Wavelet analysis of pulse oximeter waveform permits identification of unwell children

P Leonard, T F Beattie, P S Addison, J N Watson

Background: Children who are unwell often display signs of circulatory compromise. It has been observed that pronounced changes occur in the appearance of the photoplethysmogram (pulse oximeter tracing) in these children. The aim of the study was to discover if wavelet transforms can identify more subtle changes in the photoplethysmogram of children who are unwell.

Methods: Photoplethysmograms were obtained from children attending a paediatric accident and emergency department with clinical features suggestive of significant bacterial illness or circulatory compromise. Photoplethysmograms were also obtained from a control group of well children. Wavelet transforms were applied to the traces in an attempt to separate the two groups.

Results: 20 traces were obtained from unwell children and 12 from controls. Analysis of the entropy of the wavelet transform of the photoplethysmogram allows the differentiation of unwell children from controls (p = 0.00002).

Conclusions: Wavelet transform of the photoplethysmogram offers the possibility of a rapid non-invasive method of screening children for significant illness.
Figure 1 Scatter plot of wavelet power at 1 Hz against entropy at 7 Hz showing differentiation of well children from unwell children.

**DISCUSSION**

Pulse oximeters use the differential absorption of red and infrared light by haemoglobin in its oxygenated and deoxygenated forms to calculate the ratio of these two molecules in pulsatile capillary flow. The photoplethysmogram is a plot of the absorption of light at one of these wavelengths (usually the infrared) against time. In the past the photoplethysmogram has traditionally been thought to be of no value except to determine if a pulse oximeter is picking up a good signal and thus giving an accurate reading. However, recent work has shown that other cardiorespiratory variables influence the waveform. It is currently unclear which variable, or combination of variables gives rise to our findings and further work is required to investigate this.

The traditional method of analysing waveforms is Fourier analysis. However, this technique produces only globally averaged spectral-only information, leading to location specific features in the signal being lost. The complete analysis of a signal requires the deduction of both the frequency make up and temporal location of the signal components. This limitation can be partly overcome by introducing a sliding time window, which localises the analysis in time (short time Fourier transform (STFT)) and provides a degree of temporal resolution by highlighting changes in spectral response with respect to time. However, this method is always a compromise between temporal and frequency resolution, which is set by the pre-defined fixed window width. Wavelet transforms differ from the STFT as they permit arbitrarily high localisation in time of high frequency signal features. They do this by having a variable window width that is related to the scale of observation. This flexibility allows for the isolation of the high frequency features obscured by STFT analysis and make them a useful tool for the analysis of biological signals as demonstrated in this and other recent studies.

**Clinical features required for study eligibility**

- Temp>38.5°C
- Or
- Capillary refill time>3 seconds and one other feature of circulatory compromise (that is, tachycardia or hypotension or fever>37.5°C)
- Or
- Any two clinical signs of shock (tachycardia, hypotension, poor peripheral perfusion, altered GCS)

In conclusion, our study shows that wavelet transforms can be applied to the photoplethysmogram and permit the identification of features that differentiate control children from children with clinical markers of significant illness. Further work with larger numbers of children needs to be undertaken to determine the physiological basis and clinical application of this technique. However, the potential exists to improve the identification of children with serious disease using a simple, real time, non-invasive monitoring system that would also provide standard pulse oximetry.

**REFERENCES**

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