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Deep learning to predict long-term mortality from plain chest radiographs in patients referred for suspected angina

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Background: The chest radiograph (CXR) is a well-established and broadly used first line diagnostic tool in patients with suspected cardiac conditions. In previous literature, artificial intelligence (AI) based interpretation of CXR has been shown to predict follow-up mortality of patients screened for neoplastic disease.

Purpose: In this context, we summarize our experience with the training, testing, and validating (internally and externally) of a deep learning (DL) model purposefully designed for predicting, from a single projection (posteroanterior/anteroposterior) CXR, long-term mortality of patients referred for angina and suspected coronary artery disease (CAD).

Methods: Demographic, clinical, and follow-up data of patients referred for angina to our institution (located in southern Europe) and undergoing coronary angiography were analyzed retrospectively. A deep convolutional neural network (DCNN) was designed to predict follow-up mortality from CXRs. External validation was performed on patients referred to a different medical Institution (located in north-western Europe).

Results: 6031 was randomly divided for model training (70%; n=4259) and model fine-tuning/model validation (10%; n=602). Internal clinical validation (model testing) was performed with the remaining patients (20%; n=1170). Patients were stratified according to AI-based interpretation quartiles (DCNN-CXR risk score). Median follow-up was 6.1 years (IQR 3.3 – 8.7) with a Kaplan-Meier (KM) overall estimated mortality of 21.9% (CI 19.2%-24.5%). Estimated mortality increased significantly according to the DCNN-CXR risk score (Low-risk 5%, Moderate 17%, High 29%, Very High 46%; p<0.0001) (figure 1-A). At Cox regression, the AI-derived CXR-score was the strongest predictor of follow-up mortality (p<0.005; OR: 3.16; CI: 2.47-3.85) and had an AUC of 0.793 (95% AUC CI: 0.759-0.827, Sens. 78%, Spec. 0.68%), that was significantly better than that achieved when using coronary angiography findings (AUC: 0.569, 95% CI: 0.526-0.611) (p<0.001) and age (AUC 0.735, 95% CI: 0.694-0.776) (p<0.004) as predictors (figure 1-B). The DCNN-CXR mortality prediction model improved when age and CAD status at the referral time were included (AUC 0.81; CI: 0.775-0.843). Preliminary results on external validation confirmed the DCNN-CXR-risk prediction performance (AUC 0.712 CI: 0.495-0.928; Sens 0.838; Spec 0.338).

Conclusion: Our DCNN model predicted, from a CXR, long-term overall mortality of patients with suspected angina pectoris referred for coronary angiography. The performance has been confirmed at internal and external validation, on patients in a different European country. The DCNN CXR-risk score could stratify long-term mortality risk better than any other risk factor, including CAD presence and degree. These findings may be used to optimize screening and prevention actions for this very comorbid group of patients.

Figure **1-A:** Kaplan-Meier Survival Estimates by CXR-Risk Score (logrank p-value < 0.001). **1-B:** ROC curves: CAD status vs AI p-value < 0.001; Age vs AI p-value=0.004; AI+Age+CAD status vs AI p=ns).