Application of Cardiopulmonary Resuscitation Mechanism in Infant Population: A Short Review

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Abstract. Cardiac arrest (CA) is a significant issue in infants worldwide, which causes disagreeable morbidity and mortality ratios. Thus, cardiopulmonary resuscitation (CPR) is a technique performed in case of cardiac arrest to save victims' lives. The aim of CPR is to follow the blood flow promoting to the vital organs during the external chest provisional compressions. This technique has been reported to develop CA results. It was reported that CPR was not performed in high quality even when highly qualified rescuers delivered by CPR. Therefore, international guidelines have proposed for applying a CPR feedback device to release high-quality CPR to enhance survival rates. There is currently no feedback device available to guide learners through infant CPR performance compared to the adequate number of the adult in CPR feedback device. This study establishes a background knowledge to understand the CPR technique in infant populations by reviewing the following: the critical role of chest compression and rescue breath during the CPR process, the CPR standards, increasing the cardiac arrest survival rate by performing high-quality CPR, the effect of feedback on CPR performance., outlining the effect of different compression techniques on all the hemodynamic outcomes for delivering high-quality infant CPR.

Key words: Cardiopulmonary resuscitation, cardiac arrest, chest compression, rescue breaths.

1. Introduction

The CA is a significant issue in infants around the world which causes disagreeable morbidity and mortality ratios. Subjects who have CA need instant CPR to save their lives. The purpose of CPR is to supply vital organs with sufficient oxygen-rich to the blood [1]. It is a first-aid technique that allows the prevention of physiological damage (i.e., brain damage) while waiting for the arrival of a more advanced medical intervention. It is essential to perform CPR as quickly after arrest as possible, the reason is that, when cardiac arrest occurs, oxygen is no longer circulated to the brain tissues, which could result a loss in brain function [1]. Other muscle tissues in the body are considered to be regenerative, unlike brain tissues. The CPR process involves performing chest compressions (CC) with artificial ventilation to physically reserve the full function of the brain and the breathing process of a subject who has cardiac arrest [1-3]. At individually, who is implementing the CPR process must secure a set of skills for presenting a successful CPR to save the subject’s life [1-3]. Paediatric CPR differs from adult’s CPR because children are anatomically and physiologically different to adults [4]. In infants, cardiac arrest is not considered to be the only primary reason for which CPR needs to be delivered [2]. Also both...
Hypoxia, which is the ‘‘deficiency in the amount of O2 reaching tissues’’, and asphyxia (suffocation) are considered to be reasons for delivering of CPR [1]. They are challenging to identify the cause as well as the effect of the infant cardiac arrest. Thus, CPR was considered as a difficult skill when performed on an infant and young child than adult CPR. Therefore, an investigation is required to educate people about infant CPR techniques to improve the quality and rate of CPR success once performed on a child is suffering from a CA without any medical intervention [5,6].

For CPR to be efficient, the recommended standards should be achieved. This could be an issue as the layperson may not have the sufficient knowledge which allows the performance of high quality CPR. It is believed that instantaneous performance feedback could affect the performance of chest compression quality during simulated infant CPR. To perform a high quality CPR, it is essential to understand and to be able to comprehend the factors which effect it. To achieve this goal; this study aims for establishing a background knowledge as a necessity to be able to evaluate the effects of the performance of feedback system on CPR quality. This study is composed of sections as follows: section 2 explains the mechanism of CPR performance which includes rescue breaths and chest compression. Section 3 identify the CPR standards and CPR key factors, while section 4 describes the usage and the role of the feedback system through performing CPR. In section 5, the research is related to paediatric CPR performance using different processing techniques as illustrated. Finally, the conclusion and the future direction for implementing and improving the CPR performance in infant population are presented in section 6.

2. Mechanism of CPR Performance

2.1 Rescue breaths

In the paediatric population, respiratory cooperation is counted as the main event for CA. A skilled rescuer might start doing chest compression once a paediatric have a CA, which is the primary action performed at the beginning of CPR technique followed by a rescue breath action that is done by either mouth-to-mouth or bag-mask [7]. The primary function of rescue breaths through performing the CPR is to encounter the metabolic demands by retaining sufficient oxygenation and the removal of CO2 [8]. Shmolzer et al. (2010) [9] reported that the tidal volume range for infant rescue breath is 400 to 800 ml/kg compared to an adult's tidal volume range is between 700 to 100 ml/kg. Additionally, Niebauer et al., (2011) [10] outlined that hyperventilation could occur unintentionally during the delivery of rescue breaths, causing an adverse haemodynamic and augmentation of the cardiac arrest outcomes. According to Aufrdergeide et al. (2004) [11], professional rescuers went to ventilate patients excessively when performing CPR out-of-hospital. However, the study was limited by the numbers of individuals who participated in it as it was made in only one city. Delivering the rescue breaths meant to be a challenge for the rescuer because of the presumptions that the rescuer has to provide to the paediatrics by using different life support technologies. Furthermore, there are different compression-ventilation (CV) ratios based on the situations of the rescuers. The variance of CV ratio is changing according to the number of rescuers that appeared at the incident of infant CA. The recommended CV ratio in the paediatric population with one rescuer appeared at the instant of infant CA is around 30:2, similar to the adult CV ratio [1, 3]. However, if two rescuers are performing the infant CPR, the CV ratio is around 15:2. Moreover, it is essential before delivering the rescue breaths to ensure that there is no obstruction (like the tongue) at the airway path, and it is free to ventilate the patient. Otherwise, a head tilt technique needs to be used to remove the tongue; also, extreme hyperextension could obstruct the airway path and thus must be avoided [12].

2.2 Chest compression

Chest compression (CC) plays a critical role by keeping sufficient circulatory support through CA. CPR's primary purpose is to boost the vital organs by enhancing the perfusion pressures of coronary and cerebral and cardiac output (CO). The 'direct cardiac compression' model as shown in Fig. 1a is suggested
during CPR, when chest compression occurs, both the right and left ventricles are compressed between the sternum and vertebral column [13]. Thus, in between the ventricles, the aorta, and pulmonary arteries, the pressure gradient closes the mitral and tricuspid valves and generates forward blood flow by injecting blood from the ventricles [14]. Consequently, when the chest is released, the heart and the myocardium is refilled with blood as a result of negative pressure, as represented in Figure 2b, where the 'thoracic pump' model considers the heart as an inactive conduit without any pumping mechanism [15]. Therefore, it is provided by the thoracic circulation when the chest compression causes a global rise in the intrathoracic pressures. Then it forces the flow of the blood to take a specific path going from the thorax, across the heart, and into the systemic circulation. However, preparation of the next compression occurs when the chest recoils, as the venous blood returns to the thorax and heart due to the negative intrathoracic pressures [16].

Figure 1. Mechanisms of the chest compression and relaxation: (a) Direct cardiac compression model, (b) Thoracic pump model [15].

3. The quality of infant chest compression
It is essential to increase the cardiac arrest survival rate of the infant populations. Therefore, high-quality CPR is a significant factor in controlling the survival rate. Once a high-quality infant CPR is performed, the influence of its consequence even appeared to follow cardiac arrest. Hence, in terms of increasing the infant survival rate from cardiac arrest, significant studies and researches were done by specialists working in CPR, presented CPR standards and recommendations. While providing CPR, these standards and recommendations provide a reliable informing system used to supervise and document the measured quality of CC [2]. The CPR standards are recommended by the American heart association guidelines and considered as the key factors to assess the CPR quality such as: chest compression depths, chest release force, chest compression rates and compression duty cycle.
3.1 Chest compression depths
Chest compression depths are defined as the maximum displacements which appear to the sternum. It is one of the critical key factors in CPR as it stimulates the pumping of the heart and provides the brain and other vital organs with blood. Although rescuers could be aware of the necessity of achieving a recommended compression depth. Fear could limit their effort and ability to essentially compress and achieve the required depth [17]. The American heart association presented guidelines in which rescuers could identify the maximum deflection required to perform quality CPR. An infant's recommended depth should be at least one third (approximately 4 cm) of the external anterior-posterior thoracic diameters [3]. Of course, in adults, the required depth which should be achieved is larger (at least 5 cm) due to the difference of both the anatomical and physiological structures between infants and adults [4]. Infants could experience over-compression, which occurs when the residual internal thorax depths are <10 mm, during chest compressions to one-half the AP diameter [18].

3.2 Chest release force
Chest release force is the complete release of the chest when performing CPR. Leaning on the chest prevents complete release and causes the intrathoracic pressure to be increased, causing the coronary perfusion pressure to decrease [19]. It is the most common problem during CPR performance since it decreases the survival rate from cardiac arrest. On the other hand, the complete release of compression would produce a negative intrathoracic pressure that enhances hemodynamic. This was explained previously when both the compression and release mechanisms of the thoracic model were defined. During CPR, a detectable intrathoracic pressure is produced when the chest release force is about 10% of the subject body weight [20]. The European Resuscitation guidelines suggest that after each compression, the rescuers should allow complete chest wall decompression throughout chest compressions performance.

3.3 Chest compression rate
The compression rate is defined as the number of compressions delivered in a specific time (per minute) in the chest compressions series. It is an essential factor when considering the delivery of high-quality CPR, as it increases the chance of a successful resuscitation. According to the European resuscitation guidelines, infants' compression rate should be at least 100 and not exceeding 120 cycles per minute [2]. Achieving an adequate rate of compressions is considered a necessity for increasing the survival rate and performing the efficient CPR performance.

3.4 Compression duty cycle
It can be described as the compression-to-release ratio. It is defined as the fraction time with the active compression of the chest. The compression duty cycle can be estimated by calculating the area under the curve representing chest compression and then dividing it by the product of the chest compression depth and cycle time [17]. It is thought that a duty cycle of 30 % to 50 % can produce excellent coronary and cerebral perfusion pressures for infants. Therefore, the European resuscitation guidelines suggest achieving a duty cycle rate in that range [1]. In reality, it is reasonably easy to achieve a 50 % duty cycle. However, it is difficult for individuals to sustain the compression-to-release ratio when performing CPR, resulting in a prolonged duty cycle and consequently decreasing the rate of survival [21].
Figure 2. The CPR technique is represented by the following curves: (a) chest compression depth, (b) chest release forces, (c) chest compression rates and (d) compression duty cycles, where the dashed line represents a compression cycle, the circular markers represent the points recorded for each quality measure, and the shaded area represents the area and the dashed line box represents the product of compression depth and cycle time [17].

4. CPR performance using real time feedback system

For CPR to be efficient, the recommended standards should be achieved. These standards could be an issue as the layperson may not have sufficient knowledge, allowing high-quality CPR performance. It is believed that instantaneous performance feedback could affect chest compression quality during simulated infant CPR. A specific study has been conducted to investigate the effect of feedback on CPR performance see Table 1 to show 69 certified CPR providers were evaluated [20]. The participants performed both two-finger and two-thumb chest compression technique. A commercially available CPR manikin was used to simulate a three-month-old 5kg male infant. Additionally, the software was developed in order to provide real-time feedback for the participants. The software provides the recommended targets that the participants must achieve to accomplish high-quality CPR [20]. Consequently, a randomized trial was performed where two groups were allocated, one which provides CPR with real-time feedback and one with no feedback. The outcome would then be observed and analysed to illustrate if the effect of feedback increases the quality of CPR performance. The study demonstrated a significant improvement in the performance quality when real-time feedback was provided. Considering compression depth, the participants attained a high compression depth compared to that with no feedback was provided. It is also improved the accuracy of the two-finger technique, considering that the two thumb technique was performed accurately without feedback [20]. Moreover, previous researches have shown that chest compression rates were excessive when providing CPR for an infant. The study also showed an
excessive chest compression rate (approximately 200 per minute) by the participants in the 'no-feedback' group [20]. Nevertheless, the other group 'with feedback' has improved the target range required. Accomplishing of successful duty cycle is highly significant because it helps ensure sufficient opportunity for a cardiac refill. The 'no-feedback' group a two thumb compression technique exceeded the 50% required target consistently. Simultaneously, the duty cycle was accurate with the same group but using a two-finger technique [20]. Although the feedback software does not provide the participants with any specific information for enhancing duty cycle. A substantial improvement was observed in the duty cycle quality with the group provided with feedback in both compression techniques. The presented study demonstrates the significant effect of providing audible and visual metronome when performing CPR. It also demonstrates that even a trained CPR provider remains unable to achieve the required targets in all four measurements, suggesting that a layperson would be more incapable of providing high-quality CPR. The study believes that if the results were to transfer into clinical practice, the improvement in which the provision of real-time feedback proves that could enable CPR providers to accomplish all the required targets.

Recently, J. Kandasamy et al., 2019 [33], investigated whether real time feedback could improve infant CPR performance. The study as illustrated in Table 1 involved a 66 rescuers distributed into two groups to perform CPR on infant manikin with feedback and with no feedback. The CPR was performed with two thumbs (TT) compression technique. It appeared that the rescuers with performance feedback have higher than 60% compatible with CPR targets compared to the group with no feedback which shows less than 30% compatibility. However, this study has a number of functional shortages that would prevent its use within clinical system and need to be managed, such as embedding the accelerometers into a more convenient locations, transfer the data to a computer or any other handheld devices wirelessly. Also, using a pulsations and/or LED indicators to aware the rescuer upon insufficient CPR performance.

5. Two-fingers and Two-thumbs performance

There are two types of compression techniques when delivering infant’s CPR. The trainer achieved the CPR by implementing the Two Finger (TF) or the Two Thumb (TT) technique [22, 23, 24], as shown in Figure 3. The TT technique is presented by squeezing the thorax between the two thumbs and fingers for performing chest compression [23, 24]. Compared to the TF technique is presented by placing the two fingers above the lower third of the sternum and making the chest compression. Thus, the only differences between both techniques are the position of the hand and where it should be placed. Different researchers have evaluated the effectiveness and capability of these techniques by using animal surrogates [25, 26] and infant CPR model [27,28, 29]. Table 1 summaries the state-of-the-art works reported in the literature. Menegazzi, J.J., et al. [25] performed a CPR study using seven infants swine to evaluate the hemodynamic outcomes (systolic, diastolic, and arterial pressures) during the TT and TF techniques. The results outlined that the TT technique has higher effect through all the outcomes [25]. Another animal surrogate study conducted by Houri, P.K., et al. [26] using an infant swine, to evaluate the two compression techniques. The study found out the TT technique produced higher systolic pressure in comparison to the TF technique. However, there was no significant difference of the diastolic pressure across both techniques. Further, the TF CPR method wasn’t produced the same compression force compared to the other method. This study of infant CPR reported that the TT technique was more efficient than the TF technique [26].

Other researchers have assessed the difference of the two techniques by presenting a simulation study using infant manikin. Firstly, Moya et al. (1962) [27], reported that the TF technique provide systolic blood pressure in a significant efficiency compared to the TT technique. However, other researchers have questioned the outcome of Moya’s study. Dorfisman et al., (2000) [28], conducted an infant CPR simulation study to monitor and assess the systolic, diastolic, and arterial pressures by using an infant manikin. It is appeared that, by using the TT technique, there was a significant improvement in these types of pressure compared to the TF technique. Haque et al., (2008) [29], conducted a study to present
the CPR process using the two techniques for compassion purpose. The study shows that performing the TT technique when delivering the CPR reduces the rescuer fatigue in comparison to the TF technique [29]. Thus, the TT technique was advised for performing infant CPR [25, 28, 30]. The American heart association, and the International Liaison Committee on Resuscitation (ILCOR) chose the TT technique for delivering infant CPR [31].

![Figure 3](image3.png)

**Figure 3.** The CPR compressions techniques, (a) the TF method, and (b) the TT method [32].

| Author          | Study type                  | Study results                                                                 | Study shortcomings                                                                 |
|-----------------|-----------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Menegazzi et al, 1993 [25] | 5 rescuers performing CPR on 7 swine with induced cardiac arrest. CPR performed with two fingers (TF) or two thumbs (TT). | Higher diastolic, systolic and mean arterial, Coronary perfusion pressure and blood pressure with TT group. | No measure of force applied during techniques. Differences statistically relevant, not clinically. |
| Houri PK et al, 1997 [26] | Swine with induced cardiac arrest. CPR performed with two fingers (TF) or two thumbs (TT). | Diastolic blood pressure with no significant difference, systolic blood pressure shows 25% increase with TF and 57% increase in TT group when no force feedback was given. | Sternal compression force achieved was lower in the two fingers group when investigators tried to standardise this component. |
| Dorfsman ML et al, 2000 [28] | A21 rescuers performing CPR on adopted manikin. | Diastolic blood pressure is higher in TT group, Systolic | Only verbal instructions are given in performing TT technique- all rescuers experienced in TF technique. |
CPR performed with two fingers (TF) or two thumbs (TT).

blood pressure is higher in TT group.
Mean arterial blood pressure higher in TT group, perfusion pressure higher in TT group.

Whitelaw CC et al., 2000 [28].
209 subjects performing CPR on manikin. CPR performed within two fingers (TF) or two thumbs (TT).
Adequacy of CPR on skill guide shows no significant difference.
40 participants produced adequate CPR using TT and 38 using TF. TT produced more than 40 to shallow compressions in 40 participants compared with 15 in the TF group.
Heterogeneous group of participants with varying levels of experience.
71% of participants failed to give more than 60 adequate compressions in period of 2 minutes.

Haque et al., 2008 [29].
Performing the CPR using the two fingers (TF) and two thumbs (TT) techniques.
The TT technique reduce the rescuer fatigue in comparison to the TF technique.
Less reported about this study related to subjects and outcomes.

Martin, P.S., 2013 [20].
69 rescuers performed CPR using a three-month-old 5kg male infant CPR manikin with TF and TT technique. Group with feedback and other without feedback.
The no-feedback group using a two thumb compression technique exceeded the 50% required target consistently.
Have a number of functional shortages that would prevent its use within clinical system.

J. Kandasamy et al., 2019 [33].
A 66 rescuers are distributed into two groups performing CPR on infant manikin with feedback and with no feedback. CPR performed with two thumbs (TT) compression technique.
The rescuers with feedback have higher than 60% compatible with CPR targets compared to the group of no feedback which shows less than 30% compatibility.
Have a number of functional shortages that would prevent its use within clinical system, such as embedding the accelerometers into a more convenient location. Transfer the data to a computer or any other handheld devices wirelessly. Using a pulsations and/or LED indicators to aware the rescuer upon insufficient CPR performance.

6. Conclusion
This study found that, it is essential to understand the mechanism of infant CPR and to be able to perform a high-quality infant CPR to increase their survival rates. However, for enhancing the quality of CPR performance, the four infant CPR standards are chest compression depths, chest release force, chest compression rates, and compression duty cycle should be delivered effectively. The CPR performance could be improved when delivered using simulated infant CPR. By reviewing the two compression
methods of CPR with TF, and TT techniques, it appears that the TT technique was advised for performing infant CPR mechanism. Consequently, these outcomes can be used as a solid base to design and develop the feedback system that quantifies CPR performance with infant populations using the TT technique.

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