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Automatic Detection of Characteristic Points in Impedance Cardiogram

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Abstract: *Estimation of stroke volume and several other cardiovascular indices using impedance cardiography requires error-free detection of the characteristic points in the impedance cardiogram. A technique for automatic detection of B, C, and X points, using R-peaks in the simultaneously acquired ECG as reference, is presented. It does not require estimation of the baseline and selection of processing parameters. Use of the technique on pre-exercise and post-exercise recordings from healthy subjects and cardiac patients showed a very low detection error.*

1. Introduction

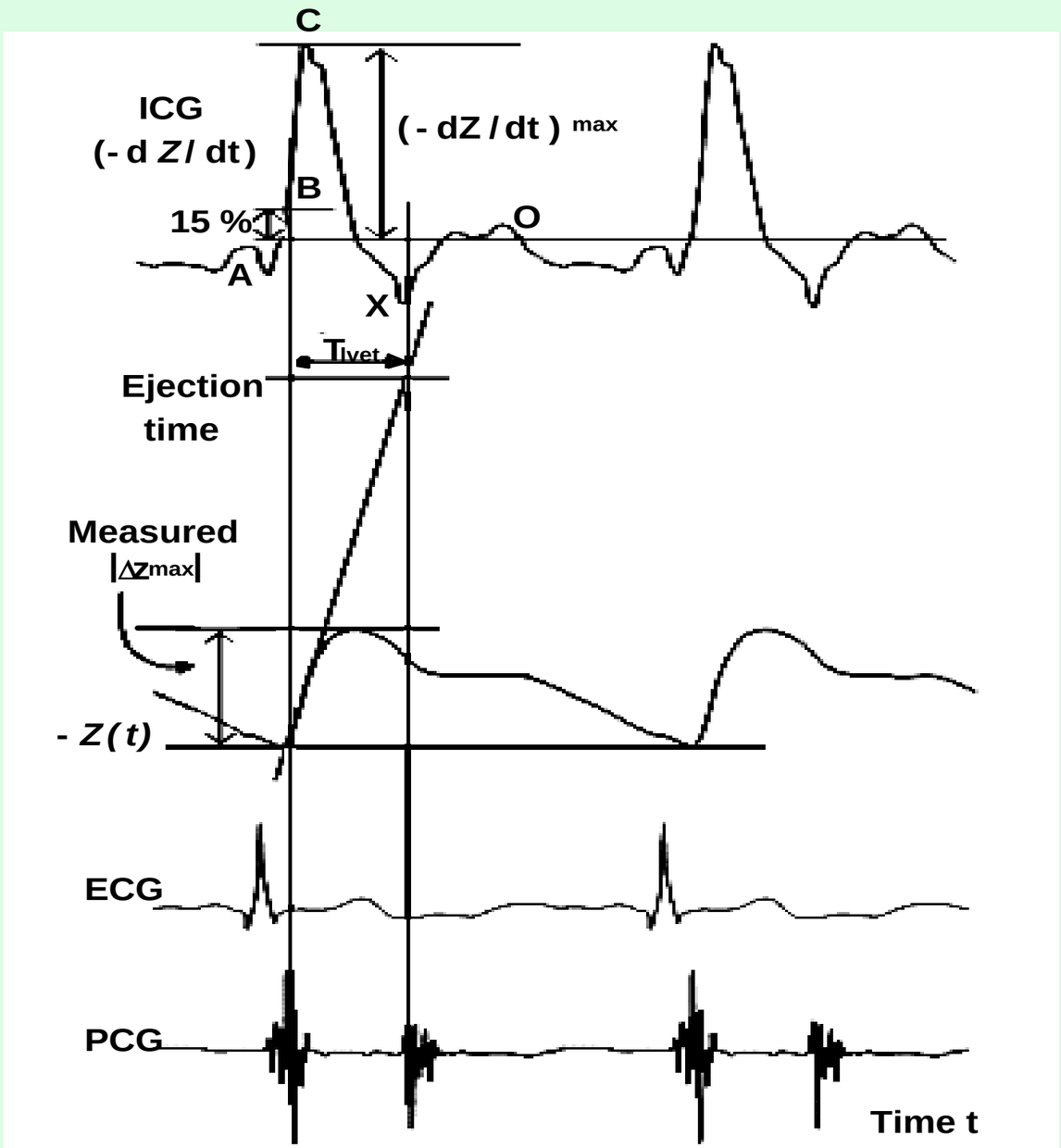
Impedance Cardiography (ICG)

A non-invasive technique based on sensing the variation in the thoracic impedance *Z*(*t*) caused by variation in the blood volume in the thorax.
ICG = – d*Z*/*dt* .

Applications: Estimation of stroke volume (SV) & other cardiac indices

ICG Characteristic Points

A point: atrial contraction, before B-point, follows ECG P-wave.
B point: aortic valve opening, 1st heart sound, deflection before C-point.
C point: ventricular contraction, ICG peak.
X point: aortic valve closure, 2nd heart sound, lowest value in ICG.
O point: wide opening of the mitral valve.



ICG & other related signals

2. Signal Processing

Detection of B, C, and X points (the points most commonly used for calculating SV and other cardiac indices)

- Beat-by-beat detection of characteristic points, without ensemble averaging.
- Developed after examining a large number of artifact-free and artifact-contaminated recordings.
- Baseline estimation & processing parameters selection not required.
- No restriction of record lengths.
- Useable in the presence of artifacts, without ensemble averaging.

Steps

- ICG cycle identification with reference to the automatically detected ECG R-peaks.
- C point: highest ICG point after the R-peak and within (R-R interval)/5.
- B point: first minimum preceding the C point.
- X point: the lowest point after the C point and within (C-C interval)/3.

3. Evaluation

Material

- Pre- & post-exercise ICG recordings taken in supine position: 9 healthy S's, 5 patients.
- Samp. rate = 500 Hz.
- ICG instruments: (i) developed in our lab, (ii) 'HIC-2000' (from Bio-impedance Tech., Chapel Hill, NC).
- Denoising: Respiratory artifact suppression by wavelet-based denoising (23 dB improvement in the signal-to-artifact ratio for signals highly corrupted by respiratory artifact).

Method

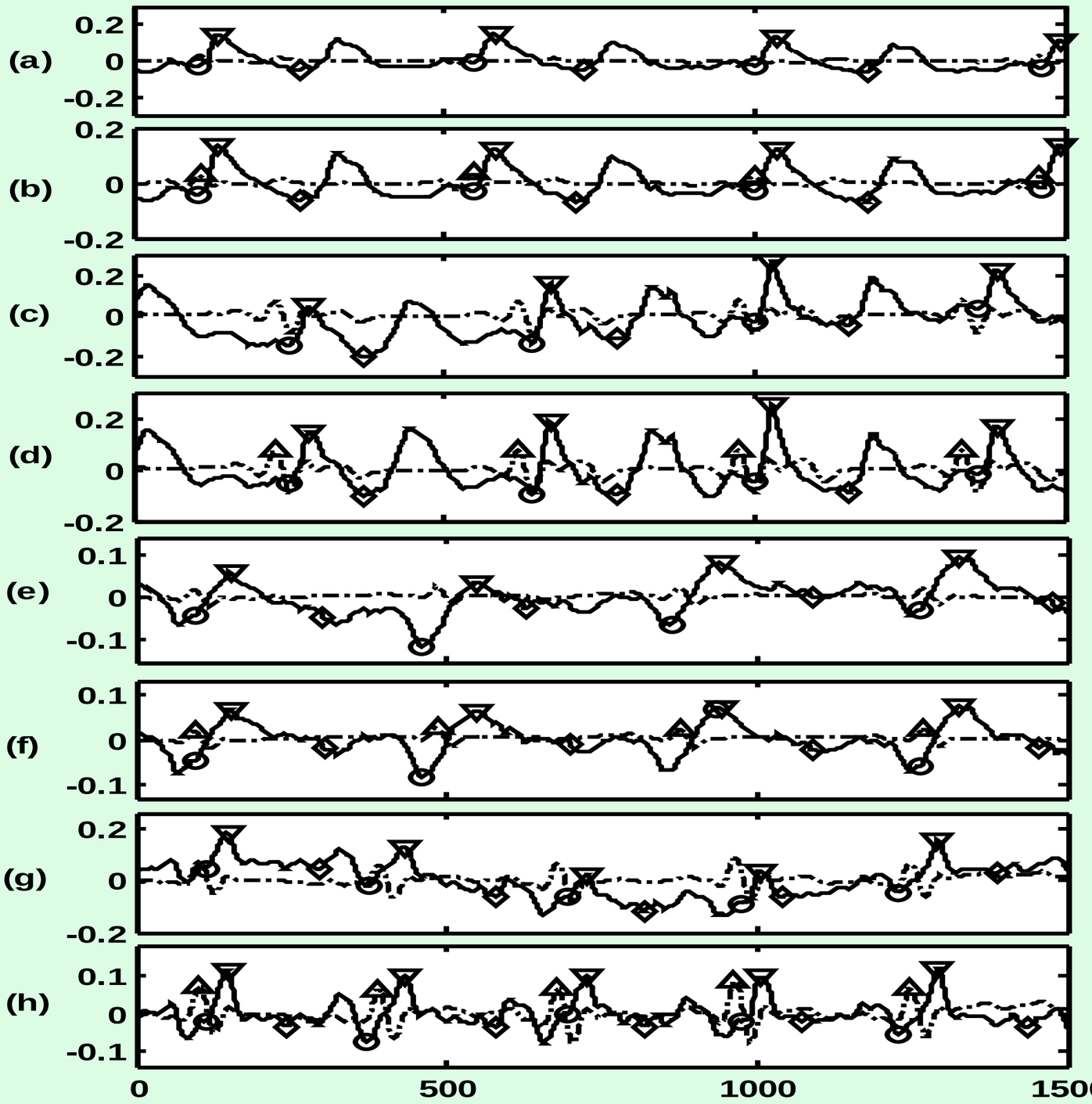
- Detection of characteristic points for unprocessed & denoised ICG.
- Detected points marked on the waveform.
- Quantitative evaluation

  Sensitivity = No. of correctly detected points / Total no. of points

  Positive predictivity = No. of correctly detected points / No. of total detected points

  Detection error = (No of failed detections + No. of missed detections) / Total no. of points

4. Results Detection of B, C, X points



Solid: ICG, dotted: ECG,
R peak: triangle, C: inverted triangle,
B point : circle, X point: diamond

(a) pre-execrcise rec. (SH9)

(b) ‘a’ after denoising

(c) post-exercise rec. (SH9)

(d) ‘c’ after denoising

(e) pre-exercise rec. (PT1)

(f) ‘e’ after denoising

(g) post-exercise rec. (PT1),

(h) ‘g’ after denoising

Evaluation indices (%) for detection of characteristic points

ICG Point	Unprocessed ICG			Denoised ICG		
	Sens.	Pos. pred.	Det. error	Sens.	Pos. pred.	Det. error
B	93.4	93.0	13.6	94.4	93.9	11.7
C	99.4	98.7	1.8	99.4	98.7	1.8
X	97.4	96.9	5.6	97.0	96.5	6.5

No of cardiac cycles = 545

Errors: mostly related to errors in R-peak detection

5. Conclusion

Result summary: BCX detection with very low errors.

Further work: Evaluation in a clinical setting for estimating SV & other indices.