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DEEP LEARNING ALGORITHM FOR THE DIGITAL DYNAMIC USM OF SUBACROMIAL IMPINGEMENT SYNDROME

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Abstract

The article we present is dedicated to dynamic ultrasound examination based on a deep learning algorithm in the diagnosis of subacromial impingement syndrome of the shoulder. Subacromial motion measurements can be extracted from dynamic ultrasound, which is useful for identifying abnormal motion patterns in painful shoulders. This study aims to investigate the feasibility of a deep learning algorithm to extract subacromial motion measurements from dynamic ultrasound.

Materials and methods: This retrospective study included patients with confirmed subacromial impingement syndrome based on physical examination using the Neer test. The supraspinatus muscle regions were manually segmented by an experienced radiologist.

Keywords: *subacromial impingement syndrome, supraspinatus tendon, USM, artificial intelligence, deep learning*

Introduction

Statistical researhces show that the absolute majority of shoulder pain complaints of patients worldwide are caused by subacromial impingement syndrome. Subacromial impingement syndrome accounts for 60% of all shoulder complaints.

First of all, it should be noted that the structure of the shoulder joint is characterized by anatomical and functional complexity, which makes it a target for the development of various pathological changes under the influence of a number of factors that lead to a deterioration in the stability and strength of the joint structures. Damage to the rotator cuff can occur due to both external and internal causes. Symptoms that arise as a result of compression of the rotator cuff mechanism between the acromion, coracoacromial ligament, coracoid process or acromioclavicular joint during movements of the shoulder joint, especially flexion and rotation, and are manifested by pain and limitation of movement in the shoulder, are considered subacromial impingement syndrome.

In the scientific literature, in accordance with the anatomical and functional-pathogenetic concept of this disease, this syndrome is called subacromial impingement syndrome. The pathogenesis of subacromial impingement syndrome is multifactorial:

1) Some authors suggest that intrinsic factors such as degenerative changes, poor vascularization, and overloading are responsible for supraspinatus tendon rupture.

2) Another group of researchers advocates the theory of extrinsic factors in the development of subacromial impingement syndrome. In their opinion, the anatomical features of the structure of the bone elements that cause narrowing of the subacromial space play a leading role.

Clinical application of artificial intelligence system in shoulder ultrasound examination

It is no secret that today there are numerous physical and radiological diagnostic methods for subacromial impingement syndrome. Our research draws on the contributions of the application of artificial intelligence to dynamic ultrasound images in the age of digital technologies for analytical analysis.

Researches show that there is no single diagnostic algorithm that would facilitate the detection of early symptoms and eliminate additional expensive diagnostic methods when examining patients with shoulder pain complaints to confirm subacromial impingement syndrome.

Subacromial motion measurements can be extracted from dynamic ultrasound results, which experts say is useful for identifying abnormal motion patterns in painful shoulders. However, manually marking anatomical landmarks on ultrasound images frame by frame is time-consuming.

Ultrasound imaging has been identified as a viable alternative to MRI. Ultrasound imaging has several advantages over MRI, such as real-time visualization, cost-effectiveness, wide availability, and dynamic evaluation. However, spectral noise in ultrasound imaging can degrade the image, rendering conventional vision-based algorithms ineffective for segmentation of affected points.

Artificial intelligence technology is an inevitable result of the era of scientific and technological development, and it is currently developing rapidly. However, scientists with opposing views on the place of artificial intelligence in clinical diagnostics believe that the real impact of artificial intelligence may emerge gradually in the long term and will not be able to replace clinicians in the short term. However, it is impossible to prevent the development of artificial intelligence applications in the field of medicine.

Research proves that by adding new artificial intelligence technologies to radiological, pathological, endoscopic, ultrasound and biochemical examinations in the field of medicine, disease diagnosis is supported with higher accuracy.

Analysis of the information content of radiological diagnostic methods has shown that, taking into account etiopathogenetic factors and the anatomical structure of the shoulder joint, the ultrasound method is more optimal and prevails in identifying early signs of subacromial impingement syndrome.

Accurate and prompt diagnosis of subacromial impingement syndrome, as well as other shoulder pathologies, is essential to provide patients with timely and appropriate treatment. In this regard, research shows that artificial intelligence technology can analyze medical images with high accuracy and significantly reduce the risk of misdiagnosis.

Today, experts believe that the advantage of artificial intelligence models is that they can significantly improve the detection of subacromial impingement pathology. These models are as skilled as musculoskeletal radiologists, especially in using ultrasound to diagnose it.

Deep Learning, a highly advanced version of Machine Learning, is a rapidly evolving field of research that uses computer algorithms and statistical analysis to identify complex trends and patterns in data that are difficult for humans to recognize. It uses data to create empirical or statistical models that describe the behavior of a system.

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In general, dynamic ultrasound examination, unlike static ultrasound, allows for real-time imaging of the mutual movements of muscles and tendons. Regarding shoulder disorders, indications for dynamic ultrasound are primarily subluxation of the long head of the biceps tendon, instability of the acromioclavicular joint, abnormal sliding of the rotator cuff tendons on the bursa above, limitation of shoulder motion, and subacromial impingement. However, ultrasound examination of the shoulder joint is associated with certain difficulties that require in-depth analysis of the anatomical features of the distribution of local structures. For this reason, experts advocate the widespread application of the achievements of digital technologies to radiological examinations.

Chinese experts have proposed the SMART-CA architecture for better segmentation of shoulder rotator cuff tears in ultrasound visualization, solving the problems caused by low resolution and spectral noise in USM images. SMART-CA mainly uses the encoder-decoder structure used in deep learning models for semantic segmentation, such as U-Net and SegNet. It consists of a binary encoder architecture by adding a pre-trained encoder to the encoder part.

SMART-CA uses a pre-trained network to extract individual features that improve segmentation accuracy. The integrated positive loss function effectively optimizes SMART-CA for unbalanced datasets such as rotator cuff tears. Experimental results showed that SMART-CA with the integrated positive loss function achieved improved precision, recall, and cubic similarity ratio, and is robust to segmentation in the presence of spectral noise, outperforming existing state-of-the-art networks.

In our research, we investigated the feasibility of using a deep learning algorithm to extract subacromial motion measurements from dynamic ultrasound results. Thus, we obtained dynamic ultrasound visualization by asking 17 participants to perform cyclic abduction and adduction along the scapular plane. As a result, the trajectory of the greater tuberosity of the humerus was described using a deep learning algorithm.

Extraction of subacromial motion measurements from USG results was performed using a convolutional neural network (CNN)-based self-learning with an autoencoder or a convolutional neural network (CNN). Using eight-fold cross-validation, it was demonstrated that the mean absolute error was significantly higher in the group using the CNN.

Conclusion

Extraction of subacromial motion measurements from USG results was performed using convolutional neural network or convolutional neural network-based self-learning with an autoencoder. The mean absolute error compared to manually labeled data served as the primary outcome variable. Using eight-fold cross-validation, it was demonstrated that the mean absolute error was significantly higher in the convolutional neural network group.

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