Cardiopulmonary Resuscitation To Save a Life: Current status and scope for improvement

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ABSTRACT:

Bystander cardiopulmonary resuscitation (CPR) is the cornerstone in managing out-of-hospital cardiac arrest (OHCA). However, India lacks a formal sudden cardiac arrest (SCA) registry and the infrastructure for a robust emergency medical services (EMS) response system. Also, there exists an opportunity to improve widespread health literacy and awareness regarding SCA. Other confounding variables, including religious, societal, and cultural sentiments hindering timely intervention, need to be considered for better SCA outcomes.

INTRODUCTION:

Worldwide, there are >135 million cardiovascular deaths each year, and the prevalence of coronary heart disease is increasing.[1] Globally, the incidence of out-of-hospital cardiac arrest ranges from 20 to 140 per 100 000 people, and survival ranges from 2% to 11%[2] A survey conducted by Lybrate, an online doctor consultation platform says that 98% of the Indian country population was not trained in Cardio Pulmonary Resuscitation. The pan India survey shows that less than 2% of the 1,00,000 surveyed agreed to be knowing the technique, while only 0.01% performed it in case of emergency.

OBJECTIVES:

There are 5 critical components of high-quality CPR:

minimize interruptions in chest compressions, provide compressions of adequate rate and depth, avoid leaning between compressions, and avoid excessive ventilation. Although it is clear that high-quality CPR is the primary component in influencing survival from cardiac arrest, there is considerable variation in monitoring, implementation, and quality improvement. As such, CPR quality varies widely between systems and locations. Victims often do not receive high-quality CPR because of provider ambiguity in prioritization of resuscitative efforts during an arrest.

This ambiguity also impedes the development of optimal systems of care to increase survival from cardiac arrest. This consensus statement addresses the following key areas of CPR quality for the trained rescuer: metrics of CPR performance; monitoring, feedback, and integration of the patient's response to CPR; team-level logistics to ensure performance of high-quality CPR; and continuous quality improvement on provider, team, and systems levels.

REVIEW OF LITERATURE

CARDIAC ARREST AND CPR KNOWLEDGE:

Most people fail to identify when a person is suffering from a cardiac arrest. A person suffering cardiac arrest will show the following symptoms: pain in the chest, palpitations or shortness of breath, collapse due to loss of consciousness and most critical, no detectable pulse. The last two are very easy to detect and are almost clear signs of cardiac arrest. When you see a person faint or become unconscious gasping for breath, the first thing is to check the pulse or heartbeat. A person suffering from sudden cardiac arrest has only seconds to survive. The next step is to call emergency medical service immediately and simultaneously should begin performing CPR [4]. At the same time, proper heart examination should be made part of routine health checkup among the people in the country. People get heart check-ups like ECG and angiographies done only when they face problems like chest pain or any other symptom of heart attack or cardiac arrest. One should never ignore unexplained weakness, tiredness, first onset chest burning or first onset breathlessness after the age of 40. Those with strong family history of heart disease should get themselves screened every 6 months at least [4].

CARDIAC ARREST REUSCITATION OUTCOME [CARO]:

Krishnan, et al published a CARO study in North India [5]. They said that out of hospital cardiac arrest (OHCA) is one of the leading cause of death in India. There are very few studies in India, on the outcome after cardiopulmonary resuscitation (CPR) in patients with OHCA. However, due to lack of premedical emergency service system (EMS), lack of EMS protocols, limited medical resources and equipment, inadequate infrastructure, lack of emergency medical personnel training, lack of knowledge and skills of CPR among bystanders and in the community; the outcome of OHCA in India are poor, as compared to western countries, where EMS systems are an integral part of the health care system, which routinely provides CPR to every victim of cardiac arrest [6].

RESEARCH METHODOLOGY:

Metrics of CPR Performance by the Provider Team Oxygen and substrate delivery to vital tissues is the central goal of CPR during the period of cardiac arrest. To deliver oxygen and substrate, adequate blood flow must be generated by effective chest compressions during a majority of the total cardiac arrest time. ROSC after CPR is dependent on adequate myocardial oxygen delivery and myocardial blood flow during CPR.[13-15] Coronary perfusion pressure (CPP, the difference between aortic diastolic and right atrial diastolic pressure during the relaxation phase of chest compressions) is the primary determinant of myocardial blood flow during CPR.[17-19] Therefore, maximizing CPP during CPR is the primary physiological goal. Because CPP cannot be measured easily in most patients, rescuers should focus on the specific components of CPR that have evidence to support either better hemodynamics or human survival. Five main components of high-performance CPR have been identified: chest compression fraction (CCF), chest compression rate, chest compression depth, chest recoil (residual leaning), and ventilation. These CPR components were identified because of their contribution to blood flow and outcome. Understanding the importance of these components and their relative relationships is essential for providers to improve outcomes for individual patients, for educators to improve the quality of resuscitation training, for administrators to monitor performance to ensure high quality within the healthcare system, and for vendors to develop the necessary equipment needed to optimize CPR quality for providers, educators, and administrators.

Minimize Interruptions: CCF >80%

For adequate tissue oxygenation, it is essential that healthcare providers minimize interruptions in chest compressions and therefore maximize the amount of time chest compressions generate blood flow.[10,20] CCF is the proportion of time that chest compressions are performed during a cardiac arrest. The duration of arrest is defined as the time cardiac arrest is first identified until time of first return of sustained circulation. Data on out-of-hospital cardiac arrest indicate that lower CCF is associated with decreased ROSC and survival to hospital discharge.[21-22]One method to increase CCF that has improved survival is through reduction in preshock pause[23]; other techniques are discussed later in "Team-Level Logistics." **Chest Compression Rate of 100 to 120/min**

The 2010 AHA Guidelines for CPR and ECC recommend a chest compression rate of ≥100/min.[20] As chest compression rates fall, a significant drop-off in ROSC occurs, and higher rates may reduce coronary blood flow[9,24] and decrease the percentage of compressions that achieve target depth.[8,25] Data from the ROC Epistry provide the best evidence of association between compression rate and survival and suggest an optimum target of between 100 and 120 compressions per minute.[26] Consistent rates above or below that range appear to reduce survival to discharge.

Chest Compression Depth of ≥50 mm in Adults and at Least One Third the Anterior-Posterior Dimension of the Chest in Infants and Children

Compressions generate critical blood flow and oxygen and energy delivery to the heart and brain. The 2010 AHA Guidelines for CPR and ECC recommend a single minimum depth for compressions of ≥2 inches (50 mm) in adults. Less information is available for children, but it is reasonable to aim for a compression depth of at least one third of the anterior-posterior dimension of the chest in infants and children (≈1½ inches, or 4 cm, in infants and ≈2 inches, or 5 cm, in children).[27,28]

Full Chest Recoil: No Residual Leaning

Incomplete chest wall release occurs when the chest compressor does not allow the chest to fully recoil on completion of the compression.[31,32] This can occur when a rescuer leans over the patient's chest, impeding full chest expansion. Leaning is known to decrease the blood flow throughout the heart and can decrease venous return and cardiac output.

Avoid Excessive Ventilation: Rate <12 breaths per minute,minimal chest rise

Although oxygen delivery is essential during CPR, the appropriate timeframe for interventions to supplement existing oxygen in the blood is unclear and likely varies with the type of arrest (arrhythmic versus asphyxial). The metabolic demands for oxygen are also substantially reduced in the patient in arrest even during chest compressions. When sudden arrhythmic arrest is present, oxygen content is initially sufficient, and high-quality chest compressions can circulate oxygenated blood throughout the body. Providing sufficient oxygen to the blood without impeding perfusion is the goal of assisted ventilation during CPR. Positive-pressure ventilation reduces CPP during CPR,[33] and synchronous ventilation (recommended in the absence of an advanced airway)[27] requires interruptions, which reduces CCF. Excessive ventilation, either by rate or tidal volume, is common in resuscitation environments.[29,33-36]

Rate <12 Breaths per minute

Current guideline recommendations for ventilation rate (breaths per minute) are dependent on the presence of an advanced airway (8 to 10 breaths per minute), as well as the patient's age and the number of rescuers present (compression-to-ventilation ratio of 15:2 versus 30:2).

Minimal Chest Rise: Optimal Ventilation Pressure and Volume

Ventilation volume should produce no more than visible chest rise. Positive-pressure ventilation significantly lowers cardiac output in both spontaneous circulation and during CPR.[33,37- 40] Use of lower tidal volumes during prolonged cardiac arrest was not associated with significant differences in PaO2 [41] and is currently recommended.[42]

HYPOTHESIS:

Monitoring and Feedback: Options and Techniques for Monitoring Patient Response to Resuscitation

The adage, "if you don't measure it, you can't improve it" applies directly to monitoring CPR quality. Monitoring the quality and performance of CPR by rescuers at the scene of cardiac arrest has been transformative to resuscitation science and clinical practice.Given the insights into clinical performance and discoveries in optimal practice, monitoring of CPR quality is arguably one of the most significant advances in resuscitation practice in the past 20 years and one that should be incorporated into every resuscitation and every professional rescuer program. The types of monitoring for CPR quality can be classified (and prioritized) into physiological (how the patient is doing) and CPR performance (how the rescuers are doing) metrics. Both types of monitoring can provide both real-time feedback to rescuers and retrospective systemwide feedback. It is important to emphasize that types of CPR quality monitoring are not mutually exclusive and that several types can (and should) be used simultaneously. Improving Resuscitation Care [CIRC],[75] Prehospital Randomized Assessment of a Mechanical Compression Device in Cardiac Arrest [PARAMEDIC],[76] and LUCAS in Cardiac Arrest [LINC])[77] may provide clarity about the optimal timing and environment for mechanical CPR. In the absence of published evidence demonstrating benefit, the decision to use mechanical CPR may be influenced by system considerations such as in rural settings with limited numbers of providers and/or long transport times

FINDINGS:

Demographically, similar to global incidences, men are more susceptible to developing SCA than women.[80,81,82,83] Globally,advanced age, cardiovascular risk factor, event location, a witnessed versus unwitnessed arrest, a shockable rhythm at onset, time to resuscitation efforts, and bystander CPR have been the driving forces in predicting mortality and morbidity.[84-87]However, for india, in addition to these factors, there are several other contributing factors at different levels that add more challenges to achieving optimal bystander CPR rates.

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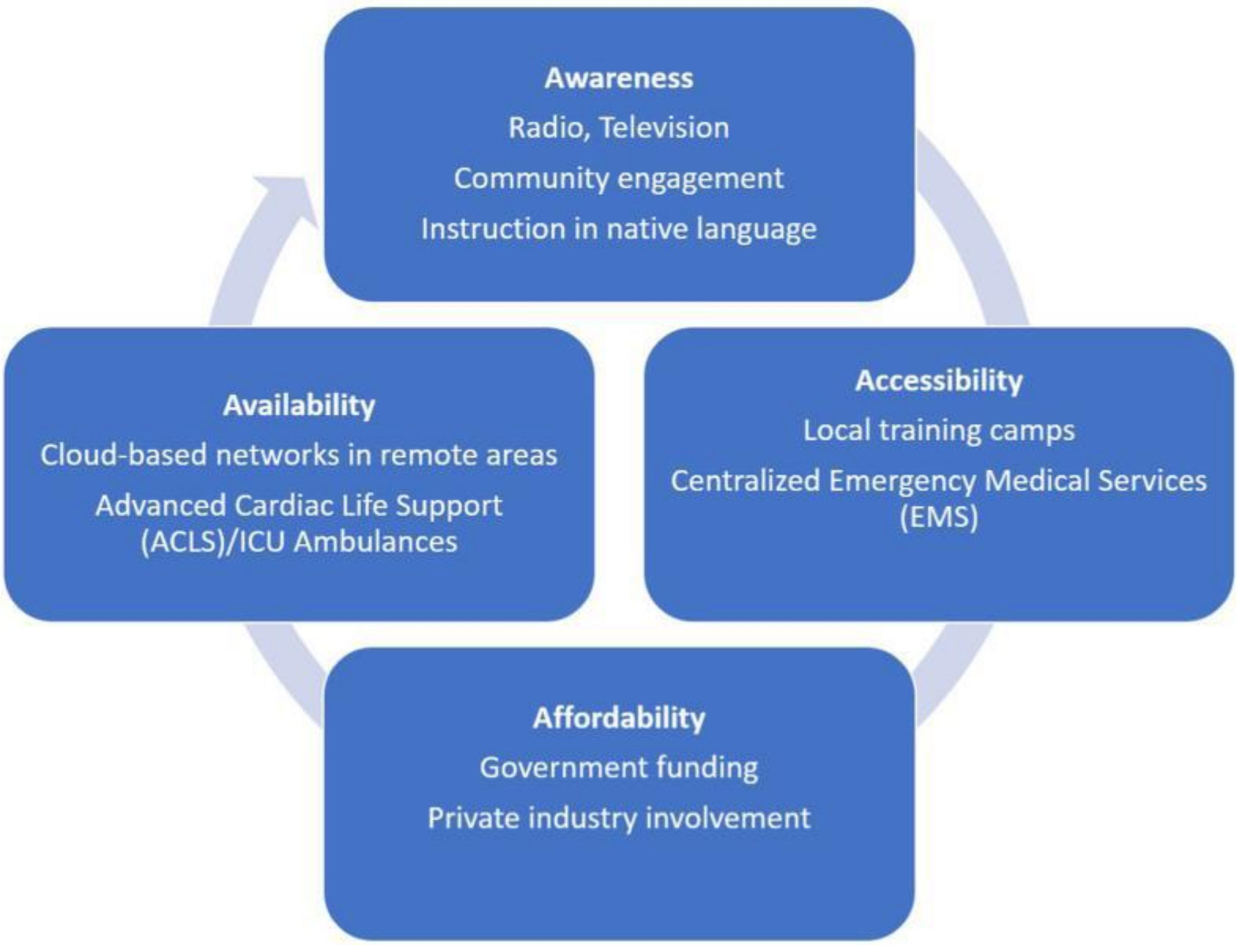
RECOMMENDATION:

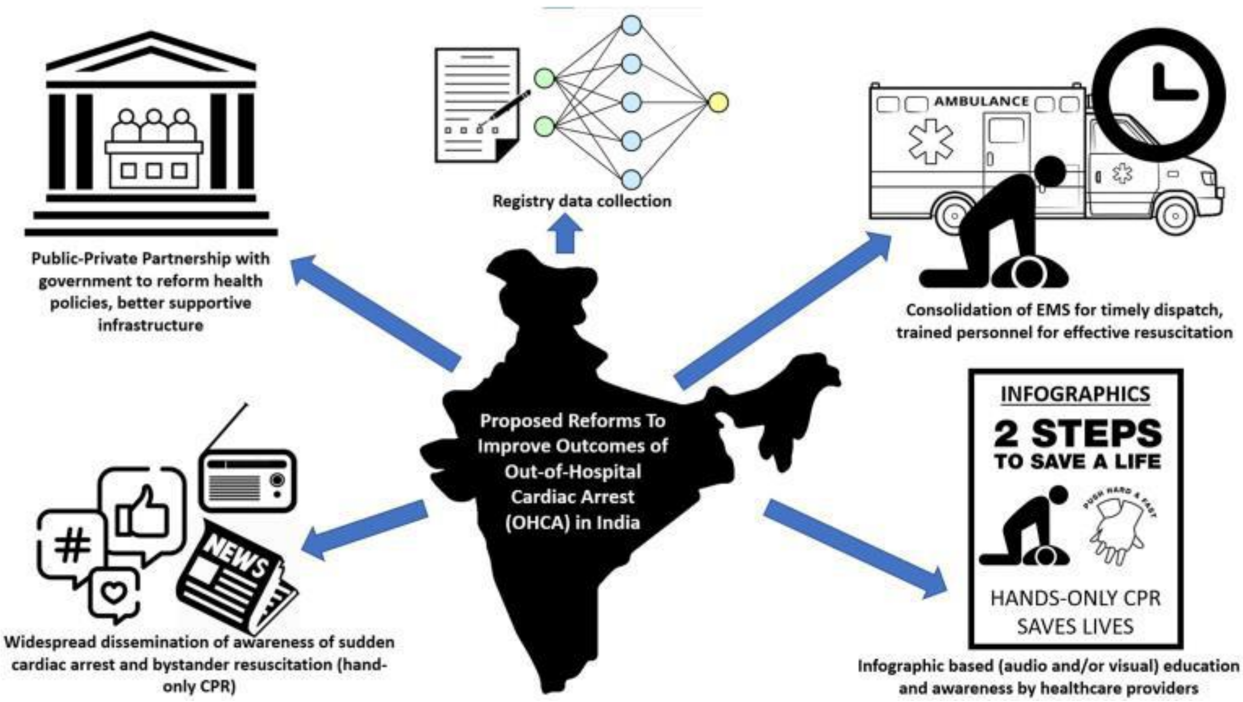
Increase accessibility by placing AEDs in strategic public locations, including malls, movie theatres, buses, trains, temples, churches,schools,universities and concert venues. BLS training must be provided to the staff on duty in such locations, including the security personnel, teachers, priests, drivers and ticket collectors.

The need of the hour is to make CPR training a must in schools and colleges and even at community level, as it can triple a patient's chance of survival, if performed in the first few minutes of cardiac arrest, health experts said. CPR consists of using chest compressions and artificial ventilation to maintain circulatory flow and oxygenation during cardiac arrests and is the cost effective way to improve survival. The American Heart Association (AHA) defines CPR as an emergency procedure to restore spontaneous blood circulation and breathing in a patient and especially, if performed immediately, it can double or triple a cardiac arrest patient's chance of survival. [4] Bystander CPR, and AED (automated defibrillators), are very useful in saving lives," “The use of AED; it is used to diagnose life-threatening arrhythmias or irregularity of heart rhythm; it can also be used to treat a dying heart by using electric shock to revive the heart's rhythm,”

Footnote APA Style(Conclusion):

Effective management of OHCA in India needs collaborative grassroots reformation. Establishing a large-scale SCA registry and creating official and societal guidelines will be pivotal for transforming OHCA patient outcomes. As the science of CPR evolves, we have a tremendous opportunity to improve CPR performance during resuscitation events both inside and outside the hospital. Through better measurement, training, and systems-improvement processes of CPR quality, we can have a significant impact on survival from cardiac arrest and eliminate the gap between current and optimal outcomes.





References(Bibliography):

1.Ahern RM, Lozano R, Naghavi M, Foreman K, Gakidou E, Murray CJ. Improving the public health utility of global cardiovascular mortality data: the rise of ischemic heart disease. Popul Health Metr. 2011;9:8. Crossref. PubMed.

2.Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: systematic review of 67 prospective studies. Resuscitation. 2010;81:1479– 1487. Crossref. PubMed.

3.Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome [published correction appears in JAMA. 2008;300:1763]. JAMA. 2008;300:1423–1431. Crossref. PubMed.

4. (March 22, 2018), "CPR training for all must to save life: Experts", ET Health world: From the Economics Time. IANS

5. Krishna, C. K., Showkat, H. I., Taktani, M., Khatri, V. (2017), "Out of hospital cardiac arrest resuscitation outcome in North India - CARO study", World journal of emergency medicine, Volume 8, Issue 3, pp. 200−205.

6. Rao, K.S. (2005), "Delivery of health services in the public sector. Financing and Delivery of Health Care Services in India", Background Papers of the National Commission on Macroeconomics and Health. New Delhi: Ministry of Health and Family Welfare, Government of India, pp. 47.

7.Peberdy MA, Ornato JP, Larkin GL, Braithwaite RS, Kashner TM, Carey SM, Meaney PA, Cen L, Nadkarni VM, Praestgaard AH, Berg RA; National Registry of Cardiopulmonary Resuscitation

Investigators. Survival from in-hospital cardiac arrest during nights and weekends. JAMA. 2008;299:785–792. Crossref. PubMed.

8.Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, Vaillancourt C, Davis DP, Callaway CW; Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med. 2012;40:1192–1198. Crossref. PubMed.

9.Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005;111:428–434. Crossref. PubMed.

10.Travers AH, Rea TD, Bobrow BJ, Edelson DP, Berg RA, Sayre MR, Berg MD, Chameides L, O'Connor RE, Swor RA. Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S676– S684. Crossref. PubMed.

11.Neumar RW, Otto CW, Link MS, Kronick SL, Shuster M, Callaway CW, Kudenchuk PJ, Ornato JP, McNally B, Silvers SM, Passman RS, White RD, Hess EP, Tang W, Davis D, Sinz E, Morrison LJ. Part 8: adult advanced cardiovascular life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [published correction appears in Circulation. 2011;123:e236]. Circulation. 2010;122(suppl 3):S729–S767. Crossref. PubMed.
12.Kleinman ME, Chameides L, Schexnayder SM, Samson RA, Hazinski MF, Atkins DL, Berg MD, de Caen AR, Fink EL, Freid EB, Hickey RW, Marino BS, Nadkarni VM, Proctor LT, Qureshi FA, Sartorelli K, Topjian A, van der Jagt EW, Zaritsky AL. Part 14: pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S876–S908. Crossref. PubMed.

13.Ralston SH, Voorhees WD, Babbs CF. Intrapulmonary epinephrine during prolonged cardiopulmonary resuscitation: improved regional blood flow and resuscitation in dogs. Ann Emerg Med. 1984;13:79– 86. Crossref. PubMed.

14.Michael JR, Guerci AD, Koehler RC, Shi AY, Tsitlik J, Chandra N, Niedermeyer E, Rogers MC, Traystman RJ, Weisfeldt ML. Mechanisms by which epinephrine augments cerebral and myocardial perfusion during cardiopulmonary resuscitation in dogs. Circulation. 1984;69:822–835. Crossref. PubMed. .

15.Halperin HR, Tsitlik JE, Guerci AD, Mellits ED, Levin HR, Shi AY, Chandra N, Weisfeldt ML. Determinants of blood flow to vital organs during cardiopulmonary resuscitation in dogs. Circulation. 1986;73:539–550. Crossref. PubMed.

16.Rubertsson S, Karlsten R. Increased cortical cerebral blood flow with LUCAS, a new device for mechanical chest compressions compared to standard external compressions during experimental cardiopulmonary resuscitation. Resuscitation. 2005;65:357–363. Crossref. PubMed.

17.Niemann JT, Rosborough JP, Ung S, Criley JM. Coronary perfusion pressure during experimental cardiopulmonary resuscitation. Ann Emerg Med. 1982;11:127–131. Crossref. PubMed.

18.Paradis NA, Martin GB, Rivers EP, Goetting MG, Appleton TJ, Feingold M, Nowak RM. Coronary perfusion pressure and the return of spontaneous circulation in human cardiopulmonary resuscitation. JAMA. 1990;263:1106–1113. Crossref. PubMed.

19.Sanders AB, Ogle M, Ewy GA. Coronary perfusion pressure during cardiopulmonary resuscitation. Am J Emerg Med. 1985;3:11–14. Crossref. PubMed.

20.Berg RA, Hemphill R, Abella BS, Aufderheide TP, Cave DM, Hazinski MF, Lerner EB, Rea TD, Sayre MR, Swor RA. Part 5: adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [published correction appears in Circulation. 2011;124:e402]. Circulation. 2010;122(suppl 3):S685–S705. Crossref. PubMed.

21.Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, Callaway CW, Bishop D, Vaillancourt C, Davis D, Aufderheide TP, Idris A, Stouffer JA, Stiell I, Berg R; Resuscitation Outcomes Consortium Investigators. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation. 2009;120:1241–1247. Crossref. PubMed.

22.Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, Cheskes S, Aufderheide TP, Berg R, Stiell IG; Resuscitation Outcomes Consortium Investigators. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. Resuscitation. 2011;82:1501–1507. Crossref. PubMed.

23.Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, Edelson DP, Sell R, May S, Menegazzi JJ, Van Ottingham L, Olsufka M, Pennington S, Simonini J, Berg RA, Stiell I, Idris A, Bigham B, Morrison L; Resuscitation Outcomes Consortium (ROC) Investigators. Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. Circulation. 2011;124:58– 66. Crossref. PubMed.

24.Wolfe JA, Maier GW, Newton JR, Glower DD, Tyson GS, Spratt JA, Rankin JS, Olsen CO. Physiologic determinants of coronary blood flow during external cardiac massage. J Thorac Cardiovasc Surg. 1988;95:523–532. Crossref. PubMed.

25.Monsieurs KG, De Regge M, Vansteelandt K, De Smet J, Annaert E, Lemoyne S, Kalmar AF, Calle PA. Excessive chest compression rate is associated with insufficient compression depth in prehospital cardiac arrest. Resuscitation. 2012;83:1319–1323. Crossref. PubMed.

26.Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, Powell J, Daya M, Bigham BL, Atkins DL, Berg R, Davis D, Stiell I, Sopko G, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation. 2012;125:3004–3012. Crossref. PubMed.

27.Berg MD, Schexnayder SM, Chameides L, Terry M, Donoghue A, Hickey RW, Berg RA, Sutton RM, Hazinski MF. Part 13: pediatric basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S862– S875. Crossref. PubMed.

28.Sutton RM, French B, Nishisaki A, Niles DE, Maltese MR, Boyle L, Stavland M, Eilevstjønn J, Arbogast KB, Berg RA, Nadkarni VM. American Heart Association cardiopulmonary resuscitation quality targets are associated with improved arterial blood pressure during pediatric cardiac arrest. Resuscitation. 2013;84:168– 172. Crossref. PubMed. .

29.Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. 2005;293:305–310. Crossref. PubMed.

30.Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, Merchant RM, Hoek TL, Steen PA, Becker LB. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation. 2006;71:137–145. Crossref. PubMed.

31.Aufderheide TP, Pirrallo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, Deja KA, Conrad CJ, Kitscha DJ, Provo TA, Lurie KG. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2005;64:353–362. Crossref. PubMed.

32.Yannopoulos D, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363–372. Crossref. PubMed.

33.Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–1965. Crossref. PubMed.

34.Milander MM, Hiscok PS, Sanders AB, Kern KB, Berg RA, Ewy GA. Chest compression and ventilation rates during cardiopulmonary resuscitation: the effects of audible tone guidance. Acad Emerg Med. 1995;2:708–713. Crossref. PubMed.

35.O'Neill JF, Deakin CD. Do we hyperventilate cardiac arrest patients? Resuscitation. 2007;73:82–85. Crossref. PubMed.

36.McInnes AD, Sutton RM, Orioles A, Nishisaki A, Niles D, Abella BS, Maltese MR, Berg RA, Nadkarni V. The first quantitative report of ventilation rate during in-hospital resuscitation of older children and adolescents. Resuscitation. 2011;82:1025–1029. Crossref. PubMed.

37.Woda RP, Dzwonczyk R, Bernacki BL, Cannon M, Lynn L. The ventilatory effects of auto-positive endexpiratory pressure development during cardiopulmonary resuscitation. Crit Care Med. 1999;27:2212– 2217. Crossref. PubMed.

38.Pepe PE, Marini JJ. Occult positive end-expiratory pressure in mechanically ventilated patients with airflow obstruction: the auto-PEEP effect. Am Rev Respir Dis. 1982;126:166–170. PubMed.

39.Cournand A, Motley HL. Physiological studies of the effects of intermittent positive pressure breathing on cardiac output in man. Am J Physiol. 1948;152:162–174. Crossref. PubMed.

40.Sykes MK, Adams AP, Finlay WE, McCormick PW, Economides A. The effects of variations in endexpiratory inflation pressure on cardiorespiratory function in normo-, hypo-and hypervolaemic dogs. Br J Anaesth. 1970;42:669–677. Crossref. PubMed.

41.Langhelle A, Sunde K, Wik L, Steen PA. Arterial blood-gases with 500- versus 1000-ml tidal volumes during out-of-hospital CPR. Resuscitation. 2000;45:27–33. Crossref. PubMed.

42.Wenzel V, Keller C, Idris AH, Dörges V, Lindner KH, Brimacombe JR. Effects of smaller tidal volumes during basic life support ventilation in patients with respiratory arrest: good ventilation, less risk? Resuscitation. 1999;43:25–29. Crossref. PubMed.

43.Crile G, Dolley DH. An experimental research into the resuscitation of dogs killed by anesthetics and asphyxia. J Exp Med. 1906;8:713–725. Crossref. PubMed.

44.Berg RA, Kern KB, Hilwig RW, Ewy GA. Assisted ventilation during "bystander" CPR in a swine acute myocardial infarction model does not improve outcome. Circulation. 1997;96:4364–4371. Crossref. PubMed.

45.Redding JS, Pearson JW. Resuscitation from ventricular fibrillation: drug therapy. JAMA. 1968;203:255– 260. Crossref. PubMed.

46.Kern KB, Ewy GA, Voorhees WD, Babbs CF, Tacker WA. Myocardial perfusion pressure: a predictor of 24-hour survival during prolonged cardiac arrest in dogs. Resuscitation. 1988;16:241–250. Crossref. PubMed.

47.Lindner KH, Prengel AW, Pfenninger EG, Lindner IM, Strohmenger HU, Georgieff M, Lurie KG. Vasopressin improves vital organ blood flow during closed-chest cardiopulmonary resuscitation in pigs. Circulation. 1995;91:215–221. Crossref. PubMed.

48.Martin GB, Carden DL, Nowak RM, Lewinter JR, Johnston W, Tomlanovich MC. Aortic and right atrial pressures during standard and simultaneous compression and ventilation CPR in human beings. Ann Emerg Med. 1986;15:125–130. Crossref. PubMed

49.Timerman S, Cardoso LF, Ramires JA, Halperin H. Improved hemodynamic performance with a novel chest compression device during treatment of in-hospital cardiac arrest. Resuscitation. 2004;61:273– 280. Crossref. PubMed.

50.Pearson JW, Redding JS. Peripheral vascular tone on cardiac resuscitation. Anesth Analg. 1965;44:746– 752. Crossref. PubMed.

51,Ornato JP, Garnett AR, Glauser FL. Relationship between cardiac output and the end-tidal carbon dioxide tension. Ann Emerg Med. 1990;19:1104–1106. Crossref. PubMed.

52.Weil MH, Bisera J, Trevino RP, Rackow EC. Cardiac output and end-tidal carbon dioxide. Crit Care Med. 1985;13:907–909. Crossref. PubMed.

53.Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. Resuscitation. 1996;33:107– 116. Crossref. PubMed.

54.Lapostolle F, Le Toumelin P, Agostinucci JM, Catineau J, Adnet F. Basic cardiac life support providers checking the carotid pulse: performance, degree of conviction, and influencing factors. Acad Emerg Med. 2004;11:878–880. Crossref. PubMed.

55.Wang HE, Simeone SJ, Weaver MD, Callaway CW. Interruptions in cardiopulmonary resuscitation from paramedic endotracheal intubation. Ann Emerg Med. 2009;54:645–652.e1. Crossref. PubMed.
56.Wang HE, Szydlo D, Stouffer JA, Lin S, Carlson JN, Vaillancourt C, Sears G, Verbeek RP, Fowler R, Idris AH, Koenig K, Christenson J, Minokadeh A, Brandt J, Rea T; ROC Investigators. Endotracheal intubation versus supraglottic airway insertion in out-of-hospital cardiac arrest. Resuscitation. 2012;83:1061– 1066. Crossref. PubMed.

57.Hanif MA, Kaji AH, Niemann JT. Advanced airway management does not improve outcome of out-ofhospital cardiac arrest. Acad Emerg Med. 2010;17:926–931. Crossref. PubMed.

58.Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation. 1997;35:23–26. Crossref. PubMed.

59.Moule P. Checking the carotid pulse: diagnostic accuracy in students of the healthcare professions. Resuscitation. 2000;44:195–201. Crossref. PubMed.

60.Nyman J, Sihvonen M. Cardiopulmonary resuscitation skills in nurses and nursing students. Resuscitation. 2000;47:179–184. Crossref. PubMed.

61.Ochoa FJ, Ramalle-Gómara E, Carpintero JM, García A, Saralegui I. Competence of health professionals to check the carotid pulse. Resuscitation. 1998;37:173–175. Crossref. PubMed.

62.Mather C, O'Kelly S. The palpation of pulses. Anaesthesia. 1996;51:189–191. Crossref. PubMed. .
63.Sell RE, Sarno R, Lawrence B, Castillo EM, Fisher R, Brainard C, Dunford JV, Davis DP. Minimizing preand post-defibrillation pauses increases the likelihood of return of spontaneous circulation (ROSC). Resuscitation. 2010;81:822–825. Crossref. PubMed.

64.Edelson DP, Call SL, Yuen TC, Vanden Hoek TL. The impact of a step stool on cardiopulmonary resuscitation: a cross-over mannequin study. Resuscitation. 2012;83:874–878. Crossref. PubMed.
65.Dickinson ET, Verdile VP, Schneider RM, Salluzzo RF. Effectiveness of mechanical versus manual chest compressions in out-of-hospital cardiac arrest resuscitation: a pilot study. Am J Emerg Med. 1998;16:289– 292. Crossref. PubMed.

66.Hallstrom A, Rea TD, Sayre MR, Christenson J, Anton AR, Mosesso VN, Van Ottingham L, Olsufka M, Pennington S, White LJ, Yahn S, Husar J, Morris MF, Cobb LA. Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial. JAMA. 2006;295:2620–2628. Crossref. PubMed.

67.Smekal D, Johansson J, Huzevka T, Rubertsson S. A pilot study of mechanical chest compressions with the LUCAS™ device in cardiopulmonary resuscitation. Resuscitation. 2011;82:702–706. Crossref. PubMed.

68.Axelsson C, Nestin J, Svensson L, Axelsson AB, Herlitz J. Clinical consequences of the introduction of mechanical chest compression in the EMS system for treatment of out-of-hospital cardiac arrest: a pilot study. Resuscitation. 2006;71:47–55. Crossref. PubMed.

69.Rubertsson S, Silfverstolpe J, Rehn L, Nyman T, Lichtveld R, Boomars R, Bruins W, Ahlstedt B, Puggioli H, Lindgren E, Smekal D, Skoog G, Kastberg R, Lindblad A, Halliwell D, Box M, Arnwald F, Hardig BM, Chamberlain D, Herlitz J, Karlsten R. The study protocol for the LINC (LUCAS in cardiac arrest) study: a study comparing conventional adult out-of-hospital cardiopulmonary resuscitation with a concept with mechanical chest compressions and simultaneous defibrillation. Scand J Trauma Resusc Emerg Med. 2013;21:5. Crossref. PubMed.

70.Yost D, Phillips RH, Gonzales L, Lick CJ, Satterlee P, Levy M, Barger J, Dodson P, Poggi S, Wojcik K, Niskanen RA, Chapman FW. Assessment of CPR interruptions from transthoracic impedance during use of the LUCAS™ mechanical chest compression system. Resuscitation. 2012;83:961–965. Crossref. PubMed.

71.Ong ME, Annathurai A, Shahidah A, Leong BS, Ong VY, Tiah L, Ang SH, Yong KL, Sultana P. Cardiopulmonary resuscitation interruptions with use of a load-distributing band device during emergency department cardiac arrest. Ann Emerg Med. 2010;56:233–241. Crossref. PubMed.
72.Fischer H, Neuhold S, Zapletal B, Hochbrugger E, Koinig H, Steinlechner B, Frantal S, Stumpf D, Greif R. A manually powered mechanical resuscitation device used by a single rescuer: a randomised controlled manikin study. Resuscitation. 2011;82:913–919. Crossref. PubMed.

73.Fischer H, Neuhold S, Hochbrugger E, Steinlechner B, Koinig H, Milosevic L, Havel C, Frantal S, Greif R. Quality of resuscitation: flight attendants in an airplane simulator use a new mechanical resuscitation device: a randomized simulation study. Resuscitation. 2011;82:459–463. Crossref. PubMed.

74.Tomte O, Sunde K, Lorem T, Auestad B, Souders C, Jensen J, Wik L. Advanced life support performance with manual and mechanical chest compressions in a randomized, multicentre manikin study. Resuscitation. 2009;80:1152–1157. Crossref. PubMed.

75.Circulation Improving Resuscitation Care (CIRC Study). ClinicalTrials.gov Web site. http://clinicaltrials.gov/ct2/show/record/nct00597207. Accessed February 28, 2013.

76.Perkins GD, Woollard M, Cooke MW, Deakin C, Horton J, Lall R, Lamb SE, McCabe C, Quinn T, Slowther A, Gates S; PARAMEDIC Trial Collaborators. Prehospital randomised assessment of a mechanical compression device in cardiac arrest (PaRAMeDIC) trial protocol. Scand J Trauma Resusc Emerg Med. 2010;18:58. Crossref. PubMed.

77.A Comparison of Conventional Adult Out-of-hospital Cardiopulmonary Resuscitation Against a Concept With Mechanical Chest Compressions and Simultaneous Defibrillation (LINC Study). ClinicalTrials.gov Web site. http://clinicaltrials.gov/ct2/show/nct00609778?term=linc&rank=1. Accessed February 28, 2013.

78.Havel C, Schreiber W, Riedmuller E, Haugk M, Richling N, Trimmel H, Malzer R, Sterz F, Herkner H. Quality of closed chest compression in ambulance vehicles, flying helicopters and at the scene. Resuscitation. 2007;73:264–270. Crossref. PubMed.

79.Olasveengen TM, Wik L, Steen PA. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. Resuscitation. 2008;76:185–190. Crossref. PubMed.

80. Ramaka S., Nazir N.T., Murthy V.S., et al. Epidemiology of out-of-Hospital Cardiac Arrests, knowledge of cardiovascular disease and risk factors in a regional setting in India: the Warangal Area outof-hospital Cardiac Arrest Registry (WACAR) Indian Heart J. 2020;72(6):517–523. - PMC - PubMed
81. Ong M.E., Shin S.D., De Souza N.N., et al. Outcomes for out-of-hospital cardiac arrests across 7

countries in asia: the Pan asian resuscitation outcomes study (PAROS) Resuscitation. 2015;96:100–108. - PubMed

82. McNally B., Robb R., Mehta M., et al. Morbidity and Mortality Weekly Report Surveillance Summaries (Washington, DC : 2002. 2011. Out-of-hospital cardiac arrest surveillance --- cardiac arrest registry to enhance survival (CARES), United States, october 1, 2005--december 31, 2010; pp. 1–19. 60(8. – PubMed

83.Cheema M.A., Ullah W., Abdullah H.M.A., Haq S., Ahmad A., Balaratna A. Duration of in-hospital cardiopulmonary resuscitation and its effect on survival. Indian Heart J. 2019;71(4):314–319. - PMC – PubMed

84.Herlitz J., Svensson L., Engdahl J., et al. Characteristics of cardiac arrest and resuscitation by age group: an analysis from the Swedish Cardiac Arrest Registry. Am J Emerg Med. 2007;25(9):1025–1031. - PubMed

85.Al-Dury N., Ravn-Fischer A., Hollenberg J., et al. Identifying the relative importance of predictors of survival in out of hospital cardiac arrest: a machine learning study. Scand J Trauma Resuscitation Emerg Med. 2020;28(1):60. - PMC - PubMed

86.Pollack R.A., Brown S.P., Rea T., et al. Impact of bystander automated external defibrillator use on survival and functional outcomes in shockable observed public cardiac arrests. Circulation. 2018;137(20):2104–2113. - PMC - PubMed

87.Dahan B., Jabre P., Karam N., et al. Impact of neighbourhood socio-economic status on bystander cardiopulmonary resuscitation in Paris. Resuscitation. 2017;110:107–113. – PubMed