Deep Learning to Estimate Biological Age from Chest Radiographs

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Introduction

• Aging is a fundamental cause of cancer, cardiovascular, and neurological diseases via chronic inflammation, cellular damage and senescence, and genomic instability.
• Chronological age (years since birth) is an imperfect measure of aging, but is routinely used in clinical care to stratify risk.
• Biological age is a number in years that quantifies an individual’s decline in function.
• Biological age is currently estimated via DNA methylation, comorbidities, or functional tests, but are rarely used clinically due to mixed results for chronic disease prediction and difficulty in obtaining source data.
• Chest radiographs (chest x-rays or CXRs) are the most common diagnostic imaging test.

Purpose

• To develop a deep learning model (CXR-Age) that estimates biological age from a single chest x-ray image.
• To assess whether CXR-Age predicts all-cause mortality better than chronological age.

Methods

A ResNet34 CNN was pretrained to predict chronological age using publicly available cohorts.

• The CNN was then fine-tuned to predict a “biological age” in 25% of the PLCO CXR Arm.
• Biological age labels for training only were defined as: BA = CA + (E-D)
• BA is the biological age label, CA is chronological age at the time of the CXR, E is an expected age at death according to US Social Security Life Tables, and D is actual age at death.
• For those who survived during follow-up D was estimated using a risk-factor based survival model developed in the control arm of PLCO.

Prostate, Lung, Colorectal, and Ovarian Cancer (PLCO) Screening Trial

• RCT of no screening vs screening with CXR
• 55-74 years old
• Non-smokers and smokers
• Enrolled @ 10 US sites
• Outcome: Median 18-year follow-up for mortality

National Lung Screening Trial (NLST)

• RCT of no screening vs CT
• 55-74 years old
• Current or former heavy smokers
• Enrolled @ 23 US sites
• Outcome: Median 12-year follow-up for mortality

Results

Kaplan-Meier survival curves by CXR-Age group in PLCO testing data for individuals with a baseline chronological age of (a) 55-59 years, b) 60-64 years, c) 65-69 years, and d) 70-74 years. CXR-Age shows a graded association with longevity in individuals with similar baseline chronological age.

Conclusions

• A convolutional neural network can estimate biological age from a chest x-ray image, and this biological age predicts mortality better than chronological age.

References

(4) Selvaraju, RR et al. (2017). Grad-CAM: Visual Explanations from Deep Networks via Gradient-Based Localization. CVPR.