

Artificial Intelligence in Histopathological Diagnosis: A Comparative Study

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ABSTRACT

Starting to apply this new technology for primary diagnosis was made possible by the FDA's recent approval of the prostate AI algorithm and WSI scanners for use in primary diagnosis. Workflow breakthroughs and advancements in anatomical and clinical pathology can be made possible by AI tools. With a focus on the future, we outline the significant studies and turning points in the application of AI in clinical pathology in this study. Many pathologists expect artificial intelligence (AI) to help them with a range of digital pathology tasks, given AI's recent success in computer vision applications. Concurrently, remarkable developments in deep learning have made it possible for AI and deep learning to work in concert, enabling image-based diagnosis against the backdrop of digital pathology. AI-based solutions are being developed to reduce errors and save pathologist's time. Here, we outline the components of computational pathology (CPATH), how it might be applied to the development of AI, and the difficulties it encounters with regard to computing systems, reimbursement, ethics, and legal issues, as well as algorithm validation and interpretability. Additionally, we provide a summary of cutting-edge AI-based methods that could be incorporated into workflows in pathology labs.

Keywords: Artificial Intelligence (AI), Histopathological Diagnosis (HD), Pathology (PP), Technology (T)

INTRODUCTION

The word "artificial intelligence" is not an unfamiliar term to society now. Many of us are quite familiar with the revolution that has come in every field of life because of artificial intelligence. Artificial intelligence has replaced human intelligence in every field of life by providing accurate and swift results. Artificial intelligence has also been used in the medical field for many recent years. In this introduction, we are going to discuss how artificial intelligence can be effectively used in Histopathological Diagnosis in various ways[1]. The word Histopathological Diagnosis means the accurate examination of tissues to understand the onset of different diseases such as cancer. The most important Histopathological disease which is common these days is cancer which is caused by mutation in genes. This mutation may lead to uncontrolled cell division which can form tumors in the body. But if these mutations are easily detected at the tissue level, the diagnosis and treatment can be proved effective and the increasing cases of cancer can easily be reduced. There are a few important steps included in effective Histopathological Diagnosis. The first and foremost step of Histopathological Diagnosis is the collection of samples from patients. The sample is mostly taken from patients through surgery or biopsy. In recent years, this step of Histopathological Diagnosis was performed by manual work of surgery or biopsy but artificial intelligence has solved this problem also[2]. Now artificial intelligence has automated systems in which these samples can be taken from patients by very minor surgery. In the manual type of survey, there was a risk of human error but when artificial intelligence is used for sample collection, there is very little or no chance of error. Secondly, the procedure done by artificial intelligence is less time-consuming as compared to manual work in Histopathological Diagnosis. The second step in Histopathological Diagnosis is the fixation of these samples in formalin to prevent any decay of these tissues. As we know tissues are groups of cells and cells need a continuous supply of oxygen for being alive. So, after sample collection, this step is taken readily to prevent any decay of these tissues. Artificial intelligence can also perform this step in less time as

compared to human manual work. The other aspect is that when samples are fixed by using human resources, there may be any risk of contamination of samples that do not provide accurate results[3]. However, by using artificial intelligence, the possibility of contamination of samples can also be reduced. The next step in Histopathological Diagnosis is processing in which the whole slice of the tissue sample is dehydrated and then it is sliced into sample pieces for better examination. This step can also be automatically performed by artificial intelligence in very little time. The proper dehydration of tissue samples is done to prevent any kind of inaccuracy in results caused by molecules of water in tissue samples[4]. The next step in Histopathological Diagnosis is the proper staining of these tissue samples to enhance the features of tissues. In manual Histopathological Diagnosis, there was a need to use such a staining process which could provide intense colour but when we use artificial intelligence for staining of tissues, we do not need such intense colours. The next and most important step of Histopathological Diagnosis is a microscopic examination of these samples to know about any abnormality in these tissues[5]. It has been proved by scientific studies that the shape and size of normal cells are different compared to the shape and size of cancerous cells. These abnormalities are observed in cells under a microscope. In manual Histopathological Diagnosis, there was a need for a lengthy and time-consuming process of preparation of slides for examination under a microscope. But when we prefer artificial intelligence for Histopathological Diagnosis, there is no need for manual preparation of slides for examination[6]. Now in modern pathology labs, automated microscopes are mostly used which provide information about the examination of slides in digital and accurate form. The next step of Histopathological Diagnosis is the identification of biomarkers which is done by applying antibodies to these samples of tissues. This step is named as immunohistochemistry. As we know the only microscopic examination is not quite enough to conclude any result about the condition of tissues. So there is a need to perform molecular diagnostics to know about deep aspects of

samples of tissues[7]. In this step, different tests such as PCR, and FISH are performed in high-quality equipment and instruments for genetic analysis of these samples of tissues. Molecular analysis is quite effective and accurate for providing a diagnostics basis. The ultimate mutation or any other abnormality in cells can easily be detected by molecular analyses. Histopathological diagnosis follows the general Diagnosis is an interpretation of results. It is the most important step of Histopathological Diagnosis because the whole diagnosis is interpreted to give the conclusion of results[8]. If interpretation is done by a human manual system, there is a possibility of human error in these interpretations. But if this interpretation is made by artificial intelligence, some automated systems are designed so to provide error-free interpretation. The next step of Histopathological Diagnosis is reporting of results of the diagnosis. The results of diagnosis are reported on the portal of the pathology lab information system. The best benefit of using artificial intelligence in Histopathological Diagnosis is that these results of diagnosis can easily be accessed by using internet only. All the information related to Histopathological Diagnosis is updated in a laboratory information system[9]. The most important aspect of such information systems is that there is very little risk of data loss in such automated computer-based systems. In recent years, all the data related to Histopathological Diagnosis was stored in manual form which resulted in data loss or data hacking. However artificial intelligence has solved this problem as well by electronic health record systems. The other important benefit of artificial intelligence in Histopathological Diagnosis is that there is no factor of fatigue in it. The Histopathological Diagnosis can be repeated many times without any risk of error[10].

Research Objective

The main objective of this research is to understand the role of artificial intelligence in Histopathological Diagnosis. This study has effectively explained about steps of Histopathological Diagnosis and how artificial intelligence can be used to get swift and accurate responses to diagnosis.

LITERATURE REVIEW

Researchers claim that using precise cancer diagnostic techniques provides early treatment opportunities against cancer. To provide cancer-related therapies to patients it is essential to assess the use of precise biomarkers for cancer therapy. The computerized pathology process is improved using AI-based deep learning algorithms [11]. Also, detecting cancer at an early stage is possible using machine learning technology in cancer detection-related pathology labs. Biopsy as well as cytology are the two important cancer detection techniques applied in pathology labs. medical imaging process to identify the size and location of cancer is applied in labs using AI models [12]. Studies suggest that breast cancer is the most prevalent type of cancer among women. To diagnose breast cancer cells through medical imaging technology the use of CAD methodology is common. CAD is a computer-aided system that provides enhanced accuracy in the process of breast cancer diagnosis[6]. Studies reveal that melanoma is a health condition that is identified in pathology labs using AI models. the pathology labs are built using high-efficiency AI models to recognize different cancer-related abnormalities. Male genital cancer as well as breast cancer in females can lead to life-threatening conditions if an early diagnostic procedure is not done. Using AI models in labs detects cancer at an early stage and helps in providing

the best treatment therapies against numerous cancer types[13]. Studies predict that alternation in the tissue-related cells results in the production of tumor cells. To detect tissue tumors the precision oncology technique is used in labs. AI models in lab settings predict that genetic alternation is associated with the onset of tissue cancer[14]. Studies show that lab digitalization is a process that improves the accurate result-providing capability of pathology laboratories. AI is the most common technology used in pathology labs for carrying out research-related experimentations. the nature of randomized samples is detected through AI lab kits[9]. Studies explain that diseases are identified by analyzing diseases-related medical images. Using high technology-based medical imaging devices serves a critical role in the disease analysis process. The physician-related workload is minimized by using AI for the interpretation of medical images. in pathology labs computer networks based on the neural network approach are employed in the process of decision making. The deep learning method used in the lab is CCN and the machine learning method used in labs is SVM. Both these methods analyze the disease condition in patients and then provide an early diagnosis approach[15]. Studies claim that skin-related cancer cells are identified using the image-based technology. medical imaging devices diagnose the presence of skin cancer in the clinical domain using AI computerized technology[16]. Studies predict that the disease-related history of a person is detained using AI models. By predicting the disease history it becomes easier to treat the complexity of the disease in the present. Fully automated systems based on AI algorithms are used for visualizing the WSI[17]. Studies suggest that risk associated with colorectal cancer can result in serious medical complications. the screening of this cancer is done using the screening colonoscopy[18]. Studies reveal that using the MRI technique for prostate cancer diagnosis holds critical importance. By using AI physicians in clinical labs have developed mp-MRI technology for advanced-level detection of prostate cancer[19]. Studies of scholars suggest that radiologists are provided aid in their working process using AI software. The commercial importance of AI is that it is fully capable of improving the radiologist's work efficiency. Radiologists either experienced or faced difficulty in interpreting the results. To aid these radiologists in their statistic-providing work the AI software is implemented in radiography machines. These machines provides a framework for the radiologist to easily predict any radiography-related medical reports[20]. Scholars predict that advancements in AI-related fields have forced researchers working in labs to adopt deep learning algorithms for achieving accuracy in their result-based work. to study the slides of BCC, the clinical lab pathologists use DL algorithms. By studying the slides physicians can provide detailed information regarding the classification of tumor type[21]. Scholars' studies made on AI use in pathology labs predict that using AI as a tool for accuracy in labs holds immense importance. The process of categorization of cancer cells using the WSI is becoming common in labs. The cancer cells of the neck and other body parts and the malignance associated with these cancerous cells is explained using the WSI technique[22]. Also, the HNC detection process is carried out using image analyzing technology. ML algorithm proves effective in determining the early diagnostic procedure for HNC[23]. Studies show that using an automated classification system for breast cancer makes the cancer identification process easier to perform in biomedical laboratories. breast cancer is a disease regarded as multi-classification cancer. to classify every type of breast cancer the use of two AI approaches is combined. Conventional machine learning and DL algorithmic

concepts are commonly used in biomedical informatics labs for multi-classification of breast cancer[24]. Studies of scholars made valid reasoning that extraction of quantitative data is achieved using digitalized images analysis. Extracting data using AI approach is suitable in pathology labs as it gives precise and consistent information. Also, by analyzing these reports the AI software predicts the possible treatment against the genetic alternations[25]. Scholars elaborate that the trend of using the AI concepts for developing diagnostic medicine is incising. By developing diagnostic medicine AI improves the health services provided by oncology as well as pathology labs. Moreover, every pathology lab works on one basic principle that is to provide the most accurate and precise diagnostic approach. AI technology plays a major role in helping pathology labs maintain their precise result-providing ability[26]. Researchers suggest that using old image analysis methods for CRC has been replaced with AI-based medical imaging technology. Deep neural algorithms optimize the working of image analysis devices to provide novel treatment opportunities[8]. Studies elaborate the derma pathology labs are using AI deep learning algorithms to diagnose and evaluate the disease associated with this branch of medical pathology. Also, melanoma is a disease that is identified through the Conventional neural network approach to predict the outcomes of this disease. Moreover, in derma pathology labs the research and education work process is performed using AI and machine learning algorithms[27].

Methodology

The research study determines that artificial intelligence in histopathological diagnosis describe the comparative study between them. the research was based on primary data analysis to determine the research used SPSS software and generate informative results including chi-squares, descriptive statistics, correlation coefficient analysis, also pair sample test analysis between them. Artificial intelligence has replaced human intelligence in many fields of life including health, medical science, communication, industry, business, research, and many others. The extensive use of artificial intelligence is because of error-free results, less time consumption, and cost-effectiveness. Now artificial intelligence has also been used in Histopathological Diagnosis. The Histopathological Diagnosis can be defined as the examination of tissues to know about the type and effects of pathogens in the body. There are many benefits of using artificial intelligence in Histopathological Diagnosis. A few implications of artificial intelligence in Histopathological Diagnosis are described as follows:

Analysis of Image, Recognition of Pattern, and Automated Analysis

In Histopathological Diagnosis, we have to take some images of damaged or infected tissues by using various medical cameras. The true and accurate detection of pathogens in tissues is based upon better analysis of these images. As we know when there is an attack of pathogens in tissue, there will be some kind of change in the cells of tissues. These images can easily be used for better Histopathological Diagnosis. If these images are analyzed by using human resources, there may be some risk of error and inaccuracy in results. But if we use artificial intelligence for image analysis, we may get error-free and timely results as well. The cost of using artificial intelligence will be less as compared to other means for image analysis. The other important implication of artificial intelligence in Histopathological Diagnosis is recognition of pattern in affected tissues. As described

earlier the cell shape changes when any pathogen attacks any specific tissue, and there may occur some kind of mutation in the cells of that particular tissue. As a result of mutation, there will be a change in the pattern of tissues because of irregularity of reproduction in cells. There may be continued and abnormal cell division which may result in the production of tumors in the body. There is a gap of time between a change in pattern and tumour formation in tissues. If the changing patterns are closely observed by using artificial intelligence, we may get to know about tumours even before the formation of those tumours. In this way, we can say that artificial intelligence helps us in the study of changing patterns in tissues because of the attack of pathogens. The other important implication of artificial intelligence in Histopathological Diagnosis is automated analysis. As we know the process of Histopathological Diagnosis is quite lengthy and time taking. There are some important steps in Histopathological Diagnosis such as taking samples of tissue, examination under a microscope, taking images, analysis of images, identification of the pathogen, concluding, and Analysis of results. If we use human intelligence in performing these steps, it will take much time for Histopathological Diagnosis. At the same time, there will be a risk of error in analysis. To overcome all of these problems, the process of automated analysis is used in which artificial intelligence works to provide accurate results without any error. Secondly, there will be less time consumption in automated analysis as compared to manual analysis. All these implications of artificial intelligence prove the importance of artificial intelligence in Histopathological Diagnosis.

Prediction Before Onset of Cancer, Support in Decision Making, and Personalized Medication

As described earlier when there is an attack of the pathogen on any tissue, there will be mutation in tissues which can cause cancer. We know that there are two types of tumour formation in the body. One type of tumour is that which is localized and thus does not affect other tissues, these tumours are called benign tumours. These tumours do not cause cancer in the body. But the other type of tumour is when tumours get into the blood and spread throughout the whole body thus forming tumours in other parts of the body as well. These tumors can cause cancer and the spread of cancer in the body is termed metastasis. The best implication of artificial intelligence in Histopathological Diagnosis is that it can predict the risk of cancer even before the spread of tumours in the body by proper examination of tumours. The genetic examination and analysis of tumours may provide information about the type of tumour. If proper analysis of tumours is done, the risk of the onset of cancer can be reduced. The other important implication of artificial intelligence in Histopathological Diagnosis is the aspect of decision-making in such diagnosis. When timely and swift analysis of pathogen is done in Histopathological Diagnosis, there will be support in decision making which treatment is suitable for the patient. Along with it, it can also provide information about the chances of the response of the body to that particular treatment. The other important implication of using artificial intelligence in Histopathological Diagnosis is that it can help in personalized medication as well. When Histopathological Diagnosis is done, there is a prescription of medication from a pathologist to treat the effect of the attack of the pathogen on tissue. All the medication of the patient will be according to the personalized needs of the body of that particular patient. In recent years, there was the same medication for the same pathogen attack but after some years, it was observed that every patient responded to the same medication differently because of individual differences.

Artificial intelligence has helped us in this way it can provide personalized medication to each patient to get positive outcomes.

Training of Pathologists, Telepathology

The proper training of pathologists is mandatory for effective Histopathological Diagnosis. When pathologists are better trained, they will be able to prescribe better medication for the treatment of affected tissues. So, we can use artificial intelligence to train pathologists for better outcomes in terms of reducing the risk of cancer because of

pathogen attacks. Artificial intelligence can provide training to pathologists by using a virtual reality training system in which an illusion is created that seems to be real. The other important implication of artificial intelligence in Histopathological Diagnosis is that it can provide remote and online services for patients to get mental satisfaction of masses. Symptom tracking, the diet plan, medication reminders, and the results of reports, all these things can be provided to patients by an online system which helps a lot in Histopathological Diagnosis.



Figure 1: Artificial Intelligence in Histopathological Diagnosis

Descriptive Statistical Analysis

Table 1: Result of Descriptive Statistical Analysis

		Paired Samples Statistics			
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Artificial Intelligence 1	1.5490	51	.61037	.08547
	Histopathological Diagnosis 1	1.6471	51	.59409	.08319
Pair 2	Artificial Intelligence 2	1.6275	51	.69169	.09686
	Histopathological Diagnosis 2	1.5294	51	.61165	.08565
Pair 3	Artificial Intelligence 3	1.3529	51	.55941	.07833
	Histopathological Diagnosis 1	1.6471	51	.59409	.08319

The results of above table 1 shows how descriptive statistical analysis can be used to explain the standard error of the mean value of each pair while also demonstrating mean values and standard deviation rates. The mean values of the first pair, artificial intelligence 1 and histopathological diagnosis 1, are 1.5490 and 1.6471. The data indicates a positive average rate, with a standard deviation rate of 61 and a mean deviation of 59%. The mean value's standard error is 83% and 85%, respectively. The results indicate that the mean value of the second pair, artificial intelligence diagnosis 2 and histopathological

diagnosis 2, is 1.6275. The positive average mean value of 1.5294 indicates that 69% of the data vary from the mean, while the standard deviation rate is 61%. The mean value's standard error is 96% and 85%, respectively. The results of the third pair, artificial intelligence 3 and histopathological diagnosis 1, indicate that the mean values are 1.3529 and 1.6471, respectively. This indicates a positive average mean value, with standard deviation rates of 55% and 59% deviating from the mean value.

Table 2: Result of Paired Samples Correlations

		Paired Samples Correlations		
		N	Correlation	Sig.
Pair 1	Artificial Intelligence 1 & Histopathological Diagnosis 1	51	.545	.000
Pair 2	Artificial Intelligence 2 & Histopathological Diagnosis 2	51	.239	.091
Pair 3	Artificial Intelligence 3 & Histopathological Diagnosis 1	51	.202	.156

The above results of table 2 demonstrates the pair correlation coefficient analysis result shows correlation values and significant values of each pair. The first pair is artificial intelligence 1 and histopathological diagnosis 1 It shows that the correlation value is 54% and a significant value is 0.000 showing positive and 100% significant level between the artificial intelligence and histopathological

diagnosis 1. The second pair is artificial intelligence 2 and histopathological diagnosis 2 its shows that the correlation level is 23% and the significant level is 0.091 its mean is positive and 9% significant rate between them. similarly, pair 3 is artificial intelligence 3 and histopathological diagnosis 1 results show that correlation values present 20% positive and 15% significant related to each other.

Table 3: Result of Paired Samples Test

		Paired Samples Test							
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Mean	Lower	Upper			
Pair 1	Artificial Intelligence 1 - Histopathological Diagnosis 1	-.09804	.57463	.08046	-.25966	.06358	- 1.218	50	.229
Pair 2	Artificial Intelligence 2 - Histopathological Diagnosis 2	.09804	.80635	.11291	-.12875	.32483	.868	50	.389
Pair 3	Artificial intelligence 3 - Histopathological Diagnosis 1	-.29412	.72922	.10211	-.49921	-.08902	- 2.880	50	.006

The above results of table 3 demonstrates that paired sample test analysis result describes those paired differences related to mean, standard deviation, and standard error means 8% respectively. The result describes that 95% confidence interval of the difference related to the lower and upper level. The result shows that the t statistic shows that -0.1218 the significant level is 0.229 shows that 22% significant

rate between them. pair 2 represent that the mean value is 0.09804 the lower bound is -0.12875 the upper bound is 32% respectively. The t statistic value is 86% the significant 38% level between them. pair 3 is artificial intelligence 3 and histopathological diagnosis 1 result shows that -0.2880 the significant level is 0.006 shows that 100% respectively.

Table 4: Result of Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.559 ^a	.312	.268	.50822

a. Predictors: (Constant), Artificial intelligence 3, Artificial intelligence 2, Artificial intelligence 1

The findings of table 4 indicate that the R-value, R square, and adjusted R square are all 0.559, as is the standard error of the calculated R-value. It displays 55% and 31%, respectively, for the R square value. The 50% error rate between them is reflected in the modified R square value of 26%. The environment known as "digital pathology" includes pathology slide digitalization and associated metadata, together with the infrastructure for storing, processing, and assessing the slides. WSI is a dependable method for regular surgical pathology diagnosis since numerous studies have shown its excellent concordance with normal light microscopy diagnosis. In actuality, WSI technology has other advantages over traditional microscopy, including work balance, portability, and ease of sharing and retrieving

images. The development of the digital pathology environment led to the emergence of the new field of computational pathology. Developments in computational pathology have led to the creation of new vocabulary and definitions. Instead of depending on a pathologist to analyze pictures on a screen, direct illness inquiry is now possible due to computational analysis of pathology slide images. Artificial intelligence techniques, bolstered by deep learning outcomes, are widely employed to merge data from digital pathology images with their corresponding metadata. The state-of-the-art in digital pathology is currently being used by researchers to identify aspects that are challenging to identify with the human eye alone by using AI techniques that computationally analyses the complete slide image.

Table 5: Result of ANOVA^a

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.507	3	1.836	7.107	.000 ^b
	Residual	12.140	47	.258		
	Total	17.647	50			

a. Dependent Variable: Histopathological Diagnosis 1

b. Predictors: (Constant), Artificial intelligence 3, Artificial intelligence 2, Artificial intelligence 1

The result represents that the ANOVA test analysis result demonstrate the sum of square rates, mean square rates, and F statistic also that significant level. The regression model shows that the sum of the square rate is 5.507 the mean square value is 1.836 also the F statistic value is 7.107 and the significant level is 0.000 showing that

positive and 100% significant between them. the residual model represents that the sum of the square value is 12.140 and the total value is 17.647 respectively. The mean square value describes the 25% average square rate between them.

Table 6: Result of Coefficients

Coefficients					
Model		Unstandardized Coefficients		Standardized Coefficients	t
		B	Std. Error	Beta	
1	(Constant)	.953	.292		3.263
	Artificial intelligence 1	.531	.124	.546	4.278
	Artificial intelligence 2	-.101	.105	-.117	-.956
	Artificial intelligence 3	.026	.136	.024	.190

a. Dependent Variable: Histopathological Diagnosis 1

The above results of table 6 demonstrates that the coefficient analysis result represents unstandardized coefficients and standardized coefficient values related to beta and standard error. According to the table-6 result, histopathological diagnosis 1 is the main dependent variable artificial intelligence 1 shows that beta value is 0.531 the t statistic value is 4.278 a significant level is 0.000 showing that positive and 100% significant level between them. similarly, artificial intelligence 2 is another independent variable result representing that the standard error value is 0.105 the t statistic value is -0.956 the

significant rate is 0.344 showing that negative but 34% significant level between them. the third variable is artificial intelligence 3 its t-statistic value is 0.190 the significant rate is 0.850 showing that positive and 85% significant levels between them. The results of table 7 represents that chi-square analysis the values of chi-square are 17.765, 11.412, 32.824, and 18.353 all values show that positive chi-square analysis. According to the above result, its significant level is 0.000 showing that 100% significant rate of each variable including dependent and independent.

Table 7: Result of Test Statistics

Test Statistics					
	Artificial intelligence 1	Artificial intelligence 2	Artificial intelligence 3	Histopathological Diagnosis 1	Histopathological Diagnosis 2
Chi-Square	17.765 ^a	11.412 ^a	32.824 ^a	18.353 ^a	18.353 ^a
df	2	2	2	2	2
Asymp. Sig.	.000	.003	.000	.000	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 17.0.

Control chart

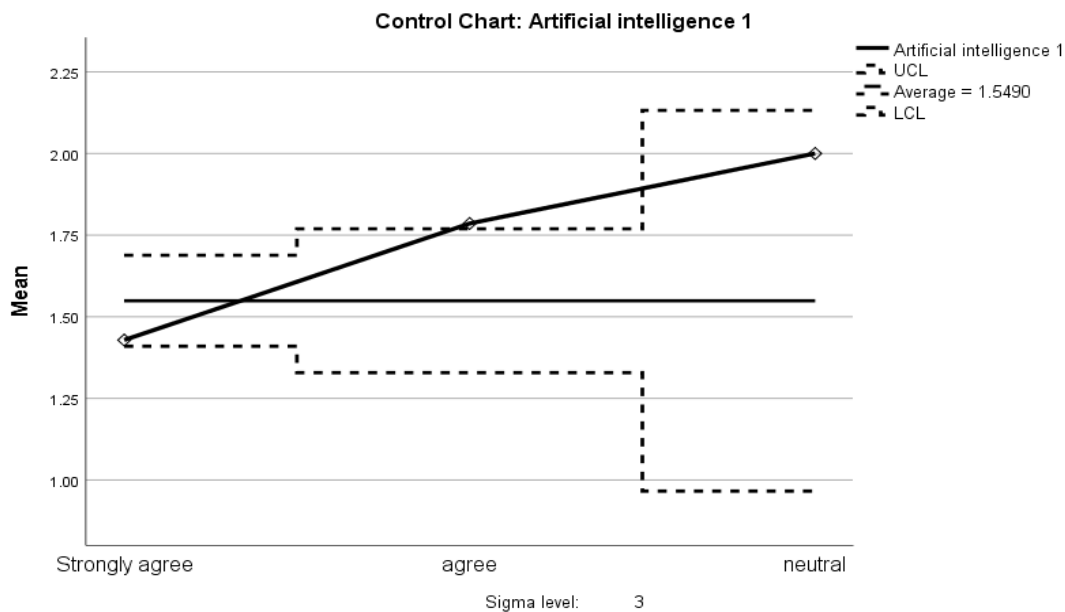


Figure 1: Control Chart

The analysis of figure 1 of the control chart is shown in the result above. The vertical side displays the mean values, which begin at 1.000 and go up to 2.25. The highly agree, agree, and neutral levels about sigma are represented by the horizontal side. The graph indicates that the average rate is 1.5490 and that there is a positive average rate between them. The graph above demonstrates the strong and positive correlation between histological diagnosis and artificial intelligence.

Conclusion

The significant effects of artificial intelligence in Histopathological Diagnosis that have been discussed above demonstrate how artificial intelligence has revolutionized pathology labs in a variety of ways. AI now has enormous potential to change pathology practice by reducing errors, improving repeatability, and fostering expert communication—all of which were previously difficult with tiny glass slides. The current advances in AI applications should be manageable, intelligible, practical, affordable, interoperable, explainable, and reimbursed. Many researchers are

persuaded that AI in general and deep learning, in particular, could help with many tedious professions involving digital pathology because of recent advancements in picture identification. However, this market currently has a limited number of AI-powered software products available. We believe pathologists should be involved from the start, even when constructing algorithms, to ensure that these much-anticipated software packages are improved or possibly replaced by AI algorithms. It will be difficult to apply AI in pathology, despite popular belief. AI tools are likely to be accepted by regulatory bodies like the Food and Drug Administration. The quantitative aspect of CPATH has the potential to transform clinical and pathological laboratory procedures. Case stratification, expedited review and annotation, and the development of practical models to guide treatment decisions and predict trends in the medical field are among the available options. More study is needed before the pathology community can develop secure and reliable AI. As the need for clinical AI becomes clearer, this gap will close. Artificial intelligence (AI) in pathology is still in its infancy, but it will expand as more technologies are created and made accessible to medical professionals by firms, government agencies,

patient advocacy groups, clinicians, and researchers. For successful implementation, several collaborating facilities must test and develop robust and standardized laboratory, clinical, and computational processes at the same time. The development of novel AI techniques has increased dramatically in the field of pathology in recent years. These technologies, when used properly, can eliminate human error, improve inter-observer repeatability, provide prognostic predictions, and expedite diagnostic procedures. Although the development of AI tools has accelerated, their implementation in clinical practice has

been delayed due to several issues with interpretability, validation, regulation, generalizability, and cost. As the demand for individualized cancer care increases, AI applications may be implemented and utilized responsibly in conjunction with human pathologists as long as they are standardized in their use and synchronized with current information systems. Comprehensive tumour precision medicine customized for each patient may require a multimodal approach combining proteomics, genomics, and AI-driven multiplexed biomarker quantifications.

REFERENCES

- [1] S. Kote, S. Agarwal, A. Kodipalli, and R. J. Martis, "Comparative study of classification of histopathological images," in *2021 5th International Conference on Electrical, Electronics, Communication, Computer Technologies and Optimization Techniques (ICEECCOT)*, 2021: Ieee, pp. 156-160.
- [2] Y. Li, D. Chen, X. Wu, W. Yang, and Y. Chen, "A narrative review of artificial intelligence-assisted histopathologic diagnosis and decision-making for non-small cell lung cancer: achievements and limitations," *Journal of Thoracic Disease*, vol. 13, no. 12, p. 7006, 2021.
- [3] J. L. Tan *et al.*, "Diagnostic Accuracy of Artificial Intelligence (AI) to Detect Early Neoplasia in Barrett's Esophagus: A Non-comparative Systematic Review and Meta-Analysis," *Frontiers in medicine*, vol. 9, p. 890720, 2022.
- [4] K. Kayser *et al.*, "AI (artificial intelligence) in histopathology--from image analysis to automated diagnosis," *Folia Histochemica et Cytobiologica*, vol. 47, no. 3, pp. 355-361, 2009.
- [5] J. Malik *et al.*, "Colorectal cancer diagnosis from histology images: A comparative study," *arXiv preprint arXiv:1903.11210*, 2019.
- [6] S. Boumaraf *et al.*, "Conventional machine learning versus deep learning for magnification dependent histopathological breast cancer image classification: A comparative study with visual explanation," *Diagnostics*, vol. 11, no. 3, p. 528, 2021.
- [7] M. M. Abdelsamea, U. Zidan, Z. Senousy, M. M. Gaber, E. Rakha, and M. Ilyas, "A survey on artificial intelligence in histopathology image analysis," *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, vol. 12, no. 6, p. e1474, 2022.
- [8] K.-S. Wang *et al.*, "Accurate diagnosis of colorectal cancer based on histopathology images using artificial intelligence," *BMC medicine*, vol. 19, pp. 1-12, 2021.
- [9] S. Försch, F. Klauschen, P. Hufnagl, and W. Roth, "Artificial intelligence in pathology," *Deutsches Ärzteblatt International*, vol. 118, no. 12, p. 199, 2021.
- [10] M. A. Abbas, S. U. K. Bukhari, A. Syed, and S. S. H. Shah, "The Histopathological Diagnosis of Adenocarcinoma & Squamous Cells Carcinoma of Lungs by Artificial intelligence: A comparative study of convolutional neural networks," *MedRxiv*, p. 2020.05. 02.20044602, 2020.
- [11] B. Acs, M. Rantalainen, and J. Hartman, "Artificial intelligence as the next step towards precision pathology," *Journal of internal medicine*, vol. 288, no. 1, pp. 62-81, 2020.
- [12] S. Agarwal, A. S. Yadav, V. Dinesh, K. S. S. Vatsav, K. S. S. Prakash, and S. Jaiswal, "By artificial intelligence algorithms and machine learning models to diagnosis cancer," *Materials Today: Proceedings*, vol. 80, pp. 2969-2975, 2023.
- [13] T. J. Brinker *et al.*, "Diagnostic performance of artificial intelligence for histologic melanoma recognition compared to 18 international expert pathologists," *Journal of the American Academy of Dermatology*, vol. 86, no. 3, pp. 640-642, 2022.
- [14] D. Cifci, S. Foersch, and J. N. Kather, "Artificial intelligence to identify genetic alterations in conventional histopathology," *The Journal of Pathology*, vol. 257, no. 4, pp. 430-444, 2022.
- [15] N. Ghaffar Nia, E. Kaplanoglu, and A. Nasab, "Evaluation of artificial intelligence techniques in disease diagnosis and prediction," *Discover Artificial Intelligence*, vol. 3, no. 1, p. 5, 2023.
- [16] M. Goyal, T. Knackstedt, S. Yan, and S. Hassanpour, "Artificial intelligence-based image classification methods for diagnosis of skin cancer: Challenges and opportunities," *Computers in biology and medicine*, vol. 127, p. 104065, 2020.
- [17] M. Haghighat *et al.*, "Automated quality assessment of large digitised histology cohorts by artificial intelligence," *Scientific Reports*, vol. 12, no. 1, p. 5002, 2022.
- [18] C. Hassan *et al.*, "Comparative performance of artificial intelligence optical diagnosis systems for leaving in situ colorectal polyps," *Gastroenterology*, vol. 164, no. 3, pp. 467-469. e4, 2023.
- [19] Y. Hou *et al.*, "Artificial intelligence is a promising prospect for the detection of prostate cancer extracapsular extension with mpMRI: a two-center comparative study," *European Journal of Nuclear Medicine and Molecular Imaging*, vol. 48, pp. 3805-3816, 2021.
- [20] H. J. Kim *et al.*, "Improving mammography interpretation for both novice and experienced readers: a comparative study of two commercial artificial intelligence software," *European Radiology*, vol. 34, no. 6, pp. 3924-3934, 2024.
- [21] S. Kimeswenger *et al.*, "Artificial neural networks and pathologists recognize basal cell carcinomas based on different histological patterns," *Modern Pathology*, vol. 34, no. 5, pp. 895-903, 2021.
- [22] H. Mahmood, M. Shaban, B. Indave, A. Santos-Silva, N. Rajpoot, and S. Khurram, "Use of artificial intelligence in diagnosis of head and neck precancerous and cancerous lesions: a systematic review," *Oral Oncology*, vol. 110, p. 104885, 2020.
- [23] H. Mahmood, M. Shaban, N. Rajpoot, and S. A. Khurram, "Artificial Intelligence-based methods in head and neck cancer diagnosis: an overview," *British journal of cancer*, vol. 124, no. 12, pp. 1934-1940, 2021.
- [24] S. Sharma and R. Mehra, "Conventional machine learning and deep learning approach for multi-classification of breast cancer histopathology images—a comparative insight," *Journal of digital imaging*, vol. 33, no. 3, pp. 632-654, 2020.
- [25] A. Shmatko, N. Ghaffari Laleh, M. Gerstung, and J. N. Kather, "Artificial intelligence in histopathology: enhancing cancer research and clinical oncology," *Nature cancer*, vol. 3, no. 9, pp. 1026-1038, 2022.
- [26] A. S. Sultan, M. A. Elgharib, T. Tavares, M. Jessri, and J. R. Basile, "The use of artificial intelligence, machine learning and deep learning in oncologic histopathology," *Journal of Oral Pathology & Medicine*, vol. 49, no. 9, pp. 849-856, 2020.
- [27] A. Wells, S. Patel, J. B. Lee, and K. Motaparathi, "Artificial intelligence in dermatopathology: Diagnosis, education, and research," *Journal of cutaneous pathology*, vol. 48, no. 8, pp. 1061-1068, 2021.



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