Screening for atrial fibrillation: improving efficiency of manual review of handheld electrocardiograms

Madhumitha Pandiaraja, James Brimicombe, Martin Cowie, Andrew Dymond, Hannah Clair Lindén, Gregory Y. H. Lip, Jonathan Mant, Kate Williams and Peter H. Charlton on behalf of the SAFER Investigators
Background

- AF affects approximately 3.3% of UK population [1]
- Intermittent and asymptomatic episodes
- 5x increased risk of thromboembolic stroke [2]
- Associated with 28% of all strokes [3]
- CHA$_2$DS$_2$-VASc score for stroke risk assessment
- Oral anticoagulation
| Criteria                                                   | Points |
|------------------------------------------------------------|--------|
| Congestive heart failure history                           | 1      |
| Hypertension history                                       | 1      |
| Age ≥ 75                                                   | 2      |
| Age 65-74                                                  | 1      |
| Diabetes history                                           | 1      |
| Stroke / TIA / thromboembolism history                     | 2      |
| Vascular disease history (prior MI, peripheral artery disease, or aortic plaque) | 1      |
| Sex category (female)                                      | 1      |

Source: [4]
Screening for AF

Simple and cost-effective screening programme ☞ ↑ AF diagnosis ☞ ↑ Stroke prevention
Screening for AF

Zenicor EKG-2 handheld ECG device
Source: zenicor.com

Single-lead 30 second ECG recording
Automated algorithm

High sensitivity

Maximises number of people **correctly** diagnosed with AF

High positive predictive value

Minimises **unnecessary** review of normal ECGs
Our aims

- Configuration 1
- Configuration 2
- Configuration 3
- Configuration 4

Manual review workload

Accurate identification of AF patients
The SAFER Feasibility Study
Dataset

- 162,515 ECG recordings
- 2,141 adults
- Aged over 65
Methods
Review Process

Cardiolund ECG Parser algorithm

First filter review

Expert reviews

Resolution of discrepancies

Final diagnosis assigned to each participant
## Algorithm configurations

| Screening algorithm configuration | Pathological recordings | Low quality recordings |
|----------------------------------|-------------------------|------------------------|
|                                  | Irregular Sequence      | Fast Regular           | Other                  |                          |
| Configuration 1                  | ✓                       | ✓                      | ✓                      | ✓                       |
| Configuration 2                  | ✓                       | ✓                      | ✓                      | ✓                       |
| Configuration 3                  | ✓                       | ✓                      | ✓                      |                          |
| Configuration 4                  | ✓                       |                        |                        | ✓                       |
Manual review workload

Number of ECGs reviewed by the first filter which meet the criteria

Number of ECGs reviewed by the expert reviewer which meet the criteria × 2
Findings
## Results

| Screening algorithm configuration | Number of manual reviews | Number of AF patients identified |
|----------------------------------|--------------------------|---------------------------------|
|                                  | First Filter  | Expert     | Total   |                          |
| Configuration 1: All pathological/low quality | 20,155        | 5,005 x2    | 30,165  | 54                      |
# Results

| Screening algorithm configuration | Number of manual reviews | Number of AF patients identified |
|-----------------------------------|--------------------------|---------------------------------|
|                                   | First Filter | Expert | Total |                      |
| Configuration 1: All pathological/low quality | 20,155 | 5,005 x2 | 30,165 | 54 |
| Configuration 2: All pathological    | 15,241 | 4,570 x2 | 24,561 | 54 |

- 23%  - 9%  - 18.6%
## Results

| Screening algorithm configuration | Number of manual reviews | Number of AF patients identified |
|----------------------------------|--------------------------|---------------------------------|
|                                  | First Filter | Expert  | Total   |
| Configuration 1: All pathological/low quality | 20,155 | 5,005 x2 | 30,165 | 54 |
| Configuration 2: All pathological  | 15,241 | 4,570 x2 | 24,561 | 54 |
| Configuration 3: Selected pathological | 11,975 | 3,299 x2 | 18,573 | 54 |
| Configuration 4: Only irregular sequences | 11,748 | 3,198 x2 | 18,144 | 53 |
## Results

| Screening algorithm configuration | Number of manual reviews | Number of AF patients identified |
|----------------------------------|--------------------------|----------------------------------|
|                                  | First Filter | Expert | Total |                                  |
| Configuration 1: All pathological/low quality | 20,155 | 5,005 x2 | 30,165 | 54 |
| Configuration 2: All pathological | 15,241 | 4,570 x2 | 24,561 | 54 |
| Configuration 3: Selected pathological | 11,975 | 3,299 x2 | 18,573 | 54 |
| Configuration 4: Only irregular sequences | 11,748 | 3,198 x2 | 18,144 | 53 |

- **38.4%**
## Results

| Screening algorithm configuration | Number of manual reviews | Number of AF patients identified |
|----------------------------------|--------------------------|---------------------------------|
|                                  | First Filter | Expert     | Total  |
| Configuration 1: All pathological/low quality | 20,155      | 5,005 x2   | 30,165 | 54   |
| Configuration 2: All pathological  | 15,241      | 4,570 x2   | 24,561 | 54   |
| Configuration 3: Selected pathological | 11,975      | 3,299 x2   | 18,573 | 54   |
| Configuration 4: Only irregular sequences | 11,748      | 3,198 x2   | 18,144 | 53   |

- 40%
## Results

| Screening algorithm configuration                      | Number of manual reviews | Number of AF patients identified |
|--------------------------------------------------------|--------------------------|----------------------------------|
|                                                        | First Filter | Expert   | Total         |                        |
| Configuration 1: All pathological/low quality          | 20,155        | 5,005 x2 | 30,165        | 54                      |
| Configuration 2: All pathological                      | 15,241        | 4,570 x2 | 24,561        | 54                      |
| Configuration 3: Selected pathological                 | 11,975        | 3,299 x2 | 18,573        | 54                      |
| Configuration 4: Only irregular sequences              | 11,748        | 3,198 x2 | 18,144        | 53                      |
Key Findings

- Configuration 3 most appropriate
  - Manual review for recordings with “Irregular Sequence” and “Fast Regular” classifications
- First filter excluded 70.4-75.2% ECGs prior to expert review
- Useful to have first filter, followed by expert review:
  1. For every first filter review, we save 2 expert reviews
  2. Each expert review likely to be more expensive than first filter review
Limitations

- Assumption that all ECGs sent for manual review were reviewed
- Might have had false negative tests among ECGs that were not sent for review under any algorithm configuration
- Cost differences between first filter and expert reviews
Future Work

- Improve ECG parsing algorithm further to incorporate P wave characteristics
- Creation of training dataset with labelled ECGs
- Prospective studies to verify findings
Conclusions
[1] Adderley, N.J.; Ryan, R.; Nirantharakumar, K.; Marshall, T. Prevalence and treatment of atrial fibrillation in UK general practice from 2000 to 2016. Heart 2019, 105, 27–33, doi:10.1136/heartjnl-2018-312977.

[2] Wolf PA; Abbot RD; Kannel WB Atrial fibrillation as an independent risk facor for stroke: the Framingham study. Stroke 1991, 22, 983–988.

[3] Perera, K.S.; Vanassche, T.; Bosch, J.; Swaminathan, B.; Mundl, H.; Giruparajah, M.; Barboza, M.A.; O’Donnell, M.J.; Gomez-Schneider, M.; Hankey, G.J.; et al. Global Survey of the Frequency of Atrial Fibrillation–Associated Stroke. Stroke 2016, 47, 2197–2202, doi:10.1161/STROKEAHA.116.013378.

[4] Lip, G.Y.H.; Nieuwlaat, R.; Pisters, R.; Lane, D.A.; Crijns, H.J.G.M.; Andresen, D.; Camm, A.J.; Davies, W.; Capucci, A.; Olsson, B.; et al. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: The Euro Heart Survey on atrial fibrillation. Chest 2010, 137, 263–272, doi:10.1378/chest.09-1584.
Thank you!