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Machine Learning Algorithms Dramatically Improve the Accuracy and Time to Diagnosis of Pulmonary Embolisms

Youqub Kashif[1], Mian Zayn[2*] and Leventhal Gary[3]

[1]*Pulmonary and critical care fellow, Mayo Clinic, Scottsdale Arizona, USA*
[2]*Research Intern, Atlantis Research Institute, USA*
[3]*Data Analytics and Machine Learning, San Francisco, CA, USA*

Abstract

Acute pulmonary embolism is a common diagnostic challenge across the all hospitals in the US. Diagnosis can be delayed due to a number of variables including, but not limited to, the diagnostic time in medical imaging. The presented algorithm offers a solution to such delays by allowing treating physicians an accurate preliminary report. This gained time advantage should translate into a faster treatment response by the ED team. Moreover, the algorithm is designed to accurately depict pulmonary artery and veins and accounts for respiratory artifact during scan acquisition. As second and third pass search is initiated, the algorithm continues to "learn" upon the subsequent pass. Hence, each application is produces greater diagnostic accuracy. We hope this abstract clearly outlines how the latest developments in machine learning algorithms can aid in diagnostic fidelity of acute embolic events.

Keywords: Machine learning algorithms; Pulmonary embolisms

Introduction

Pulmonary embolism is a life threatening condition with a relatively rapid onset [1,2], often without sentinel warning sign or symptoms. Diagnosis can often be delayed due to the high volume of cases waiting to be interpreted in the imaging department of any ED or hospital [3-5]. By employing software aimed at identifying the radiographic signs of pulmonary embolism, the diagnosis can be made more rapidly and with greater diagnostic fidelity.

Objective

Demonstrate that the addition of a self-learning algorithm in the normal workflow of a diagnostic workup for pulmonary embolism would aid the radiologist in accuracy and in time-to-diagnosis.

Methods

A retroactive review was performed in analyzing CT angiograms of the pulmonary arteries between the period of 1/5/2016 and 5/12/2016. In this timeframe, 600 studies were identified. Reports were reviewed and the imaging findings were initially confirmed by a licensed radiologist. Subsequently, the studies were uploaded into proprietary software for analysis of the data. The software utilized 3D mapping and density attenuation algorithms to identify a sudden change in the contrast-associated Hounsfield units (HU) within a pulmonary artery [6-8]. This sudden change in HU is highly indicative of the presence of an embolic event. Mapping consisted of sequential analysis of predetermined volume of blood (5 × 5 × 5 pixel voxel) in the pulmonary arteries (Figure 1). Once this voxel is identified, it was then compared with the voxel immediately upstream and downstream to assess for any abrupt change in contrast density. The abrupt change in HU was set at +/- 10 HU for a 95% confidence level. Mapping results were then compared to the interpretation of the radiologist (Figure 2).

Results and Discussion

First pass analysis demonstrated 20 (600 case cohort) false positive results when compared to the official report which was set to standard. 12 false positive results were due to motion artifact during the exam, which was erroneously interpreted by the software as a statistically significant HU change within two adjacent voxels. 5 false positive results were attributed to arterial and venous blood mixing artifact as the 3D mapping erroneously tracked the pulmonary veins instead of the arteries. 3 false positive results were attributed to a non-diagnostic contrast bolus: a technical error at the time of CTA acquisition. Zero false negative results were reported. 580 results were in concordance with the official report. Subsequently, the algorithm was further refined following the first pass results with increasing differentiation of pulmonary arteries and veins and, with addition to a blur reduction module, improved fidelity in cases of patient movement on the exam. Second and third pass results demonstrated zero false negative results and only 3 false positive results related to incomplete/non-diagnostic contrast bolus. The original 12 false positive results were resolved on the second and third pass analysis as the software's mapping ability to track

Figure 1: Normal well defined branch patterns of the pulmonary arteries. No embolism identified.

***Corresponding author:** Mian Zayn, Atlantis Research Institute, Atlantis Health Systems, 390 Enterprise, CT Bloomfield, Michigan, United States, Tel: 4802540478; E-mail: fsm456@hotmail.com

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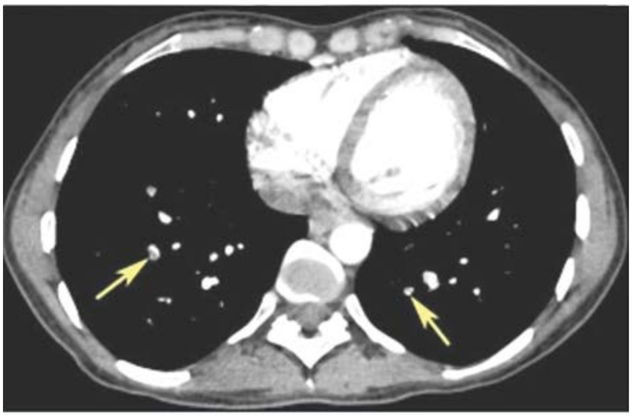

Figure 2: Bilateral pulmonary emboli in third and fourth order branch points of the pulmonary arteries. Small emboli distally located can be a diagnostic challenge.

the branch point of arteries was improved. Time-to-analysis was also tracked. Mean time required for a result was 34.6 seconds. In the initial 12 cases of motion artifact, mean time for results was 97.4 seconds. As the software "learned" to more accurately track the pulmonary arteries, the second and third pass analysis of these 12 cases approached the study average of 42.5 sec *vs.* 34.6 sec.

Conclusion

All conditions in medicine, and particularly those that pose a life threating risk to patients, can benefit from algorithms that offer the trifecta in diagnosis [9,10]: increase fidelity, decrease error rate, and decrease time required for diagnosis [11-14]. As computing power increases and software continues to improve in learning abilities, many tests, particularly in radiology, will greatly benefit from "preliminary analysis" which can be sent to the referring physician often times 30 min to 90 min before the official interpretation is available [15]. Often, this gap in time to diagnosis can mean the difference between proper/timely treatment and an adverse event [16].

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