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Original Research

The assessment of deep learning computer vision algorithms for the diagnosis of prostatic adenocarcinoma

Diagnosis of prostatic adenocarcinoma using computer vision

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Abstract

Aim: In this study, we aimed to evaluate the effectiveness of artificial intelligence for the histopathological diagnosis of prostatic adenocarcinoma by analyzing the digitized pathology slides.

Materials and Methods: After the approval of the research project by the Ethics Committee of the University of Lahore - Islamabad Campus, a total of eight hundred and two (802) images were obtained from the anonymized slides stained with hematoxylin and eosin, which included 337 anonymized images of prostatic adenocarcinoma and 465 anonymized images of nodular hyperplasia of prostate. Eighty percent (80%) of the total digital images were used for training and 20% for testing. Three ResNet architectures ResNet-18, ResNet-34, and ResNet-50 were employed for the analysis of these images.

Results: In the present study, the analysis of pathology images by convolutional neural network architecture ResNet-50 has revealed the diagnostic accuracy of 99.5 %, while the other convolutional neural network architectures ResNet-18 and ResNet-34 showed the diagnostic accuracy of 97.1% and 98 %, respectively.

Discussion: The findings of the present study suggest that an intelligent vision system is possibly a worthwhile tool for the histopathological evaluation of prostatic tissue to differentiate between benign and malignant disorders. The application of deep learning for the histological diagnosis of malignant tumors could be quite a helpful tool for better patient care.

Keywords

Prostate; Adenocarcinoma; Deep learning; Computer vision

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Introduction

Prostatic carcinoma is the second most prevalent type of malignant tumor diagnosed in males all over the world [1]. In 2018, more than one million (1,276106) patients have been diagnosed as a case of prostatic cancer around the globe, and this malignant tumor caused 358989 deaths during that time period [1].

Variation in the prevalence of cancers exists among the different geographic regions [2]. Some tumors are more prevalent in one region and less common in other. The prostatic cancer is the most frequent malignant tumor of the male population in one hundred and five countries, which mainly include the countries from the continents of Europe, Africa, North and South America [3]. The geographic variation in the prevalence of prostatic cancer has been attributed to genetic and environmental factors. Higher consumption of meat has been linked to a higher risk of development of prostatic carcinoma [4,5].

The incidence of prostatic malignancy rises with an increase in age. The prostatic malignancy is more common in the 7th decade with a mean age of sixty-six years [3]. An increased incidence of prostatic adenocarcinoma has been observed in the younger population. This rising trend in the incidence of prostate cancer in the younger age group has been attributed to improved diagnostic techniques and environmental factors including the rising incidence of obesity among the adolescent and younger age groups [6].

The prostatic carcinoma causes urinary tract symptoms due to the enlargement of the prostrate. The spread of prostatic adenocarcinoma to the vertebral column causes backache. The common symptoms with which these patients present usually include urinary obstruction, urgency, hesitancy, discomfort, frequency, and hematuria [7-9]. The suspected cases of prostatic malignancy are tested for a prostate-specific antigen. There is an increased suspicion of prostatic carcinoma in case of elevated blood PSA level [10]. But the definitive diagnosis of prostatic malignant tumor is confirmed by the histopathological examination of a tissue specimen from the prostate. The rising number of prostatic biopsies for the histopathological examination will increase the stress on the histopathologists in the future, as more than two million cases of prostatic cancer are expected by the year 2040 [3].

The application of artificial intelligence and the development of Computer-aided diagnostic programs may be instrumental in enhancing laboratory efficiency by reducing turnaround time, cost, and the likelihood of human errors. Artificial intelligence is yielding very good results in the interpretation of digital images by analyzing them using Deep learning architecture.

The main focus of this study is to assess the usefulness of machine learning for the histological diagnosis of prostatic adenocarcinoma.

Material and Methods

The research project has been approved by the Ethics Committee of the University of Lahore - Islamabad Campus. Eight hundred and two (802) digital anonymized images were collected, which included 337 images of prostatic adenocarcinoma and 465 images of prostatic hyperplasia. We have used three ResNet convolutional neural network architectures, ResNet -18, ResNet -34 and ResNet-50. Due to dataset limitation, the transfer learning approach has been employed to train the models using the ImageNet dataset [11].

A total of 337 images of prostatic adenocarcinoma and 465 images of nodular hyperplasia of the prostate were used in the present research project. These images have been reviewed and labeled by two histopathologists.

A random approach of FastAI API (available at: https://www.fast.ai/) was used to load the data into train and test sets, to avoid the likelihood of selecting images of the same class for a mini-batch input, that could impact the performance of model validation.

Two sets (training set and test set) were made from the whole dataset. The training set was comprised of 80% of the total dataset, while the Testing set made up 20% of the total dataset. For image, we used data augmentation for regulation.

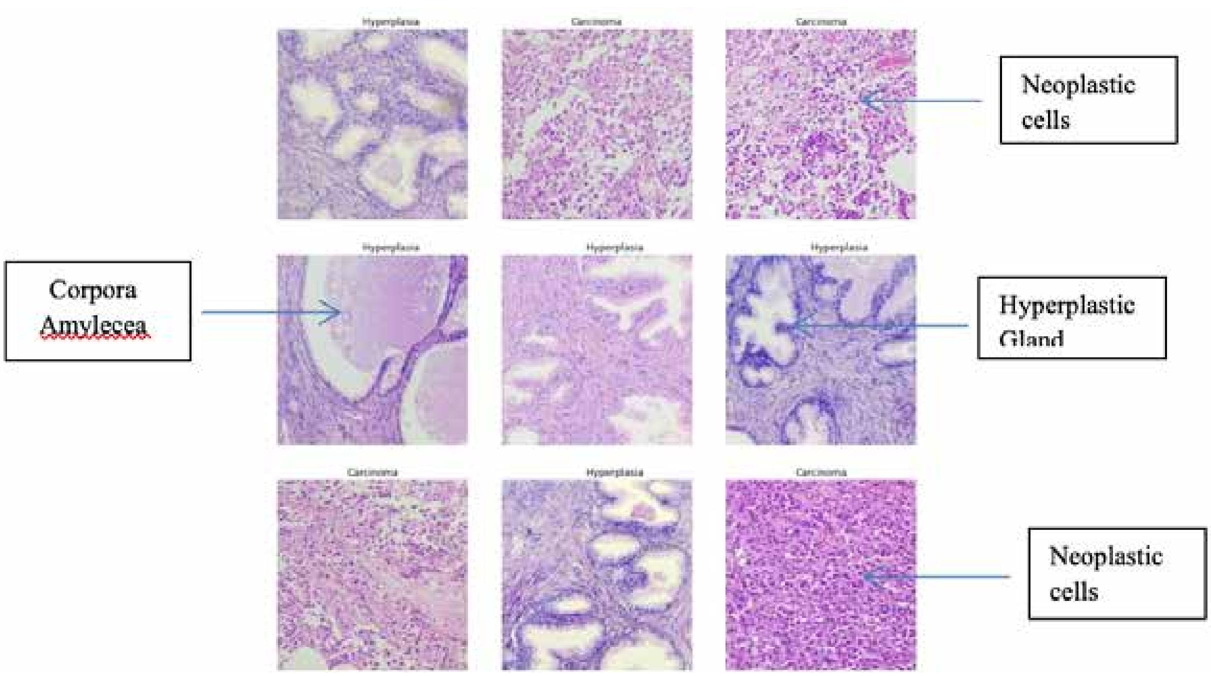

Figure 1. Example of Data and labels loaded using FastAI (randomly)

Table 1. Confusion Matrix of Train and Test Datasets

Architectures	Train Data Set				Test Data Set			
ResNet 18	Actual	Carcinoma	273	6	Actual	Carcinoma	58	1
		Hyperplasia	14	347		Hyperplasia	2	101
			Carcinoma	Hyperplasia			Carcinoma	Hyperplasia
			Predicted				Predicted	
ResNet 34	Actual	Carcinoma	268	3	Actual	Carcinoma	64	0
		Hyperplasia	13	356		Hyperplasia	0	98
			Carcinoma	Hyperplasia			Carcinoma	Hyperplasia
			Predicted				Predicted	
ResNet 50	Actual	Carcinoma	262	3	Actual	Carcinoma	72	0
		Hyperplasia	1	374		Hyperplasia	0	90
			Carcinoma	Hyperplasia			Carcinoma	Hyperplasia
			Predicted				Predicted	

Table 2. Detail Results of Test Dataset

Architectures	Precision	Recall	F-1 Score	Accuracy
ResNet-18	0.966	0.983	0.974	97.1%
ResNet-34	1.0	1.0	1.0	98.0 %
ResNet-50	1.0	1.0	1.0	99.5 %

Results

A total of eight hundred and two (802) images were collected of which, three hundred and thirty-seven digital images (337) of adenocarcinoma of prostate and four hundred and sixty-five (465) images of prostatic hyperplasia. Six hundred and forty (640) images, randomly chosen from both carcinoma and prostatic hyperplasia images accounting for 80% of the total data set, were employed for training data set. One hundred and sixty-two (162) images were randomly chosen from both carcinoma and hyperplasia images that is 20% of the total data set, were employed in the test data set.

Three ResNet architecture models (ResNet-18, ResNet-34 and ResNet-50) were used to classify the input image. The results of training data set and test data set are shown in Table 1 and Figure 1. The diagnostic accuracy of 97.1%, 98 %, and 99.5 % have been achieved with ResNet-18, ResNet-34, and ResNet-50, respectively. The results are depicted in Table 2.

Discussion

The convolutional neural network has been applied in this research project to diagnose prostatic adenocarcinoma by analyzing the digital pathology images which revealed excellent results. The other published series that assessed the accuracy of deep learning for the diagnosis of cancers of lung, breast and prostate also showed very encouraging results [12-15]. In the present study, we applied three architectures of deep leaning (ResNet-18, ResNet-34 and ResNet-150) for the prostatic tissue image analysis to diagnose prostatic adenocarcinoma and to differentiate it from nodular hyperplasia. The ResNet-50 architecture revealed the highest diagnostic accuracy (99.5 %) which is followed by ResNet-34 (98%) and ResNet-18 (97.1%), respectively. A study conducted by Pantanowitz L et al. in which they applied convolutional neural network revealed that the disagreement between the histopathologists and artificial intelligence algorithm for the diagnosis of prostatic carcinoma was only in nine percent of biopsy parts [16].

The rapid advancement in field of artificial intelligence in the recent past has drawn the attention of health care providers to apply this technology for the solution of complex medical problems. The artificial intelligence is characterized by development of machines which have the capability to do cognitive assignments for the achievement of desirable output based on given input. The application of artificial intelligence has been expected to revolutionize the patient care by improving the diagnostic accuracy and reducing the cost with better choices for the management of diseases [17]. An important sub group of artificial intelligence is deep learning. The application of deep learning revealed very encouraging results in the field of radiology for image interpretation. A study conducted by Pasa F et al. showed very encouraging results of Convolutional neural network (CNN) for analysing X-ray images. They used convolutional neural network to diagnose tuberculosis [18].

The histopathological assessment is a quite subjective matter which may be a possible reason of the inter-observer discrepancies. The advancement in the computational image technology may be able to make the histopathology more objective and quantitative [19].

The histopathological diagnosis of malignant tumors is based upon certain specific microscopic features such as pleomorphism, hyperchromasia, high nucleus to cytoplasmic ratio, atypical mitosis, necrosis, multinucleated giant cells and pattern of arrangement of neoplastic cells. The assessment of digital pathology images with machine learning may provide valuable assistance in the interpretation and differentiation of neoplastic and non-neoplastic lesions.

The application of a computer-based diagnostic system in histopathology will be a great help to the histopathologists in the current scenario of a rising trend in the incidence of neoplastic lesions leading to an increase in the number of biopsies.

Adenocarcinoma of the prostate is a quite prevalent tumor in the majority of the countries of the world. More than one million cases of prostate cancer are diagnosed every year around the globe. By 2040, approximately two million persons may become victims of prostatic malignancy every year [3]. The rising number of prostatic biopsies for the purpose of histopathological diagnosis will increase the burden on the diagnostic laboratories and increase the stress on the histopathologists. In order to overcome this situation, the application of smart technology such as artificial intelligence may be very helpful.

The application of digital pathology could be a good substitute for the glass slides for diagnostic purposes in histopathology [20]. The data sets of digital pathology images which have been labeled by histopathologists are employed as training data sets for the convolutional networks. These online available datasets could be used as a training and complementary leaning for the residents [21].

One of the limitations of the present study is the non-segmentation of the image, as architecture is not employed to mark or circle the site of carcinoma on the digital image. Further studies are suggested in which the computer vision system should encircle the segment containing cancerous areas in the digital image, as it would be more helpful for histopathologists to concentrate on that specific site to review it for the diagnosis of malignancy, particularly in the whole digitalized slides.

Conclusion:

1. The findings of the present research project favor the potential application of computer vision-based systems as a valuable tool for the histopathological evaluation of prostatic tissue in differentiating benign from malignant disorders.
2. The use of intelligent vision system in the field of histopathology for the diagnosis of malignant disorders may also lessen the risk of human errors.
3. The application of artificial intelligence in the field of histopathology will reduce the stress and decrease the workload on histopathologists.
4. The application of convolutional neural network architecture may provide the second opinion to the histopathologists.
5. Collections of pathology images datasets may be made available online and these could be used as training and complementary learning resources for the residents.

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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