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Two-stage artificial intelligence model for jointly measurement of atherosclerotic wall thickness and plaque burden in carotid ultrasound: A screening tool for cardiovascular/stroke risk assessment

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Abstract

Motivation: The early screening of cardiovascular diseases (CVD) can lead to effective treatment. Thus, accurate and reliable atherosclerotic carotid wall detection and plaque measurements are crucial. Current measurement methods are time-consuming and do not utilize the power of knowledge-based paradigms such as artificial intelligence (AI). We present an AI-based methodology for the joint automated detection and measurement of wall thickness and carotid plaque (CP) in the form of carotid intima-media thickness (cIMT) and total plaque area (TPA), a class of AtheroEdge™ system (AtheroPoint™, CA, USA).

Method: The novel system consists of two stages, and each stage comprises an independent deep learning (DL) model. In Stage I, the first DL model segregates the common carotid artery (CCA) patches from ultrasound (US) images into the rectangular wall and non-wall patches. The characterized wall patches are integrated to form the region of interest (ROI), which is then fed into Stage II. In Stage II, the second DL model segments the far wall region. Lumen-intima (LI) and media-adventitial (MA) boundaries are then extracted from the wall region, which is then used for cIMT and PA measurement.

Results: Using the database of 250 carotid scans, the cIMT error using the AI model is 0.0935±0.0637 mm, which is lower than those of all previous methods. The PA error is found to be 2.7939±2.3702 mm^2. The system's correlation coefficient (CC) between AI and ground truth (GT) values for cIMT is 0.99 ($p < 0.0001$), which is higher compared with the CC of 0.96 ($p < 0.0001$) shown by the earlier DL method. The CC for PA between AI and GT values is 0.89 ($p < 0.0001$).

Conclusion: A novel AI-based strategy was applied to carotid US images for the joint detection of carotid wall thickness (cWT) and plaque area (PA), followed by cIMT and PA measurement. This AI-based strategy shows improved performance using the patch technique compared with previous methods using full carotid scans.

Keywords: AI; Carotid plaque; Common carotid artery; Deep learning; Noninvasive cardiology; Plaque area; Wall thickness; cIMT.

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