

The U Wave in Atrial Fibrillation

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Abstract

The U wave in ECGs of patients is difficult to observe because it is hidden under the atrial fibrillatory wave. Measurement and characteristics of the U wave in atrial fibrillation have not previously been described.

Beat averaging was used to reveal the U waves in 12-lead ECGs of 8 patients with atrial fibrillation taking account of heart rate dependency of U wave characteristics. U wave polarity and amplitude in 12-lead ECG and the amplitude ratio of U wave to atrial fibrillatory wave in lead V1 were measured.

U waves were measureable in all patients. U waves were predominantly positive in leads I, II, aVF, V2, V3, V4, V5 and V6, negative in leads aVR. Amplitudes were largest in the precordial leads measuring up to 55 μ V. In lead V1 the U wave amplitude was on average 0.17 (range 0.1 to 0.4) times the amplitude of the atrial fibrillatory wave.

U waves can be measured by ventricular beat averaging in AF patients. U waves were normal in this small group of patients.

1. Introduction

The U wave is an ECG feature with small amplitude occurring at the end of the T wave [1]. Its origin is disputed, with the two main hypotheses being that it is an intrinsic part of ventricular repolarisation, due for

example to late repolarisation of regions of the myocardium, such as M cells or is due to mechano-electrical coupling [2,3]. Although not generally considered diagnostically significant abnormal U waves are associated with cardiac pathology such as ischaemia, hypertrophy and hypertension or due to hypokalemia or drug effects [1]. The U wave has also been shown to be a potential marker of Torsade de Pointes [4].

So far the U waves of patients in atrial fibrillation have not been described. Measurement is difficult because U waves are often masked by the atrial fibrillatory wave that results from the continuous and rapid atrial activations. It is important to understand the characteristics of the U wave since the leading cardiac organisations recommend that all U wave abnormalities should be reported on ECG interpretation [1]. In addition the U wave also often neglected during QRST cancellation when analysing the atrial fibrillatory wave.

The aim of this study was to describe U wave characteristics such as amplitude and polarity in the 12-lead ECGs of patients with atrial fibrillation.

2. Methods

2.1. ECG recordings

The 12-lead ECG of 8 patients with atrial fibrillation at the time of the recording were analysed. ECGs were recorded at a sample rate of 500 Hz and amplitude resolution of 5 μ V. Minimum duration of recording was 5

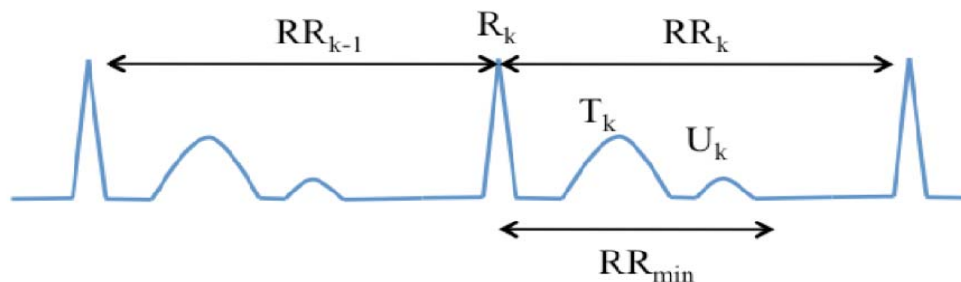


Figure 1 The average beat comprising QRS complex (R_k), T wave (T_k) and U wave (U_k) was constructed from all beats with $RR_{k-1} = \text{mode } RR \pm 25 \text{ ms}$ and $RR_k > RR_{\min}$.

minutes. Ethical approval and informed consent was obtained.

2.2. ECG processing

The U wave is a ventricular beat-wise feature dissociated from the atrial fibrillatory wave therefore standard beat averaging techniques can be used to generate an average beat free of atrial fibrillatory activity. However, the heart rate dependency of the U wave must be considered since the QU interval is known to be rate dependent [5]. Methodological details are as follows.

ECGs were bandpass filtered in the range 0.5 to 45 Hz. This removed excessive baseline wander and power-line interference. R wave peaks were automatically detected in the lead with the most prominent R peaks and RR intervals calculated. Intervals adjacent to ectopic beats were removed. RR histograms with a bin size of 50 ms were constructed and the mode RR interval identified.

With reference to figure 1, the average beat was constructed by identifying all beats with a preceding RR interval (RR_{k-1}) within the mode RR bin, ie $RR_{k-1} = \text{mode } RR \pm 25 \text{ ms}$. In order to avoid contamination of the average U wave due to beats with short RR intervals a further requirement was to exclude beats with an RR interval in the current beat (RR_k) less than a minimum value (RR_{\min}). This value was determined on a patient-by-patient basis according to location of the U wave.

All qualifying beats were aligned to their R wave peaks (R_k) and the average beat in each lead calculated as the mean amplitude across beats at each sample point.

2.3. ECG measurements

From the average beat in each lead U waves were characterised in terms of amplitude and polarity (positive, negative, biphasic and flat).

The atrial fibrillatory wave amplitude was measured as the peak-to-peak amplitude in the longest U-Q segment of lead V1 in the original ECG and the amplitude ratio of U wave to atrial fibrillatory wave in this lead was calculated.

3. Results

Figure 2A illustrates the difficulty of observing the U wave in the 12-lead ECG due to the atrial fibrillatory wave. The atrial fibrillatory wave is most clearly seen in leads V1, V2 and V3 in this example. In all leads it is unclear whether the large deflection following the T wave is due to a U wave or due to the atrial fibrillatory wave.

Figure 2B shows the corresponding average beat in each lead. U waves can be clearly seen in most leads.

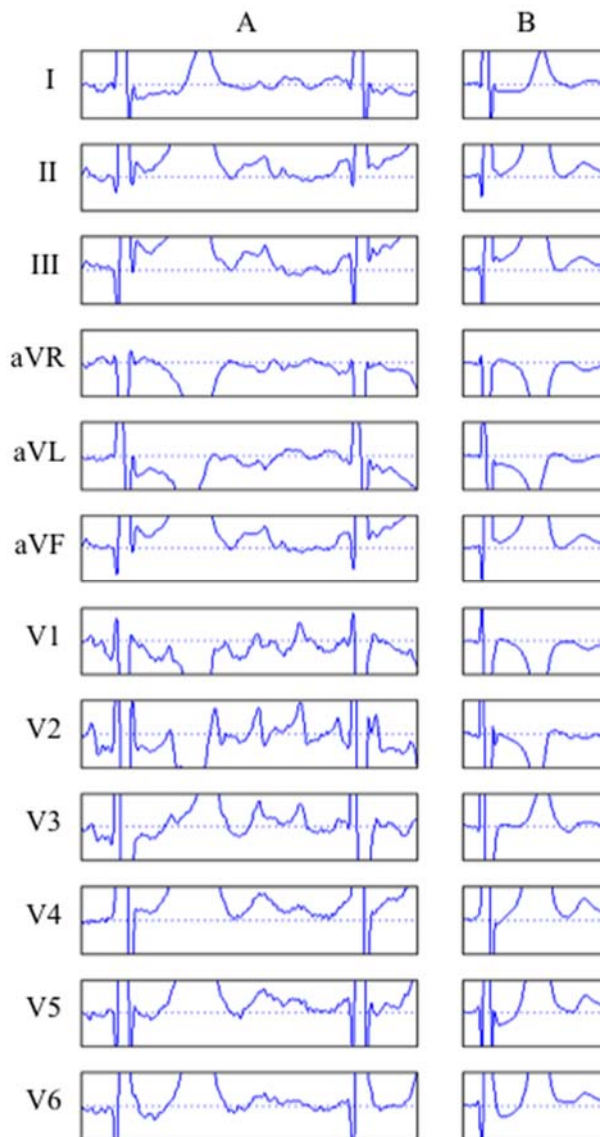


Figure 2 A) 12-lead ECG segment of 1.2 s duration showing the difficulty of observing the U wave in the presence of the atrial fibrillatory wave. B) The average beat showing distinct U waves in most leads. Amplitude scale is limited to $\pm 100 \mu\text{V}$ partly obscuring the QRS complex and T wave in all leads.

In this recording positive U waves occurred in leads II, III, aVF, V4, V5 and V6 with amplitudes of $44 \mu\text{V}$, $39 \mu\text{V}$, $41 \mu\text{V}$, $55 \mu\text{V}$, $52 \mu\text{V}$ and $25 \mu\text{V}$ respectively.

Corresponding T waves were also positive in those leads. Negative U waves occurred in leads aVR, aVL, V1 and V2 with amplitudes of $-28 \mu\text{V}$, $-23 \mu\text{V}$, $-24 \mu\text{V}$ and $-24 \mu\text{V}$ respectively. Again these were in accord with their corresponding T wave polarities. Leads I and V3 had biphasic U waves with amplitudes of $20 \mu\text{V}$ and $28 \mu\text{V}$. The atrial fibrillatory wave in lead V1 had amplitude of $60 \mu\text{V}$ giving a U to T ratio of 0.4.

Across all patients, U waves were more likely to have positive polarity in leads I, II, aVF, V2, V3, V4, V5 and V6 and negative polarity in aVR. Leads III, aVL and V1 had a mix of U wave polarities. The distribution of lead polarities across the ECG leads is illustrated in figure 3.

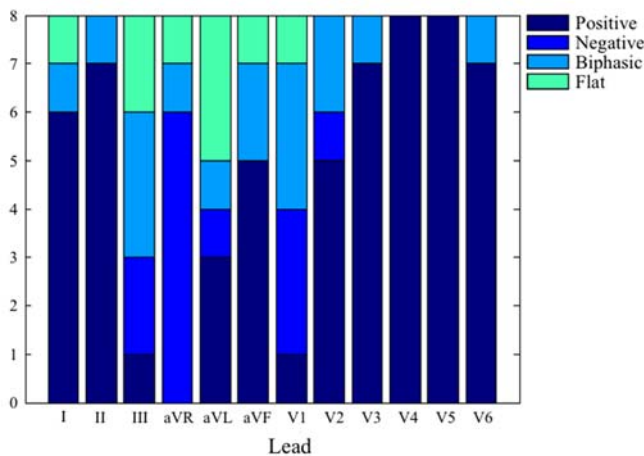


Figure 3 Distribution of polarity of U waves in the 12-lead ECGs of 8 patients with atrial fibrillation

U waves had largest amplitudes in precordial leads V2 to V6 with largest median amplitude in lead V3. The largest amplitude across all subjects and leads was $55 \mu\text{V}$ (figure 2, lead V4). Smallest amplitudes were in leads aVL and III. Figure 4 shows the distribution of U wave amplitudes across the 12 leads.

In lead V1 the U wave amplitude was on average 0.17 (range 0.1 to 0.4) times the amplitude of the atrial fibrillatory wave.

4. Discussion

Measurements of U waves in atrial fibrillation have not previously been described. A technique to extract the U wave from the atrial fibrillatory wave using beat averaging has been demonstrated allowing the characteristics of U waves in atrial fibrillation to be measured. In this small group of patients the U waves had normal morphology with low amplitude and polarity in accord with T wave. Given that many atrial fibrillation patients have underlying cardiac pathology this technique facilitates measurement of U waves in this patient group and enables reporting of abnormal U waves in as recommended by the professional societies.

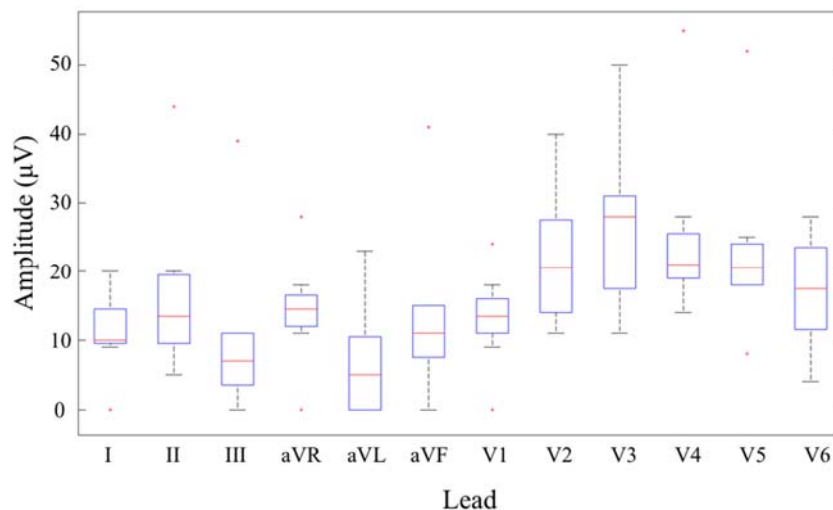


Figure 4 Amplitude distribution of U waves across the 12-lead ECG in atrial fibrillation patients

References

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