, and what are some of the most important elements that contribute to these shifts?

3. In the future, what new therapies and technological improvements are being researched that have the potential to enhance the health of older adults?

This systematic review seeks to give a complete knowledge of the changes in physical and mental health that are associated with aging as well as the important variables that contribute to these changes by answering these research questions and analyzing the results of the relevant research.

Research Methodology

General Background

The fundamental objectives of a narrative review are to firstly offer the author and the reader with a comprehensive overview of the subject matter at hand, and secondly, to call attention to key areas of research that have been carried out on the issue in question. Narrative reviews are effective tools for discovering errors in a study, as well as for refining and identifying new areas for further exploration. The literature search was conducted by utilizing a number of different database systems (for example, Medline, PubMed, and Google Scholar) with a combination of broad search terms, such as "aging", "physical health", "mental health", "wellbeing", "lifestyle interventions", "age-related health problems", "literature evaluation", "future perspectives", "key factors", "potential new interventions", and "health outcomes". The search was successful.

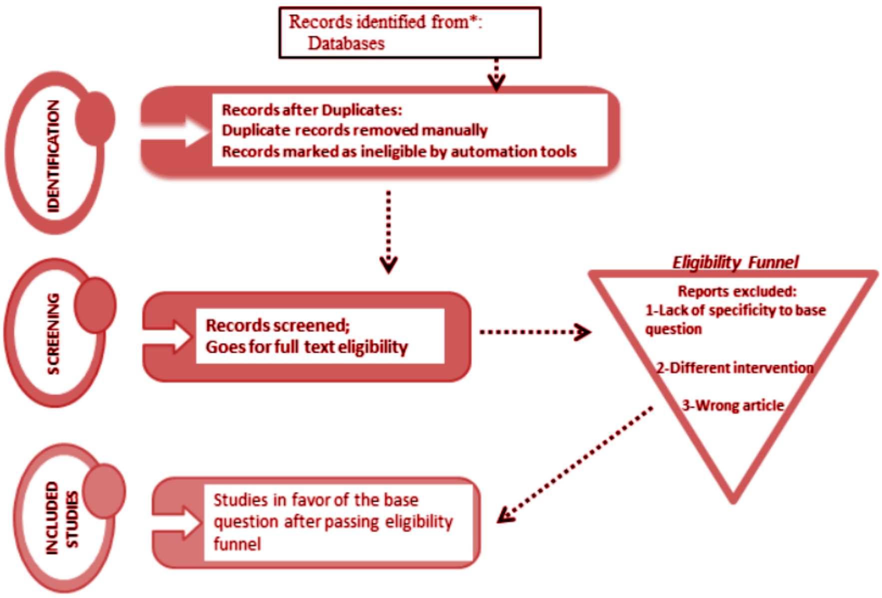

Figure 1. **The graphical representation of literature search and studies selection**

Source: *Author's own development*

Data Analysis

The procedure for carrying out the analysis of the data started with the selection of the pertinent particulars as the initial step of the process. The information that was gathered was first organized into a table, which was the second step in the process, which was followed by the drawing of conclusions about the study. After the articles that had been selected for further examination were reviewed one at a time, the overarching notion that most effectively demonstrates the relevance of the study issue was then determined (see figure 1).

Research Results

Analysis

It was determined that a total of studies met the inclusion criteria after conducting the search. (Table 1). However, in the future, there will be a need for more research of this kind that is randomized and strictly monitored in order to determine how aging affects one's physical and mental health.

Table 1. The extracted information from screened studies

	Highlight of the review	Extracted information from Analysis	References
Physical based aging effects	Bone density loss	Aging leads to osteoporosis. Occur more in male and in menopause females	[13, 14]
	Decrease in muscle flexibility	Aging leads to sarcopenia	[12, 13]
	Increased risk of heart problems	Frailty, obesity, and diabetes increase adult cardiovascular disease (CVD) risk. These factors exacerbate advanced age-related cardiac risk factors. Since older women have a higher CVD risk than age-matched men, sex is another risk factor in aging adults.	[15, 16]
	Digestive changes	Leads to dysbiosis. Gut-microbial get low immunity.	[17, 27]
	Changes in skin, hair, and nails	Hair and nail gerontobiology has been less studied than skin aging. Signaling pathways involved in hair follicle melanogenesis help us comprehend greying. Nail plate lipid concentration determines nail structure and quality in older people.	[18-20]
	Vision	The central vision is impacted by age-related macular degeneration (AMD), which also has a significant negative effect on quality of life as a result of vision impairment.	[21]

Physiological based aging effects	Decreased executive functioning	Executive functions grow into early adolescence and decline in later life. Children and adults exhibit this trend.	[22-24]
	Memory changes	Temporal lobe structures, which are crucial for cognitive health in old age yet prone to aging-related disorders, may explain the substantial relationship between temporal lobe gray matter abnormalities and cognitive loss.	[25]
	Anxiety	Suffered from generalized anxiety disorder.	[26]

Source: Author's own development

Interpretation

The table includes a collection of numerous physiological and physical impacts of aging as well as information gleaned from research and references. The physical side effects of aging include changes in skin, hair, and nails, vision, digestion, bone density, muscle flexibility, and heart disease risk. Anxiety, memory alterations, and impaired executive functioning are some physiologically grounded impacts of aging. There are additional references given for each consequence.

Discussion

The process of aging is an unavoidable part of the life cycle that occurs in all creatures that are still alive. As humans get older, their bodies go through a wide variety of physiological and structural changes, which results in a gradual loss of function and an increased susceptibility to illness [28]. In this article, we investigated the physiological and physical repercussions of aging, as well as the ways in which these effects manifest themselves in various parts of the body. The functionality of bones and muscles is significantly affected by aging, which is one of the most severe physical impacts of aging. Not only are bones and muscles necessary for movement, but they also have an important function in the endocrine and metabolic systems of the body. As people get older, their bones lose some of their density and their muscles lose strength, which can result in conditions such as osteoporosis and sarcopenia[29]. Because of their decreased estrogen production, which is a major factor in both bone and muscle mass, women who have gone through menopause and are now in their postmenopausal years are particularly susceptible to these problems [29, 30]. On the other hand, because males have more androgens in their bodies, such as testosterone, they are better protected against the age-related bone and muscle loss that affects females. However, both men and women can experience sarcopenia and osteoporosis as a natural part of the aging process. Diagnosis and treatment methods for osteoporosis in men are comparable to those used for postmenopausal women with the condition [31, 32]. Another one of aging's physical effects is an increased likelihood of developing cardiovascular disease (CVD). When it comes to cardiovascular disease in adults, age is a risk factor, and additional factors such as frailty, obesity, and diabetes can further enhance that risk [33, 34]. As people get older, their levels of sex hormones, especially testosterone and estrogen, decline, which is one factor that can contribute to the development of cardiovascular disease (CVD) in both men and women. It is commonly believed that women have a higher risk of cardiovascular disease (CVD) than males of the same age; nevertheless, the risks associated with CVD grow with age for both sexes [35, 36]. Along with the rest of the body, the microbiome in the gut goes through significant shifts as we get older, which can result in an increased likelihood of catching infectious diseases and a reduced immune response to vaccinations [37]. Because of the symbiotic interaction that exists between the immune system and the microbiome, treating age-related dysbiosis may result in an increase in both health and lifespan [38]. Both systemic inflammation and immunosenescence are hallmarks of the aging process, and age-related dysbiosis has been linked to both of these phenomena [39]. A variety of physical changes that occur as we age can have an impact on our overall health and happiness. Sarcopenia and osteoporosis are two examples of these alterations. Although they can affect both men and women, it is assumed that women are more likely to experience them due to their lower amounts of androgens like testosterone. For men and women, osteoporosis treatment and diagnosis approaches are comparable. As people get older, cardiovascular disease (CVD) can also become a problem. In addition to age being a risk factor for CVD, other variables like frailty, obesity, and diabetes can further raise the risk. Both men and women may acquire CVD as a result of hormonal changes brought on by aging, such as diminishing levels of estrogen and testosterone. The risk of CVD rises with age for both sexes, despite the belief that women have a larger risk than males of the same age. Age-related alterations in the gut microbiome also have a substantial impact on immune function and raise the danger of contracting infectious diseases. Age-related dysbiosis, systemic inflammation, and immunosenescence may all be associated with these alterations. Dysbiosis treatment may lead to increased longevity and health. Although typically true, other elements like nutrition, lifestyle, and environmental variables may also have a big impact on age-related health problems. When discussing health issues related to aging, it is crucial to approach the material cautiously and take a variety of elements into account.

Alterations in the way that the skin, hair, and nails appear are also common side effects of becoming older. The process of aging can alter several aspects of hair and nail growth, including color, arrangement, and growth rate [40]. The comprehension of the stages involved in the graying of hair has been significantly aided by studies of the signaling pathways that are active during melanogenesis in the hair follicle. The age-dependent changes in the lipid content of the nail plates are the principal factor responsible for the differences in structure and performance in general of the nails that occur with advanced age. These changes occur as a result of the natural process of aging [41]. Age-related macular degeneration has a major negative influence on quality of life due to vision impairment [42]. Structural alterations in the eye lead to impairments in near and distant vision, and these impairments are caused by age-related macular degeneration [43]. Deficits in visual field induced by cerebral causes also have a detrimental influence not only on the patient's quality of life but also on the outcomes of rehabilitation for neurological illnesses in patients who have several deficits. Patients with multiple deficits are more likely to develop neurological disorders [44, 45]

Aging has a negative impact not just on a person's appearance but also on their physiological functioning. The decline in executive functioning that comes with becoming older is one of the most important physiological repercussions of getting older. The term "executive functions" refers to higher-order cognitive abilities such as memory retention, control based on inhibition, mental flexibility, organization, deductive reasoning, and the ability to solve problems [46, 47]. They are an essential component in achieving one's goals, adjusting successfully to the unexpected challenges that come in one's day-to-day life, and successfully navigating one's interpersonal interactions. Executive functioning requires contributions from multiple parts of the brain, including the frontal, posterior, and subcortical areas of the brain. It has been demonstrated through research that aging causes a loss in executive functioning, which can have an effect on the quality of life of an individual [48] A decrease in sensory functioning is another one of the physiological effects of getting older. The process of aging can have an impact on a variety of sensory capabilities, including one's ability to hear, taste, and smell. Hearing loss, in particular, is a problem that is commonly associated with aging and can lead to social isolation and diminished quality of life [49, 50].

The field of anti-aging therapy is expanding, but there are numerous products and treatments that lack scientific backing for their claims. Slowing, stopping, or reversing the process of aging and its negative consequences, such as disease and weakness, are the goals of anti-aging medicine. Recently, aging in place has become more prevalent in healthcare services and policies. Technology has the ability to promote domestic independence. There is a dearth of literature on technology to support aging that is based on studies done in real homes and under controlled conditions. Therefore, a thorough investigation of the subject is required. Utilizing a biofeedback machine, an accessible computer, a pedometer wristband, a neurofeedback headband, and a platform for videoconferencing can add value. Both sexes are affected by the importance of bone and muscle function for mobility, the endocrine system, and the metabolic process, with postmenopausal women being more susceptible to age-related bone and muscle loss.

Conclusions

1. Age is a risk factor for cardiovascular disease (CVD), and other risk factors like frailty, obesity, and diabetes raise the risks for senior persons.

2. Changes in the structure and function of the gut are linked to an increased risk of developing infectious diseases and a decreased response to immunizations, and the gut plays a significant role in the development and management of the immune system.

3. In addition to changes in the lipid composition of nail plate structures and signaling pathways regulating hair color, aging has an impact on the look of hair, nails, and skin.

4. Age-related structural changes can impair near and far vision, whereas age-related macular degeneration (AMD) affects central vision. Vision impairment is an agreed-upon age-related alteration.

5. Executive functioning, which encompasses higher-order cognitive skills like memory recall and inhibitory control, declines with age.

6. Steroid hormonal substances, especially testosterone and estradiol, are to blame for gender dimorphism in musculoskeletal structure.

7. Age-related alterations in musculoskeletal structure are mostly caused by innate aging mechanisms such cellular senescence and oxidative stress.

8. The cause of osteosarcopenia, a disorder where muscle wasting and bone loss coexist, is unknown.

9. Despite the fact that there are fewer random clinical research studies in men, data suggests that detecting and treating osteoporosis in men is comparable to treating it in postmenopausal women.

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The role of robotics and automation in surgery: critical review of current and emerging technologies

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Abstract

This article focuses on "The role of robotics and automation in surgery a critical review of current and emerging technologies".

Aims: The aim of this study is to explore the role of robotics and automation in surgery as well as to accomplish a critical review of current and emerging technologies.

Methodology: A descriptive, cross-sectional study design was used. Secondary data was collected from published studies and official citations. Descriptive statistics were obtained and utilised.

Results: The results showed that general surgery procedures have been progressively adopting robotic surgery, and cholecystectomy being the most frequent procedure done. While the proportion of open surgery has reduced from 42.4% in 2012 to 32.4% in 2018, the use of robotic surgery has significantly increased from 1.8% in January 2012 to 15.1% in June 2018. The FDA-approved and pending robotic platforms and systems that were examined highlighted the developments in robotic surgery technology. High precision, smaller incisions, improved visibility, decreased surgeon fatigue, and the capacity to easily conduct difficult procedures are among benefits of robotic surgery. Additionally, it may result in fewer hospital stays, less blood loss, and better treatment outcomes. Though, robotic surgery is not without its drawbacks. These drawbacks include higher costs, a learning curve for surgeons, limited availability in some settings, technical difficulties, diminished tactile feedback, longer operating times, dependence on technology, and more setup and maintenance time and effort.

Scientific Novelty: An analysis of current and emerging technologies, including robotics and automation in surgery.

Conclusion: While robotic surgery has many benefits in terms of accuracy, a minimally invasive procedure, and better patient outcomes, there are also drawbacks and difficulties that must be taken into account for a responsible and successful deployment in surgical practice. To guarantee the safe and moral application of robotics and automation technology in surgery, more investigation, instruction, and regulation are required.

Keywords: robotics, automation, surgery, critical review, current technologies, emerging technologies.

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Introduction

Surgeons that use the robotics and automation system in surgical procedures claim that it improves precision, flexibility, and control throughout the surgery and gives them a better view. In 1985, the PUMA 200 became the first robot surgeon to perform surgery. Risks associated with robotic surgery may be similar to those associated with traditional open surgery, such as chance of infection and other problems. Not everyone has the option of robotic surgery. There may not be any medical facilities offering robotic surgery in any area [1-2]. Around 3% of operations are thought to be carried out robotically providing patients with the advantages of minimally invasive surgery worldwide. The use of robots in telemedicine during a pandemic is considerably more crucial as this maintains the social distance and offers safety to medical equipment for the patient and surgeon as well. Hospitals are settings where there is a greater probability of getting encounters and infections [3].

The recent years, together with the advancement in technology the use of robotics and automation in surgery has been gaining more and more attention. Numerous studies have proven the potential benefits of these technologies in various surgical specialties. For example, in urology, a robot-assisted radical prostatectomy has been shown to offer improved outcomes in terms of less blooding, early discharge and quick recovery compared to a traditional open surgery. Similarly, in gynaecology, a robot-assisted hysterectomy has been associated with decreased complications and improved patient satisfaction compared to conventional laparoscopic surgery [4]. In addition to urology and gynaecology, robotics and automation have also been increasingly used in general surgery and orthopaedics. In general surgery, these results in less postoperative pain, reduced complications, and faster return to normal activities compared to open surgery [5]. In orthopaedics, the robot-assisted joint replacement surgery has been reported to improve implant alignment, reduce complications, and enhance functional outcomes. These studies highlight the potential advantages of robotics and automation in improving surgical outcomes in various specialties [6].

The market growth of surgical robots was 16% in but it is anticipated to increase at a compound annual growth rate of about 17.5% from 2021 to 2027. The development of new surgical robots has been and continues to be financed by the European Union throughout the past few decades. For this business to certify the surgical treatments, it often takes a lot of time, money, and research [7].

In surgical robots, there are five key components that make up the autonomy that cover decision-making at progressively higher levels. There is no decision autonomy at the 0 level and the majority of commercial platforms are at this level. At level 1, the robot can physically and mentally aid the surgeon, while at level 2 it can surgically operate on its own. Conditional autonomy is a feature of Level 3, allowing the robot to plan a job and modify it as it is being carried out. Finally, level 4 robots are capable of independently planning and carrying out a series of surgical tasks [8-9].

Over the past few decades, robotic and automation in surgery has developed more rapidly due to the creation of new technologies and the advancement in the old ones. The da Vinci Surgical System, which is widely utilised in urology, gynaecology, and general surgery, is the state of the art in surgical robotics at the moment. This system provides surgeons with a 3D view of the surgical field and allows more precise movements of the surgical instruments. Other emerging technologies include the Senhance Surgical System, which uses haptic feedback to provide surgeons with a sense of touch, and the Versius Surgical System, which is designed to be more compact and portable than existing systems [10-11].

With the advancement in technology there is evidence for need of training. These reality and simulation-based training are effective in improving surgical skills and reducing errors highlighting the importance of incorporating these technologies into surgical training programs to improve patient safety [12-13].

There are five generations of surgical robots. The invention of robotic arms that surgeons could control characterised the first generation. In the second generation, computerised control systems were implemented, and in the third generation, sensors and cameras were used to give surgeons a better view of the operating field. Advanced robotic systems were created in the fourth generation, while the fifth generation is distinguished by the use of AI and machine learning into surgical robots [14].

This robotics and automation surgery have not only the impact on patients and surgeon but also on nursing practice as these devices have the potential to offload and alleviate the nurses workloads, allowing them to focus on more complex tasks and ensure that they are safe and effective [15].

Also of current concern are the societal and political effects of evolving artificial intelligence technologies. No doubt that there are potential benefits of AI, including improved healthcare outcomes, but this also raised concerns about the impact of AI on employment and privacy [16].

Despite the encouraging outcomes, using robotics and automation in surgery has its limitations and difficulties. High costs of acquiring and maintaining robotic systems, longer learning curves for surgeons, and concerns about patient safety and ethical considerations are some of the challenges that need to be addressed [17] . Moreover, there is a need for standardised training and credentialing for surgeons to ensure safe and proficient use of robotic systems, as well as robust research to establish the long-term clinical and cost-effectiveness of these technologies [18].

The combination of robotics and automation in surgery with artificial intelligence and machine learning algorithms has also gained popularity in recent years. These technologies hold the potential to further enhance surgical decision-making, optimise surgical workflows, and improve patient outcomes. For example, AI-based image recognition algorithms can assist surgeons in identifying and delineating tumour margins during surgery, while machine learning algorithms can analyse large datasets to predict surgical complications and optimise patient management [19]. However, the integration of AI in surgical practice also raises concerns about data privacy, bias, and algorithmic transparency, which need to be carefully addressed.

Overall, the research points to the possibility that robotics and automation could enhance patient safety and surgical outcomes. There are still issues to be resolved, such as the high cost of these technologies and the requirement for additional study to determine their efficacy. It is important for healthcare professionals to be involved in the development and implementation of these technologies to ensure that they are safe, effective, and accessible to all patients. The use of robotics and automation in surgery has emerged as a promising field with potential advantages in terms of improved surgical outcomes and patient recovery. However, there are also challenges and limitations that need to be addressed.

Research Problem

The research problem for this study could be framed as follows:

1. Although robotics and automation in surgery have quickly advanced, there is still a need for a critical review of the existing and new technologies to determine how they will affect clinical outcomes, comparative effectiveness, surgical specialty-specific outcomes, technology evaluation, ethical issues, surgeon training and education, and future directions.

2. There is no agreement on how robots and automation should be used in surgery, and more study is required to fill in the gaps in the body of knowledge and offer evidence-based recommendations for current clinical practice and potential future advancements.

3. In order to guide evidence-based decision-making and shape the future of surgical care, the research problem for this study is to critically evaluate the role of robotics and automation in surgery, including their benefits, drawbacks, impact on patient outcomes, surgical practice, and future directions.

Research Focus

In this study, the current state of surgical robot development and automation technology is critically examined. A detailed analysis and comparison of the various robotic surgery systems and automation modalities, including teleoperated, autonomous, image-guided, robotic-aided, and minimally invasive techniques is conducted. A comprehensive examination of the benefits and drawbacks of robotic surgery, including financial implications, educational needs, and potential adoption hurdles. An examination of the ethical concerns presented by the use of automation and robotics in surgery, including those including permission, privacy, and patient safety is effectuated. The creation of suggestions for further study and clinical practice, including locating knowledge gaps, possible solutions for problems, and implications for future clinical practice and policy-making in the area of robotics and automation in surgery.

Research Aim and Research Questions

The aims of this study are to:

1. Critically examine the newest developments in robotics and automation for surgery.
2. Give a general review of the various robotic system and automation modalities used in surgery.
3. Highlight the advantages and limitations of these technologies.
4. Explore the ethical considerations.
5. Provide recommendations for future research and clinical practice.

Research Questions

1. What are the existing and upcoming robotic and automated surgical technologies, and how do they differ in terms of their potential and constraints?

2. What are the various robotic system and automation modalities used in surgery, and what surgical specialisations do they apply to?

3. What are the benefits and drawbacks of robotic surgery, including the associated costs, educational requirements, and potential obstacles to their general adoption?

4. What ethical issues, such as patient autonomy, informed consent, and potential effects on the doctor-patient relationship, should be taken into account when introducing robotics and automation in surgery?

5. What recommendations may be made for additional study and clinical application in the realm of robotics and automation in surgery, as well as for potential future directions for clinical practice and policy-making?

Research Methodology

General Background

The robotics and automation, which provide cutting-edge medical technology for better patient results has transformed the field of surgery. These technologies have a fast development, with a wide range of applications in different surgical specialties, going from teleoperated to autonomous robots. A lot of interest has been generated because of the Image-guided surgery, robotic surgery, and minimally invasive surgery. While these technologies have benefits like accuracy, precision, and little invasiveness, they also have drawbacks including high costs, training needs, and ethical issues. Future developments in artificial intelligence and machine learning will influence robots and automation in surgery. Realising the full potential of these technologies to enhance surgical outcomes requires more study and recommendations for clinical practice.

Sample / Participants / Group

Surgical practitioners, patients, health researchers, health industry representatives, scholars or professionals with expertise in medical ethics or bioethics, and health policymakers were implemented into the search.

Instrument and Procedures

Depending on the research topics and objectives, the study may combine quantitative and qualitative research approaches. The subsequent steps may be used in the research investigation.

Data Analysis

The pretested questionnaire was utilised in order to collect the secondary data from the document related to the robotics and automation in surgery. Data was analysed using descriptive and inferential statistical methods, such as frequencies and percentages.

Research Results

Status of the Robotic and Automation in Surgery for Common Surgical Procedures

Results (Table 1) of a study revealed that total participant were 169 404 with 53.5% women and 46.5% men, having a mean age of 55.4 (16.9) years. The most frequent procedure 37.1% performed with a robotic aid was a cholecystectomy.

Table 1. **Status of the Robotic and Automation in Surgery for Common Surgical Procedures**

Particular	Frequency
Total participant	169 404 patients
Female	90 595 (53.5%)
Male	78 809 (46.5%)
Total Hospital	73
Mean age for all patients	55.4 (16.9) years
Common Operation (Cholecystectomy)	62 854 (37.1%)

Increased use of robotic surgery	1.8% to 15.1%
laparoscopic and open surgery decline	32.4%
Increased the use of robotic surgery for inguinal hernia repair	0.7% to 28.8%
increased use of robotic surgery in hospitals and among surgeons	8.7% to 35.1%
Decreased the use of laparoscopic surgery	53.2% to 51.3%

Source: Authors' development based on JAMA Network n.d.

The use of Robotic surgery for all general surgery procedures increased from 1.8% to 15.1% between January 2012 and June 2018, whereas the proportionate use of open surgery decreased from 42.4% to 32.4%. Robotic surgery was used more frequently in repairing inguinal hernias, rising from 0.7% to 28.8%. There was an increased trend in robotic general surgery from 8.7% to 35.1%. The percentage of hospitals and physicians performing robotic surgery was also showed an upward surg. Hospitals started performing robotic surgery, which resulted in a drop in the utilisation of laparoscopic surgery from 53.2% to 51.3%. Hospitals started using laparoscopic surgery more frequently before beginning robotic surgery. After hospitals started doing robotic surgery, there was a tendency toward less laparoscopic surgery. When results were stratified across certain techniques, they remained unchanged [20].

Status of robotics and automation technology in surgery

Robotic surgery and minimally invasive surgery are two cutting-edge developments in surgery. These interventions have increased the surgeon's capabilities and level of precision. There are multiple robotic assisted surgical systems that are available in market. There is a long list but few are shown in (Table 2).

Table 2. **Status of Robotics and Automation Technology in Surgery**

FDA Approved	Non-FDA Approved
da Vinci Surgical System	MiroSurge
Sensei X Robotic Catheter System	ViaCath System
FreeHand 1.2	SPORT™ Surgical System
Invendoscopy E200 system	SurgiBot
Flex® Robotic System	Versius Robotic System,
Senhance	Master and Slave Transluminal Endoscopic Robot
ARES	Verb Surgical
the Single-Port Instrument Delivery Extended Research (SPIDER)	Miniature In Vivo Robot
NeoGuide Colonoscope	Einstein Surgical Robot

Source: Authors' development based on National Library of Medicine n.d.

The da Vinci Surgical System, Sensei X Robotic Catheter System, Free Hand 1.2, invendoscopy E200 system, Senhance, ARES, the Single-Port Instrument Delivery Extended Research, and the NeoGuide Colonoscopy are among those devices approved by the FDA for robotic surgery. While MiroSurge, ViaCath System, SPORTTM Surgical System, SurgiBot, Versius Robotic System, Master and Slave Transluminal Endoscopic Robot, Verb Surgical, Miniature In Vivo Robot, and the Einstein Surgical Robot are among those yet not approval by FDA [21].

The result in (Table 3), outline the main enabling technologies on the basis of autonomy that advance this area of research and divide them into five major sections that deal with ever higher levels of autonomy. The robot lacks decision autonomy falls at level 0. At level 1, the robot can aid the surgeon physically and mentally, while at level 2, it can operate surgically on its own. Conditional autonomy is a feature of Level 3, allowing the robot to plan a job and modify it as it is being carried out. Finally, level 4 robots are capable of independently planning and carrying out a series of surgical tasks [22-23].

Table 3. The Evolution of Five Generations of Surgical Robotics

Generation	Description
1st	Stereotaxic robots
2nd	Endoscopic robots
3rd	Bioinspired robots
4th	Microbots
5th	autonomous systems

Source: Authors' development based on Pros and Cons of Robotic Surgery n.d.

This study examined the present or emerging technologies in medical and surgical field. Each technology' have its own advantages and drawbacks. Robotic and automation systems are becoming more and more popular, and new technologies are constantly being created to meet the current and future need. More and more new technologies are used to enhance the functionality of existing systems. Future researches are required to assess the advantages and disadvantages of each robotic surgical tool and platform used in the operating room.

Robotic Surgery Advantages and Disadvantages

Results in (Table 4) showed that there is high precision and accuracy due to robotic arms with enhanced dexterity and range of motion; Smaller incisions and minimally invasive approach, resulting in less scarring, reduced pain, and faster recovery times for patients; Enhanced visualisation through high-definition 3D imaging, allowing for detailed visualisation of structures during surgery; Reduced surgeon fatigue and improved ergonomics due to the use of robotic arms, which can be controlled from a console; the ability to access tight spaces and perform complex procedures with greater ease using robotic arms; potential for patients to recover more quickly and spend less time in the hospital; less blood loss and decreased infection risk than with traditional surgery better results for specific procedures, such gynaecological and prostate surgery [24].

The result also showed there are higher cost associated with acquiring and maintaining robotic systems, as well as training and specialised instruments; steeper learning curve for surgeons to become proficient in using the robotic system; limited availability in some hospitals or surgical centers due to cost and infrastructure requirements; potential for technical difficulties, such as system malfunction or connectivity issues; reduced tactile feedback compared to conventional surgery, as the surgeon does not directly touch the tissues; the possibility of increased operative time due to setup and docking of the robotic system; dependency on technology, which may introduce risks of technical failures or complications and additional time and effort required for setup, calibration, and maintenance of the robotic system [24].

Robotic and automation technology in surgery improves precision, accuracy, incision size, visualisation, surgeon weariness, and specific operation outcomes. However, high costs, a period of adjustment for surgeons, limited accessibility in some contexts, technical challenges, decreased haptic perception, and long operating times are impediments. Despite these limitations, robotic and automation technology in surgical procedures can improve patient outcomes. For successful implementation, costs and challenges must be carefully assessed.

Ethical Concerns and Robotics and Automation Technology in Surgery

The analysis in (Table 5) of patient autonomy, informed consent, surgeon competency, cost and access, ethical use of data, human touch and compassion, social and economic impact, stakeholders, legal and ethical implications, misplaced ethical concerns, training, and informed consent yielded notable results. Patient autonomy and informed consent help patients choose treatment options. Surgeon skill is essential to safe and successful healthcare outcomes.

Cost and access were linked to healthcare delivery issues and patient outcomes. Resource allocation and affordability ethics were also important. To guarantee patient privacy and confidentiality, data ethics must be addressed. Human touch and compassion in healthcare improve patient satisfaction and wellness. Social and economic effects showed the need to address healthcare access and outcomes inequities. Patients, healthcare professionals, lawmakers, and payers must work together to shape healthcare policies [25–27].

Discussion

Status of the Robotic and Automation in Surgery for Common Surgical Procedures

Discussion on results (Table 1) revealed 169,404 patients who underwent general surgery operations, had a mean age of 55.4 (16.9) years and somewhat more women (53.5%) than men (46.5%) and the cholecystectomy was the most frequent surgery done. A major trend that was noticed was the rise in the usage of robotic assistant general surgery operations. During this time, the percentage of robotic surgeries rose from 1.8% to 15.1%, while laparoscopic and open surgery rates fell. In particular, the percentage of open procedures fell from 42.4% in 2012 to 32.4% in 2018. From 0.7% to 28.8%, the usage of robotic general surgery for specialised operations, such the treatment of inguinal hernias, has rose dramatically during this time. Additionally, throughout time, more hospitals and surgeons started doing robotic surgery. Robotic surgery usage increased from 8.7% of surgeons in 2012 to 35.1% in 2018. It's interesting to note that after hospitals started offering robotic surgery, the utilisation of laparoscopic surgery dropped from 53.2% to 51.3%, indicating a change in surgical methods. However, there was a tendency toward higher usage of laparoscopic surgery before hospitals started practicing robotic surgery, showing a shift in surgical procedures [20]. In a study done in the USA, the use of robotic surgery rose with time, showing a similar pattern. The overall number of robotically assisted procedures increased from 2018 to 2019 by 17.26%. The COVID-19 pandemic's effects on surgical procedures may have contributed to the 0.79 percent decline in cases in 2020 [28-29].

The data as a whole point to a growing trend in the use of robotic and automation for general surgery operations, with an increasing number of hospitals and surgeons adopting this method. This could be related to developments in robotic technology and its prospective advantages, including lowered morbidity, shorter hospital stays, and quicker patient recovery. To evaluate the safety, effectiveness, and cost-efficiency of robotic surgery in contrast to traditional surgical techniques, however, more research and long-term studies are required.

According to study findings robotic surgery has just recently gained popularity in the Middle East; the region's first da Vinci robotic system was installed in the country of Saudi Arabia in 2003. Eight main hospitals in the KSA currently have 10 da Vinci robots installed, and Qatar opened the Qatar Robotic Surgery Centre (QRSC) in 2010 with three da Vinci robots. Notably, other from the KSA, Qatar, and Egypt, no other Middle Eastern nations have been known to have da Vinci robots in operation. The Middle East has a very restricted use of robotic surgery, which is highlighted by the region's recent acceptance of this technology as well as the small number of recorded case series. It may imply that robotic surgery is still being adopted and used at a relatively early level in Middle Eastern nations, with the KSA and Qatar leading the way [30–32].

Due to factors like robotic system accessibility, cost, surgical team training, and cultural and legislative restraints, robotic surgery may be slower to adopt in the Middle East. More research and studies are needed to understand robotic surgery usage in the Middle East and its benefits and drawbacks. The Middle Eastern study suggests that further data and research from other Middle Eastern nations is needed to completely understand regional robotic surgery trends. As robotic surgery advances, Middle Eastern governments may need to work together to improve and maximise its use for patients.

Status of Robotics and Automation Technology in Surgery

This study reviewed the current and emerging robotics and automation technologies in surgery, and their effectiveness. There are two kinds of system FDA approved and non FDA approved The da Vinci Surgical System, Sensei X Robotic Catheter System, etc belongs to Fda approved group while MiroSurge, ViaCath System, etc belong to NnonFda approved group of robotic and automation system in surgery [21].

Although there are 10 da Vinci® robots in the KSA, a different study found that the low amount of robotic cases impairs resident training and severely affects resident instruction. Throughout these, six robotic systems were dispersed throughout Riyadh's four main hospitals, two of which were in the Eastern Province and two in the Western

Region [33]. Human surgeons can operate an advanced console called the da Vinci system, which was developed by Intuitive, during surgery. The device provides high-definition visuals that are 10 times more magnified than what the human eye can see. The surgeon controls microscopic instruments that have an amasing range of motion and are wielded like human hands. Additionally, the instruments are stabilised for accuracy thanks to an integrated tremor-filtration technology.

Regarding the various generations, literature revealed that the da Vinci Surgical System, a fourth-generation endoscopic robot, is the only robotic surgical system approved by the FDA to perform a range of treatments. Thanks to the da Vinci Surgical System, more than three million patients have endured difficult, minimally invasive surgery [34]. Robotic surgery uses specialised technology to assist surgeons in carrying out complex procedures, and it's safe, precise, and treats a variety of conditions

The literature analysis showed the Arthrobot, is a system that is used in positioning the patient during an orthopaedic surgery operation and the Unimation Puma 200, used to orient a needle for brain biopsy, among the first surgical robots. The Da Vinci robotic system from Intuitive Surgery, which is utilised in a range of surgical specialties and is capable of carrying out technically demanding surgeries, was a breakthrough. Now, a number of additional robotic systems have been created and are marketed for use in numerous surgical operations across numerous disciplines [35, 36]. The literature showed that as per UC Health, the da Vinci surgical system, one of the most well-known robotic technologies, is already used in 1,700 hospitals worldwide. Moreover, robotic laparoscopic surgery has helped save close to 800 000 lives. It's even more incredible to consider that the da Vinci system, which has been in operation since 2000, is the first surgical robot to be regularly utilised during a laparoscopic procedure [37-38].

Robotic Surgery Advantages and Disadvantages

Numerous benefits of robotic surgery over conventional surgery are shown in (Table 4).

Table 4. Robotic Surgery Advantages and Disadvantages

Advantages	Disadvantages
High precision and accuracy.	Higher cost
Smaller incisions and minimally invasive approach	Steeper learning curve
Enhanced visualization of structures during surgery.	Limited availability.
Reduced surgeon fatigue and improved ergonomics	Potential for technical difficulties
Perform complex procedures with greater ease.	Reduced tactile feedback
shorter hospital stays and quicker recovery times.	Possibility of increased operative time due to setup and docking of the robotic system.
Lower blood loss and lower risk of infection	Dependency on technology
Better outcomes	Additional time and effort required

Source: Authors' development based on Pros and Cons of Robotic Surgery n.d.

Smaller incisions and a minimally invasive approach lead to less scarring, less pain, and quicker recovery times for patients [39]. Robotic arms with enhanced dexterity and range of motion provide high precision and accuracy during surgery [40]. High-definition 3D imaging improves visualisation and allows for detailed visualisation of structures during surgery [41]. Because robotic arms may be operated from a console, their adoption lessens surgeon fatigue and enhances ergonomics. Additionally, robotic arms make it easier for surgeons to work in confined locations and complete difficult procedures [42].

Robotic surgery is improving surgery because it is more accurate, steady, and dexterous. Compared to traditional procedures, robotic ones provide a number of benefits, such as less loss of blood, less time in the hospital, and faster recovery times [43]. Robotic surgery is typically connected to minimally invasive procedures, which have a quicker return to regular activities and less pain and scarring. Heart surgery, prostate surgery, and gynaecologic surgery are just a few operations that have used robotic surgery [24].

To summarise, robotic surgery has a number of benefits over conventional surgery, including high precision and accuracy, smaller incisions, improved visualization, decreased surgeon fatigue, and the capacity to enter confined locations and carry out challenging procedures with more ease. Robotic surgery improves surgery through increased precision, stability, and dexterity and has been tried in a number of surgeries with positive results.

The outcomes demonstrate many drawbacks of robotic surgery that should be taken into account. The higher expense of purchasing and maintaining robotic systems, as well as training and specialised tools, is one of the key drawbacks [44]. The expense of robotic surgery can prevent some hospitals or surgical facilities from offering it because they lack the means or infrastructure to do so [45]. In addition, employing the robotic system requires a steeper learning curve for surgeons, which may necessitate additional training and practice [46-47].

The potential for technical concerns such system failure or communication problems are another drawback of robotic surgery. As the surgeon does not directly contact the tissues, there is less tactile feedback compared to traditional surgery. Another drawback is that the robotic system's setup and docking may lengthen operative time1. Additionally, there is a dependence on technology, which may increase the danger of technical difficulties or breakdowns and add to the time and effort needed for the robotic system's setup, calibration, and maintenance [44-48].

Robotic surgery has a number of benefits over conventional surgery, despite these drawbacks, including increased precision, stability, and dexterity, fewer incisions, improved visibility, and less pain and scarring for patients. With positive results in a handful of surgeries, robotic surgery has been used, and more research and development is anticipated to address some of these systems' current shortcomings. In conclusion, robotic surgery has a lot of advantages over traditional surgery, but there are a number of disadvantages that should be considered as well, including increased expense, technological problems, a reduction in tactile feedback, and longer operating hours. In order to assure the safety and effectiveness of these systems, healthcare providers must carefully weigh the risks and advantages of robotic surgery and make sure that the necessary training and safety measures are in place [24].

Ethical Concerns and Robotics and Automation Technology in Surgery

Results in (Table 5) Patient Autonomy, Informed Consent, Surgeon Competency, Cost and Access, Ethical Use of Data, Human Touch and Compassion, Social and Economic Impact, Issues, Stakeholders, Legal and Ethical Implications, Misplaced Ethical Concerns, Training, Informed Consent [25–27].

Table 5. **Ethical Concerns and Robotics and Automation Technology in Surgery**

Ethical Concerns
Patient Autonomy
Informed Consent
Surgeon Competency
Cost and Access
Ethical Use of Data
Human Touch and Compassion
Social and Economic Impact

Source: Authors' development based on JSTOR n.d.

One of the ethical concerns presented by the use of robots and automation in surgery, according to the literature, is the patient's autonomy. Informed consent is a prerequisite for moral surgical practice because it promotes patient autonomy and strengthens the doctor-patient relationship. To make informed decisions about their care, patients need to be fully informed about the benefits and drawbacks of robotic surgery. Additionally, robotic surgery may lack the empathy and personal connection of traditional surgery, which may have an adverse effect on the autonomy and contentment of the patient [49-50].

Other ethical concerns associated with the use of robotic surgery include surgeon competency, cost and access, ethical use of data, social and economic impact, and legal and ethical implications245. The increasing levels of autonomy in surgical robots also raise ethical issues, such as the need for meaningful human control and the potential for robots to replace human surgeons [51-52].

Several studies have addressed the ethical concerns associated with robotic surgery. For example, a study published in 2020 highlighted the need for informed consent and patient autonomy in the use of robotic surgical systems. Another 2019 study looked at the moral ramifications of surgical robot autonomy growth and the necessity of meaningful human control. These studies and others highlight how crucial it is to address ethical issues in the creation and application of robotic surgical systems [50]. A number of ethical questions are raised by the use of robotic surgery. The use of the Three Laws to investigate ethical dilemmas is one of the ethical concerns regarding the training of resident physicians in robotic surgery [53]. There are several ethical issues to take into account when using a robotic system, albeit not all of them are specific to robotic systems. Robotic surgery has ethical concerns around the dependability and safety of the equipment, the provision of proper information, and the maintenance of secrecy [54]. Human-robot interaction, notably during operations, raises a number of societal and ethical challenges that have been the subject of discussion on the subject of ethics in robotics [55-56].

Robotic and automation technology in surgery is quickly advancing and being more widely used across a range of surgical specialties. Increased accuracy, a decrease in bleeding, less time in the hospital, and speedier recovery times are just a few advantages of robotic surgery. Additionally, there are two drawbacks: the excessive cost of robotic systems and the challenging learning curve for surgeons. Patient safety, informed consent, and the possibility of job displacement for surgical professionals are among the ethical issues raised by robotics and automation in surgery. To ensure the proper and moral application of new technologies in surgical practice, more study, regulation, and training are required.

Conclusions and Implications

Robotics and automation use in surgery has significantly advanced, and it has the potential to improve accuracy, reduce blood loss, and speed up recovery. However, there are also disadvantages to consider, including greater costs and a learning curve for surgeons. Addressing ethical issues including patient safety, privacy, and professional responsibility is also crucial. The following are implications and conclusions:

1. Robotic and automation technology in surgery has significantly advanced and is increasingly being used for common surgical procedures.

2. Compared to conventional surgery, robotics and automated surgery has been found to provide advantages such greater precision, decreased loss of blood, less time in the hospital, and quicker recovery times.

3. Robotic surgical systems continue to evolve with advancements in robotics, imaging, and artificial intelligence, leading to increased adoption and improved outcomes for patients.

4. Automation technology, such as computer-assisted surgery and surgical navigation systems, can aid surgeons in planning and executing surgeries with enhanced accuracy and safety.

5. Robotic surgical systems can enable surgeons to perform complex procedures with enhanced dexterity and visualisation, potentially leading to improved patient outcomes.

6. Robotic surgery may also have disadvantages, including higher costs, longer operating times, and a learning curve for surgeons, and potential technical challenges.

7. Ethical concerns related to robotics and automation technology in surgery include issues such as patient safety, privacy, informed consent, professional responsibility, potential impacts on the workforce, issues related to autonomy, accountability, transparency, and equity.

8. Ethical frameworks and guidelines have been proposed to address these concerns, but there may be ongoing debates

Implications:

1. The increased adoption of robotic and automation technology in surgery for common procedures may lead to patient outcomes improvement and reduced complications.

2. Surgeons and healthcare providers need to stay updated with the latest advancements in robotic surgical systems to optimise patient care and outcomes.

3. There may be a need for training and credentialing programs to ensure that surgeons are proficient in using robotic surgical systems safely and effectively.

4. In certain hospital settings, the accessibility and availability of robotic surgery for routine procedures may be impacted by financial factors, notably the price of robotic surgical equipment and maintenance.

5. The use of robots and automation technology during operation has the potential to completely alter the way procedures are carried out while also enhancing patient care.

6. In order to guarantee patient safety and high standards of care, regulatory agencies may need to create rules and specifications for the use of automation and robotic technology in surgery.

7. The advantages of robotic surgery may lead to improved patient outcomes and enhanced surgical techniques, but the higher costs associated with robotic surgical systems may impact their accessibility in certain healthcare settings.

8. The ongoing monitoring and evaluation of patient outcomes and cost-effectiveness of robotic surgery are needed to inform decision-making and ensure optimal resources utilisation.

Despite these difficulties, incorporating robots and automation technologies into surgery has the potential to completely change the way surgeries are performed and enhance patient care. In order to guarantee the safe and efficient use of these technologies in the future, ongoing research, training, and regulatory supplies are required. Healthcare professionals can make well-informed choices regarding integrating robotic and automation technology into their surgical practice to improve patient outcomes and the standard of care by carefully evaluating the conclusions and implications presented above.

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The role of artificial intelligence in the management of lung cancer: a narrative review

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Abstract

Background: Lung cancer is the primary reason for cancer-related fatalities worldwide. The majority of lung cancer patients experience delayed diagnosis and ineffective treatment. Artificial intelligence is the term used to describe a computer or robot that enables certain tasks under the supervision of a computer in a way that satisfies human demands.

Aim: This study was evaluated in order to comprehensively estimate the advancements achieved by artificial intelligence technology in pathological diagnosis, early detection of cancer through screening based on imaging, prognostic evaluation, genomes examination, and lung cancer treatment.

Methods: In this review, English studies from common databases such as Pubmed/MEDLINE, Web of Science, Scopus, and the Cochrane Library with the keywords “Artificial intelligence,” “Machine learning,” “treatment,” “Diagnosis,” combined with keywords, involving “Lung cancer”, were involved. The end date for this review is March 2022.

Scientific novelty: Most of the previous studies focused on the diagnostic value of AI evaluation in lung cancer cases without assessing the role of AI in the treatment of lung cancer. The given article evaluated AI's therapeutic and diagnostic advantages for patients with lung cancer.

The practical significance of the result obtained: The results can help physicians to determine the best ways to manage lung cancer and diagnose it early to avoid complications. Additionally, the value of developing AI focused in early lung cancer diagnostic and providing more options for the treatment of lung cancer was explained.

Conclusion: Imaging, histopathological, and genetic analyses of lung cancer all significantly benefit from artificial intelligence. Additionally, artificial intelligence can identify a small number of biomarkers, which is helpful for lung tumor surveillance. Moreover, whether by internal medicine or surgical intervention, the intelligent management of lung tumors has progressively grown to represent the future development trend. AI is anticipated to aid in the early detection of lung tumors and help medical professionals treat each patient uniquely.

Keywords: artificial intelligence, lung cancer, individual treatment, and early diagnosis.

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Introduction

Lung cancer, also known as bronchogenic carcinoma, refers to malignancies that begin in the lung parenchyma or the bronchi. It is a leading cause of cancer-related death. Women have died from lung cancer more frequently than from breast cancer since 1987. Lung cancer is most frequently caused by smoking. 90% of lung cancer cases are thought to be caused by smoking [1,2]. Artificial intelligence (AI) is the term used to describe a computer or robot that can do certain tasks under the supervision of a computer in a way that satisfies human demands [3]. Numerous research has shown that AI is a significant ability for cancer care as it is valid in detection, dynamical monitoring, and quantitative treatment during health protection [4,5]. In this review, the obstacles in clinical application and the use of AI in lung tumors will be covered.

Research Problem

Lung cancer is the primary reason for fatalities related to cancer worldwide [6–9]. Most lung tumor patients experience delayed diagnosis and ineffective treatment [10]. Rapid, sensitive, and precise detection procedures require more focus. Currently, clinicians mostly use imaging characteristics and the clinical characteristics of their patients to diagnose lung tumors. However, these techniques fail to detect lesions fully and promptly [3].

Research Focus

In this article, the current effect of AI utilisation in the management of lung cancer and the advantages of the development of AI in lung cancer diagnosis and treatment were discussed.

Research Questions

1. How is lung cancer usually detected?
2. Is lung cancer easily detected?
3. What is the role of AI in lung cancer detection?
4. What are the recent advances of AI in the field of a lung cancer diagnosis?
5. What is the role of AI in lung cancer treatment?

Research Aim

This study comprehensively evaluated the advancements achieved by artificial intelligence technology in pathological diagnosis, early screening-based medical imaging, prognostic evaluation, genomes examination, and lung cancer treatment.

Research Methodology

In this review, English studies from common databases such as Pubmed/MEDLINE, Web of Science, Scopus, and the Cochrane Library with the keywords “Artificial intelligence,” “Machine learning,” “treatment,” “Diagnosis,” combined with keywords, involving “Lung cancer were involved.” The end date for this review is March 2022. The studies using each set of keyword combinations were then pooled to create an impartial collection of publications. Studies and/or articles that weren't subjected to peer review, as well as proposals, procedures, reviews, letters, and opinions, were eliminated. The references include publications that were chosen according to their relation to the topic. One concentrated on providing an overview of the advancements achieved by artificial intelligence technology in pathological diagnosis, early screening-based medical imaging, prognostic evaluation, genomes examination, and lung cancer treatment.

Research Results | Literature review

The result of the search using the search strategy was 3868 articles. These articles were screened to choose the works related to our topic. A full-text screening of 437 articles after excluding the remaining article by title and abstract screening was accomplished. Finally, 63 articles to gather information about our topic and write this review were used (Figure 1).

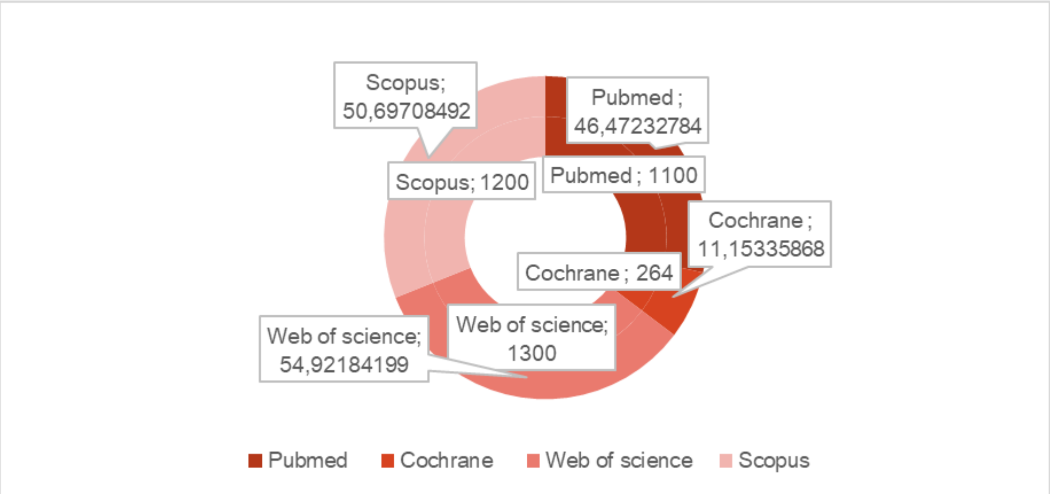

Figure 2 Research results

Detection and AI

Imaging inspection

When a patient feels anxious or has suspected lesions, a clinical scan using digital radiography (DR), magnetic resonance imaging (MRI), positron emission computed tomography (PETCT), or computed tomography (CT) will be performed on the entire body of the patient or only a specific section in order to make a right diagnistic [11,12]. As was already established, these imaging methods are crucial in cancer detecting. The primary practical issue clinicians face is that digital images of visual defects cannot be consistently and accurately integrated into their access to information [13,14]. So, AI should be developed to deal with images with visual defects.

AI created its logical algorithm to detect photographs quickly and gather information. Clinical images determine the target site using computer-aided detection (CAD) technologies [15]. AI-based detection techniques can identify the locations of lesions, decrease observational mistakes, and provide readers with convenience. For example, CAD systems can differentiate bronchioles, walls of the lung, and the lung parenchyma during highlighting abnormal lesions, allowing doctors to detect alterations without error. In contrast, CAD is dedicated to identifying malignant and benign lesions [16]. New methods have so far been developed to find and identify lung nodules smaller than 3 mm [17]. Based on the tumor's texture, personality, stage, and invasion area, AI tries to customise particular solutions for a specific individual.

Early lung cancer imaging findings include pure ground-glass nodules (GGN), partially solid nodules, and solid nodules [18]. The 5-year survival rate for lung cancer, which manifests as partial solid nodules or GGN, can reach over 95% with the early identification and surgical resection of the tumor [19]. It might be challenging to differentiate between benign and cancerous lung nodules early on. Low-dose CT (LDCT) is the best option for lung cancer screening [20]. The early detection and management of lung cancer is the key to its elimination.

The use of AI may help with the radiologists' limited number and may allow for the early diagnosis of lung tumors. The system of CAD of pulmonary lesions has advanced significantly in recent years utilising conventional machine learning (ML) techniques [21]. New articles have demonstrated that the technology of AI is more effective than radiologists in detecting GGNs larger than 5 mm and screening nodules ranging from 0 to 3 mm [22]. But, in practical practice, systems of CAD cannot be used exclusively. The system of vasopressors (VS)-CAD, also known as the ClearRead CT software, can enhance the probability of identification of small pulmonary lesions by suppressing the natural lung structures, especially blood vessels [23]. The CAD system has the ability to detect the small lesions of the lung that radiologists might miss.

Convolutional neural networks (CNNs) and Deep learning (DL) have demonstrated their great potential in the identification of pulmonary lesions and are successful in segmenting and categorising pulmonary lesions with the development of AI [24]. Hua et al. developed a system of DL-based CT detection for the nodules of the lung that exceeds the conventional CAD method in terms of sensitivity and specificity, with 73% and 80%, respectively [25]. By examining the patient's most recent and past CT volumes, Ardila and his colleagues could construct a DL-based model to determine the probability of developing a lung tumor [26]. However, the accuracy of lung nodule detection by AI needs to be tested in real-world scenarios, and additional cases must be corrected [27]. We believe that DL-based CT is more accurate than conventional CAD for detecting lung lesions.

Histopathology inspection

Historically, the most crucial factor in lung cancer diagnosis has been pathological examination, which is a useful method for distinguishing alterations from the tissue surroundings and determining the biopsy species [28–30]. However, the majority of patients that get biopsies are terminal and incurable. Additionally, the sample only represents a portion of the tumor, making it impossible to identify all abnormalities [31]. Most pathological techniques, particularly in poorly differentiated tumors, are restricted to differentiating ambiguous histological characteristics. Histological analysis may create thorough AI diagnosis strategies for biopsy samples using many aspects of AI research [31].

Studies on the development of sensitive and precise diagnostic techniques are well established. A fresh source of huge data for tailored treatment was gathered using image computing and high-throughput whole-slide scanning methods. AI is combined with information of data predicatively and prognostically, as opposed to standard clinical pictures, to produce correct histology slide analysis [32]. Additionally, pathologists can improve efficiencies by utilising mechanised equipment that can provide large volumes of slides and do great analysis [33]. An accessible technique that aids in standardising the assessment of the lung tumor subtype is immunohistochemical (IHC) staining, which uses mucin staining [34]. A trustworthy IHC panel was used in the Koh et al. study to identify the histological subtype of lung cancer. They used a decision tree with a support vector machine (SVM) as two AI techniques to determine the equivocal morphology in 30 tiny lung cancer biopsy cases. They got the maximum accuracy of about 72% using the decision tree model that processed two markers (p63 and CK5/6) in the absence of a 3-marker IHC panel (i.e., TTF-1, Napsin A, and p40) [35]. Although AI speeds up processes and offers priceless images to aid in diagnosing lung cancer, its use in clinical settings is limited. The algorithm of technology has not been adequately enhanced to suit the requirements of extended patients, which is the main cause. The high cost is just another obstacle to AI's wide-scale application.

Monitor and AI

A liquid biopsy is a screening tool that differs from the conventional methods of invasively and laboriously extracting biopsy samples. Liquid biopsy is very helpful in identifying potential genetic changes that will inform therapy choices. Tumor-associated autoantibodies (TAAbs), tumor-associated antigens (TAAs), tumor-educated platelets (TEP), circulating tumor DNA (ctDNA), and other biomarkers have all been the subject of study in recent years [36]. The liquid biopsy is safer, less invasive, and more accurate than the conventional one.

Articles on liquid biopsy for tumor diagnosis now use AI-developed machine learning to find a limited number of biomarkers. As a subset of AI, machine learning (ML) is considered a fantastic technique for discovering millions of fragments of microcirculatory genomes fragments that are easier and more sensitive to discover than conventional approaches [37]. However, there is still much to be done before liquid biopsy can be used in clinical practice because of the restriction of tumor-interstitial heterogeneity [38]. The combination between liquid biopsy and AI will be beneficial for investigating lung lesions.

Treatment and AI

Intelligent lung cancer detection and therapy have gradually become a trend for future development as a result of the advancement of AI. A clinical decision support system (CDSS) is a tool that uses AI to analyse a wide range of clinical experiences (such as evidence-based medicine, clinical guidelines, prescription instructions, etc.) as well as clinical and fundamental data on patients to help doctors make decisions about patient care [39]. Some cancers, including lung cancer, have been diagnosed and treated using Watson for Oncology (WFO), the greatest representative of CDSS. A retrospective study was carried out to assess the consistency of multidisciplinary teams (MDT) and WFO in managing lung tumor cases [40]. According to the findings, lung cancer patients had a 92.4% overall coincidence rate between WFO and MDT. The recommended treatments for lung tumors in stages I and IV are consistent. However, it is relatively low in localized small-cell lung cancer and stage II-III NSCLC. The stage III NSCLC compliance rate, in particular, was only 80.8%.

But CDSS can't take the position of doctors entirely. Instead, it might serve as a complement, particularly for people with complicated illnesses. Additionally, due to the complexity of clinical medicine, shared decision-making and doctor-patient communication can become more crucial in treatment [40]. We can not use AI for the entire process of the management of lung cancer, but the combination between AI and doctors is the ideal way to deal with the disease.

Surgery

Lung cancer has been successfully treated with a lot of video-assisted thoracic surgery (VATS) [41,42]. Numerous earlier research has shown that thoracoscopic lobectomy is associated with a quicker postoperative recovery, less trauma, and fewer problems than thoracotomy [43]. There will be some blind spots throughout the procedure, nevertheless, because of the limitations of surgical equipment and thoracoscopy. Additionally, the instrument arm lacks the flexibility to do more complicated thoracoscopic surgery [44].

AI has the potential to completely change how surgery is learned and performed [45]. Surgeons play a crucial part of incorporating AI into clinical practice. The use of AI by surgeons helps them to assess intraoperative developments in real time, enhance their capacity to make intraoperative decisions, and ultimately improve surgical results. Robotic surgery is a new development of minimally invasive surgery, which is part of the physical branch of artificial intelligence. The Da Vinci-robot-assisted thoracic surgery (RATS), a representative of robot surgery, offers a convenient operation function, and precise system, breaking the limitations of eyes and hands while minimising trauma and discomfort for patients. Several studies have shown the safety and viability of the surgical system of Da Vinci for lobectomy [46–48]. VATS and RATS are similarly efficient and secure in managing non-small-cell lung tumors, although the half-life of RATS is longer. The incidence of surgical complications, intraoperative blood loss, postoperative drainage days, postoperative in-hospital mortality, and postoperative hospital stay was also not significantly different between RATS and VATS. Despite the previous-mentioned benefits of RATS, there are some issues with the RATS technology, such as greater hospital expenses and lengthier operative time, which might prevent RATS from progressing further [46–48]. The utilisation of AI by surgeons may lead to excellent outcomes in surgeries and make them easier and shorter. Also, AI may help the surgeon make the right decision quickly.

Radiotherapy

The conventional therapy for advanced non-small cell lung cancer (NSCLC) that cannot be surgically removed is chemotherapy [49]. Radiology has greatly benefited from the development of AI and radiation, which helps achieve precision therapy [50]. The utilisation of knowledge-based algorithms to plan management, a clinical example of stereotactic body radiation (SBRT) for patients with lung tumors, was created in a study. This article included 105 SBRT plans for treating lung tumor patients, involving 2 three-dimensional conformal radiation therapy (CRT), 6 VMAT, and 97 IMRT. Combining the technologies mentioned above allowed for knowledge-based model (KBM) training, and numerous verification results revealed that the plans of SBRT for lung tumors produced by KBM were comparable to clinical plans. Current radiation treatment methods are intended to destroy malignancies, but they frequently harm healthy tissue. AI will be used to successfully fix the issue and be able to modify the treatment's dosage. In addition, the ideal radiation beam and angle can be chosen automatically without regard to the patient's position [51]. Additionally, intelligent systems can control image, dose rate, and exposure time. Physicians are anticipated to use AI to make decisions quickly and efficiently [52]. Using AI for managing lung cancer by radiotherapy showed good results as it helps in planning, determining dose, and following up.

Targeted therapy

By focusing on chemicals in cancer cells and creating potent blockers to interfere with the process of carcinogenesis, targeted therapy is a novel method for treating cancer with little harm to healthy tissues [53]. When we wish to move forward, figuring out what transpired and which place changed in the region of mutation is a crucial step. AI offers a wealth of data and permits a thorough study, which helps us develop different strategies for preparing for valuable options. Additionally, an intelligent computer creates a linked model to locate and highlight a targeted gene or associated biological pathway. With AI aid, newly identified therapeutic targets may be virtually screened to quickly uncover targeted old medications or new compounds [54]. Reapplying natural items or old medications to new indications may be successful using AI-assisted reverse docking. The DL model of AI can also predict the features of excretion, absorption, toxicity, metabolism, and distribution (ADMET), which will increase the rate of success of in vivo tests [55]. Targeted therapy is developing daily, and its combination with the developing AI will provide good options for managing lung cancer.

Challenges in the future

The use of AI to understand and cure lung cancer is developing, but there are still many challenges to be solved. AI should adhere to unified planning and overall targets in healthcare settings and standard and normalised principles defined by the authorities, which easily provide precise practice details in a real situation [50]. AI, which learns from examples rather than being programmed, is implemented through machine learning (ML). Generally speaking, ML needs more examples to learn a skill than someone does [56]. Data collection is very important. Electronic health records, which provide all the specific information about hospital patients, are a simple method to acquire information on patients' medical records. But many fragmented records offer a problem for AI clinical use due to various recording requirements in various departments or districts [57]. Additionally, sample quantities, patient privacy, language, cultural difficulties, and other issues prevent access to available data [58,59]. AI should be used in different healthcare settings as it gets information from learning, not programming.

Discussion

The findings of Liu et al. demonstrate the high usefulness of the AI-aided diagnosis system based on CT images in diagnosing lung cancer and suggest that it may be pushed as a technique to diagnose lung cancer in clinical settings. Future directions for AI development include integrating various data, including CT images, patient history, pathology, patient follow-up, physician diagnosis, and clinical features, into the AI-assisted diagnosis system to in order provide a complete evaluation of patients. This will not only increase the accuracy of lung cancer diagnosis and lighten the workload of doctors, but it may also alter the established order of medicine and encourage the balanced development of medical resources [60]. One believes that with more development of AI, the diagnosis of lung cancer will be easier and faster than these days with more accuracy.

Thong et al. performed a study that concluded that AI-based imaging could be used in lung cancer screening programs to accurately diagnose the disease. Additional high-quality diagnostic test accuracy (DTA) research on large lung cancer screening populations is needed to support AI's significance in early lung cancer detection [61].

According to Abadia et al., the sensitivity of AI is comparable to a skilled radiologist in a group of patients with complex lung illness, and the tool aids in discovering previously undetected lesions. Due to the rising patient load and requirement for quicker turnaround times, AI also makes it possible for specialists to analyse lung nodules more quickly and assertively, which is advantageous to both patients and hospitals [62]. Thus, the development of AI will make it more sensitive than the skilled radiologist.

A non-randomised clinical study was performed by Chen et al. to determine the role of AI in the diagnosis of non-small-cell lung cancer (NSCLC). They found that doctors can use the AI film reading system based on deep learning as a secondary detection tool to screen for NSCLC; however, it has a greater false positive rate than radiologists for diagnosing the disease. In the meantime, the deep learning-based AI film reading system also has some guiding value for NSCLC diagnosis and therapy monitoring [63]. The diagnosis of lung lesions by AI is steel under question as it has a high rate of false positive diagnosis. So AI needs more developments in this area.

Wu et al**.** compared two methods of double sleeve lobectomy, including thoracotomy and VATS, for the management of NSCLC. They concluded that treating NSCLC with uniportal VATS double sleeve lobectomy is efficient and safe. The uniportal VATS cohort had lower levels of postoperative discomfort. The postoperative survival and complication rates were comparable to those of the conventional thoracotomy method with a large incision [42]. AI needs more development to make a significant difference in the surgical treatment of lung cancer.

AI is able to aid in the treatment of lung cancer, from detection, diagnosis, and decision making through prognosis prediction. AI could reduce the labour work required for low-dose computed tomography (LDCT), chest X-ray (CXR), and pathology slide reading. AI as a second reader in LDCT and CXR scanning minimises radiologists' effort while increasing the accuracy of nodule detection. The future of AI applications in lung cancer may be focused on integration and applications. First, because AI is a data-driven technology, scientists can combine small datasets to produce large data sets for training. But, restrictions governing data sharing provide a significant barrier for researchers. Federated learning, an approach that shares learnt parameters rather than data, is a simple solution. Integrating all variables such as radiography, pathology, demography, and clinical data, as well as both old and new technology, could better reflect reality. The combination of several elements also aids researchers in the development of predictive models. AI models of lung cancer exhibit objectivity, high efficiency, multiplicity, and repeatability. This will surely reduce the stress on clinicians, reduce misdiagnosis due to tiredness, and may transform the current medical model. A rising variety of AI models are being used to monitor diverse data sets, such as electronic health record data, imaging modalities, histopathology, and molecular biomarkers, in order to enhance the accuracy of disease risk prediction, detection, and treatment response prediction. However, AI is still in its infancy and has limitations in lung cancer application. The vast majority of medical AI technologies are only capable of detecting a particular disease. As a result, another difficulty for AI development is disease diagnosis and differentiation. Despite the early findings' potential, more study is needed to standardise AI data and increase both the generalizability and interpretability of outcomes. AI integrated with radiography, genomics, pathology, electronic health records, and other data streams and combined with 5G may be of considerable therapeutic utility in lung cancer. The use of computer-aided detection of lung nodules in screening programmes has changed disease detection. Furthermore, the ability to apply AI techniques to identify patients at risk of acquiring lung cancer during their lifetime can aid in the development of a more targeted screening programme.

Conclusion

1. The aspirations to increase the effectiveness and efficiency of health care continue to stimulate a wide range of innovations, including AI.

2. Medical professionals may make judgments quickly and accurately by using AI technologies in order to evaluate huge amounts of data, including physiological imaging and clinical presentations.

3. The computer-assisted diagnosis will assist in identifying early lesions, improving the prognosis for patients. Although there is still much to be done, the use of AI in lung tumors has a bright future due to the lack of standard databases, standardised principles established by different institutes, and related national policies and regulations. More sensitive and accurate algorithms or machines are required to achieve the goal of individual treatment.

4. AI has become widely used and is crucial for resolving challenging problems across various fields.

5. Research on AI in oncology mainly focuses on dynamic monitoring, diagnosis, and individualised treatment.

6. The use of AI to understand and cure lung cancer is developing, but there are still many challenges to be solved.

7. The use of AI in lung tumors has a optimistic future due to the lack of standard databases, standardised principles established by different institutes, and related national policies and regulations.

8. More sensitive and accurate algorithms or machines are required to achieve the goal of individual treatment.

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Peculiarities of carrying out pre-vaccination diagnostics in Ukraine in order to determine the organism adaptability

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Abstract

This article focused on peculiarities of carrying out pre-vaccination diagnostics in Ukraine in order to determine the organism adaptability.

Aims: The aims of this study are to investigate the peculiarities of performing pre-vaccination diagnostics in Ukraine to ascertain the adaptability of the organism.

Methodology: A descriptive cross-sectional study design was used. Secondary data was utilised and analysed. Descriptive statistics obtained and utilised

Results: showed that Ukraine has over 4,000 registered microbiological laboratories, but only 2 are allowed to work with microorganisms of the first pathogenic group, 402 with the second, and all others with the third and fourth. The relevant information indicates that there are no BSL-4-compliant laboratories in Ukraine. The barriers and facilitators are such as organisational, logistical, and resource-related challenges, as well as factors that promote or delay the use of diagnostic tests in the vaccination process. In 2021, 88.5% of individuals received the first dose of the measles vaccine, while in 2020 and 2019 the coverage rates were 84.9% and 93.2%, respectively. Similarly, for the second dose of the measles vaccine, the coverage rates were 85.9%, 81.9%, and 91.7% in 2021, 2020, and 2019, respectively. Among the reasons, the desire to protect oneself (63.6%) and to others (12.5%) were the most frequent justifications for vaccination; 12.8% of respondents chose to be vaccinated for employment-related reasons. As the study found among other reasons there was the lack of awareness and knowledge about the importance of pre-vaccination diagnostics among healthcare providers and the general public, a significant barrier to compliance with national and international guidelines.

Scientific Novelty: Pre-vaccination diagnostic peculiarities

Conclusion: The research findings suggest that there may be peculiarities in the implementation of pre-vaccination diagnostics in Ukraine, with potential challenges related to adherence to established guidelines, stakeholder perspectives, and organisational factors.

Keywords: Pre-vaccination, Diagnostics, Adaptability, Organism, Ukraine, Peculiarities.

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Introduction

Vaccination is a critical technique for preventing the spread of infectious diseases and protecting public health. Pre-vaccination diagnostics must be carried out to ascertain the adaptability of the recipient's organism before vaccinations are given. These tests include the serological tests, molecular tests, Skin tests, Antigen tests and others. These reduces the possibility of negative responses while assisting in ensuring the vaccine's effectiveness and safety. In Ukraine, pre-vaccination diagnostics are a critical component of the immunisation program. More than 20 lethal illnesses may now be prevented with vaccinations. Vaccinations currently save 3.5-5 million lives each year from diseases such as measles, diphtheria, tetanus, pertussis, and influenza [1].

Ukrainian diagnostic facilities availability in order to determine the adaptability of the organism provide information on immunological considerations for vaccine strategies [2,3], the use of diagnostic testing to make vaccination programs more effective [4-5], and checklists for COVID-19 vaccination [6]. Additionally, the FDA closely monitors vaccine development and safety through various surveillance systems [7], and vaccines typically contain an active component that generates an immune response [8].

Ukraine's national immunisation program covers a broad variety of diseases, including measles, polio, hepatitis, and influenza [9]. According to UNICEF, 10,682,752 persons in Ukraine have gotten at least one dose of the COVID-19 vaccine, and 7,596,587 were given two doses and are fully protected. For practical public health considerations for the prevention and management of infectious diseases, The Lancet provides information on the pre-war health burden of Ukraine [10].

As of the month of February in the year 2022, almost 31 million doses of vaccination had been distributed across Ukraine. There is a problem in Ukraine with vaccine reluctance since just 53% of Ukrainians have been immunised against polio. The Centers for Disease Control and Prevention advises unvaccinated travellers under 60 who are visiting Ukraine to acquire the hepatitis B vaccine [11].

17.2% of persons were vaccinated with AstraZeneca, 29.6% were vaccinated with Coronovac, 41.7% were vaccinated with Pfizer-BioNTech, and 11.5% were vaccinated with Moderna, according to a study from November 2021 [12–14]. However, there is a problem in Ukraine with people being reluctant to be vaccinated, since just 53 percent of the population has been immunised against polio. According to recent research conducted by UNICEF, 42 percent of Ukrainians who have not had the COVID-19 vaccination are open to receiving it [15]. Unvaccinated travellers under the age of 60 who are going to Ukraine are encouraged by the Centers for Disease Control and Prevention to be vaccinated against hepatitis B.

Vaccinations are routinely administered in accordance with the immunisation schedule in Ukraine. The vaccination schedule defines the exact vaccinations that are to be provided at various ages, and pre-vaccination diagnostics are carried out to confirm that recipients are eligible for immunisation based on their current state of health and their medical history [16].

In Ukraine, pre-vaccination diagnostics helps in checking for contraindications. Severe allergic responses, immunodeficiency, pregnancy, or an acute sickness are a few examples of contraindications. It's crucial to screen for contraindications to find people who may not be a good candidate for vaccination or who might need extra care. In Ukraine, there is a widespread immunisation program that protects against illnesses including measles, polio, hepatitis, and influenza. Only 53% of Ukrainians have had a polio vaccine, raising concerns about vaccine reluctance in that country [17].

Pre-vaccination diagnostics in Ukraine also include testing that is performed in the laboratory. It is possible that blood tests will be required to screen for immunity levels, such as antibodies against a certain illness, in order to establish whether or not the vaccination is required [18] and place a significant emphasis on the monitoring of patients for the occurrence of adverse effects after immunisation. This information is used to evaluate the safety of vaccinations [19].

The pre-vaccination diagnostics process is affected because of limited access to healthcare services, inadequate laboratory facilities, a lack of awareness and education among healthcare providers and the community about the importance of pre-vaccination diagnostics, as well as variations in vaccine availability and administration practices across different regions of Ukraine. Vaccines are also administered differently depending on the region of Ukraine [20].

The pre-vaccination diagnostics in Ukraine are a crucial part of the whole vaccination procedure. They are carried out to evaluate the degree to which the recipient's body can adapt to the vaccine and to guarantee that vaccinations are provided in a manner that is both safe and effective. The pre-vaccination diagnostics continue to play an important part in preserving public health and halting the development of infectious illnesses in Ukraine, despite the difficulties and factors that must be taken into account. It is necessary to do further research and make additional efforts in order to improve the execution of pre-vaccination diagnostic and guarantee that vaccination programs are implemented effectively throughout the whole country.

Research Problem

Our research problems may be the following:

1. Access and availability of healthcare services, laboratory facilities and testing

2. Awareness and Education

3. Vaccination coverage, contraindication screening and vaccine adverse event monitoring

There are many research issues surrounding the pre-vaccination diagnostics in Ukraine, including access to healthcare services, knowledge and education, laboratory supplies and testing, contraindication screening, vaccine adverse event monitoring, geographic variations, and effects on vaccination coverage. The deployment of pre-vaccination diagnostics may be strengthened, and vaccination programs in Ukraine can be made safer and more successful by tackling these research issues via thorough study.

Research Focus

The research should target the following key areas, including assessment of current practices, identifying barriers and facilitators, evaluating the impact on vaccination outcomes, developing Interventions, and policy implications. The research should focus on the peculiarities of performing the pre-vaccination diagnostics to determine the adaptability of the organism in Ukraine. In conclusion, research on the distinctive methods of pre-vaccination diagnostics to ascertain the adaptability of the organism in Ukraine should include assessment of current practices, identification of challenges and enablers, assessment of impact on vaccination outcomes, development of interventions, and informing policy development.

Research Aim and Research Questions

The aims of this study are to investigate

1. Current practices of pre-vaccination diagnostics.
2. Barriers and facilitators to pre-vaccination diagnostics.
3. Compliance with national and international vaccination guidelines.
4. Knowledge, attitudes, and practices of stakeholders.

Research Questions

1. What are the existing norms for pre-vaccination diagnostics in Ukraine, particularly the accessibility and calibre of laboratory resources, adherence to screening protocols for contraindications, and observation of adverse reactions to vaccination?

2. What are the vaccination results in Ukraine, such as vaccine acceptability, uptake, and coverage rates, affected by pre-vaccination diagnostics?

Research Methodology

General Background

To stop the spread of infectious illnesses and safeguard the community health, vaccine research is crucial. Vaccination programs are intended to provide protection against certain illnesses by inducing an immunological response from the body without actually transmitting the disease. Pre-vaccination diagnostics, often referred to as pre-vaccination screening or evaluation, are a crucial stage in the vaccination process to analyze how well a person's body will respond to the vaccine.

Due to a variety of issues, such as disparities in healthcare infrastructure, resources, cultural attitudes, and socioeconomic considerations, the implementation of pre-vaccination diagnostics in Ukraine may encounter anomalies or particular problems. For pre-vaccination diagnostics to be implemented as effectively as possible and for Ukraine's vaccination programs to be successful, it is crucial to comprehend these differences.

Research on the unique aspects of performing pre-vaccination diagnostics in Ukraine may add to the body of knowledge in this area and provide light on present procedures, difficulties, and areas for development. With the use of such research, evidence-based strategies and policies may be developed to increase the use of pre-vaccination diagnostics, streamline vaccination campaigns, and boost public health outcomes in Ukraine.

Sample / Participants / Group

Individuals who are eligible for immunization in Ukraine, including children, adolescents, adults, and the elderly, would make up the sample/participants/group for this research study. In terms of age, gender, geography, and vaccination status, the sample/participants/group would probably be heterogeneous.

Instrument and Procedures

The research study may utilize a combination of quantitative and qualitative research methods, depending on the research questions and aims. The research study may involve the following procedures:

Data Analysis

Data collection: A pretested questionnaire was utilized to collect the secondary data from the document related to vaccination policies, guidelines, and reports. Data was analyzed using descriptive and inferential statistical methods, such as frequencies, percentages, to examine the current practices and outcomes of pre-vaccination diagnostics.

Research Results

Current practices of pre-vaccination diagnostics

The results from (Table 1) show that Ukraine has over 4,000 registered microbiological laboratories, but only 2 are allowed to work with microorganisms of the first pathogenic group, 402 with the second, and all others with the third and fourth. That's why Ukraine's official categorisation of high-containment labs includes those that operate with first- and second-pathogenic microorganisms [21].

Table 1. **Current Practices of Pre-Vaccination Diagnostics in Ukraine**

Variable	Frequency
Availability of Laboratory Facilities	(402)
First group Lab	(02)
2nd group Lab	(402)
3rd & 4th group	(3596)
BSL4	(0)
Adherence to Contraindication Screening Guidelines	(WHO, CDC)
Monitoring of Adverse Events Following Vaccination	(WHO, CDC)

Source: Authors' development based on The National Academies Press n.d.

Results also demonstrate careful adherence to contraindication screening guidelines of WHO and CDC. A vaccination schedule for Ukraine from the WHO website is used to determine vaccine timing and kinds [22]. The Centers for Disease Control and Prevention (Ukraine), website of the World Health Organization offers screening checklists and a global manual on surveillance of adverse events following immunisation, which offers instructions on monitoring and reporting AEFI [23-24]. The information at hand indicates that there are no BSL-4-compliant laboratories in Ukraine. In order to reduce the possibility of an unintentional release, the World Health Organisation encouraged Ukraine to get eliminate of the high-threat viruses that were still present in the nation's public health labs. Despite the effect of the ongoing war on crucial medical services and supplies, the Ukrainian health system is nonetheless resilient [25]. The condition of the availability and calibre of laboratory facilities for performing pre-vaccination diagnostics, including the accessibility of essential equipment, qualified employees, and resources in Ukraine, is not up to global standard [26].

According to Ukrainian research, various systemic weaknesses are indicated by current pre-vaccination diagnostic techniques. The accessibility and quality of testing facilities, the detection of contraindications, and the monitoring of adverse responses to immunisations are all reportedly issues. These findings suggest that the current system need improvement.

Barriers and facilitators to pre-vaccination diagnostics

The results (Table 2) uncovered the barriers and facilitators to the implementation of pre-vaccination diagnostics in Ukraine, such as organisational, logistical, and resource-related challenges, as well as factors that promote or hinder the use of diagnostic tests in the vaccination process [26–28].

Table 2. Barriers and facilitators to pre-vaccination diagnostics

Variable	Barriers	Facilitators
Healthcare Providers	Limited access to diagnostic facilities, Lack of awareness among patients and providers	Clear guidelines and protocols, Training and education for healthcare providers
Public Health Officials	Limited resources and logistical in remote areas	Government support and funding Strong collaboration and coordination among stakeholders
Laboratory Personnel	Lack of standardized protocols and guidelines Limited resources and infrastructure	Quality assurance programs and proficiency testing technical training and support for laboratories

Source: Authors' development based on Essential Programme on Immunization n.d.

Organisational barriers are related to the coordination, management, and include an absence of clear guidelines and protocols for the use of diagnostic tests in the vaccination process and fragmented healthcare system due to decentralised healthcare system, with multiple stakeholders involved in the vaccination process [29]. Logistical challenges refer to issues related to the availability, storage, transportation, and distribution of diagnostic tests [29]. Resource-related challenges include issues such as limited funding and budget constraints. Results also showed that among the factors that can promote the use of diagnostic tests in the vaccination process in Ukraine are, evidence-based guidelines and protocols, strong leadership, effective coordination among healthcare providers, and adequate training and capacity-building, leveraging existing healthcare infrastructure and resources, such as utilising established laboratory networks or leveraging digital health technologies for data management and reporting [30].

The findings highlight organisational, logistical, and resource-related difficulties in conducting pre-vaccination diagnostics in Ukraine. Organisational obstacles include a disjointed healthcare system with many stakeholders and a lack of defined norms and practices. The restricted availability of diagnostic tests and the need for a cold chain are logistical problems, while financing and budget restrictions are resource-related challenges. Evidence-based recommendations, strong leadership, efficient coordination among healthcare practitioners, and the utilisation of already-existing healthcare infrastructure and resources are all factors that might encourage the use of diagnostic testing throughout the immunisation process.

Compliance with national and international vaccination guidelines

The results from (Table 3) of the available statistics showed that the year 2021, 88.5% of individuals received the 1st dose of the measles vaccine, while in 2020 and 2019, the coverage rates were 84.9% and 93.2%, respectively. Similarly, for the 2nd dose of the measles vaccine, the coverage rates were 85.9%, 81.9%, and 91.7% in 2021, 2020, and 2019, respectively. The BCG vaccine coverage rates were 86.5%, 92.7%, and 83.8% in 2021, 2020, and 2019, respectively.

Table 3. Vaccinations Coverage from 2019 to 2021

Vaccination Name	2021
Corona full vaccination 18-59 years	46%
Corona full vaccination 60 years &above	33%
Corona Booster Vaccination 18-59 years	2%
Corona Booster Vaccination 60 years &above	2%
Measles-containing vaccine, 1st dose	88.5%
Measles-containing vaccine, 2nd dose	85.9%
BCG	86.5%
DTP-containing vaccine, 1st dose	90.8%
DTP-containing vaccine, 3rd dose	78.1%
Hib, 3rd dose	87.2%
HepB, 3rd dose	77%
HepB, birth dose (given within 24 hours of birth)	56.3%
HepB, birth dose total (including those given within and after 24 hours of birth)	90.4%
Influenza child age group 1	0.27%
Influenza child age group 2	0.68%
Polio, 3rd dose	78.3%

Rubella-containing vaccine, 1st dose	88.5%

Source: Authors' development based on WHO Immunization Data portal n.d.

For the DTP-containing vaccine, the coverage rate for the first dose was 90.8%, 92.6%, and 88.9% in 2021, 2020, and 2019, respectively. However, for the third dose, the coverage rates were 78.1%, 81.3%, and 79.9% in 2021, 2020, and 2019, respectively. The coverage rate for the 3rd dose of Hib vaccine was 87.2%, 85.2%, and 80% in 2021, 2020, and 2019, respectively. The Hepatitis B vaccine coverage rate at birth was 90.4% and 100% in 2021 and 2020, respectively. The coverage rate for the 3rd dose of polio vaccine was 78.3%, 84.2%, and 77.8% in 2021, 2020, and 2019, respectively. For the 1st dose of rubella vaccine, the coverage rates were 88.5%, 84.9%, and 93.2% in 2021, 2020, and 2019, respectively. Corona full vaccination 18-59 years 46% full vaccination and 2% booster dose while Corona full vaccination 60 years and above 33%% full vaccination and 2% booster dose [31].

Results (Table 4) showed the extent to which healthcare providers and laboratories in Ukraine comply with National and international guidelines for pre-vaccination diagnostics, the availability and accessibility of diagnostic tests, quality assurance measures, Strengthening data reporting mechanisms, High level of awareness, Training and education, Laboratory infrastructure and equipment requirements are followed as per national and international guidelines for pre-vaccination diagnostics, such as those recommended by the World Health Organisation (WHO) or other relevant authorities [32–34].

Table 4. Compliance with national and international guidelines

Variables Area of Compliance
National and international guidelines for pre-vaccination diagnostics
Enhancing the availability and accessibility of diagnostic tests
Improving quality assurance measures,
Strengthening data reporting mechanisms
High level of awareness
Training and education
Laboratory infrastructure and equipment requirements

Source: Authors' development based on National Library of Medicine n.d.

These studies highlight the importance of assessing the compliance of healthcare providers and laboratories in Ukraine with national and international guidelines for pre-vaccination diagnostics. Identifying areas of non-compliance can help inform strategies for improvement, such as enhancing the availability and accessibility of diagnostic tests, improving quality assurance measures, and strengthening data reporting mechanisms. Aligning Ukrainian practices with established guidelines can contribute to the effective implementation of pre-vaccination diagnostics and enhance the overall vaccination process.

Knowledge, attitudes, and practices of stakeholders

Results (Figure 1) examined the knowledge, attitudes, and behaviours of health care professionals, patients and co-workers.

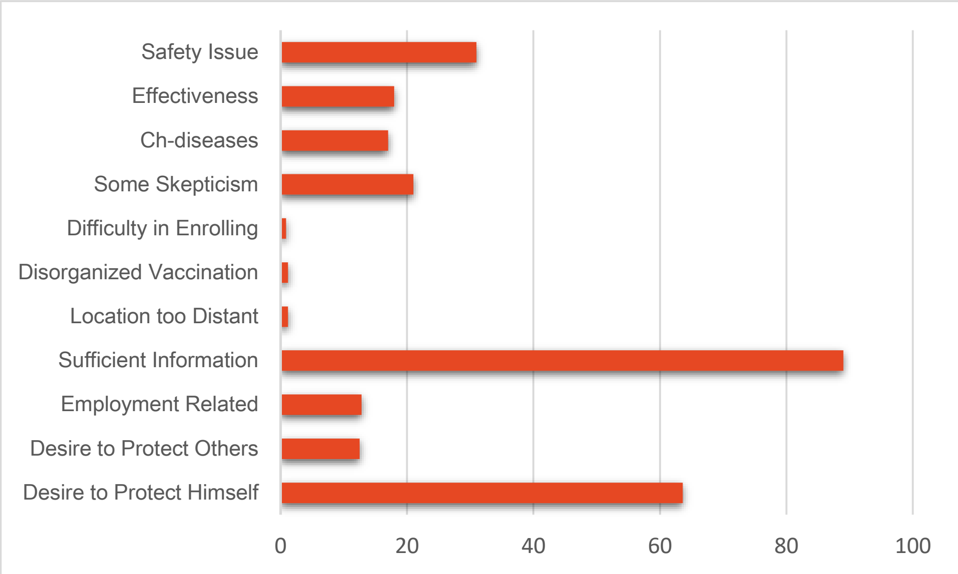

Figure 1. Knowledge, attitudes, and practices of stakeholders

Source: Authors' development based on COVID-19 KAP n.d.

Total participants were 1390 out of them being women and 21.7% being males and the majority, were over 65 years old and Ukraine's 18 regions were covered. Among the reasons, the desire to protect oneself (63.6%) and to others (12.5%) were the most frequent justifications for vaccination; 12.8% of respondents chose to be vaccinated for employment-related reasons, 89% of respondents claimed to have gotten sufficient information prior to vaccination, 8% complained that they had no information, and 3% were unsure of their response. Four out of seven respondents who accepted vaccination due to job security also said that they were at danger of losing their employment if they declined. Amongst them 95.8% of respondents said they had no trouble getting their shots, while 1.2% said the vaccination locations were too distant from their homes,1.2% of participants saw a generally disorganized vaccination site, 0.9% reported trouble enrolling for vaccinations, 0.9% complained about uncomfortable work hours and lengthy lines, 21% expressed some scepticism; and 3% did not reply. The effectiveness of the vaccination (18%), current chronic conditions and contraindications (17%), as well as side effects and vaccine safety (31%), were often raised as concerns by respondents [35]. A connected study discovered, among other things, a lack of awareness and knowledge about the necessity of pre-vaccination diagnostics among healthcare practitioners and the general public, which is a significant barrier to complying with national and international requirements [36]. A recent study conducted on vaccination issues, beliefs, and practices among Ukrainian migrants has highlighted the necessity of identifying their attitudes and practices towards vaccination in order to enhance their vaccination coverage [25-36]. With more than 50% of Ukrainians believing that vaccines have not been adequately studied, vaccine hesitancy is a serious problem in that country. The WHO European Region's current vaccination coverage rates are insufficient to provide protection and halt the spread of diseases that can be prevented by vaccination. Vaccine hesitancy, which is driven by a variety of factors including lack of trust in the vaccine or provider, no perceived need for a vaccine, and access concerns, is a barrier to achieving high vaccination uptake [37].

The research discovered that healthcare professionals and the general population in Ukraine lack understanding and information about the value of pre-vaccination diagnostics, which is a major obstacle to adhering to national and international norms. More than 50% of Ukrainians believe that vaccinations have not been adequately evaluated, which contributes to the WHO European Region's poor immunization coverage rates. Vaccine hesitancy is a serious problem in Ukraine. The lack of faith in the vaccine or the provider, the absence of a perceived necessity for a vaccine, and access concerns are obstacles to achieving high vaccination uptake in Ukraine.

Discussion

Current practices of pre-vaccination diagnostics

The findings from the study in Ukraine highlight several important issues related to pre-vaccination diagnostics. One key issue is the limited availability and quality of laboratory facilities in the country. The study revealed that out of over 4,000 registered microbiological laboratories in Ukraine, only 2 are allowed to work with microorganisms of the first pathogenic group, and 402 with the second, while the rest work with the third and fourth groups. This suggests that Ukraine's official categorisation of high-containment labs may not align with international standards, as laboratories that are permitted to work with first-pathogenic microorganisms in Ukraine may not be equivalent to BSL-4 or BSL-3 labs found in other countries. There are only two such facilities in India, the National Institute of Virology in Pune, which is a facility specifically designed to investigate human viruses, and the High Security Animal Disease Laboratory in Bhopal, which is a facility specifically designed to study animal infections, according to a study conducted there [38]. Similarly, there are just four BSL-4 laboratory suites that are currently in use in the United States [39].

Furthermore, the study highlighted the importance of adhering to contraindication screening guidelines before administering vaccinations. The study mentioned the use of vaccination contraindication and precaution screening guidelines established protocols. These all follow the CDC's standard recommendations to make vaccinations as safe and effective as possible. Assessment of patient immunisation status and determination of necessary vaccines, screening for precautions and contraindications, patient education, correct preparation and administration of vaccines, and documentation of the vaccines provided are all steps in the administration process. When applicable, organisational policies and procedures, manufacturer directions, and professional standards for pharmaceutical administration should always be followed [40]. Numerous investigations show that the majority of clinical laboratories in developing nations are of poor quality. For instance, the majority of clinical laboratories in Africa do not adhere to international standards because there are insufficient funds, appropriate rules, and a supportive healthcare system [41].

Ukrainian research found that the pre-vaccination diagnostic procedures used today indicate certain systemic flaws. According to the report, there are problems with testing facility accessibility and quality, with screening for contraindications and with keeping track of adverse reactions to vaccinations. These results imply that the present system needs to be improved. The results of the research conducted in Ukraine show how few labs are authorised to operate with higher-pathogenic microorganisms, as well as how poor the quality of those that is available. This raises questions about how well Ukraine's lab classification adheres to global norms. In accordance with international norms and CDC recommendations, emphasis was placed on following the contraindication screening procedures before providing immunisations. The research also uncovered widespread problems with facility accessibility, contraindication screening, and adverse reaction monitoring in pre-vaccination diagnostic practices. These findings highlight the need of strengthening Ukraine's present system in order to guarantee secure and efficient immunisation procedures.

Barriers and facilitators to pre-vaccination diagnostics

The results uncovered the barriers and facilitators to the implementation of pre-vaccination diagnostics in Ukraine, such as organisational, logistical, and resource-related challenges, as well as factors that promote or hinder the use of diagnostic tests in the vaccination process [26–28]. Organisational barriers are related to the coordination, management, and administration of pre-vaccination diagnostics and the key organisational challenges include an absence of clear guidelines and protocols for the use of diagnostic tests in the vaccination process and fragmented healthcare system due to decentralised healthcare system, with multiple stakeholders involved in the vaccination process [29]. Logistical challenges refer to issues related to the availability, storage, transportation, and distribution of diagnostic tests. In Ukraine, some of the key logistical challenges include limited availability of diagnostic tests and cold chain requirements [29]. Resource-related challenges can also be a barrier in pre-vaccination diagnostics implementation in Ukraine and include issues such as limited funding and budget constraints. Results also showed that among the factors that can promote the use of diagnostic tests in the vaccination process in Ukraine are, evidence-based guidelines and protocols, strong leadership, effective coordination among healthcare providers, and adequate training and capacity-building, leveraging existing healthcare infrastructure and resources, such as utilising established laboratory networks or leveraging digital health technologies for data management and reporting [30]. Uncertainty about the safety and effectiveness, a lack of faith in those factors, and a lack of safety and effectiveness evidence were among the hurdles identified by a different study. In a similar vein, it discovered facilitators such as healthcare professionals' recommendations, news from television, radio, and newspapers as primary sources of information, vaccine-related health education provided by healthcare professionals, and Expectation of returning to a normal social life by receiving all recommended vaccinations [42–44].

The research in Ukraine found both facilitators and obstacles to the use of pre-vaccination diagnostics. Organisational obstacles include a fragmented healthcare system brought on by decentralisation and a lack of defined norms and practices. Limited diagnostic test availability and cold chain needs are two logistical issues. Budget restrictions and a lack of money are resource-related issues. On the other hand, enablers include using current healthcare infrastructure and digital health technology for data management, strong leadership, and efficient coordination among healthcare practitioners, proper training, and evidence-based recommendations. The need for precise standards and procedures, enhanced stakeholder coordination, expanded diagnostic test accessibility, resolving budget limitations, and improving vaccine-related health education via various public awareness channels are just a few of the recommendations. The findings highlight organisational, logistical, and resource-related difficulties in conducting pre-vaccination diagnostics in Ukraine. Organisational obstacles include a disjointed healthcare system with many stakeholders and a lack of defined norms and practices. The restricted availability of diagnostic tests and the need for a cold chain are logistical problems, while financing and budget restrictions are resource-related challenges. Evidence-based recommendations, strong leadership, efficient coordination among healthcare practitioners, and the utilization of already-existing healthcare infrastructure and resources are all factors that might encourage the use of diagnostic testing throughout the immunisation process.

Compliance with national and international vaccination guidelines

The World Health Organisation's standards for herd immunity against serious illnesses have not been satisfied by Ukraine, which has one of the lowest vaccination rates in Europe. In 2021, 13% of Ukrainian children and 20% of adults lacked the poliovirus vaccine and adequate measles immunization, respectively. In contrast, measles vaccination rates ranged from 80.3% to 99.8% in other European nations like Hungary, Portugal, Russia, Turkey, Finland, and Poland in the same year. In order to eradicate the disease and stop its spread to at-risk groups, Hungary, in particular, immunizes almost all of its children against measles. To develop herd immunity, the WHO recommends that at least 95% of the population take the measles vaccine [45-46].

Europe was deemed polio-free by the World Health Organisation in 2002. But to keep this status, youngsters must continue to receive vaccinations. In 2018, Hungary had 99.9% of children vaccinated against polio, while Turkey had a polio vaccination rate of 98%. In stark contrast, just 71% of children in Ukraine were immunised against polio that year [47]. Low vaccination rates in Ukraine are the result of a number of issues, including widespread vaccine reluctance, which has been exacerbated in part by social media campaigns that propagate false information about vaccines and erode public confidence in Ukrainian institutions.

Low vaccination rates in Ukraine have led to disease outbreaks that could have been stopped. With almost 115,000 cases and 40 recorded fatalities, Ukraine saw the worst measles outbreak in Europe between 2017 and 2020. A type 2 vaccine-associated paralytic poliovirus epidemic was identified in 2021, with two cases of acute flaccid paralysis and more than 20 children testing positive for the virus. Measles outbreaks increased in other European nations in 2017 and 2018, with about 3,500 cases, but in Ukraine, rates peaked in 2019 at a significantly lower rate. However, there has been a recent increase in measles infections, which may be related to the widespread anti-vaccination attitudes in some European nations. It is significant to note that the monthly reported cases of [48].

This also showed the extent to which healthcare providers and laboratories in Ukraine comply with National and international guidelines for pre-vaccination diagnostics, the availability and accessibility of diagnostic tests, quality assurance measures, Strengthening data reporting mechanisms, High level of awareness, Training and education, Laboratory infrastructure and equipment requirements are followed as per national and international guidelines for pre-vaccination diagnostics, such as those recommended by the World Health Organisation (WHO) or other relevant authorities. These studies highlight the importance of assessing the compliance of healthcare providers and laboratories in Ukraine with national and international guidelines for pre-vaccination diagnostics. Identifying areas of non-compliance can help inform strategies for improvement, such as enhancing the availability and accessibility of diagnostic tests, improving quality assurance measures, and strengthening data reporting mechanisms. Aligning Ukrainian practices with established guidelines can contribute to the effective implementation of pre-vaccination diagnostics and enhance the overall vaccination process.

Knowledge, attitudes, and practices of stakeholders

A total of 1390 people from Ukraine's 18 regions participated in the survey; the majority of them were women (78.3%), and 53.4% of them were over 65. Participants came from all regions of Ukraine, with the Eastern and Western regions having the most presence. The desire to protect oneself (63.6%) and others (12.5%) were the most common motivations for vaccination, whereas 12.8% of respondents decided to get vaccinated for employment-related reasons. Information received prior to vaccination: 89% of respondents said that they felt they had gotten enough information, 8% said they had not, and 3% were unclear. The majority of respondents (95.8%) said they had no problem obtaining their injections; however some said they had difficulties enrolling in vaccinations (0.9%) or travelling to far-off vaccination places (1.2%). Concerns regarding vaccination efficacy (18%), present chronic diseases and contraindications (17%), side effects and vaccine safety (31%) and current chronic conditions were also brought up by respondents. The identification of vaccine hesitancy as a key obstacle to high vaccination uptake in Ukraine revealed that it was affected by mistrust, a false perception of necessity, and access problems. It was determined that a key obstacle to following recommendations is the lack of awareness and understanding regarding pre-vaccination diagnostics among healthcare professionals and the general population. To boost vaccination coverage, it is important to understand the attitudes and vaccination habits of Ukrainian migrants. These findings highlight the need for focused efforts to overcome obstacles like ignorance, vaccine hesitancy, and access problems, while also encouraging adequate information dissemination, addressing issues, and enhancing infrastructure and services for vaccination in order to ensure high vaccination uptake in Ukraine.

Similar findings from another study indicate that many participants, particularly children, had insufficient knowledge. The majority of individuals opposed immunizing boys. Compared to the other groups, parents and community members are less in favour of vaccination. Active community participation in primary preventive methods may increase vaccination uptake through strong awareness, the eradication of anti-vaccine prejudice, and the promotion of the acceptability of HPV vaccination [49]. Another study found safety issue, efficacy of vaccination, knowledge, associated with this vaccination [50]. On the tracking of negative reactions to vaccination in Ukraine, there is no precise information available. However, after vaccinations are authorized for use, the European Medicines Agency and state authorities continuously monitor the vaccine side effects [51]. In the US, the Vaccine Adverse Event Reporting System keeps track of any negative side effects following vaccination [52]. Growing numbers of civilians are finding it increasingly difficult to receive basic services due to rising costs, logistical difficulties, and destroyed infrastructure, according to a WHO evaluation of the country's health needs [53]. The monitoring of unfavourable reactions to vaccination was not mentioned directly in the assessment Ukraine was urged by the WHO to eradicate high-threat viruses kept in the nation's public health laboratories in order to stop "any potential spills" that would spread illness among the populace. The WHO has been working with Ukrainian public health labs to enhance security standards that help prevent unintentional or intentional release for a number of years [54].

In conclusion, the results of the study as well as those of other research shed light on the difficulties and obstructions that stand in the way of a high vaccine uptake in Ukraine. It was shown that one of the most significant barriers is hesitation about vaccination, which is caused by factors such as distrust, a lack of understanding, and access issues. It is necessary to make efforts to overcome these obstacles, including enhancing infrastructure and services for immunization, fostering community engagement, and ensuring that appropriate information is disseminated. In addition, it is essential to address the widespread lack of knowledge and comprehension of pre-vaccination diagnostics among medical professionals and the public community. It is feasible to achieve high vaccination coverage and protect the population from illnesses that may be prevented by addressing the concerns that have been raised and encouraging vaccination practices among migrants from Ukraine.

Conclusions and Implications

To ensure the security and effectiveness of vaccination programs, it is essential to understand the peculiarities of conducting the pre-vaccination diagnostics in Ukraine to ascertain the adaptability of the organism. Like many other nations, Ukraine has a distinct healthcare environment, which includes elements like the frequency of particular diseases, population demographics, and healthcare infrastructure. Ukraine can make sure that vaccination programs are successfully implemented improving the public health outcomes and safeguarding the welfare of its population by taking into account the unique aspects of the local context, such as the prevalence of particular diseases or risk factors, and incorporating them into the pre-vaccination diagnostics process.

1. It is possible that pre-vaccination diagnostics are not consistently implemented in Ukraine, with variances in adherence to recommended standards, especially in terms of the kinds of tests that are utilised, the time of testing, and the availability of diagnostic facilities.

2. Obstacles associated with organisational, logistical, and resource management may have an effect on the execution of pre-vaccination diagnostics in Ukraine, which may result in a less-than-optimal level of adherence to the standards that have been developed.

3. The viewpoints of stakeholders, such as healthcare professionals, public health authorities, and laboratory workers, play an essential part in the execution of pre-vaccination diagnostics. Furthermore, the perspectives of stakeholders may have an influence on the efficacy and efficiency of vaccination programs.

4. To maximise the pre-vaccination diagnostics in Ukraine and guarantee consistent adherence to established recommendations, there may be a need for greater stakeholder participation, changes to legislation, and interventions.

Implications:

1. The study's conclusions emphasize the necessity of pre-vaccination diagnostics in Ukraine being standardized and applied consistently. This could entail the creation of national standards for pre-vaccination diagnostics, the implementation of training programs for medical professionals and laboratory staff, and the improvement of diagnostic facilities to guarantee the accessibility and caliber of tests.

2. Policy modifications may be required to address organizational, logistical, and resource-related issues. These policy adjustments may be necessary as a result of the research findings for public health authorities in

Ukraine. This could involve allocating sufficient funds, setting up systems to track and assess the application of pre-vaccination diagnostics, and creating plans to increase stakeholder engagement.

3. The results of the study might show where there are gaps or questions that need to be answered. This might involve conducting additional study to investigate the causes of Ukraine's unsatisfactory adherence to pre-vaccination diagnostics, analyze the effectiveness of treatments designed to increase adherence, and evaluate the cost-efficiency of various diagnostic modalities.

4. Since precise pre-vaccination diagnostics are essential to the success of immunization programs, the research findings may have ramifications for public health in Ukraine. Pre-vaccination diagnostic procedures should be consistently followed to help identify people who might not be good candidates for vaccination, potentially minimizing side effects and improving overall vaccination outcomes.

In conclusion, the research findings suggest that there may be peculiarities in the implementation of pre-vaccination diagnostics in Ukraine, with potential challenges related to adherence to established guidelines, stakeholder perspectives, and organizational factors. The implications of these findings include practice and policy changes, as well as the need for further research to address the identified gaps. Improving pre-vaccination diagnostics can have significant implications for public health in Ukraine, optimizing vaccination programs and ultimately improving population health outcomes.

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