Removing Mechanical Chest Compression Artefacts induced by a Load Distributing Band Device from the ECG

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INTRODUCTION

Chest compressions delivered by a **Load Distributing Band (LDB)** compressor induce **artefacts** in the ECG that may make the **shock advice algorithms** inaccurate.

Goal: To design an **adaptive filter** to remove the LDB-artefact preserving ECG quality and allowing a **reliable rhythm analysis** during LDB use.

MATERIALS AND METHODS

Data collection

Data from **362 out-of-hospital cardiac arrest patients** treated with the LDB from one **Circulation Improving Resuscitation Care (CIRC)** Trial site.

ECG and **TI** from the **LP15 monitor-defibrillator**. Multiple records per patient were extracted during LDB use.

Final database

A total of **1686 records** of **22-sec** were extracted, whereof **235** were **shockable** rhythms and **1451 non-shockable** (677 asystole, 774 organized).

Artefact model

The artefact follows the **additive model**:

$$s_{cor}(n) = s_{ecg}(n) + s_{cc}(n)$$

The artefact was modelled as an N -term **Fourier series** with a constant fundamental frequency equal to the CC rate ($f_0=80 \text{ min}^{-1}$):

$$s_{cc}(n) = \sum_{k=1}^N \underbrace{a_k(n) \cos(k\omega_0 n)}_{S_{I,k}(n)} + \underbrace{b_k(n) \sin(k\omega_0 n)}_{S_{Q,k}(n)}$$

Database segment

Two consecutive **intervals**, 16-sec **during compressions** to test **artefact suppresion** followed by 6-sec **without compression** for ground truth rhythm labels.

Artefact suppression filter

The **Recursive Least Squares (RLS)** filter was used. Two parameters to optimize:

- N , Number of harmonics or **complexity**
- λ , Forgetting factor or **adjustability** and **stability**

EVALUATION

Artefact characterization

Peak to peak amplitude (V_{pp})

The median (95% conf interval) V_{pp} of **asystole segments** before and after filtering.

Signal to Noise ratio (SNR)

The **SNR** (dB) level was calculated as $10 \log_{10} \frac{P_{free}}{P_N}$ where $P_N = P_{cor} - P_{free}$ is the power of the artefact.

Performance metrics

• **Shock (Sh)/No-Shock (NSh)** diagnoses compared with the **rhythm annotations** to obtain: sensitivity (**SE**), Specificity (**SP**) and Balanced Accuracy (**BAC**).

- Filter configuration: $0.98 < \lambda < 1$ and $25 < N < 40$.
- Data was partitioned patient-wise into training (%60) and test (%40). **Training** set was used to **optimize filter parameters** taking **BAC** as objective function. **Test** set was used to **obtain SE, SP and BAC** on unseen data.
- The procedure was repeated 500 times to estimate the **statistical distributions of the performance metrics**, reported as mean (standard deviation, SD).

RESULTS

The mean values of the **optimal RLS solution** in the 500 repetitions were: $\lambda=0.988$ and $N=31$.

	Unfiltered	Filtered
Artefact		
V_{pp} (mV)	4.78 (0.58-23.58)	0.25 (0.04-1.76)
SNR (dB)	-9.96 (8.48)	-
Filtering		
SE (%)	31.9	91.5 (2.0)
SP _{ORG} (%)	89.4	82.4 (2.0)
SP _{AS} (%)	95.6	95.3 (1.3)

CONCLUSIONS

- 1 Adaptive filtering considerably reduced the LDB-artefact.
- 2 Accuracy good for shockable rhythms and asystole, needs improvement for organized rhythms.