

# Applying Deep Learning and Radiomics to Determine Biological Lung and Heart Age from Chest Radiographs

Guanxun Cheng<sup>1,12</sup>, Puxuan Lu<sup>5,13</sup>, Peijun Wang<sup>3</sup>, Wen Zhou<sup>1</sup>, Weiye Yu<sup>5</sup>, Stefan Jaeger<sup>6</sup>, Jing Li<sup>10</sup>, Teresa Wu<sup>10</sup>, Xiaowen Ke<sup>2</sup>, Bin Zheng<sup>9</sup>, Sameer Antani<sup>6</sup>, Sema Candemir<sup>7</sup>, Shenwen Quan<sup>2</sup>, Fleming Y. M. Lure<sup>2,11</sup>, Hongjun Li<sup>4,14</sup>, Lin Guo<sup>2,15</sup>

1. Peking University Shenzhen Hospital, Shenzhen, Guangdong Province, China
2. Shenzhen Zhiying Medical Imaging, Shenzhen, Guangdong Province, China
3. Shanghai Tongji Hospital, Shanghai, China
4. Beijing Youan Hospital, Capital Medical University, Beijing, China
5. Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, China
6. National Library of Medicine, National Institute of Health, Bethesda, MD
7. The Ohio State University Wexner Medical Center, Radiology Department
8. Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, China
9. Department of Electrical Engineering, University of Oklahoma, Norman, OK, USA
10. School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Tucson, AZ, USA
11. College of Engineering, University of Texas, El Paso, TX, USA
12. **First author (第一作者):** The first two authors contributed equally to this paper.
13. **Joint first author (并列第一作者):** The first two authors contributed equally to this paper.
14. **First correspondence author (第一通讯作者)**
15. **Second correspondence author (第二通讯作者)**

## Purpose

Age is an important risk factor for disease. The study goal is to establish a mean value of the size of lung parenchyma (SLP) and the cardiothoracic ratio (CTR) of healthy population in Southern China using a large-scale chest radiograph (CXR) dataset as baseline for different ages and genders. The result is used to generate prediction models for biological lung or heart age to monitor aging processes and early detect lung or heart diseases.

## Material and methods

A large PA/AP CXR dataset was acquired from six sources in Southern China, from 2012 to 2018, including 249,858 and 222,011 CXRs for SLP and CTR, respectively. All cases were confirmed by at least one radiology report, EKG, or other clinical report to exclude abnormal SLP and pre-existing heart conditions.

CXR image was first resized and converted into PNG format. An adaptive histogram equalization was applied to improve the contrast. A deep learning artificial intelligence (AI) technique was trained and applied to automatically segment the left and right lung, and the heart area with a very high accuracy

(DICE value $<0.017$ ). The left and right SLP was calculated for different ages and genders. The CTR was calculated for each age and gender by dividing the transverse cardiac diameter by the maximum internal thoracic diameter.

## Results

The mean right and left SLP increased with age until it peaked at gender specific maturity age. Figures 1 and 2 show the SLP and CTR profiles for each age, referred as lung and heart age, with a 95% confidence level. The mean SLPs of the study population were 399, 368, and 435 cm<sup>2</sup>, and the mean CTRs of the study population were 0.417, 0.420, and 0.413, for general, female, and male population, respectively.

## Conclusion

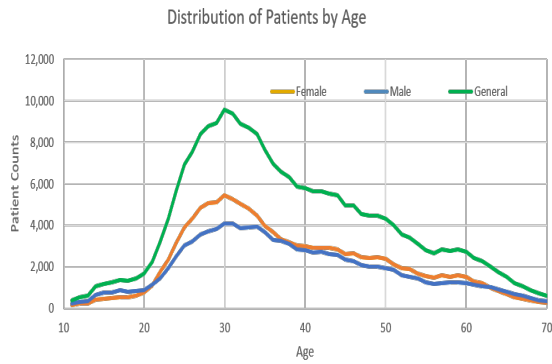
This is the first large-scale study on radiological lung and heart age measured using PA/AP CXR images. The study generated prediction models and obtained the averaged biological lung and heart age using deep learning AI and radiomics. The trend of lung and heart age profiles are similar to various reported disease risks and growth trends.

**Key Words:** Deep Learning Convolutional Neural Network, Artificial Intelligence, Chest Radiograph, Lung Age, Heart Age, Biological Age

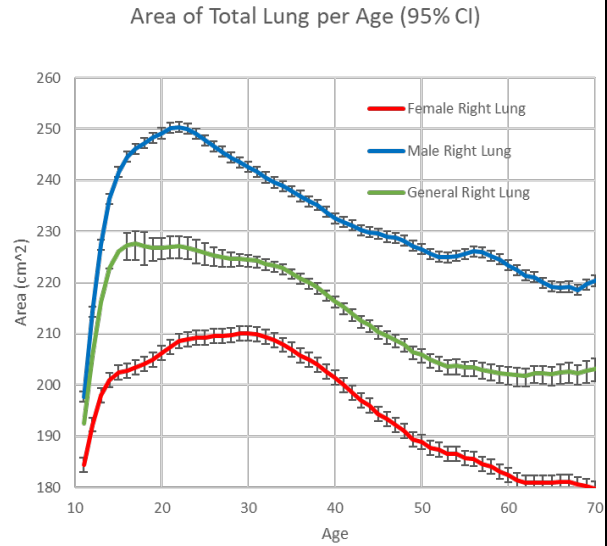
## References:

1. Parkes G, Greenhalgh T, Griffin M, et al. Effect on smoking quit rate of telling patients their lung age: the Step2quit randomised controlled trial[J]. *Bmj*, 2008, 336(7644): 598-600.
2. Gollogly S, Smith J T, White S K, et al. The volume of lung parenchyma as a function of age: a review of 1050 normal CT scans of the chest with three-dimensional volumetric reconstruction of the pulmonary system[J]. *Spine*, 2004, 29(18): 2061-2066.
3. Kovalev V, Prus A, Vankevich P. Mining lung shape from x-ray images[C]//International Workshop on Machine Learning and Data Mining in Pattern Recognition. Springer, Berlin, Heidelberg, 2009: 554-568.
4. Mensah Y B, Mensah K, Asiamah S, et al. Establishing the cardiothoracic ratio using chest radiographs in an indigenous Ghanaian population: a simple tool for cardiomegaly screening[J]. *Ghana Medical Journal*, 2015, 49(3): 159-164.
5. Hansen J. Lung age is a useful concept and calculation[J]. *Primary Care Respiratory Journal*, 2010, 19(4): 400.
6. Li Z, Hou Z, Chen C, et al. Automatic Cardiothoracic Ratio Calculation With Deep Learning[J]. *IEEE Access*, 2019, 7: 37749-37756.
7. Waziry R, Gras L, Sedaghat S, et al. Quantification of biological age as a determinant of age-related diseases in the Rotterdam Study: a structural equation modeling approach[J]. *European Journal of Epidemiology*, 2019: 1-7.
8. Jia L, Zhang W, Chen X. Common methods of biological age estimation[J]. *Clinical interventions in aging*, 2017, 12: 759.

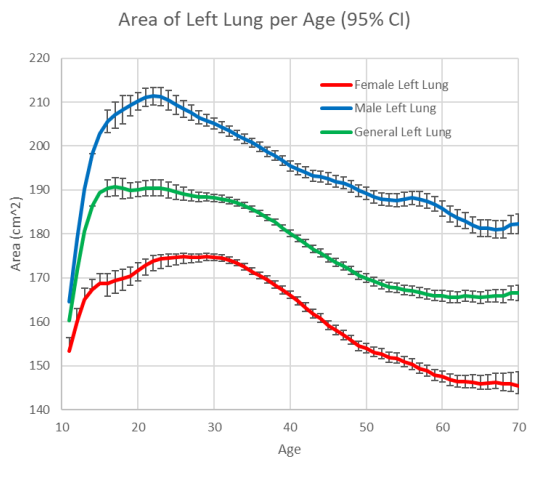
Figure 1. Distribution of patients by age (a) used to generate SLP; Total SLP distribution by age (b); Left SLP distribution by Age (c); and Right SLP distribution by Age (d). The mean SLP increased gradually from Age 12 till Age 24, with females having less values than males. The right SLP is greater than the left SLP.



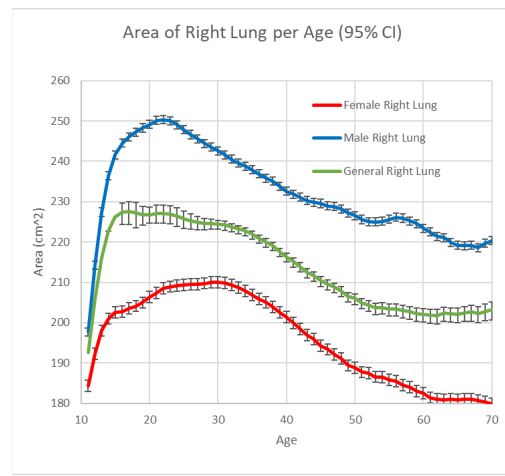
(a) Distribution of Patients by Age



(b) Total SLP Distribution by Age

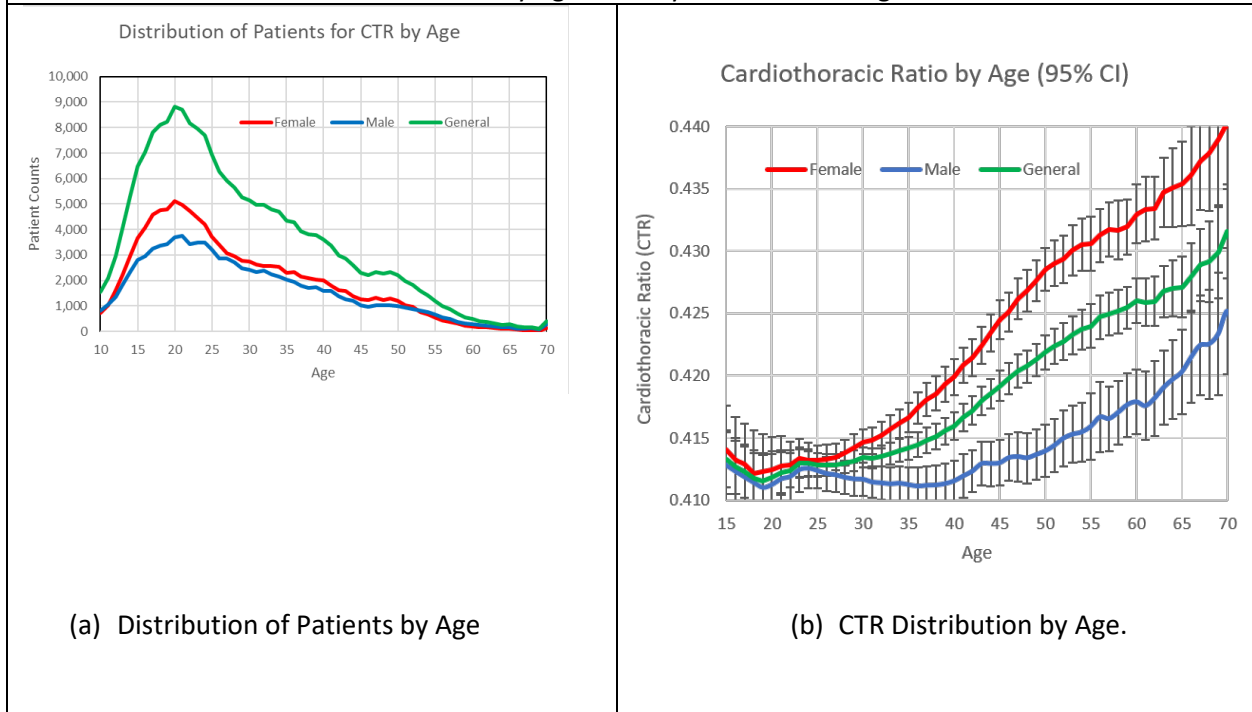


(c) Left SLP by Age



(d) Right SLP by Age

Figure 2. Distribution of patients by age (a) used to generate CTR profile and average CTR distribution by age (b). The mean CTR increased with age, with females having greater values than males, and the CTR for males staying relatively flat until after Age 35.



**Authors:**

**Name: Guanxun Cheng**

Degree: MD., Ph.D.

Title: Director, Department of Radiology

Organization: Peking University Shenzhen Hospital, Shenzhen, Guangdong Province, China

Address: No. 1120th Futian Lianhua Road, Shenzhen, Guangdong, China

Phone: +86-139-2520-0816

E-mail address: chengguanxun@outlook.com

**Name: Pu-xuan Lu**

Degree: M.D., Ph.D.

Title: Radiologist

Organization: Shenzhen Center for Chronic Disease Control, Guangdong Province, China.

Address: NO.2021, Buxin Road, Luohu District, Shenzhen, Guangdong, China 518020

Phone: +86-0755-25503845

E-mail address: Lupuxuan@126.com

**Name: Peijun Wang**

Degree: M.D., Ph.D.

Title: Director, Department of Radiology,

Organization: Shanghai Tongji Hospital, Shanghai, China.

Address: 389 Xincun Rd. Shanghai 200065,P.R.C.  
Phone: +86-139-0169-0566  
E-mail address:tongjipjwang@vip.sina.com

**Name:Wen Zhou**

Degree: M.D.,Ph.D.

Title: Deputy director of radiology

Organization: Peking University Shenzhen Hospital, Shenzhen, Guangdong Province, China

Address: No. 1120th Futian Lianhua Road, Shenzhen, Guangdong, China

Phone: +86-138-2889-6802

E-mail address: 798380277@qq.com

**Name: Weiye Yu**

Degree: M.D., Ph.D.

Title: Director, Department of tuberculosis

Organization: Shenzhen Center for Chronic Disease Control, Guangdong Province, China.

Address: NO.2021, Buxin Road, Luohu District, Shenzhen, Guangdong, China 518020

Phone: +86-0755-25503845

E-mail address: [ywy2002@163.com](mailto:ywy2002@163.com)

**Name: Stefan Jaeger**

Degree: Ph.D.

Title: Research Fellow

Organization: National Library of Medicine, National Institute of Health

Address: 8600 Rockville Pike, Bethesda, MD 20894

Phone: 301-435-3198

E-mail address: stefan.jaeger@nih.gov

**Name: Jing Li**

Degree: Ph.D.

Title: Associate Professor

Organization: School of Computing, Informatics, and Decision Systems Engineering, Arizona State University

Address: 699 S. Mill Ave., Tempe, Arizona, 85281-8809

Phone: 480-965-0125

E-mail address: [jing.li.8@asu.edu](mailto:jing.li.8@asu.edu)

**Name: Teresa Wu**

Degree: Ph.D.

Title: Professor

Organization: School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Phoenix, AZ

Address: 699 S. Mill Ave., Tempe, Arizona, 85281-8809

Phone: 480-965-4157

E-mail address: teresa.wu@asu.edu

**Name: Xiaowen Ke**

Degree: M.S.

Title: AI Engineer  
Organization: Shenzhen Zhiying Medical Imaging, Shenzhen, China  
Address: Building 9-C-1606, Baoneng Science & Technology Park  
Longhua District, Shenzhen, China  
Phone: +86-135-3888-7747  
E-mail address: [xiaowen.ke@zying.com.cn](mailto:xiaowen.ke@zying.com.cn)

**Name: Bin Zheng**

Degree: Ph.D.  
Title: Professor  
Organization: University of Oklahoma  
Address: 110 W. Boyd Street, Devon Energy Hall 150  
Norman, Oklahoma 73019-1102  
Phone: 405-325-3597  
E-mail address: [bzheng5911@gmail.com](mailto:bzheng5911@gmail.com)

**Name: Sameer Antani**

Degree: Ph.D  
Title: Staff Scientist  
Organization: National Library of Medicine, National Institute of Health  
Address: 8600 Rockville Pike, Bethesda, MD 20894  
Phone: 301-435-3218  
E-mail address: [sameer.antani@nih.gov](mailto:sameer.antani@nih.gov)

**Name: Sema Candemir**

Degree: Ph.D.  
Title: Radiology Department  
Organization: The Ohio State University Wexner Medical Center, Radiology Department  
Address: 444 Faculty Office Tower, 395 W 12th Avenue, Columbus, OH, 43210  
Phone: 614939978  
E-mail address: [candemirsema@gmail.com](mailto:candemirsema@gmail.com)

**Name: Shenwen Quan**

Degree: B.S.  
Title: Sr. Engineering Manager  
Organization: Shenzhen Zhiying Medical Imaging, Shenzhen, China  
Address: Building 9-C-1606, Baoneng Science & Technology Park  
Longhua District, Shenzhen, China  
Phone: +86-0755-23702592  
E-mail address: [shenwen.quan@zying.com.cn](mailto:shenwen.quan@zying.com.cn)

**Name: Fleming Y. M. Lure**

Degree: Ph.D.  
Title: Chief Technology Officer  
Organization: Shenzhen Zhiying Medical Imaging, Shenzhen, China  
Address: Building 9-C-1606, Baoneng Science & Technology Park  
Longhua District, Shenzhen, China

Phone: +86-188-2529-1652

E-mail address: [f.lure@hotmail.com](mailto:f.lure@hotmail.com)

**Name: Hongjun Li**

Degree: M.D., Ph.D.

Title: Director, Department of Radiology,

Organization: Beijing Youan Hospital, Capital Medical University, Beijing, China.

Address: Rm 205, Bldg D, No. 8, Xi Tou Tiao, You An Men Wai

Feng Tai District, Beijing, 100069, China

Phone: +86-135-2027-8511

E-mail address: lihongjun00113@126.com

**Name: Lin Guo**

Degree: Ph.D.

Title: Clinical Researcher Manager

Organization: Shenzhen Zhiying Medical Imaging, Shenzhen, China

Address: Building 9-C-1606, Baoneng Science & Technology Park

Phone: +86-136-1283-0660

E-mail address: guolin913@outlook.com