Archives of Academic Emergency Medicine. 2025; 13(1): e30

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CASE REPORT

Application of Refill, Recoil, Rebound (3R) as a Novel Chest Compression Technique in Cardiopulmonary Resuscitation; Report of Two Cases

Georgia Tsoungani[1], Sayed Nour[2]*

1. Lifeguard Instructor, Edem Beach, 72 Poseidonos Avenue, 175 62 Paleo Faliro, Athens-Greece

2. Head of Cardiovascular Division, Therapeutic Innovations Hub, Biruini University, Zeytinburnu, Istanbul, Turkey

Received: November 2024; Accepted: December 2024; Published online: 23 January 2025

Abstract: Cardiopulmonary resuscitation (CPR) remains controversial with dismal outcomes for cardiac arrest (CA) victims. Inadequate organ perfusion and frequent CPR-related trauma most likely occur due to inappropriate adaptation to hemostatic conditions, electrophysiology, cardiotorsal anatomy, and thoracic biomechanics. Alternatively, we propose a new technique compromising chest compressions through the 5th intercostal space while placing the victim in the left lateral decubitus position with wrapped abdomen and raised legs, allowing to: bypass the sternal barrier, refill the heart, and then recoil-rebound the chest (3R /CPR), within the axis of the cylindrical ribcage. Our goal is to evaluate the technique following its necessary application on two drowning victims. It seems that, 3R/CPR adapts the pathophysiological conditions of CA victims promoting a less traumatic return of spontaneous circulation (ROSC), making it worthy of further investigation and study.

Keywords: Heart Arrest; Cardiopulmonary resuscitation; Return of Spontaneous Circulation; Out of Hospital Cardiac Arrest

Cite this article as: Tsoungani G, Nour S. Application of Refill, Recoil, Rebound (3R) as a Novel Chest Compression Technique in Cardiopulmonary Resuscitation; Report of Two Cases. Arch Acad Emerg Med. 2025; 13(1): e30. https://doi.org/10.22037/aaemj.v13i1.2447.

1. Introduction

Cardiopulmonary resuscitation (CPR) modalities may combine noninvasive-procedures such as mid-sternal chest compressions, whether manually or mechanically; Automated external defibrillator (AED); Mouth-to-Mouth ventilation; and invasive-procedures like injection of epinephrine, mechanical ventilation, extracorporeal membrane oxygenation (ECMO) or E-CPR, implantable cardioverter defibrillators (IDC), and direct cardiac massage with cardiopulmonary bypass (CPB) under certain circumstances (1-8).

However, outcomes of CPR remain quite poor since the 30-day brain injury-free survival of out-of-hospital cardiac arrest (OHCA) still hovers around 2% (9, 10). In addition to frequent CPR-related trauma, most post-arrest survivors succumb to multiorgan failure shortly after return of spontaneous circulation (ROSC), due to inadequate organ perfusion during the procedure (11-13). Such controversial CPR results require an overhaul of the entire cardiac arrest (CA) structure through in-depth and meticulous analysis.

Yet, the primary goal of CPR, namely rapid ROSC while ensuring adequate perfusion of vital organs, still remains elusive, likely due to the aforementioned obstacles, outlined thereafter.

Hypothetically, we need to create an action potential at the intracardiac conducting system, while compressing/decompressing the rigid sternum, the loose mediastino-cardio-pulmonary compartments and then the more distant left ventricle (LV), to deliver an adequate stroke volume with a coronary perfusion pressure ≥ 15 mmHg (14).

The heart becomes nearly empty within 30 seconds of the hemostatic condition of CA, due to shifting of massive blood volumes (BV) to low-pressure zones via the valveless vena cava, thereby increasing the hepatosplanchnic venous capacitance (15).

Besides, the heart, which is, as described by Claude Beck, anchored in the body by the great vessels (16), is also separated from the sternum by a few centimeters to be considerably increased by the cardiotorsal gravitational effect once the victim is placed in the supine position for CPR. Also, we must take into account the human cardiotorsal anatomy and biomechanics of the cylindrical shell-shape thoracic cage, in particular the ribs' orientations and axis of their movements controlled by the sternocostal, costochondral, costovertebral, and costotransverse joints (17). Such severe anatomical and hemorheological disturbances during CPR compromise circulatory flow restoration (CFR) dynamics, which enhances biochemical-electrophysiological processes via wall shear stress, thereby triggering and maintaining heartbeat since intrauterine life (18).

Of note, rapid intracardiac CFR, either with the lifeguard's Heimlich maneuver or with the cardiac surgeons' CPB, in-

***Corresponding Author:** Sayed NOUR; Therapeutic Innovations Hub, Biruini University, Merkezefendi, 75 Sk No:1-13 M. G, 34015 Zeytinburnu/ Istanbul, Turkey. Tel: +90 212 444 82 76, Fax: +90 212 416 46 46, ORCID: https://orcid.org/0000-0002-3853-0942 .

duces ROSC in ≥70% of drowning victims, and in ≥90% of open-heart patients, respectively (19-21).

Previously, we demonstrated the benefits of prioritizing prompt CFR over exhorting return of heartbeat in pediatric CA models using a noninvasive CFR device (22). In this study, we propose a novel chest compression technique capable of adapting and overcoming clinical obstacles confronted during CA management, namely hemostatic state, electrophysiology, cardiotorsal anatomy, and thoracic biomechanics.

In this study, we aim for a rational evaluation of the technique following its inevitable application in OHCA drowning incidents, as a feasible, tireless and less traumatic method promoting ROSC, thereby significantly improving CPR outcomes.

We first simulated the method, aided by one of the most experience Lifeguard squads in Europe (23), before being presented in several meetings. Then, Ms. G.T., a lifeguard instructor convinced by the technique, found herself in unavoidable situations requiring its employment.

2. Novel chest compression technique

We modeled the proposed method through our experimental studies with a CFR device in CA models (22). Thus, creating a similar intracardiac hemorheological effect promoting ROSC through the following steps:

1. Place the victim in the left-recovery position to clear the airways, overrule the sternal barrier, bring the heart apex closer to the chest wall, then with the right palm at the victim's 5th intercostal space, check whether there is still a heartbeat or not (Figure 1).
2. Refill the near-empty heart by lifting the victim's hips-legs while mildly wrapping the trunk promoting mobilization of massive hepatosplanchnic blood volume (BV) towards the chest.
3. Adjust and block the victim's body with both thighs, then lean forward and, with both forearms, compress the victim's right chest wall downward, countered with upward-backward pressure on 5th intercostal space with both palms (Figure 1). Thus, recoiling the chest in a near-circumferential manner within the thoracic biomechanics' rules.
4. Maintain the recoil-maneuver for a few seconds, then suddenly release all pressure points on the chest, so the ribcage and cardiopulmonary compartments rebound, creating a water hammer-like hemorheological effect with intracardiac blood volume on the conducting system.
5. Installation of the AED electrodes in the anteroposterior position, then after 2 minutes without ROSC, a DC shock of 100-150 J can be delivered, to be repeated after a further 2 minutes before a 3rd final attempt in an interval of 3 - 4 minutes.
6. After ROSC, keep the victim in the left-recovery position with slight abdominal compression, otherwise continue the recoil-rebound maneuvers until arrival of emergency squads.

Precaution: The method is unsuitable for infants (We may continue with actual method in infants as far as we can perform a circumferential chest compression) and in particular the rebound maneuver should not be attempted on living person as it may cause Commotio Cordis-like syndrome (In our demonstration, we used to simulate the rebound maneuver on the water bags, lower intercostal spaces and abdomen as in the appendicitis test).

3. Case presentation

3.1. Case 1

On August 13, 2023, at 5:48 p.m., a 36-year-old man was spotted by the lifeguard's binoculars motionless, drowning far from the shore. It took ≥ 15 minutes to bring him back ashore with the surfboard, to be managed with the Heimlich maneuver and conventional CPR for ≥ 5 minutes, without effect. The victim remained unresponsive for quite a long time with a full, frothy mouth. Therefore, he was placed in the left recovery position, legs raised, and managed with rebound-recoil chest compressions, which successfully cleared his mouth with ROSC after 2 minutes. He was placed on his back with an oxygen mask to suffer another CA managed via mid-sternal chest compressions with ROSC. Then he was placed again in the left recovery position with an oxygen mask. Unfortunately, he suffered 2 additional CAs with short ROSC after recoil-rebound chest compressions, representing a total duration of ≥ 42 minutes of CPR interrupted by 4 short ROSCs. He remained unresponsive until he was transferred to hospital, where he was officially pronounced dead. The autopsy report revealed a significant alcoholemia due to consumption of ≥30 pints of beer, as stated by his friends.

3.2. Case 2

On August 30, 2023, at 5:35 p.m., a drowning 75-year-old lady was quickly pulled out of water pulseless, breathless, and then subjected to conventional CPR with ROSC in ≤ 3 minutes. She was placed in the left-recovery position with an Oxygen mask. She then suffered breathing difficulties, followed by another CA with zero blood pressure as demonstrated by the monitor placed on her right arm. As a result, the lifeguard, Ms. G.T., quickly executed the refill maneuver wrapping the victim's abdomen with the lifeguard belt and lifting her legs, which induced instant ROSC. She maintained normal vital signs and was safely discharged from the hospital a few days later.

4. Discussion

The exceptional application of the proposed method in these drowning incidents induced ROSC instantly with the refill maneuver in one victim, and several times with recoil-rebound chest compressions in another victim despite CA of ≥ 25 minutes with ultimately severely depleted myocardial oxygen reserves and alcoholemia.

This may highlight the feasibility and potential advantages of the proposed so-called 3R/CPR, opening promising prospects for improving the dismal outcomes of current CPR.

Figure 1: Placing the victim on the left recovery position and checking the heartbeats via the 5th intercostal space (left). Simulation of 3R/CPR. Raising the victim's legs, wrapping his abdomen (e.g., with lifeguard's belt), then leaning forward to compress his chest with both hands, forearms, and thighs in near-circumferential manner (right).

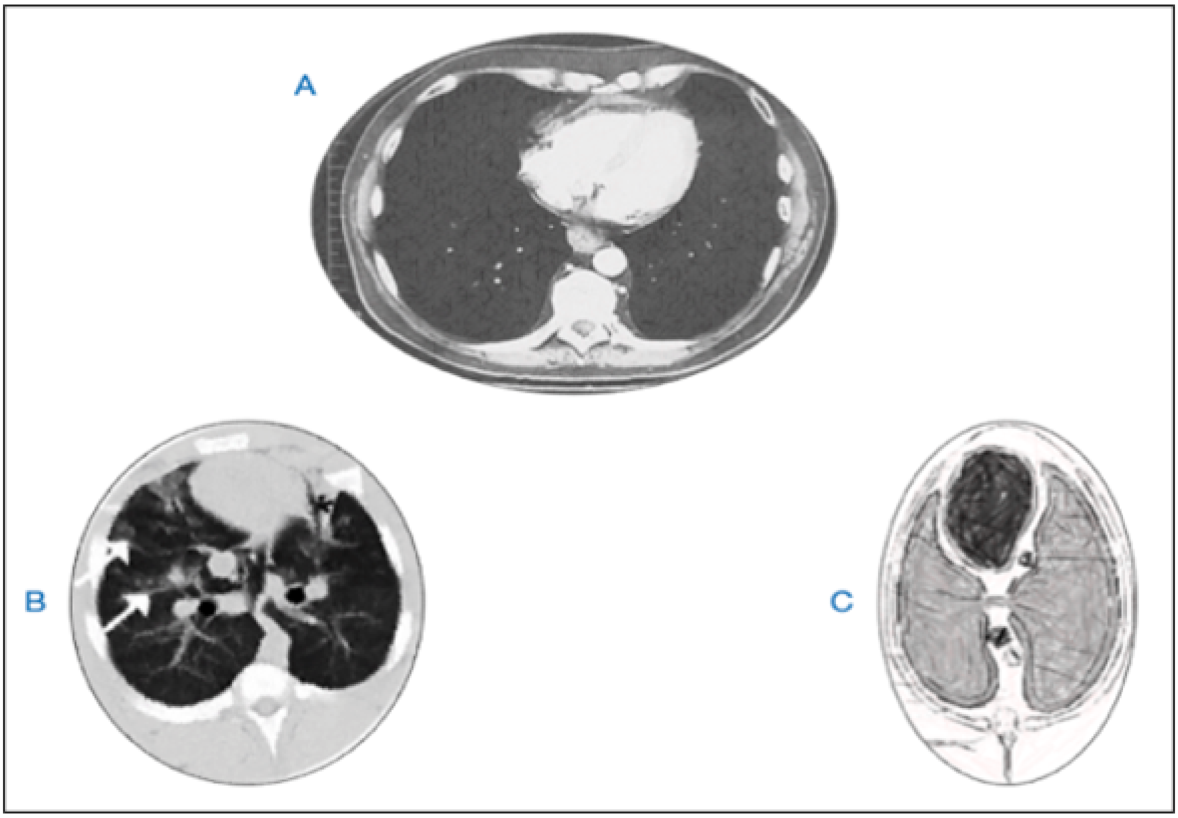

Figure 2: Morphological discrepancy between species. Upper panel (A): Midsternal chest computed tomography (CT) scan showing the cardiotorsal anatomy of the shell-shaped cylindrical thoracic cage of a living adult person. Lower panel: Midsternal CT scans showing the variation in cardiotorsal anatomy between pig (left panel; B) and canine (right panel; C).

First, ROSC, which is entirely dependent on action potentials via intracardiac hemorheological-biochemical processes, can be enhanced by the refill-maneuver shifting a massive amount of the stagnant infra-diaphragmatic blood volume to the cardiothoracic compartments, and then be sheared properly with the recoil-rebound maneuvers. Also, ROSC can be enhanced by near-homogeneous circumferential cardiac massage through the surrounding mediastinum, parenchyma, and diaphragm with trunk wrapping. This can literally explain the claimed benefits of CPR in prone position or with retained lungs inflation (24, 25).

Second, chest compressions through the left 5th intercostal space while leaning on the victim body, provides near-circumferential (hoop) stress to the cylindrical ribcage in complete harmony with costal axial motion and thoracic biomechanics (26). This makes the technique less traumatic as well as less exhausting for rescuers. In contrast, vigorous mid-sternal chest compressions induce deviated longi-

tudinal stress causing the well-known serious CPR-related trauma (27-29).
Third, the left recovery position allows the rescuer to secure the victim's airway and easily check the heartbeat so as not to confuse CA with other clinical conditions such as syncope or cardiogenic shock.
Fourth, in addition to enhancing ROSC, the technique can significantly improve myocardial contractility and hemodynamics by increasing right ventricular (RV) preload (Frank-Starling law). This was demonstrated in our studies with low-pressure pulsatile infradiaphragmatic garments showing an instantaneous ROSC in a ≤8 minutes CA models and significant improvement in hemodynamics in acute RV failure models (22, 30).
Also, ensuring vital organ perfusion during refractory CA and post-arrest has been clearly demonstrated by studies showing significant improvement in brain injury with E-CPR (E-CPR remains a work in progress due to the difficulties of its installation through near-empty flattened arteries in outdoor environments) (31, 32). Thus, regardless of ROSC, pursuing the proposed method can improve organ perfusion through rational hemorheological exploitation of stagnant blood volume, thereby contributing to successful subsequent refractory and post-arrest management.
In correlation with the other CPR modalities, insofar as ventilation is pointless due to the hemostatic state leading to lack of alveolar gas exchange (33), it is preferable to continue the 3R/CPR without interruption until arrival of emergency squads.
Regarding controversies between prior initiation of chest compressions or AED, we note that there is still a lack of studies showing prompt ROSC with a first DC shock. CPR was adopted randomly in the early 1960s, following early experiments with external defibrillators in the anterolateral position on canine models, morphologically sorely different from humans as shown (Figure 2) (34). Consequently, the morphologically unadopted anterolateral electrodes position in humans, results in a ≥ 95% deviation of the shocking energy from the cardiac electrical field, requiring stronger shocks (≥ 300 J) with serious consequences (35, 36). Besides, a prolonged depolarization period after strong shocks may cause myocardial necrosis and electroporation of the precious pacemaker cells that represent only about 1% of cardiomyocytes (37). Also, since sensitivities of conventional 12-lead ECG systems are still imprecise (38), it is therefore obvious that AED data can be compromised by only two electrodes placed far apart in the anterolateral position. Thus, it would be more effective to perfuse and predispose cardiomyocytes with an appropriate massage before using AED in the anteroposterior position allowing ≥90% of the shocking energy reaching the heart.
Despite apathetic undebated receptions of the method in the literatures over the past two years (39), some media have broadcast successful clinical 3R/CPR simulations, even executed in haphazard untrained manners. Constructive scientific debates, w/wo computational model inspectors (40), can therefore approve or disapprove the benefits of 3R/CPR over CPR, which has been costing hundreds of thousands of lives yearly for more than six decades.

5. Limitations

The study is limited to two exceptional drowning incidents, firstly because of fierce strain in evolving current CPR doctrine, as well as lack of animal models that would be compromised by great morphological discrepancies between species (Figure 2).

6. Conclusions

CA is a hemostatic condition reversible only via intracardiac hemorheological-biochemical processes requiring dynamic shear stress of adequate BV. Unlike CPR, it seems that 3R/CPR adapts and overcomes the clinical barriers imposed by CA promoting a less-traumatic ROSC across all ages, genders and environments.

7. Declarations

7.1. Acknowledgments

We would like to thank the whole group of Hellas Lifeguards School, Athens, Greece.

7.2. Ethical considerations

Not applicable, as the study was conducted by a competent rescuer as a last-chance intervention after failed CPR, providing data anonymously without revealing the victims' identities, as reported subsequently.

7.3. Conflict of interest

None.

7.4. Funding

Nothing to declare

7.5. Authors Contributions

S.N. conceived, developed the concept and designed the study, G.T. provided the acquired data. All authors interpreted the data and revised the manuscript for intellectual content and approved the submission of the manuscript. G.T. had access to the raw data.

7.6. Using artificial intelligence chatbots

None.

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