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Deep neural networks improve atrial fibrillation detection in Holter: first results

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Background: Atrial fibrillation (AF) is the most common human arrhythmia. High prevalence in the aged population (0.5% for 50–59 to 9% for 80–89), and increased risks of hospitalisation, strokes and death call for early detection using long-term ambulatory electrocardiogram (Holter ECG). Previous works concluded that algorithms using RR interval durations as input yield a good sensitivity while being robust to noise. However, such algorithms are characterised by poor specificity and positive predictive value (PPV); no previous algorithm which uses shape information, such as atrial fibrillatory pattern, achieved better overall results. We used deep convolutional neural networks (DNNs) to overcome this difficulty, since such models are known to be well suited for solving pattern recognition problems.
Methods: We trained a DNN (20 M parameters, 1.6 M neurons, 16 layers) on a set of 200,000 annotated 20 seconds ECG in order to classify AF and other arrhythmias. We then processed Holter data by splitting it into 20 second periods, and classified AF episodes (AF vs not AF). The reference standard for performance evaluation was the independent MIT BIH arrhythmia database (not used for training). The MIT BIH arrhythmia database is a reference dataset annotated by cardiologists for automatic arrhythmia detection benchmarking; it consists of 48 30-minute ECG recordings extracted from long-term 24-hour ambulatory ECG recordings, half of which manifest clinically significant arrhythmias. Specificity (Sp), sensitivity (Se), accuracy (Acc) and PPV were calculated for AF episode detection and compared to that of RR-interval method results as reported in the literature.
Results: Performance of the previously published RR dynamic method compared to the tested DNN method was Sp¼ 82.8 (81.6–84.0) vs Sp¼ 98.5 (98.1–98.9), Se¼ 96.3 (94.5–98.1) vs Se¼ 96.9 (95.2–98.6) Acc ¼ 85.53 (84.43–86.63) vs Acc ¼ 98.3 (97.9–98.7) and PPV¼ 58.7 (54.0–63.4) vs PPV¼ 89.6 (86.7–92.5) (confidence intervals 95%). The DNN was therefore much more specific without any loss of sensitivity. Evaluation for episodes containing either AF or atrial flutter episodes yielded Sp¼ 99.2 (98.9–99.5), Se¼ 96.8 (95.1–98.5), Acc ¼ 99.0 (98.7–99.3) and PPV¼ 92.3 (89.7–94.9), hence improving detection again.
Conclusions: This deep neural network performed significantly better in the detection of AF than previously published RR interval-based methods. This method may be more reliable and accurate than previous methods in the diagnosis of AF on long duration ambulatory ECG and other monitoring devices.