# Pulse Annotation of Automatic External Defibrillator Recordings during Out Of Hospital Cardiac Arrest

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**Abstract**

*Obtaining information about the circulatory status of a patient during resuscitation is crucial. Attempts have been made toward integrating into automated external defibrillators a pulse detection algorithm based on the thoracic impedance signal. The lack of information about the hemodynamic status during out of hospital cardiac arrest (OHCA) has made the validation of such algorithms a challenging task. This study aims at proposing an annotation scheme for the assessment of pulse in OHCA. Being independent from the recording device, several databases could be annotated using the same protocol.*

## 1. Introduction

Differentiating patients in cardiac arrest from syncopal patient with cardiac output is essential in a resuscitation scenario. Carotid pulse checking has proven to be unreliable (90% sensitivity and 55% specificity for detection of cardiac arrest) and time consuming (median 24s) [1]. Thus checking for signs of circulation has been dropped by the 2000 European Resuscitation Council guidelines [2]. In this context, there is a need for a real-time hemodynamic sensor during out of hospital cardiac arrest (OHCA).

Impedance plethysmography was proposed for non-invasive measurements of cardiac output and stroke volume in critical care. Pulse generating heartbeats produce small variations of the thoracic impedance (TI) that are related to changes in arterial blood volume [3]. It has been suggested to adapt this four-electrodes system to automated external defibrillators (AED) [4,5]. The TI signal recorded through defibrillator pads would be used in an automated circulation detector. Implemented in an AED jointly with the shock advice algorithm, the rescuer would receive meaningful help to identify whether circulation is present.

Designing and testing a pulse detection algorithm require data from OHCA. However the lack of information during field interventions does not facilitate the creation of databases containing the real circulatory status of the patient.

This study intends to give restrictive criteria to help building such databases.

## 2. Materials and methods

### 2.1. Data material

The data were obtained from a prospective study of out of hospital cardiac arrest (OHCA) episodes recorded by the fire brigade of Paris (BSPP) between June and September 2011 and during two preliminary studies in November and December 2010. These studies were designed to assess the efficiency of a chopped biphasic defibrillation waveform. The surface ECG (500Hz, 20µV/LSB) and TI (250Hz, 29mOhms/LSB) were recorded by the AED FRED Easy (Schiller Médical SAS, Wissembourg, France). Events occurring during the intervention were also available. Whenever the AED indicated a non-shockable rhythm, educated first responders checked for presence of pulse as indicated by the French rescue protocol. Upon arrival of the emergency medical team (EMT), the pulse presence was also checked by a physician. The data and documentation of each intervention have been anonymized.

### 2.2. Methods

The database consisted of segments extracted from the analysis period of the defibrillator in order to obtain signals free of chest compression (CC) artefacts. Several annotations steps were necessary to classify these segments into 3 classes: 'presence of pulse, 'absence pulse' and 'undetermined circulatory status'.

Initial information came from the shock advisory algorithm implemented into the AED. A shock was recommended when a ventricular fibrillation (VF) or a rapid ventricular tachycardia (VT) was detected. Whether a shock had been delivered was annotated for each analysis period.

Expert reviewers annotated the ECG segments extracted from the analysis periods. The rhythms were divided into the following categories: VF, rapid VT (VT hi) defined as VT associated with rushes lasting more than 8 seconds with a frequency higher than 150bpm, normal sinus rhythm (NSR), other ventricular tachycardia (VT lo), asystole (Asys) and a category (N) gathering other non-shockable rhythms such as atrial fibrillation, sinus bradycardia, supraventricular tachycardia, premature ventricular contractions or heart blocks.

Most of the segments had been classified using the information provided by the ECG signal annotation alone. The absence of pulse was established for segments annotated as VF or Asys which account for most of the rhythms encountered in OHCA.

The real challenge lies in the classification of VT, N and NSR segments. Among those rhythms, two categories arise, pulseless electrical activity (PEA) and pulsatile rhythms (PR), according to the presence of circulation. Additional annotations were added to enable the correct classification of these segments.

The TI signal is a key element in the recognition of PEA. Each pulse generates a small variation in the impedance likely due to the redistribution of blood in the thorax [3]. Reviewers identified these variations on TI segments. Whenever variations were synchronous with complexes on the ECG segments, a pulse was suspected. A PEA was established when no variation was visible on the TI signal while neither the first responder nor the physician detected a palpable pulse during the intervention. Reviewers needed to take heed of the noise presence on the segments. Noises included movements, CC, insufflations, presence of a pacemaker or an electrode connection failure. The amplitude of TI variations due to cardiac contractions is usually under 100mΩ. A maximum threshold of 80mΩ for the noise amplitude was selected to correctly assess the origin of the variations. Above this threshold segments were not included in the study.

To identify PR, the return of spontaneous circulation (ROSC) was surveyed for each intervention. For interventions where the first-aid team and the physician detected a palpable pulse, a ROSC was suspected. To locate its beginning, following each analysis leading to an absence of shock, the rhythm was studied until the next analysis. During this period of about 120 seconds, an organized rhythm (OR) was searched. It is defined by the presence of at least 2 complexes that are distant of at most 10 seconds. The presence of CC was also forbidden to discriminate between an OR induced by CC or a spontaneous one. If two consecutive analyses led to an absence of shock while an OR with no CC was present during and between them, a ROSC was assumed at the beginning of the first analysis.

Given the annotations and criteria described above and summarized in figure 1, a restrictive classification was established. Segments not meeting those criteria were classified in the 'undetermined circulatory status' group.

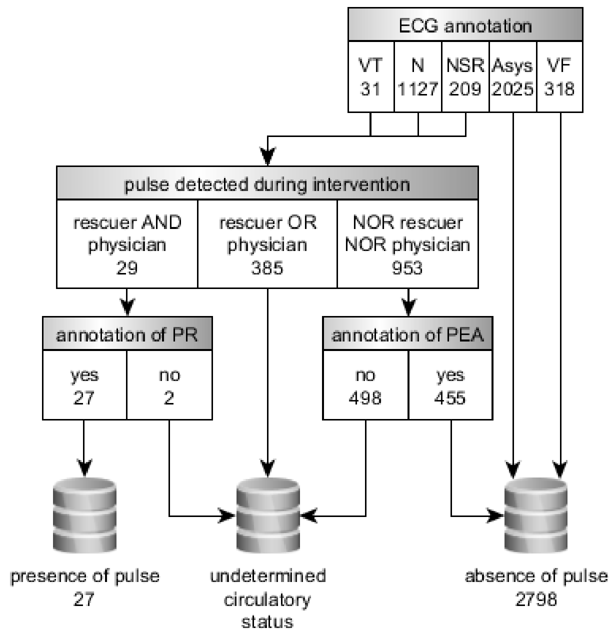



Figure 1. Illustration of the classification method with the number of segments annotated at each steps.

## 3. Results

Table 1. Classification of the 3,710 ECG segments extracted from the analysis period.

| Annotated rhythm | Number of segments |
|---|---|
| Ventricular fibrillation | 318 |
| Asystole | 2025 |
| Rapid ventricular tachycardia | 18 |
| Other ventricular tachycardia | 13 |
| Normal Sinus Rhythm | 209 |
| Other rhythms (group N) | 1127 |

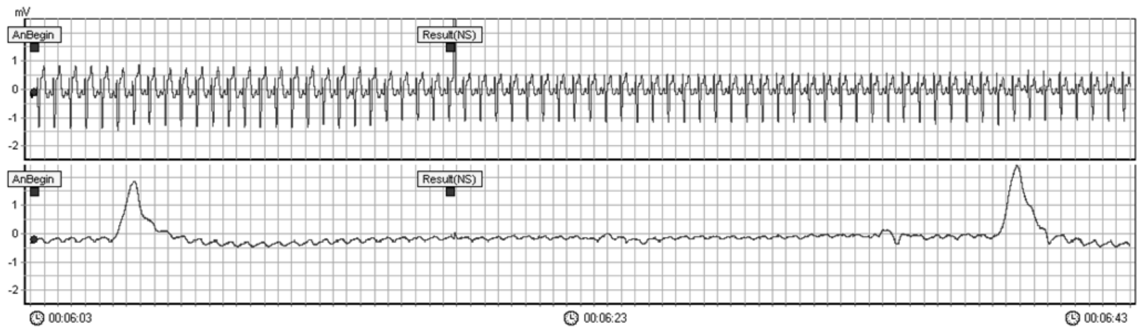
A total of 965 interventions were recorded from the three studies. Among those, 6 interventions were unexploitable due to technical problems. 6,497 analyses were extracted including 3,710 uncorrupted by noise or artefacts, thus eligible for classification.

Table 1 shows the classification of the ECG segments extracted from the analysis period.

2,343 segments, corresponding to Asys and VF rhythms, could already be classified in the 'absence of pulse' group.

The results of the classification of the VT, N and NSR rhythms are given in figure 2. 455 segments complied with the PEA annotation and 27 with the PR one. This method allowed the classification of 2,872 segments: 2798 in the 'absence of pulse' group and 27 in the 'presence of pulse' one.

Figure 2 shows examples of segments classified using the criteria described above.




(a)


(b)

Figure 2. Two segments showing the ECG (top) and the TI signal (bottom). (a) NSR segment classified in the 'presence of pulse' group. Both rescuer and physician detected a pulse and an organised rhythm with no chest compression is present during at least 120s. (b) N rhythm segment annotated as pulseless electrical activity through the use of the TI signal.

## 4. Discussion

Losert *et al.* [6] and Risdal *et al.* [7] were the first to design algorithms addressing the detection of pulse using a combination of the ECG and TI signals. They searched for features extracted from the waveforms to discriminate between segments with systolic arterial pressure above and below 80mmHg. Cromie *et al.* [8,9] proposed a method based on the Fourier transform of the TI signal. It was applied in an animal then in a clinical study. More recently Ruiz *et al.* [10] improved the classification by designing an adaptive filter to extract the circulation component from the TI signal.

In order to develop and test their algorithms, the authors needed annotated databases. Losert *et al.* carried out their study with in hospital cardiac arrest and Cromie *et al.* used an animal design for one of their study. Having access to an arterial line, the annotation of the circulatory status was easy. However for studies conducted out of the hospital, the annotation process was challenging. Risdal *et al.* and Cromie *et al.* used annotation of the rhythm and the EMT documentation to discriminate between the two classes.

The data recorded during our study showed the importance of having strict criteria when combining information from the EMT documentation and the annotation of the ECG signal. For 65 interventions, the first responder and the physician did not agree on the pulse check diagnostic. Among those, 11 interventions were false negative: no organized rhythm was present although a pulse was detected by either the first rescuer or the physician. In perspective, no false positive were detected. When both the first responder and the physician agreed on pulse presence, no records contained an absence of an OR.

Distinguishing a patient with pulseless VT or other PEA from pulsatile rhythms need further annotation. Ruiz *et al.* were the first to use the TI variation to tackle the classification of PEA.

This study brings a reliable way to classify segments extracted from OHCA. By combining criteria from EMT documentation, the ECG and TI signals, it allows to select segments were the circulatory status is well defined.

The database constructed suffers some limitations due to balance in the classified segments. Segments with no pulse represented a large majority (more than 95%) of the total set. Nonetheless, the underrepresentation of segments with pulse reflects the real conditions of OHCA. The development and training of pulse detection algorithms would require tools adapted for skewed datasets [11].

## 5. Conclusion

Having access to a reliable database for the assessment of circulation in OHCA is a necessary step toward implementation of pulse detection algorithms into defibrillators. This study presents a rigorous method to annotate segments and allocate them in the correct class. This method will be used in the future to train and test our algorithms.

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