Implementation of Artificial Intelligence In Prostate Cancer Detection using SWE Elastography Measurements

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ABSTRACT

Introduction and objectives

Globally, prostate cancer (PCa) is a hazard for public health. Male adult PCa is the most commonly diagnosed malignant tumor, and its incidence rate is steadily rising. After lung cancer, prostate cancer ranks second among cancer-related deaths in men. It has previously been established that transrectal elastosonography, one of the techniques for detecting prostate cancer, is practical for directing biopsies and effective in enhancing the identification of prostate lesions. The goal of this research was to create an artificial intelligence system that could forecast prostate cancer by utilizing data from the prostate's shear wave elastography and comparing it to reference standard data from the biopsy specimens' histopathological analysis.

Patients, material and methods

We conducted a prospective trial involving over 350 patients who first appeared for consultation in our specialized outpatient clinic. These patients were subsequently booked for a prostate biopsy guided by transrectal ultrasonography, due to probable prostate cancer. Of the individuals who were initially enrolled, 223 had their PCa diagnosis and confirmation via a prostate biopsy and histological investigation. We built the data set taking into account each biopsy fragment's measurement values expressed in kPa. Three Artificial Intelligence Machine Learning classification algorithms were employed for the set analysis: a fully connected feed-forward deep neural network, a decision tree classifier, and logistic regression.

Results

223 of the 356 patients who had examination and were assessed under our protocol had prostate cancer, according to the results. After analyzing the three AI systems' output, we found that the neural network classifier had the best accuracy (AUC = 0.94), followed by logistic regression (AUC = 0.88) and decision trees (AUC = 0.78). The primary cause of this is a little disparity between positive and negative cases, wherein the dataset has a greater percentage of positive instances of prostate cancer. The final accuracy results for the neural network were as follows: root mean square error = 0.0513, mean absolute value = 0.1272, and loss = 0.0513. We found that the mean absolute error for ExHP was 0.12 for the test set. In order to prevent the freshly generated samples from affecting the model prediction, we solely applied the SMOTE oversampling approach to the training set in order to correct the imbalance. With 290 entries in the training data, we have a completely balanced dataset after using SMOTE. The deep neural network classifier's AUC marginally increased to AUC = 0.95

Conclusions

When used in conjunction with ordinary B-mode ultrasonography, 2D-SWE elastography is a dependable technique that is quite useful for studying prostate anatomy. It can accurately distinguish between benign and potentially cancerous tumors as well as normal tissue. The diagnosis and prognostic processes for prostate cancer can be greatly streamlined by using Artificial Intelligence technologies to process the data from SWE exams.

Key-words: prostate cancer, prostate biopsy, elastography, artificial intelligence

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Introduction

Globally, prostate cancer (PCa) is a hazard for public health. In adult men, PCa is the most common malignant tumor identified with a constant increase in incidence [1]. After lung cancer, prostate cancer ranks second among cancer-related deaths in men. The detection, diagnosis, and treatment of prostate cancer have undergone significant changes in the last 20 years due to the application of screening methods such as transrectal ultrasound (TRUS), digital rectal examination (DRE), and prostate specific antigen (PSA) determination.

Elasticography is a new ultrasound technique that has been proposed and is currently being utilized to guide prostate biopsies. Rectal examinations are frequently used to detect PCa because of its increased cellularity, which makes it stiffer than normal tissue [2]. It has previously been demonstrated that transrectal elastosonography is practical for directing biopsies and beneficial for enhancing the identification of prostate lesions [3].

Recently, very accurate data and measurements have been made available by increasingly sophisticated and effective medical imaging techniques. These data and measurements can be combined and quantified in matrices, networks, and algorithms utilized in artificial intelligence systems. Artificial intelligence (AI) is being used more and more in medicine to help practitioners diagnose patients and choose the best course of treatment by quickly assessing a huge number of parameters and suggesting management strategies and behavioral changes.

The ability of digital technology to imitate human intelligence, at least in some domains like decision-making, is what defines and characterizes artificial intelligence (AI) [4]. Its primary subfield is machine learning, which itself has a subfield called deep learning.

Within the medical domain, the interpretation of medical pictures is a natural level of data processing at which artificial intelligence can be applied.

AI can be used in numerous ways to improve Pca screening, including increasing the rate of detection for MRI and ultrasound, decreasing inter-observer variability among radiologists, and helping pathologists identify and categorize cancer on histopathological pictures. AI-based elastographic image analysis programs are becoming more and more popular as elastography—which provides information on tissue elasticity—becomes a more useful adjunct to traditional ultrasonography. The created models made it possible to increase the accuracy of picture interpretation and, implicitly, the elastography-based diagnosis by doing away with examiner variability.

Objectives

The goal of this research was to create an artificial intelligence system that could forecast prostate cancer by utilizing data from the prostate's shear wave elastography and comparing it to reference standard data from the biopsy specimens' histopathological analysis.

Patients, material and methods

We conducted a prospective trial involving over 350 patients who first appeared for consultation in our specialized outpatient clinic [5]. These patients were subsequently booked for a prostate biopsy guided by transrectal ultrasonography, due to probable prostate cancer. Of the individuals who were initially enrolled, 223 had their PCa diagnosis and confirmation via a prostate biopsy and histological investigation. In order to identify patients, we employed the following inclusion criteria: either an abnormal digital rectal examination that raised the suspicion of prostate cancer, or a total PSA value exceeding 4 ng/ml. Then, we implemented the subsequent exclusion criteria: history of endoscopic or surgical lower urinary tract procedures; history of prostate cancer; and history or recent indications of acute or subacute prostatitis. Following the acquisition of elastographic images, a combined ultrasonographic examination consisting of both conventional transrectal ultrasonography and SWE elastography was performed for direct biopsy. Twelve circular target regions, six peripheral and six

para-urethral, each measuring 5 mm in diameter, were made in the prostate and spaced about 1 cm apart. Grayscale ultrasound was used to first determine whether or not hypoechoic lesions were present in each location, and two-dimensional shear wave elastography was then performed.

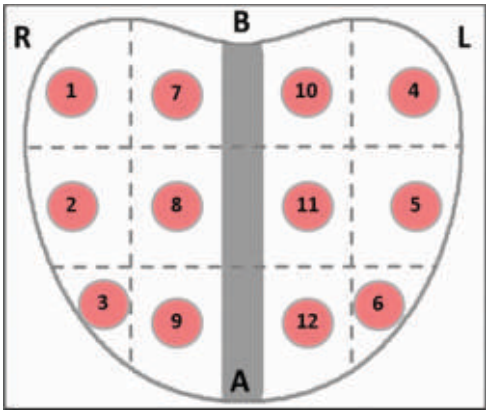


Image 1: Prostate divided into twelve target areas, resulting in a total of twelve biopsy fragments approximately 1 cm apart. Each target area and tissue fragment corresponds to a region evaluated with SWE measurements before biopsies were taken (R = right, L = left, B = base, and A = apex) [5].

We built the data set taking into account each biopsy fragment's measurement values expressed in kPa. We used three machine learning classification algorithms for the set analysis: fully connected feed-forward deep neural network, decision tree classifier, and logistic regression [6].

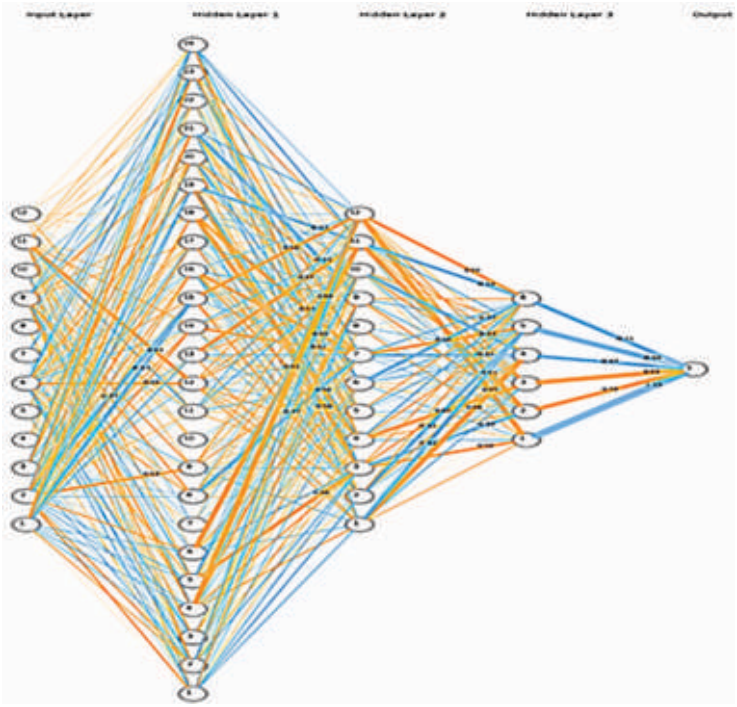
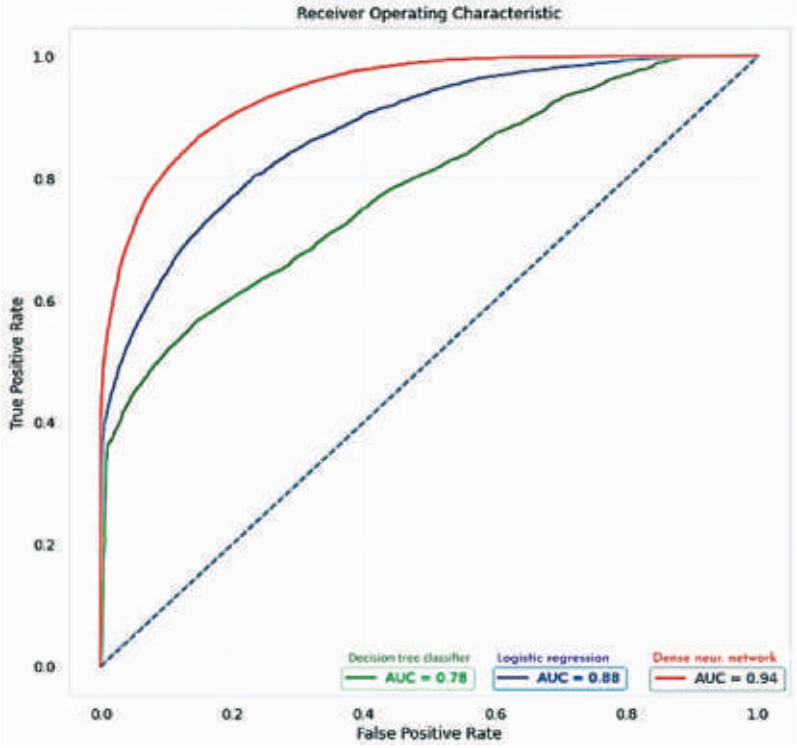


Image 2: Deep learning model visualization. The neurons represented by the small circles are numbered from bottom to top in each layer, in ascending order. The first layer is the input layer with the elasticity values. The other four processing layers (three hidden and one output) are described in the table V. Activation weights are marked with a bold line [5].



IImage 3: ROC curves of the three systems used for prediction: logistic regression (trained with gradient descent instead of ordinary least squares, marked in blue; AUC = 0.88), decision tree classifier (using the ID3 algorithm, marked in green; AUC = 0.78) and the dense neural network (with three hidden layers, marked in red; AUC = 0.94) [5].

Discussions

The major goal of our research was to develop an intelligent system consisting of a clinical and learning component for the ensemble, where we compared the predictions of three supervised classifiers, a logistic regression system, a decision tree, and a dense neural network. This allowed us to prospectively assess the diagnostic performance of two-dimensional shear-wave elastography (2D-SWE) in the detection of prostate cancer. Since TRUS-guided prostate biopsy still has a low sensitivity for identifying CaP, other imaging modalities were investigated. With so many studies focusing on the utility of MRI/TRUS fusion biopsy and multiparametric prostate MRI and showing encouraging findings, several writers have declared that the days of systematic randomized biopsy are coming to an end [9]. Notwithstanding these assertions, there are a few things to keep in mind.

Firstly, mpMRI is a laborious process that needs advanced technology, highly skilled technicians, and physicians to provide high-quality scans and consistent reports [10]. Second, because fusion technology and equipment still greatly vary, fusion biopsy can occasionally not yield repeatable findings even with pricey ultrasound instruments and the right training [11]. Naturally, artificial intelligence has the potential to revolutionize this industry as well. Recent developments have shown that integrating AI into fusion software can have positive effects [145]. Conversely, elastography's advancement over the past 20 years has enhanced the non-invasive evaluation of organ elasticity and made it possible to identify stiff regions that may be tumorigenic [12]. The majority of research has been done on liver elastography, but in the last few years, a lot of effort has been done to analyze the prostate,

breast, thyroid, and spleen [13]. 2D-SWE is the best technique for assessing prostate stiffness because it uses color-coded imaging, which has a higher sensitivity than normal ultrasonography for detecting and evaluating stiff spots that could indicate prostate cancer. In the end, our intelligent approach yielded a high degree of accuracy; nonetheless, we were unable to replace systematic randomized biopsy with SWE targeted biopsy due to the very moderate size of the data set.

Conclusions

When used in conjunction with ordinary B-mode ultrasonography, 2D-SWE elastography is a dependable technique that is quite useful for studying prostate anatomy. It can accurately distinguish between benign and potentially cancerous tumors as well as normal tissue.

The diagnosis and prognostic processes for prostate cancer can be greatly streamlined by using Artificial Intelligence technologies to process the data from SWE exams.

We believe that further study in the area of AI-assisted integration and analysis of pertinent clinical data is imperative, given the positive outcomes of the trials reported in this work.

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