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A Systematic Review of the Mechanical CPR and Manual CPR on Out-of-Hospital Cardiac Arrest Occurring in High-rise Building

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Abstract

CPR in High-rise building is one of the challenging tasks to 119 paramedics, evacuating patient from the narrow and vertical area. This study was built to compare the method of mechanical CPR and manual CPR is to maximizing on-scene treatment time, and minimizing the hand-off time in cardiac arrest, transporting patient as fast as possible. The electronic data research (Science, Pubmed, Medline, Medline and 55 academic DB interworking) was conducted, and five articles were included by reviewing and excluding through the Covidence program and Review Manager version 5.4(Cochrane Collaboration). OHCA occurring on the higher floor indicates lower in survival. A total studies uniformly reported mechanical CPR is more effective during the high-rise building evacuation, than manual CPR in rate, depth, and hands-on time of chest compression. Use of mechanical CPR device is more suitable in case of High-rise building OHCA to improve the survival rate which is affected by high-quality CPR.

Keywords: *Out-of-hospital Cardiac Arrest, High-rise Building, Mechanical CPR, Manual CPR*

1. INTRODUCTION

Out of hospital cardiac arrest (OHCA) that often happens at home is escalating as expanding into urbanization in recent days, and offers a laborious challenge for 119 paramedics in resuscitation[1]. Maintaining high-quality CPR determines by the adequate compression depth and rate, Hands-on time, full chest recoil, and ventilation[2]. Effective chest compression is essential for delivering sufficient blood flow to the heart and brain during cardiopulmonary resuscitation, and the lower middle of the sternum needs to be strongly compressed with rate and regularity. Chain of survival has been known as an important factors for survival in OHCA patients. Among the 6 links in out-of-hospital chain of survival, performing early cardiopulmonary resuscitation followed by high-quality CPR directly determines patients' resuscitation[3].

Not only high-quality CPR, but also a quick detection of patient and transporting to the hospital is the other factor influencing recovery and survival rate[4]. Lots of residents in Korea consist of the apartments that more than 40% of population live in, and the fifteen-person elevator is composed of 900 mm door width and 1600 x 1500 mm inside, that is shorter than the general stretcher for transportation, which means vertical height delays time accessing the patient and transporting to the ambulance via elevator or staircase. Also, effective

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cardiopulmonary resuscitation is a heavy work to perform while the patient is removed out of the building, because of confined spaces that districts every movement for 119 paramedics to move[5,6]. There are a variety of studies reported to discover an ideal method of CPR on OHCA occurring in high-rise building, by measuring the factors influencing the survival rate. And one of the methods is application of CPR devices. The prominent advantage of mechanical CPR is fixed chest compression function without exhaustion during evacuation[7]. From the point of view in neurological outcomes and survival-rate after discharge, there were no significant differences found between mechanical CPR and manual CPR in OHCA[8]. The survival rate to discharge is too low compared to the number of OHCA incidence rate in worldwide, despite of installation of automated external defibrillation is increased and being educated to be used in public[9]. However, a specific guidance of the rescue and the resuscitation for OHCA occurring in High-rise building is not established, and an issue of preponderance between manual CPR and mechanical CPR in the clinical outcomes is not confirm yet[10,11]. This study aimed to investigate the factor that interrupt evacuation in high-rise building by analyzing the current study of comparing mechanical CPR and manual CPR on OHCA, focusing on high-quality chest compression.

2. METHODS

2.1 Study Design

This systematic review followed the Preferred Reporting Item for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

2.2 Eligibility Criteria

PICO (Population, Intervention, Comparison, Outcome) format was used to frame the study question: Participants who were adult (>18 years old) medical personnel such as 119 paramedics (P) with Out-of-Hospital Cardiac Arrest (OHCA) in the high-rise building (I), Does the Mechanical Cardiopulmonary Resuscitation (CPR), compared to the Manual Cardiopulmonary Resuscitation (CPR) (C), adequate compression depth, compression rate, compression recoil and proportion of compression that affects the survival rate (O). Return of Spontaneous Circulation (ROSC) was not included as an outcome. Since this research was built to evaluate the quality of cardiopulmonary resuscitation performed mechanically and manually, and some of the selected researches did not propose the rate of ROSC compared events. Randomized manikin simulation trials, observation studies, clinical studies were included. The researches were restricted to the publication period was, at least, to be 2010, and the written language in Korean and English.

2.3 Data Collection and Criteria for Study Selection

Systematic literature searches were conducted from 2010 to 2022 in the electronic data research (Science, Pubmed, Medline, Medline, and 55 academic DB inter-working), using the library of Konyang University. And they comprised of the following search terms (combination of subject heading and keywords): “Out of Hospital Cardiac Arrest (OHCA),” “Mechanical CPR,” “Manual CPR,” and “High-rise building.” the writer reviewed the references of eligible papers and published articles from the database to identify the candidate trials. As 596 articles were found in the initial search, two investigators independently screened the titles and abstracts. After then, studies were considered eligible for inclusion, if the study environment presents at the High-rise building and proceeded with comparative experiment. 16 articles were selected by reviewing the full-text articles with precise deliberation. 5 were finally selected through the Covidence program to conduct

conformity assessment with other reviewers. We performed a meta-analysis of the data using Review Manager version 5.4 (Cochrane Collaboration).

2.4 Data Extraction

Two investigators extracted data independently that does not fits to the purpose of the study. And the third investigator inspected the rest to evaluate. Standard was as follows: the specific measurement in chest compression (rate, depth, hand-on time, or flow time), no use of AEDs, and the whole route of evacuation inside the building to an ambulance.

3. RESULTS

3.1 Results of the Literature Search

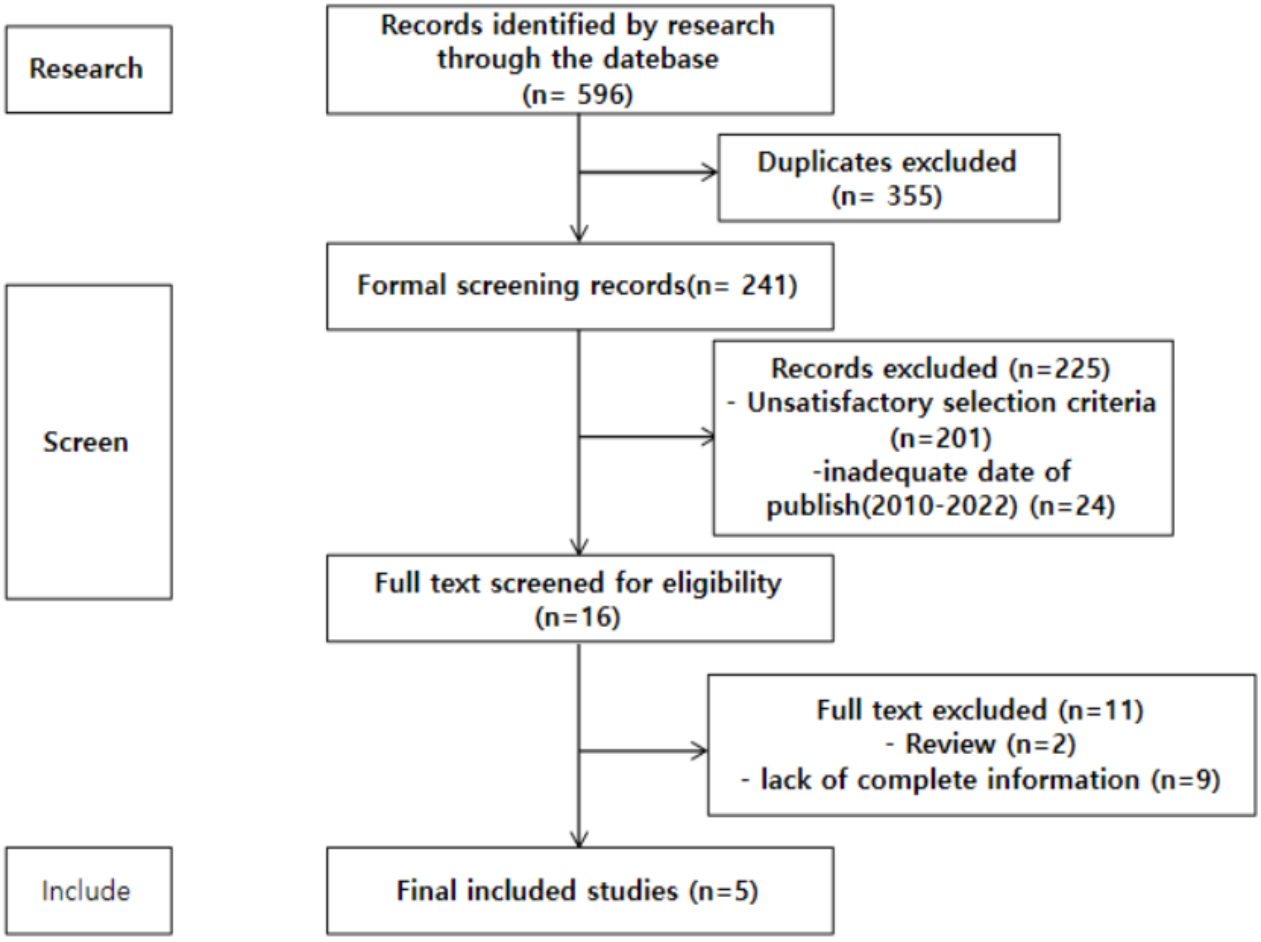

Figure 1. PRISMA diagram of study selection process

Figure 1 show the process of study selection. In total, 596 articles were identified from the database, and 355 articles were excluded because of duplication. A total of 225 articles were excluded reviewing its publication period (2010-2022), title, and abstract, during the formal selection. Of 11 articles were removed from the qualitative assessment, since they did not meet the inclusion criteria and 2 were systematic reviews.

In the end, 5 studies were included in review, analyzing selected data, setting the quality of evidence, and evaluation summary.

Table 1 summarize the characteristics of the included study. The studies are as follows: a simulation study, a randomized Crossover simulation study, a clinical study, and two manikin trials. Each studies compared the method of mechanical CPR and manual CPR, and measured a value to find out the quality CPR performing in the unstable environment <Table 1>.

Table 1. Main Characteristics of Data Analysis and Summary

N	Author, Year	Country and study setting	Number of Partici-pants	Study Design	Intervention and control Groups for Comparison	Results	Conclusion
1	Bekgoz, et al. 2020	Ankara, Turkiye Start: 3rd floor End: 1st floor	20	Manikin trial n=male(10) female (10) 119 paramedics	Manual CPR and Mechanical chest compression device (MCCD)	manual chest compression in rate: 142/min, depth: 25.2mm hands-on time: 92% mechanical chest compression in rate: 102.3/min, depth: 52.mm hands-on time: 100%	MCCD was closer to the resuscitation guideline in rate, depth, and hands-on time
2	Dranhaus et al. 2020	Brühl, Germany 5th floor	40	Manikin Trial n= male: 33 female: 7 119 paramedics	6 experiment trials: manual CPR and lift manual CPR and ladder manual CPR and staircase mechanical CPR and lift mechanical CPR and ladder mechanical CPR and staircase	lift route depth: no significant difference between two frequency: lower in manual than mechanical chest compression. (58 ± 34 vs. 94 ± 2, p = 0.02) ladder route depth: significant lower in manual than Mechanical chest compression.(18 ± 21 vs. 92 ± 7, p = 0.04) frequency: significant lower in manual than Mechanical chest compression.(61 ± 17 vs. 96 ± 1, p = 0.04) staircase rout: depth: Significantly lower for manual than mechanical chest compression.(25 ± 16 vs. 86 ± 28, p = 0.02;) frequency: significant lower in manual than mechanical chest compression (22 ± 30 vs. 96 ± 2, p = 0.02)	mechanical CPR is more effective in consistent high-quality CPR in transportation lift is recommende d for the route of evacuation.

3	T. H. Kim et al 2016	Seoul, Korea 6th floor	27	Randomized crossover manikin simulation trial 44 simulation of 9 teams	3 cycle of Manual CPR for 2 min. using standard stretcher (SS-CPR) and reducible stretcher (RS-CPR)	no flow fraction: higher in SS-CPR than RS-CPR (32.9 vs. 31.6, p = 0.14) depth: significant higher in RS-CPR than SS-CPR (97.8 vs. 83.7 , p < 0.01) rate: significant higher in RS-CPR than SS_CPR (95.9 vs. 92.9, p = 0.05)	using reducible stretcher in vertical transportation improved CPR quality
4	T. H. Kim et al 2017	Busan, Korea	5	Clinical study Before phase for 6 week, and after phase:	S-CPR: manual compression on standard stretcher in Before-phase and M-CPR: mechanical compression on reducible stretcher in After-phase	Mechanical CPR on after-phase (median: 85.2, 83.4~86.3%) was significantly higher in Chest compression fraction, than manual CPR on before-phase. (median: 80.1, 68~85.2%)	Mechanical CPR with reducible stretcher increased chest compression fraction.
5	J. H. Kim et al. 2018	Jeonju, Korea 42th floor	24	Randomized manikin simulation 4 scenarios phase 1: initiating until performing CPR according to 1 of 4scenarios phase 2: leaving the scene to entering elevator phase 3: entering till exiting elevator phase 4: exiting elevator till loading into ambulance	4 scenarios: MAB(manual compression with bag-valve mask) MAS(manual compression with supraglottic airway) MEB(mechanical chest compression with bag-valve mask) MES(mechanical chest compression with supraglottic airway)	phase 1: manual groups was significantly higher in flow time fraction (MAB: 80.5/ MAS: 81.4 and MEB: 63.5/MES: 67.1) phase 2,3,4: among the groups, MES was the highest in flow time (100)	use of mechanical compression and a supraglottic airway (MES) increased most effectively in flow time

3.2 High-rise Building Cardiac Arrest

Four studies were performed in Asia, one in Europe. As shown in Table 2, high-rise OHCA studies were mostly happened in densely populated and metropolitan cities such as Korea, because out-of-hospital cardiac arrest (OHCA) is the problem to be resolved of this last days. OHCA occurring on the higher floor indicates lower in survival, as highlighted by Ian R et al. (2016), who reported vertical distance delays the arrival of 119 paramedics to treat the patient and were no survivors above floor 25[12]. Unlike the other OHCA, the limited exit in the high-rise building challenges 119 paramedics to find out the best way to transport the CA patient to an ambulance and the hospital. The study of T. H. Kim reported that good-quality compressions with adequate arm position and force is difficult to maintain with the width of elevator that is shorter than the general stretcher with 190 to 210cm[7].

The included studies conducted their experiments of evacuating route via elevator or staircase. A total of 3 studies reported the advantage of using the equipment on performing chest compression in an elevator. That is, a good substitute for manual chest compression that prevents the provider from fatigue and danger offers continuous chest compression, minimizing hands-off time from the moment in an elevator and an ambulance [13]. J. Kim et al study reported the percentage of flow time in mechanical compression was as high as time takes, in contrast with manual compression that was higher than mechanical compression during the first phase of deploying equipment[6].

On the other hand, Bekgoz et al. and Drinhaus et al. prepared the evacuating scenario by stepping down through the staircase and reported mechanical CPR is closer to the current guidelines, which is a depth of 50mm-60mm and a rate of 100-120 per min[14, 15]. In the study of Drinhaus et al, the quality of chest compression in depth and in rate differs mostly in CPR-method, not in the way of evacuation, but in use of elevator was recommended because carrying out the patient tiling with the stretcher, accompanies a severe dislocation of CPR-device and a risk of strain on personnel[15]. In addition, in the finding of Bekgoz et al, hands on time with manual CPR was recorded in lower percentage than mechanical CPR due to the non-stationary condition of evacuation via staircase that hardly apply chest compression effectively in balance[14].

3.3 Outcomes

A total studies uniformly reported mechanical CPR is more effective during the high-rise building evacuation, than manual CPR. however the pointing index was not exactly the same, because CPR was conducted in a different condition, respectively[6, 7, 13, 14, 15].

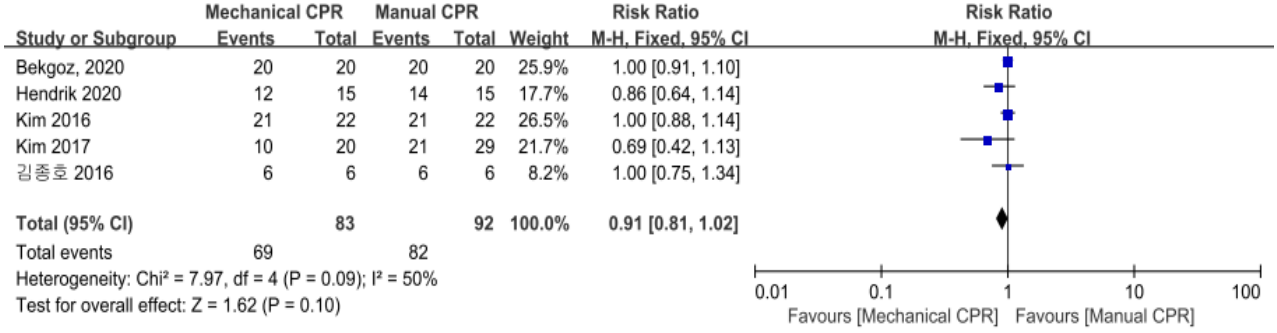

Figure 2. Cases included in the study

175 cases (including 83 manual CPR groups and 92 mechanical CPR groups) were conducted from the included studies to test and summarize the specific characteristics <Figure 2>. Among of them, 14 cases of mechanical CPR cases were removed due to registration errors (n=2), equipment failure (n=1), mechanical error of manikin (n=1), Field ROSC (n=4), arrest after transport (n=1), contraindication of mechanical CPR (n=5), and 10 cases in manual CPR were cancelled due to registration error (n=1), field ROCS (n=2), Arrest after transport (n=1), no flow fraction, not measured (n=5), respectively. [7, 13, 15]. Contraindication of mechanical CPR was the upmost common reason because the device was unable to apply to the weak patient with skinny body or scoliosis that may cause musculoskeletal or visceral injuries, even liver or spleen laceration.

T. Kim et al divided the experiment into two scenarios and analyzed their results of manual CPR and mechanical CPR at scene and CPR during moving. Two methods had an adequate chest compression without significant difference in CPR at scene. However the proportion of depth (60.9mm) and recoil (4.1%) in manual chest compression decreased significantly (depth: 32.7mm, recoil: 2.8%), maintaining the rate of chest compression during moving (113/min to 117.3/min)[7]. On the other hand, mechanical CPR with reducible stretcher were in the adequate range in chest compression measurements (depth: 60.5mm to 52.9mm, rate: 113/min to 102/min, full recoil: 9.9% to 29.8%). The only difference between two methods was the use of a single reducible stretcher in the elevator, of course, mechanical CPR was performed by LUCAS2-chest compression system.

The similar results were found in the other studies of Drinhaus et al. and Bekgoz et al., reporting the depth and rate of mechanical chest compression was in the normal range to the American Heart Association guidelines[14, 15]. However, mechanical CPR did not predominate with the quality of chest compression in every moment of arrival to transportation, because manual chest compression was able to conduct chest compression without make-ready time, unlike mechanical device that needs the time to deploy it [6].

Also, the study of J. Kim et al. was the only study that applies a ventilation-assist device to minimized the interruption, splitting the scenarios up into 4 phases. During the first phase of initiating CPR, manual groups highest in flow time fraction than mechanical groups, and there was no significant differences in rate, depth, and recoil during phase1. However, as time goes by, flow time increased most effectively when the researcher initiate mechanical chest compression and supraglottic airway and insertion of supraglottic airway, while manual groups were almost unable to continue chest compression in moving[7].

4. DISCUSSIONS

In this systematic review, we analyzed the characteristics of mechanical chest compression and manual chest compression on OHCA occurring in high-rise building[16]. The urbanized and densely populated region is challenging to 119 paramedics. Evacuating vertically to the ground is the main challenge in this matter due to the limited areas, such as the aisle, the elevator, and stairs, of which a standard stretcher does not fit enough to enter in and hardly perform CPR by efficiency even with multifunctional reducible stretcher cart. In the study of Morrison et al, investigators carry out research the time consumptions in response time and on-scene time between high floor group and low floor group. The high floor group took 8 minutes in 119 paramedic response time and 12 minutes in on-scene time which was longer than low floor group (7 minute and 10 minute, respectively)[18]. In the real situation, certain elevators, which are used by the resident or unable to activate by regular inspection, cause more time delay arrival to patients life threatening. The worse is the building without the elevator that makes 119 paramedics carry their heavy equipment marching up to the target spot, and their strength may be undermined before the patient management, affecting negatively on efficiency of chest compression.

In addition, the selected simulation studies were conducted by setting buildings[6, 7, 13, 14, 15]. That means the scene in real-life may have different designs and structures inside bringing out different results, unlike the simulations. What is important in this simulation is that aware of location of AED and quick access by the first responders before 119 paramedics arrive to the building. The first responder could be the apartment manager, a neighbor or the family of patient. For that reason CPR training included AED and the awareness of AED placement are the first key of initiating the quality CPR to have better neurological outcomes in high-rise building[16, 17]. There are some systematic reviews that analyzed the neurological measurement recorded in pre-hospital cardiac arrest comparing mechanical CPR and manual CPR, but no specific result of cardiac arrest in high-rise building could investigate[19, 20].

These studies concluded manual chest compression was preferred to in expecting the better rate of return of spontaneous circulation (ROSC), but on different rate in ROSC between mechanical CPR and manual CPR [20].

There were limitations under the comparative study. first, lots of manikin trials used for the same purpose of performing the high-quality chest compression during evacuation, but few observational evidences could found during the researches, which the real neurological outcomes are hard to identify and analyze. In addition, the measurement of chest compression enforcing to the human is different compared to manikin, due to various body size. Second, the number of real-life cases that conducted for the study was insufficient to compare of. Most of studies included was a small groups, and number of repetitions was low. The more controlled trials(RCTs) with human patients that measure the survival rate in high rise building cardiac arrest need to be designed to establish the systematic guidelines of OHCA in High-rise building.

5. CONCLUSIONS

The reason of comparing the method of mechanical CPR and manual CPR is to maximizing on-scene treatment time, and minimizing the hand-off time in cardiac arrest, transporting patient as fast as possible. Five studies were analyzed and realized that OHCA in High-rise building is challenging for 119 paramedics who struggles against the unfavorable condition in the building to evacuation the patient in safety and efficacy. The various devices in this specific conditions were applied to perform the adequate CPR in the confined places like aisles and elevators, comparing to manual CPR. The general measurements of mechanical chest compression in frequency, depth, recoil, and fraction during the evacuation was higher than manual CPR. Manual chest compression was still effective in flow time fraction and no significant different found in the value of chest compression at the first moment of patient access. Rather, manual chest compression was able to perform immediately, while the installation of the mechanical device. In this systematic review, we recommend that mechanical CPR be performed in case of OHCA occurring in High-rise building to rescue patient. But use of device may require the personnel ability and expertise to apply quickly and not to be buggy.

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