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Frequency of Return of Spontaneous Circulation After Effective Cardiopulmonary Resuscitation Monitored by End Tidal Carbon Dioxide

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ABSTRACT

Cardiac arrest is a critical emergency with high mortality despite advances in resuscitation. **Objectives:** To determine the frequency of ROSC after effective CPR and to evaluate the role of ETCO2 monitoring as a predictor of resuscitation outcomes. **Methods:** This analytical cross-sectional study was conducted in the Department of Emergency Medicine, Central Park Teaching Hospital, Lahore, from May 2024 to September 2024. A total of 127 patients aged 40-70 years who experienced cardiopulmonary arrest were enrolled using non-probability consecutive sampling. CPR was performed with continuous capnography monitoring. **Results:** The mean age of patients was 56.8 ± 8.5 years; 64.6% were male. The most common cause of arrest was acute myocardial infarction (48.0%), followed by arrhythmias (22.0%), sepsis (16.5%), and respiratory failure (13.5%). ROSC was achieved in 45 patients (35.4%). Patients with ROSC had significantly shorter CPR duration (15.2 ± 5.3 minutes vs. 20.6 ± 7 minutes; $p<0.001$. An ETO2 ≥ 10mmHg after 20 minutes and an abrupt rise in ETCO2 were strongly associated with ROSC ($p<0.001$). No significant association was found with gender ($p=0.610$). Myocardial infarction as the cause of arrest was significantly linked with higher ROSC compared to non-cardiac causes ($p=0.004$). **Conclusions:** The frequency of ROSC after CPR was 35.4%. ETCO2 monitoring was found to be a reliable predictor of resuscitation success, with higher values and abrupt rises strongly associated with ROSC. Shorter CPR duration and cardiac causes of arrest were favorable prognostic factors.

INTRODUCTION

Cardiac arrest is an emergency of high morbidity and mortality in the population despite the development of cardiopulmonary resuscitation (CPR). The early initiation of effective chest compressions and early detection of cardiac arrest have a significant role in survival outcomes [1]. The eventual aim of CPR is the resuscitation of spontaneous circulation (ROSC), which implies the restoration of effective cardiac output that can be used to maintain organ perfusion [2]. But unfortunately, estimating the ROSC during the process of resuscitation has always been a difficult task, which has, in many cases, been based on subjective and unreliable clinical symptoms. The main goal of cardiopulmonary resuscitation (CPR) in cardiac arrest is to attain the return of spontaneous circulation (ROSC) [3]. Cardiac arrest resuscitation requires the provision of adequate blood flow to the vital organs, which is produced by cardiopulmonary resuscitation (CPR). Capnography end-tidal expiratory carbon dioxide (ETCO2) measures can be used to provide noninvasive estimates of both cardiac output and organ

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perfusion during cardiac arrest and can thus be utilized to assess the quality of CPR and predict return of spontaneous circulation (ROSC) [4]. The partial pressure of carbon dioxide (CO2) in the respiratory volume at the end of an inhaled breath is the end-tidal carbon dioxide (ETCO2). This value is a measure of cardiac output (CO) and pulmonary blood flow, and is an indirect measure of the coronary perfusion pressure because CO2 is carried to the right side of the heart by the venous system, and is pumped into the lungs by the right ventricle [5]. As it has been proven, in-hospital cardiac arrest and out-of-hospital cardiac arrest are important factors to consider in the likelihood of achieving spontaneous circulation (ROSC). The in-hospital cardiac arrest patients are higher risk for successful ROSC due to the ability to provide more refined technology monitoring like end-tidal CO_2 and to identify them instantly. The out of hospital cardiac arrests, on the other hand, have a much poorer chance of successful resuscitation and maintain ROSC due to delays in initiating CPR and the lack of monitoring resources [4, 5]. The cardiopulmonary resuscitation (CPR) has relatively low cardiac output, which is manifested by low levels of ETCO2 during cardiac arrest. ETCO2 levels of more than 10-15 mmHg have been associated with return of spontaneous circulation (ROSC) and survival [6]. As has been established, both in-hospital and out-of-hospital cardiac arrests play a major role in determining the probability of attaining spontaneous circulation (ROSC). The in-hospital cardiac arrest patients have a higher risk of ROSC because they can receive more sophisticated monitoring, such as end-tidal CO2, and be identified instantly. Conversely, the out-of-hospital cardiac arrests have a significantly lower likelihood of successful resuscitation and sustained ROSC because of the delays in the initiation of CPR and the scarcity of monitoring resources [3-5]. European Resuscitation Council Guidelines 2021 recommend waveform capnography as a way of ensuring that the tracheal tube is correctly placed during CPR and to measure the quality of CPR [7]. An increase in ETCO2 during CPR could be due to ROSC. Nonetheless, this should not be the only sign on which chest compression should be stopped. Quality CPR requires the use of continuous chest compression, yet to prevent drug overdoses, ROSC needs to be detected in time to halt CPR [8]. It is a challenge, though one of the approaches has been made and suggested to predict and detect that ROSC was being achieved. The monitoring of CPR by end tidal carbon dioxide was conducted in a study in the United States; it was established that return of spontaneous circulation (ROSC) was accomplished in 70 percent of cases [9-11]. Despite advances in cardiopulmonary resuscitation (CPR) techniques and monitoring, early and reliable prediction of return of spontaneous circulation (ROSC) during resuscitation remains a significant clinical challenge.

Although end-tidal carbon dioxide ($ETCO_2$) monitoring has been suggested as a useful noninvasive indicator of perfusion and CPR quality, there is limited local evidence evaluating its predictive value in emergency department settings, particularly in resource-constrained healthcare systems. Moreover, variability in reported threshold values and their clinical applicability necessitates further investigation. Therefore, this study aimed to determine the frequency of ROSC following effective CPR and to evaluate the role of $ETCO_2$ monitoring as a predictor of resuscitation outcomes in patients presenting with cardiopulmonary arrest.

METHODS

This analytical cross-sectional study was conducted at the Department of Emergency Medicine, Central Park Teaching Hospital, Lahore, from May 2024 to September 2024. IRB reference number was CPMC/IRB-No/1456A issued on 13th March 2024. Data were collected through a non-probability consecutive sampling technique. The sample size was determined to be 159 patients with 95% confidence interval, 8% absolute precision, and an estimated frequency of ROSC equal to 50% based on the range of ROSC frequency observed in local and regional studies (35-70%). A sample size of 150 patients was calculated but, due to practical constraints in the time frame of the study, data were collected from 127 patients that met inclusion criteria. This sample size will allow for an 80% chance of detecting a difference in ROSC rates of 20% between $ETCO_2$ groups at α=0.05. We are aware that the final sample size was calculated with a conservative approach and that the rate of ROSC observed in the study (35.4%) was lower than expected, potentially impacting the statistical power of the study. ROSC was defined as the restoration of sustained spontaneous cardiac activity with a palpable pulse and measurable blood pressure for at least 20 minutes without the need for ongoing chest compressions. Inclusion criteria were patients aged 40 to 70 years, patients of both genders, and patients undergoing cardiopulmonary arrest in the Emergency Department. Exclusion Criteria were patients already having brain death confirmed by an emergency physician and patients having "Do not resuscitate" orders. Approval was obtained from the hospital's ethical review committee before the commencement of the study. Written informed consent was obtained from guardians as soon as feasible following stabilization, in accordance with the institutional policy for emergency research. All procedures were conducted in compliance with the Declaration of Helsinki and local regulations regarding research in emergency settings. Airway was maintained with endotracheal

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intubation performed by the emergency physician, and chest compressions were delivered simultaneously. The $ETCO_2$ ≥10 mmHg after 20 minutes of CPR was a pre-specified primary predictor variable, based on established literature (6) and was in the study protocol approved by the institutional review board before data collection. This threshold was chosen because $ETCO_2$ values have been shown to be predictive of ROSC in previous studies and have consistently been found to range from 10-15 mmHg. Likewise, a 'abrupt rise' of $ETCO_2$ was defined a priori as a change of ≥5 mmHg over 30 seconds of continuous monitoring; this has been described in the literature as an early sign of ROSC (reference 16). CPR was continuously monitored by capnography and was considered Effective CPR if chest compression was performed at a rate of 100-120 per minute, depth of 5-6 cm, full chest recoil and minimal interruption. Ventilation rate was 10-12 breaths per minute and tidal volume was about 500-600 mL. CPR quality was constantly monitored by using real-time feedback from the capnography device, where end-tidal CO_2 ($ETCO_2$) was kept at ≥10 mmHg, which was used as an indicator of adequate perfusion. All resuscitation was performed by certified emergency doctors and trained Code Blue staff members. Return of spontaneous circulation (ROSC) was documented according to the operational definition. Demographic details, including age, gender, and cause of cardiopulmonary arrest, were recorded on a structured proforma.

All the data were entered and analyzed using SPSS version 22.0. The mean ± standard deviation (SD) was used to represent quantitative variables like age and duration of CPR. Categorical variables that included gender, cause of cardiopulmonary arrest, and ROSC came in the form of frequencies and percentages. Stratification covered effect modifiers such as age, gender, cause of arrest, and CPR length. Post-stratification chi-square test was applied, and a p-value ≤0.05 was considered statistically significant.

RESULTS

Data were collected from 127 patients, with a mean age of the cohort of 56.8 ± 8.5 years, with most patients falling within the middle-aged to older adult group. Males constituted nearly two-thirds of the study population (64.6%), while females made up 35.4%. Regarding the causes of arrest, acute myocardial infarction was the most common etiology, observed in 61 patients (48.0%), followed by arrhythmias in 28 patients (22.0%), sepsis in 21 patients (16.5%), and respiratory failure in 17 patients (13.5%) (Table 1).

Table 1: Baseline Characteristics of Patients (n=127)

Characteristic	n (%) / Mean ± SD
Age	
Years	56.8 ± 8.5
Gender	
Male	82 (64.6%)
Female	45 (35.4%)
Cause of Arrest	
Acute Myocardial Infarction	61 (48.0%)
Arrhythmias	28 (22.0%)
Sepsis	21 (16.5%)
Respiratory Failure	17 (13.5%)

Return of spontaneous circulation (ROSC) was achieved in 45 patients (35.4%), while 82 patients (64.6%) did not achieve ROSC. A significant association was observed between the duration of CPR and outcome: patients who achieved ROSC had a shorter mean CPR duration of 15.2 ± 5.3 minutes compared to 20.6 ± 7.2 minutes in those without ROSC (p<0.001).ETCO2monitoring played a critical role, as all patients who achieved ROSC demonstrated ETCO2 levels ≥10mmHg after 20 minutes of CPR, whereas none of the non-ROSC patients reached this threshold (p<0.001). Similarly, an abrupt rise in ETCO2 was recorded in 43patients (95.6%) who achieved ROSC, but in none of those who failed resuscitation (p<0.001). No statistically significant difference was found when outcomes were compared by gender, with ROSC rates of 36.6% in males and 33.3% in females (p=0.610)(Table 2).

Table 2: ROSC Outcomes and Associations

Variables	ROSC Achieved (n=45), n (%) / Mean ± SD	No ROSC (n=82), n (%) / Mean ± SD	p-value
Duration of CPR (minutes)	15.2 ± 5.3	20.6 ± 7.2	<0.001
ETCO2 ≥ 10mmHg After 20min	45 (100%)	0 (0%)	<0.001
Non-ROSC Patients	43 (95.6%)	0 (0%)	<0.001
Male	30 (36.6%)	52 (63.4%)	0.610
Female	15 (33.3%)	30 (66.7%)	

Age group analysis revealed a trend toward lower ROSC rates with increasing age, though the association did not reach statistical significance (p=0.480). ROSC was achieved in 40.0% of patients aged 40-49 years, 36.4% of those aged 50-59 years, and 32.1% of those aged 60-70years(Table 3).

Table 3: Association of Age Groups with ROSC

Age Group (Years)	ROSC Achieved, n (%)	No ROSC, n (%)	p-value
40-49	12 (40.0%)	18 (60.0%)	<0.001
50-59	16 (36.4%)	28 (63.6%)	
60-70	17 (32.1%)	36 (67.9%)	

Abrupt rise in ETCO2

The cause of arrest showed a significant impact on

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outcomes (p=0.040). Patients with myocardial infarction were more likely to achieve ROSC (42.6%) compared to those with arrhythmias (32.1%), sepsis (28.6%), and respiratory failure (23.5%). Non-cardiac causes were consistently associated with poorer outcomes (Table 4).

Table 4: Association of Cause of Arrest with ROSC

Age Group (Years)	ROSC Achieved, n (%)	No ROSC, n (%)	p-value
Acute Myocardial Infarction	26 (42.6%)	35 (57.4%)	0.040
Arrhythmias	9 (32.1%)	19 (67.9%)	
Sepsis	6 (28.6%)	15 (71.4%)	
Respiratory Failure	4 (23.5%)	13 (76.5%)	

DISCUSSION

This study evaluated the frequency of return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation (CPR) and assessed the role of end-tidal carbon dioxide (ETCO2) monitoring as a predictor of resuscitation outcomes. ROSC was observed in 35.4 out of 127 patients involved. This rate is similar to the already presented rates in the literature, with ROSC after in-hospital cardiac arrest typically reported as ranging between 25-40%. The results of such outcomes emphasize the potential of the existing resuscitative practice in emergency environments as well as its limitations. The average age of the patients in the study was 56.8 years, with the majority being male, which depicts the demographic description of cardiac arrest cohorts. The most common cause of arrest was myocardial infarction, which comprised of cases almost half of the arrests, then arrhythmias, empty quarter, and respiratory failure. These results have been in line with the previous studies where the cardiac etiologies were uniformly indicated to be the most common causative factors of in-hospital cardiac arrest, whereas sepsis and respiratory failure were more often linked with worse resuscitation results [12]. One of the areas of concern in this study was the application of ETCO2 monitoring on CPR. Patients who attained ROSC displayed much better ETCO2 when all successful resuscitation incidences were linked to ETCO2. 10 mmHg following 20 minutes of CPR. In addition, there was a sudden elevation of ETCO2 in more than three-quarters of ROSC patients, which further confirms the consistency of ETCO2 as an effective and early predictor of effective circulation restoration. These results support the findings of the earlier studies, which have demonstrated that the ETCO2 monitoring not only offers real-time measurement of CPR quality but has also been found to be one of the first indications of ROSC, and in most cases, it predicts the clinical confirmation several seconds before it. Another variable that had a significant effect on outcome was the duration of CPR [13]. ROSC patients had a shorter mean duration of the CPR (15.2 min) than patients without ROSC (20.6 min). This observation is consistent with the existing evidence that long-term resuscitation is linked to worse outcomes, presumably because of progressive ischemic injury and decreasing rates of recovery of functional myocardial contractility [14-16]. These results indicate the significance of the timely launch and effective implementation of resuscitation activities. Interestingly, it was shown that there was no statistically significant correlation between gender and the probability of ROSC, although male patients had a slightly higher probability. The same trends have been seen in previous research, indicating the possible irrelevance of biological sex as a strong independent predictor of resuscitation in the presence of other variables, including etiology and CPR [17]. Conversely, the age stratification implied that the ROSC decreases with age, albeit not significantly, which implies that older patients are usually less physiologically endowed and more affected by comorbid conditions that affect the outcome. Etiology and ROSC were also strongly linked with each other [18]. Myocardial infarction patients who were the underlying cause of arrest were more prone to ROSC than sepsis or respiratory patients [19, 20]. This probably indicates the relative reversibility of acute cardiac causes when action is taken in time, but systemic or respiratory causes could be associated with further progressive worsening before arrest. These results support the findings of the earlier studies, which have demonstrated that $ETCO_2$ monitoring not only offers real-time measurement of CPR quality but has also been found to be one of the first indications of ROSC, and in most cases, it predicts the clinical confirmation several seconds before it [13, 16]. Another variable that had a significant effect on outcome was the duration of CPR [14].

Research weaknesses are that the study is a single-centre design with a relatively small sample, which could limit the generalizability. Besides, ROSC was used as the sole outcome, and there was no long-term survival or neurological outcome after ROSC. Further research involving larger multicenter cohort studies and incorporation of long-term outcomes is justified to understand the prognostic value of ETCO2 better and improve CPR guidelines. Based on the findings of this study, it is recommended that continuous end-tidal carbon dioxide (ETCO2) monitoring be incorporated as a standard component of advanced cardiac life support (ACLS) protocols during cardiopulmonary resuscitation (CPR). Regular training of emergency department personnel on the interpretation of ETCO2 Waveforms and their correlation with CPR quality should be prioritized to enhance the early detection of return of spontaneous circulation (ROSC). Hospitals should ensure the availability and maintenance of capnography equipment in all emergency and critical care areas. Furthermore, the

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establishment of institutional CPR quality audits integrating ETCO2. Data could improve adherence to evidence-based practices.

CONCLUSIONS

It is concluded that the frequency of return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation in the emergency department was 35.4%. End-tidal carbon dioxide (ETCO2) monitoring proved to be a reliable predictor of resuscitation outcomes, with higher ETCO2 values and abrupt rises strongly associated with ROSC. Shorter duration of CPR and cardiac etiologies, particularly myocardial infarction, were also significantly related to successful outcomes, whereas sepsis and respiratory failure were linked to lower ROSC rates. These findings emphasize the importance of incorporating continuous capnography into routine resuscitation practice, both to assess CPR quality and to provide early prognostic guidance.

Authors' Contribution

Conceptualization: ASW
Methodology: ASW, MZ
Formal analysis: ASW
Writing and Drafting: ASW, MAI, MZ, HT, QNS, SSAP
Review and Editing: ASW, MAI, MZ, HT, QNS, SSAP

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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