Chapter 19
Detection of ROSC in Patients with Cardiac Arrest During Chest Compression Using NIRS: A Pilot Study

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Abstract Return of spontaneous circulation (ROSC) during chest compression is generally detected by arterial pulse palpation and end-tidal CO_2 monitoring; however, it is necessary to stop chest compression during pulse palpation, and to perform endotracheal intubation for monitoring end-tidal CO_2. In the present study, we evaluated whether near-infrared spectroscopy (NIRS) allows the detection of ROSC during chest compression without interruption. We monitored cerebral blood oxygenation in 19 patients with cardiac arrest using NIRS (NIRO-200NX, Hamamatsu Photonics, Japan). On arrival at the emergency room, the attending

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physicians immediately assessed whether a patient was eligible for this study after conventional advanced life support (ALS) and employed NIRS to measure cerebral blood oxygenation (CBO) in the bilateral frontal lobe in patients. We found cerebral blood flow waveforms in synchrony with chest compressions in all patients. In addition, we observed abrupt increases of oxy-hemoglobin concentration and tissue oxygen index (TOI), which were associated with ROSC detected by pulse palpation. The present findings indicate that NIRS can be used to assess the quality of chest compression in patients with cardiac arrest as demonstrated by the detection of synchronous waveforms during cardiopulmonary resuscitation (CPR). NIRS appears to be applicable for detection of ROSC without interruption of chest compression and without endotracheal intubation.

Keywords Cardiac arrest • Cardiopulmonary resuscitation • Near-infrared spectroscopy • Quality of cardiopulmonary resuscitation • Return of spontaneous circulation

1 Introduction

Cardiac arrest is a major public health problem worldwide. Despite decades of efforts to promote cardiopulmonary resuscitation (CPR) science and education, the survival rate for out-of-hospital cardiac arrest remains low [1, 2]. In Japan, the JCS-ReSS study showed that a favorable neurological outcome at 30 days was extremely rare in patients with out-of-hospital cardiac arrest who arrived at the emergency hospital in cardiac arrest [3–5]. The 2010 CPR Guidelines indicated that rescuers should attempt to minimize the frequency and duration of interruptions in compressions to maximize the number of compressions delivered per minutes [1, 2]. Although return of spontaneous circulation (ROSC) during chest compression is generally detected by arterial pulse palpation, it is necessary to stop chest compression during pulse palpation. In addition, healthcare providers may take too long to check for pulse, and have difficulty determining if a pulse is present or absent. Furthermore, the 2010 CPR Guidelines indicated that it is reasonable to consider using quantitative waveform capnography in intubated patients to monitor CPR quality, optimize chest compressions, and detect ROSC during chest compression or when rhythm check reveals an organized rhythm [1, 2]. If the pressure of end-tidal CO_2 ($PETCO_2$) abruptly increases to a normal value (35–40 mmHg), it is reasonable to consider that this is an indicator of ROSC [1, 2]. However, it is necessary to perform endotracheal intubation for monitoring $PETCO_2$. In the present study, we evaluated whether near-infrared spectroscopy (NIRS) allows the detection of ROSC during chest compression without interruption. NIRS, an optical technique, is potentially an attractive tool for this purpose because it allows noninvasive, continuous measurements of cerebral blood oxygenation (CBO) changes with high time resolution and is easy to use [6, 7].

2 Methods

2.1 Patients

Between November 2009 and March 2014, we employed NIRS (NIRO-200NX, Hamamatsu Photonics, Japan) to measure CBO in the bilateral frontal lobe in patients transported to the emergency room (ER) after out-of-hospital cardiac arrest. The patients were included in a prospective observational study. They were enrolled in this study when they met the following criteria: presumed cardiac etiology of cardiac arrest according to the Utstein style guidelines [8]; persistent cardiac arrest on arrival at the ER; and successful ROSC after arrival at the ER with conventional advanced life support (ALS) and/or extracorporeal CPR (ECPR) using an emergency cardiopulmonary bypass (CPB) [9–11]. Exclusion criteria were a tympanic-membrane temperature below 30 °C on arrival at the ER; non-cardiac etiology of cardiac arrest; or pregnancy. Patients were also excluded if their families refused to give informed consent for participation in this study.

2.2 Procedures

On arrival at the ER, the attending physicians assessed as soon as possible whether a patient was eligible for this study after conventional ALS, and employed NIRS to measure CBO in the bilateral frontal lobe in patients. CPB was initiated when defibrillation by bystander and/or emergency medical personnel using an automated external defibrillator had been unsuccessful, and ROSC could not be achieved within 10 min of arrival [10, 11].

2.3 Statistical Analysis

All analyses were performed using the SPSS software package (version 20.0 J SPSS, Chicago, IL, USA). Continuous variables are expressed as mean ± SD.

3 Results

During the study period, 19 patients met the above criteria and NIRS was employed to measure their CBO. Among them, 2 patients achieved ROSC after arrival at the ER with conventional ALS, and 17 patients were performed ECPR using emergency CPB. Characteristics of these patients are presented in Table 19.1. The mean

Table 19.1 Baseline characteristics of the study population

Characteristics	Patients (n = 19)
Age (years)	60.9 ± 14.6
Male sex (no. (%))	18 (94.7)
Prehospital treatment (no. (%))	
Defibrillations	16 (84.2)
Administration of intravenous epinephrine	10 (52.6)
Initial cardiac rhythm	
VF/pulseless VT	16 (84.2)
PEA	2 (10.5)
Asystole	1 (5.3)
Time interval (min)	
From collapse to implementation of CPB (n = 17)	51.8 ± 15.6
From arrival at the ER to implementation of CPB (n = 17)	17.6 ± 7.3
From collapse to ROSC (n = 2)	62.5 ± 32.5
Cause of cardiac arrest	
Acute coronary syndrome	12 (63.1)
Cardiomyopathy	2 (10.5)
Acute aortic dissection	2 (10.5)
Others	3 (15.8)

VF/pulseless VT ventricular fibrillation/pulseless ventricular tachycardia, *PEA* pulseless electrical activity, *CPB* cardiopulmonary bypass, *ER* emergency room, *ROSC* return of spontaneous circulation

age was 60.9 ± 14.6 years. The proportion of male patients was 94.7 %. The proportion of patients due to acute coronary syndrome (ACS) was 63.1 %.

Figure 19.1 show a typical case where ROSC was achieved after arrival at the ER with conventional ALS, and NIRS was employed to measure CBO in the bilateral frontal lobe. The cerebral blood flow waveform was in synchrony with chest compressions, and abrupt increases of oxy-hemoglobin concentration and tissue oxygenation index (TOI) were seen in association with ROSC detected by pulse palpation. The cerebral blood flow waveform was in synchrony with chest compressions in all patients, and both patients with successful ROSC showed abrupt increases of NIRS-detected oxy-hemoglobin concentration and TOI.

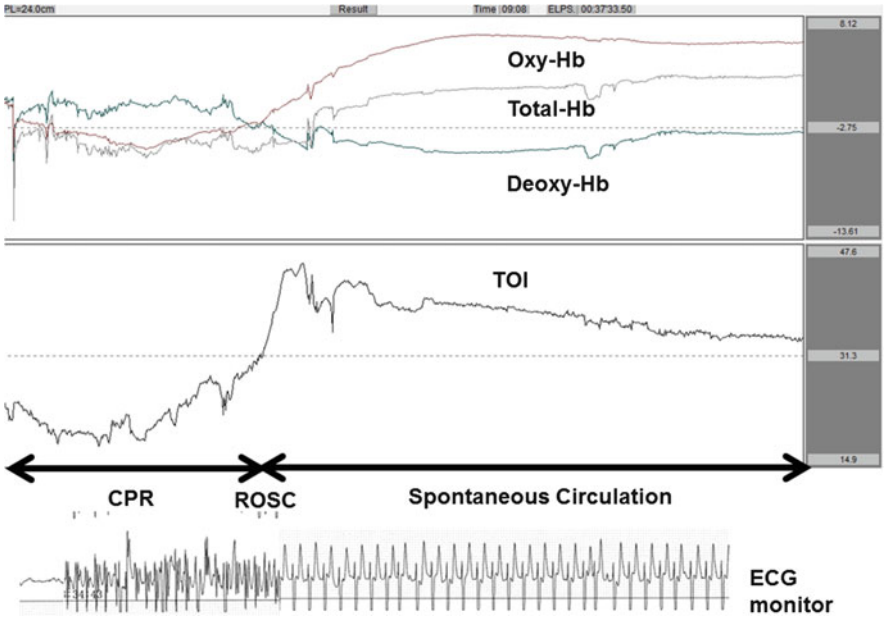

Fig. 19.1 NIRS-detected cerebral blood flow waveform is in synchrony with chest compressions in a patient who achieved return of spontaneous circulation (ROSC). Abrupt increases of oxy-hemoglobin concentration and tissue oxygenation index (TOI) were associated with ROSC detected by pulse palpation

4 Discussion

Our observation of synchronous NIRS-detected waveforms during CPR, in accordance with another recent study [12], suggests that NIRS would be suitable to reliably assess the quality of the chest compression in patients with cardiac arrest. This is important, because NIRS represents easy-to-use technology for noninvasive, continuous measurements of CBO changes with high time resolution, and it should be highly advantageous for real-time CPR prompting and feedback, and for the detection of ROSC without interruption of chest compression and without endotracheal intubation. The 2010 CPR Guidelines indicated that the quality of unprompted CPR is often poor, and methods should be developed to improve the quality of CPR delivered to victims of cardiac arrest [1, 2]. In particular, the guidelines indicated that real-time CPR prompting and feedback technology, such as visual and auditory prompting devices, can improve the quality of CPR [1, 2].

In the present study, we detect ROSC, which occurred in 2 of 19 patients, by using NIRS without interruption of chest compression, although endotracheal intubation was performed in all patients. It has been reported that NIRS can be used to measure CBO in cardiac arrest patients with/without endotracheal intubation [11–13], so NIRS should be suitable for detection of ROSC without

endotracheal intubation. Further studies seem warranted. Interestingly, our preliminary study indicated that increase of TOI during implementation of CPB might reflect an improvement in cerebral blood flow [11]. TOI increased following implementation of CPB in 17 patients who received ECPR in addition to emergency CPB.

4.1 Study Limitations

There are several limitations to our study. First, it was not a multicenter study for resuscitation after out-of-hospital cardiac arrest. Second, our findings should be considered preliminary because of the small sample size: there were only 19 patients in the present study, and only 2 achieved ROSC after arrival at the ER with conventional ALS.

5 Conclusions

Our findings support the idea that NIRS would be suitable for allow the detection of ROSC without interruption of chest compression and without endotracheal intubation.

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