Applying Artificial Intelligence and Radiomics for Computer Aided Diagnosis and Risk Assessment in Chest Radiographs

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Introduction

- **In urban areas of China, air pollution and particulate exposure seriously affect population lung and cardiovascular health.**
- **The incidence and severity of lung cancer and lung diseases progressively increase each year.**
- **Chest radiography is the most utilized imaging technique among all modalities because it can provide an overall health conditions aiding diagnosis for the thoracic region.**
- **In China, chest radiography is also a standard procedure for the annual physical health exam and for job entry.**
- **Over 800 million chest radiographs annually are interpreted in China for multiple diseases by wide varieties of radiologists ranging from small amount of highly experienced to large amount of less or little experienced radiologists, who may have inadequate formalized training.**
- **For these reasons timeliness of accurate interpretation can be poor.**
- **Excluding infection and trauma, most chest diseases are not acute. By the time symptoms become obvious or severe, the condition is already advanced.**
- **Salient signs in "normal" chest radiographs can be used to analyze the disease risk for diseases and triage examinations which need further, urgent review.**
- **Further development of computational decision support tools should improve diagnosing multiple diseases earlier and analyzing risks for clinically asymptomatic patients from chest radiographs; and thus will improve the quality of healthcare.**

Methods

- **We developed multiple machine learning and artificial intelligence technologies for radiomics on chest radiographs as an integrated automatic system to assist radiologists in detecting TB, lesions, pneumonia, and heart diseases as well as in analyzing scoliosis, chest region, and contrastive follow-up images. Our system can also assess the risk for potential heart disease, COPD, nodules, and pneumonia based on the cardiothoracic ratio (CTR), costophrenic angle and diaphragmatic surface evaluation, analysis of small abnormalities, and appearance of lung markings, as shown in Figure 1.**
- **These technologies were applied on 2,376 chest radiographs with pathological or follow-up confirmation of various diseases, acquired from hospitals in China and in the U.S. Additionally, over 400 healthy patients with longitudinal chest radiographs and confirmation of disease onsets have also been collected for the evaluation of the performance for risk assessment.**
- **We have applied a graph-cut based segmentation of the lung region, a partitioning of the lung into different zones, a set of texture and shape features, and a classification into normal or abnormal using various machine learning algorithms including support vector machine, convolutional neural network, and transfer learning.**
- **Because a large number of abnormal manifestations are obscured by bones, we further applied a bone suppression method to remove the ribs and clavicles from a chest radiograph in order to reveal the tissue beneath, using rib and clavicle structure detection and deep learning, and profile estimation. We also applied a temporal subtraction method to highlight the pathologic change across serial chest radiographic images using rigid body transformation based on a global alignment criterion, piece-wise image warping under the maximum cross-correlation criterion, and subtraction between the registered previous and current images. Multiparametric analysis across multiple modalities including imaging and patient survey information is also applied to further improve the diagnostic accuracy.**
- **A diagnostic report, such as the example shown in Figure 2, is generated for each disease to associate image findings with clinical diagnoses based on a reinforcement learning Markov decision processing.**

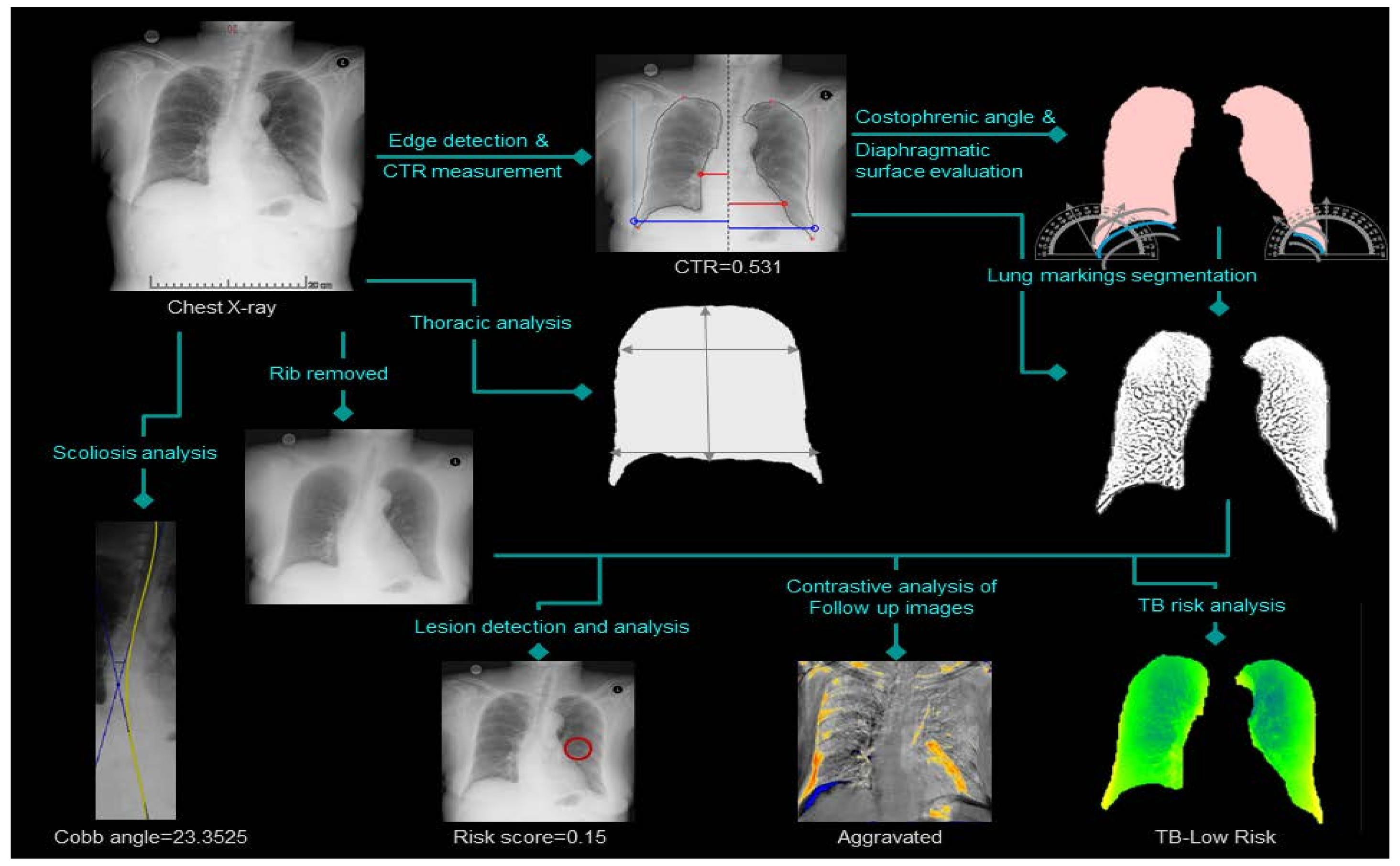

Figure 1: Overall system schematic diagram showing detection of diseases, assessment of risk, and analysis of abnormalities on chest radiograph

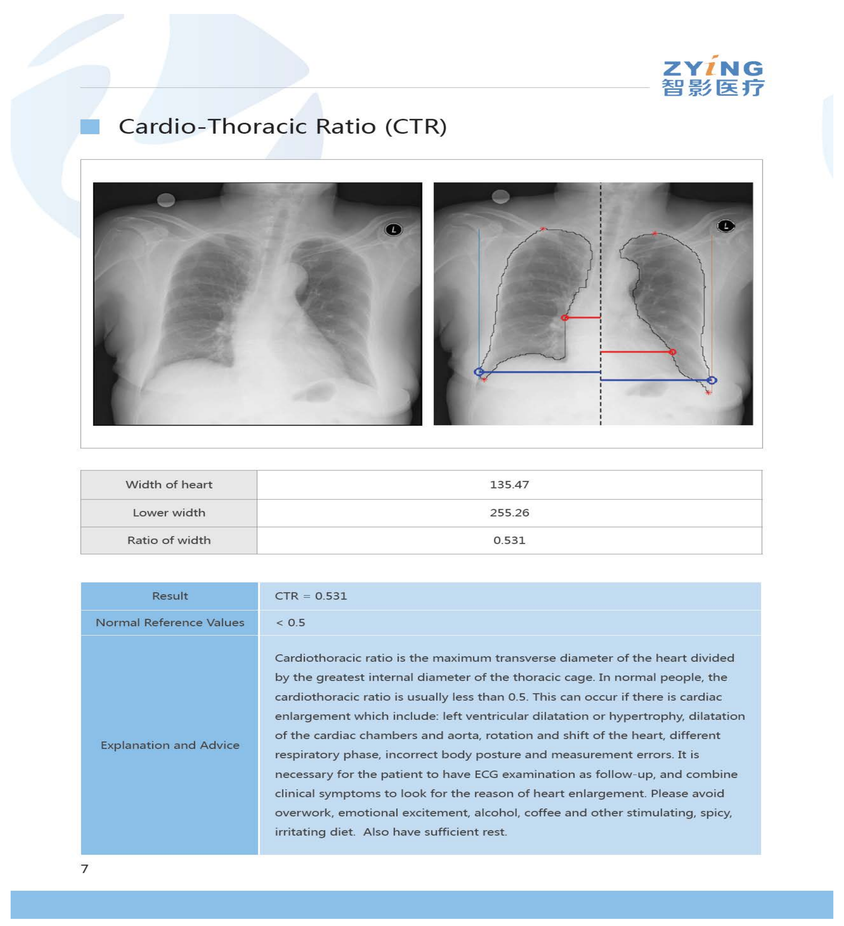

Figure 2: An example of diagnostic report of including image, its findings, measurements, explanation and advice for a patient

Results

No	Clinical Application	Performance
1	Identification of the lung region	Dice coefficient of 91%.
2	Chest x-ray screening during annual physical exam	• 20% of individuals selected to be read by doctors • 2.5 times higher detection rate of abnormalities
3	Identification of TB-suspicious cases	• overall accuracy: 99.3% • false positive rate: 7%
4	Thresholds between high-risk and low-risk • Enlarge heart • Potential COPD • Pneumonia	 • CTR: 0.43 • diaphragm smoothness: 0.70; costophrenic angle of 45 degree • Lung markings distribution in the peripheral region: 30%
5	Changes of lung area, thorax, diaphragmatic surfaces, costophrenic angle, and CTR with a list of possible abnormalities over a period of time	

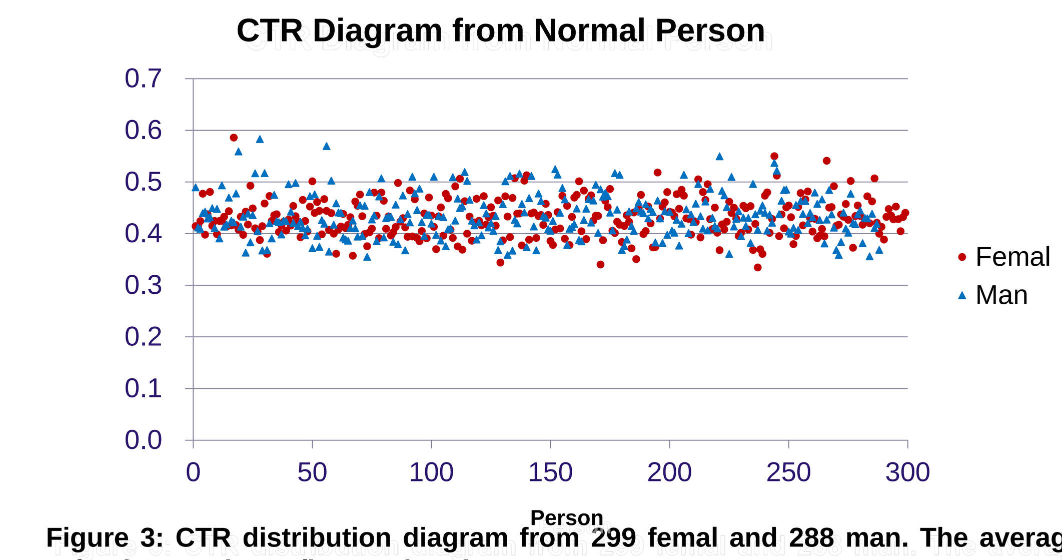

Figure 3: CTR distribution diagram from 299 femal and 288 man. The average value is 0.431(Femal), 0.435(Man).

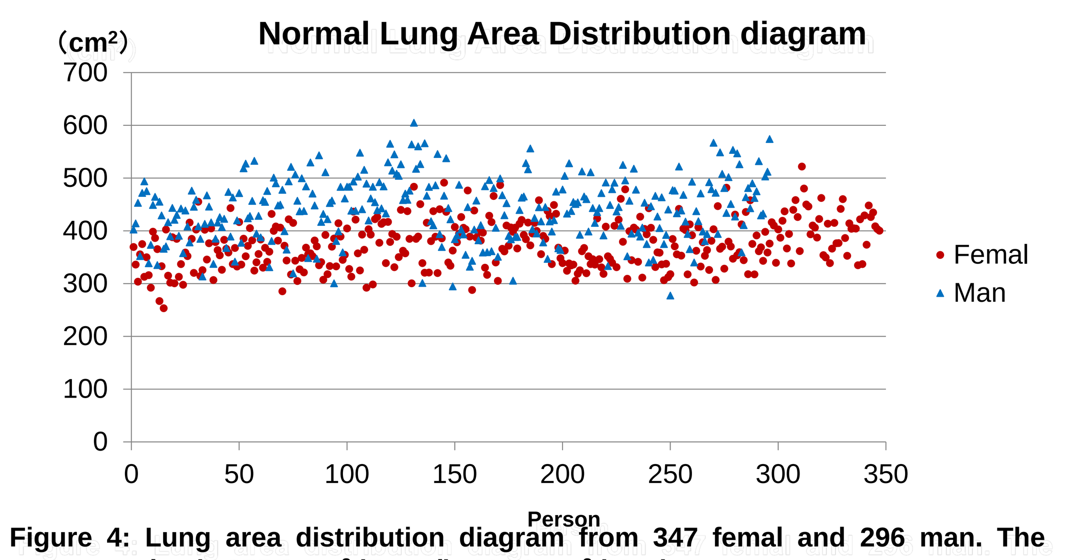

Figure 4: Lung area distribution diagram from 347 femal and 296 man. The average value is 375.9 cm² (Femal), 441.2 cm² (Man).

Discussion

- **One of the first automatic systems in a hospital for diagnosis of more than one lung abnormality on chest radiographs**
- **The first one to automatically assess risks for various diseases in chest radiographs of asymptomatic individuals**
- **Automatically associate image findings with diagnostic reports**

- Stored in electronic health/medical records (EHR/EMR)
- Provide health management capability

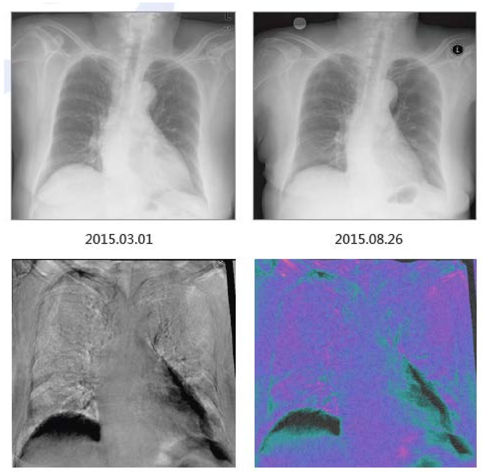

Figure 5. Temporal Subtraction of two CXR taken from same patient. Dark areas in the subtracted image shows the interval changes of the symptom.

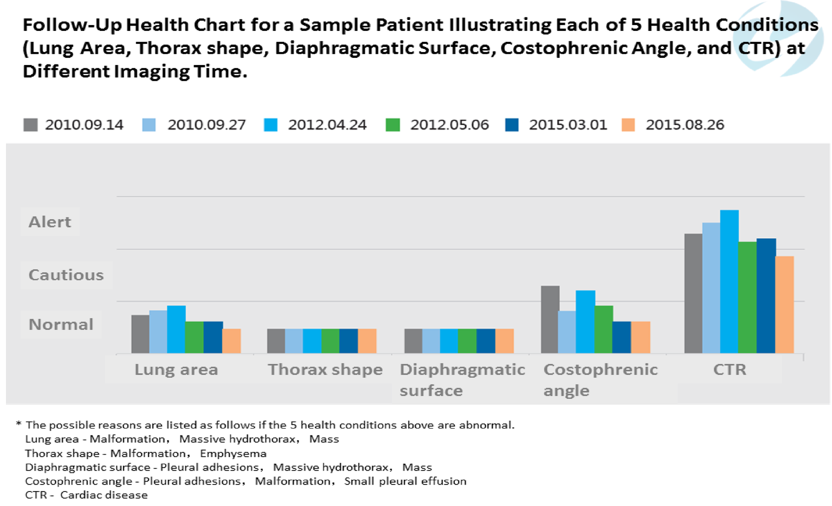

Figure 6: An example of follow up health chart for a patient showing the changes of lung area, thorax, diaphragmatic surfaces, costophrenic angle, and CTR associated with a list of possible abnormalities over a period of time

Conclusions

- **An integrated system based on artificial intelligence, radiomics, advanced image processing to detect abnormalities and to assess the risk for various chest and heart diseases.**
- **Transfer radiological findings from images to electronic medical records (EMR).**
- **Health charts provides a summary of the analysis for effective communication and tracking of findings for health management for each individual.**
- **Use of this system can improve the diagnostic accuracy, shorten the diagnostic time, assess progress of disease, and improve efficiency of health providers.**

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