Technique of Automated Control Over Cardiopulmonary Resuscitation Procedures

2016 J. Phys.: Conf. Ser. 671 012026

(http://iopscience.iop.org/1742-6596/671/1/012026)

Technique of Automated Control Over Cardiopulmonary Resuscitation Procedures

A Sh Bureev[1], E Yu Kiseleva[2], M S Kutsov[3] and D S Zhdanov[4]

[1]Head of laboratory "Instrumentation", Tomsk State University, Tomsk, Russia
[2]Engineer, Tomsk State University, Tomsk, Russia
[3]PhD student, Tomsk State University, Tomsk, Russia
[4]Jr. researcher, Tomsk State University, Tomsk, Russia
E-mail: eka.kiselyova@gmail.com

Abstract. The article describes a technique of automated control over cardiopulmonary resuscitation procedures on the basis of acoustic data. The research findings have allowed determining the primary important characteristics of acoustic signals (sounds of blood circulation in the carotid artery and respiratory sounds) and proposing a method to control the performance of resuscitation procedures. This method can be implemented as a part of specialized hardware systems.

1. Introduction

Sudden cardiac death is the leading cause of death in the world. Thus, in the US, the number of sudden cardiac death is 1 case per 1000 people per year, while in Russia - up to 2 cases per 1000 people. Emergency assistance for people with cardiac failure - sudden cardiac death - remains an urgent problem not only in emergency medicine, but also in therapy and cardiology in particular [1, 2, 3].

According to the statistical data, up to 90% of the patients who faced clinical death could survive, if they received adequate medical care within the first 5 minutes after cardiac arrest. Unfortunately, even at large medical institutions, physicians often cannot perform the cardiopulmonary resuscitation (CPR) procedure in compliance with recommendations.

According to the data of All-Russia Non-Government Organization Russian Red Cross, the share of people who underwent special pre-doctor (first) aid courses is extremely low. For example, only 392 people were trained in first aid principles in the territory of Tomsk Oblast in 2013 (with the population of 1,070,128 people). In this situation, it is essential to develop a device that will be able to recommend the order of procedures for resuscitators and automatically monitor the adequacy of performed resuscitation measures by controlling and coordinating the CPR procedure.

2. Method

The performance of resuscitation measures can be controlled by means of analyzing acoustic blood circulation sounds registered at the carotid bifurcations and airflow sounds in the resuscitated patient's trachea.

The force of noises occurring at the carotid bifurcations is proportional to the volume of blood passing these bifurcations. Similarly, the volume of air is proportional to the intensity of respiratory sounds [4].

It is possible to experimentally establish a functional relation between the dynamics of blood circulation in the carotid arteries and blood circulation sounds at the carotid bifurcations and between the intensity of airflow in the upper respiratory tracts and respiratory sounds in the trachea. This functional relation has the following properties:

- non-negative and step-by-step character;
- direct proportionality;
- normability.

The step-by-step character of the functional relation is conditional to a clear border between the presence and the absence of blood circulation and respiration sounds.

Direct proportionality is conditional to the following fact: the more intensive blood circulation and respiration are, the louder the sounds are.

The normability property consists in the following: during the CPR measures, observed blood circulation and respiration sounds will have quite distinct values; therefore, the loudness scale and calibration will depend on the current set of measured values and sensitivity of devices in each measurement [5].

The human resuscitation cycle can be represented in the form of a chronological sequence of CPR measures (see the figure 1):

T_0 – moment of time, when the resuscitation personnel attaches an auxiliary device on a patient's body;

T_i – time of actual initiation of the cardiopulmonary resuscitation. The auxiliary device is turned on at this moment of time;

T_{CPR} – timing cycle of the CPR measures consisting of sequential intervals T_{CCCM} and T_{ALV} and two intervals Tch;

T_{CCCM} – time interval of closed-chest cardiac massage (CCCM);

T_{ALV} – time interval of artificial lung ventilation (ALV);

T_{CH} – time interval of checking for the presence of primary vital functions;

T_{PC_CCCM} – time interval of performance control for CCCM [6].

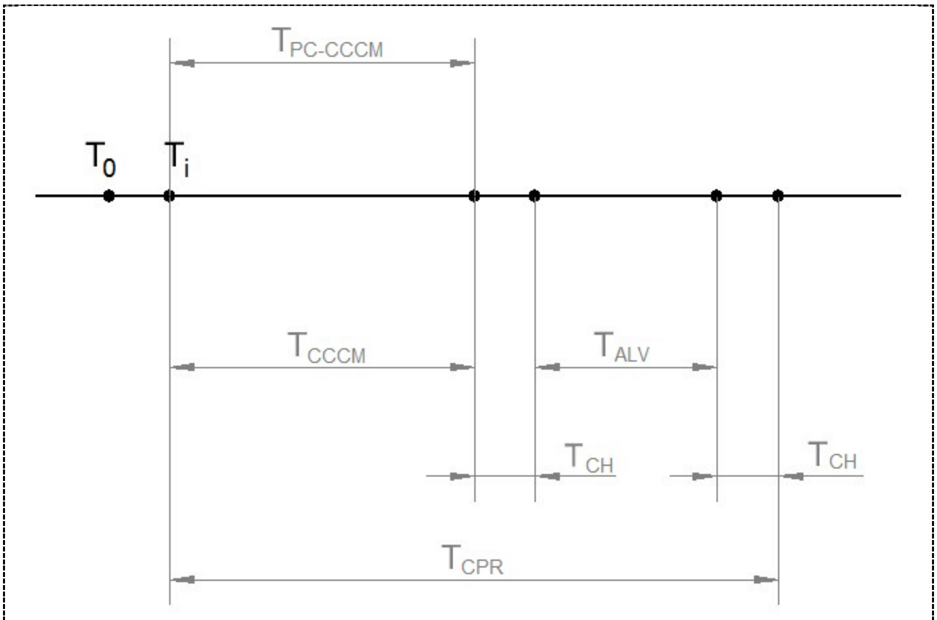

Figure 1. Chronological sequence of the CPR measures.

In order to assess the dynamics of changes in the blood flow velocity at the carotid bifurcations, it is possible to measure changes in blood circulation sounds registered by means of acoustic sensors. In this case, it is necessary to analyze only the sounds caused by blood flow at the bifurcations of the common carotid arteries. Laminar blood flow is transformed into turbulent flow at this place, which generates sounds.

The following is necessary for this purpose:

- registering a basic level of blood circulation sounds at the bifurcations of the common carotid arteries over a time interval (T_0, T_{CH}) prior to the initiation of CPR;
- registering the dynamics of changes in blood circulation sounds within T_{CCCM}, when the resuscitation personnel performs closed-chest cardiac massage (CCCM), and simultaneously assessing the efficacy and correctness of CCCM by evaluating the speed of chest compressions;
- performing a check for the presence of independent blood circulation and airflow sounds (T_{CH}).

In further CPR measures are necessary, points 2-3 are repeated cyclically and consistently with the chronological sequence of the CPR procedure.

The dynamics of changes in the airflow speed in the patient's respiratory tracts can also be assessed by means of registering and analyzing acoustic information received from a sensor located at the level of the resuscitated patient's trachea. The presence of independent airflow in the upper respiratory tracts can be detected by analyzing respiratory sounds generated in the process of artificial lung ventilation, when air passes through the resuscitated patient's throat or independent breathing is restored.

The following is necessary for this purpose:

- determining a basic level of airflow sounds in the upper respiratory tracts within a time interval (T_0, T_{CH}), when resuscitation measures have not been initiated yet;
- acquiring the dynamics of changes in airflow sounds within T_{ALV}, when the resuscitation personnel performs artificial lung ventilation (ALV), and simultaneously assessing the efficacy and correctness of ALV by analyzing the flow of air passing the resuscitated patient's trachea;
- performing a check for the presence of independent blood circulation and airflow sounds (Tch).

In further CPR measures are necessary, points 2-3 are repeated cyclically and consistently with the chronological sequence of the CPR procedure.

Besides controlling the CRP procedure, this technique also allows detecting positive (emergence of independent blood and air flow and increase in these parameters) or negative (disappearance of independent blood and air flow or reduction in the intensity of blood circulation and airflow) dynamics of the patient's health during the resuscitation procedure [7].

3. Summary

The analytical research has been focused on the detection of the intensity of respiratory sounds in the patient's trachea and registration and analysis of the intensity of blood circulation sounds at the bifurcations of the common carotid arteries. The research has revealed that the use of hardware auscultation systems is the simplest and most effective method from the viewpoint of technical and software implementation. This technique can be used to develop a device for automated control over the CPR procedure. It will allow assessing not only the correctness of CRP but also the efficacy of this procedure thanks to the control over parameters of the patient's health.

Aknowledgments

The work has been performed under Agreement #14.578.21.0078 (unique agreement identifier #RFMEFI57814X0078) on the subject Device for Control over Cardiopulmonary Resuscitation Procedures between National Research Tomsk State University and the Ministry of Education and Science of the Russian Federation.

Journal of Physics: Conference Series **671** (2016) 012026 doi:10.1088/1742-6596/671/1/012026

References

[1] Bokerija L A, Bokerija O L, Kislicina O N (2010) Randomized clinical research aimed at prevention of sudden cardiac death: principles and results *Annaly aritmologii* **2** 5–13 (in Russian)

[2] Kobylkin I S (2012) Review of quality control devices for performing of chest compressions during CPR *Medicinskij alfavit. Neotlozhnaja medicina* **4** 58–62 (in Russian)

[3] Field J M, Hazinski M F, Sayre M R, Chameides L, Schexnayder S M, Hemphill R, Samson R A, Kattwinkel J, Berg R A, Bhanji F, Cave D M, Jauch E C, Kudenchuk P J, Neumar R W, Peberdy M A, Perlman J M, Sinz E, Travers A H, Berg M D, Billi J E, Eigel B, Hickey R W, Kleinman M E, Link M S, Morrison L J, O'Connor R E, Shuster M, Callaway C W, Cucchiara B, Ferguson J D, Rea T D, Vanden Hoek T L (2010) Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care *Circulation* **122** (3) S640–S656

[4] Bonow R O, Mann D L, Zipes D P, Libby R 2005 *Braunwald E.. eds. Braunwald's Heart Disease* (Philadelphia Pa: Elsevier Saunders)

[5] Cooper J A, Cooper J D, Cooper J M (2006) Cardiopulmonary Resuscitation: History. Current Practice, and Future Direction *Circulation* **114**(25) 2839–2849

[6] Safar R 1989 *History of cardiopulmonary cerebral resuscitation*, in; Kaye W.. Bircher N.. eds. Cardiopulmonary Resuscitation (New York, NY: Churchill Livingstone) pp 1–53

[7] Zoll P M, Linenthal A J, Gibson W *el al*. (1956)Termination of ventricular fibrillation in man by externally applied electric countershock *The New England journal of medicine* 727–732