CPR and YOU

What every medical student needs to know about performing CPR

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BACKGROUND

Due to the difficulties associated with recording and analyzing low-frequency emergency events, in-hospital cardiac arrest (IHCA) intervention has historically been less rigorously studied than out-of-hospital cardiac arrest (OHCA). Survival of IHCA is low: reported survival to hospital discharge (SHD) rates range from 6.6% to 18%, with 5.2% of patients surviving to one year.¹⁻⁴ Survival rates have not significantly improved in decades,⁵ and studies of in-hospital cardiopulmonary resuscitation (CPR) quality have found that CPR provided by trained in-hospital staff often does not conform to published American Heart Association (AHA) guidelines.⁶ Hesitancy of first responders, typically nurses and residents, to initiate CPR in the absence of an attending physician,⁷ despite measurable survival benefits associated with rapid initiation of CPR and other resuscitation system errors,⁸⁻¹³ such as delayed or incorrect medication administration,¹⁴ may also contribute to reduced survival rates for IHCA. Studies of skill acquisition and retention in medical students have demonstrated that CPR proficiency deteriorates rapidly over time, resulting in suboptimal CPR quality upon entry into a clinical setting.¹⁵ This paper aims to familiarize medical learners with basic indicators of CPR quality.

INDICATORS OF CPR QUALITY FOR MEDICAL LEARNERS

Indicators of CPR quality have been linked to increased likelihood of return of spontaneous circulation (ROSC) and improved SHD and include time to respond, chest compression fraction (CCF), rate of compression, chest compression depth and leaning and ventilation.

1. Time to Respond

Time to respond is the time from cardiovascular collapse to the initiation of chest compressions or defibrillation. Rapid initiation of CPR is important for the maintenance of organ and tissue perfusion during cardiac arrest (CA).⁹ Two groups have found that odds of SHD were approximately halved when CPR and defibrillation was initiated more than 60 seconds postcollapse,^{11,12} and several groups have observed significant correlations between decreased survival rate and increased response time.^{13,16}

Current AHA recommendations state that teams should initiate compressions and defibrillation less than 120 seconds following collapse.⁸ Studies on IHCA response times found an average of 180 seconds elapsed before response team arrival.⁷ As well, once the team had arrived, a further 35 seconds elapsed before initiation of CPR.¹⁷ First responders, typically residents or nurses, were hesitant

to check pulse, analyze rhythm and initiate CPR or defibrillation in the absence of an attending physician.⁷ Trained and qualified first responders failed to initiate CPR and defibrillation 12% and 44% of the time, respectively.⁷ The rate of SHD following IHCA at this institution did not differ significantly from national averages, suggesting that reluctance of trained ward staff to initiate treatment prior to arrival of the emergency response team could be contributing to the low survival rates observed across institutions.⁷

2. Chest Compression Fraction (CCF)

CCF is the proportion of total time from CA to ROSC or death spent performing chest compressions. Clinical studies have shown that a higher CCF increases the likelihood of ROSC and SHD.¹⁹⁻²² A prospective observational study of ventricular tachycardia (VT) and ventricular fibrillation (VF) found that every 10% increase in CCF resulted in a 1.11-fold increased odds ratio (OR) of SHD.¹⁹ Minimal-pause CPR protocols have also been widely studied; reduced pre-, peri- and post-shock pause and increased CCF have been associated with improved SHD.²⁰⁻²² A trial using mechanical chest compressions found decreased likelihood of cerebrovascular incidents and increased likelihood of ROSC and SHD with use of a minimal-pause CPR protocol.²³ AHA guidelines suggest that CA response teams use a minimal-pause protocol and aim for a CCF of greater than 0.8.⁸

3. Rate of Compression

2010 AHA guidelines recommend a rate of greater than 100 compressions per minute.²⁴ Data from the Resuscitation Outcomes Consortium (ROC) Cardiac Arrest Epistery suggest that compression rates follow a dose-dependent curve, finding that rates between 100 and 125 compressions per minute have been associated with the highest likelihood of ROSC.²⁵ Rates lower than 100 may reduce tissue oxygenation and rates greater than 120 may compromise compression depth and coronary artery perfusion (CAP).^{27,28} Compressions are often performed too slowly, with one study finding average rates of less than 80 in 36.9% of resuscitation episodes.²⁹ Receiving less than 80 compressions per minute was associated with a 30% reduction in likelihood of attaining ROSC.²⁹

4. Chest Compression Depth and Residual Leaning

Chest compression depth measures the sternal displacement during compressions while residual leaning refers to continued pressure on the chest between compressions. The AHA recommends a compression depth of at least 50 mm in adults and minimal residual leaning.⁹

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Compression depth greater than 50 mm during the 30 seconds before defibrillation has been associated with increased likelihood of successful defibrillation, ROSC and SHD.^{10,25} Despite the importance of compression depth in maintaining adequate perfusion, studies of out-of-hospital CPR have found that suboptimal compressions during CPR are common. One observational study of Canadian and American hospitals found that compressions performed by trained emergency medical responders did not meet the 2010 AHA guidelines 91% of the time.¹⁰

Residual leaning between compressions may result in reduced cardiac output due to inhibition of venous return.³⁰⁻³² Studies in porcine models have demonstrated that residual pressure between compressions may be associated with increased right atrial pressure, decreased coronary and cerebral artery perfusion and poor neurological outcome.³⁰⁻³² Studies of human rescuers have found that leaning was present during half of recorded compressions.³³ Rescuers may be more prone to leaning if they are very tall or perform compressions using a stool.³⁴

5. Ventilation

Rate and magnitude of ventilation are important indicators of CPR quality.^{19,35,36} AHA guidelines recommend a ventilation rate of less than 12 breaths per minute and that rescuers refrain from overinflating lungs.¹⁰ Physiologic studies using the porcine model found that overventilation resulted in decreased CAP and venous return to the heart as well as decreased survival.^{19,35} End tidal CO₂ (ETCO₂) concentrations may also be used as an indicator of CPR quality and tissue perfusion during ICHA.^{37,38} The AHA expert panel has recommended that ETCO₂ not fall below 10 mmHg during CPR and that abrupt increase in ETCO₂ to greater than 35 to 40 mmHg be considered an indicator of ROSC.⁸

KEY POINTS FOR MEDICAL LEARNERS DURING ICHA

Resuscitation errors in the hospital setting are common, with one study of 118,387 IHCA reporting that 40.4% of in-hospital VF/pulseless VTs were associated with a resuscitation system error.³⁸ Delayed defibrillation and chest compression were among the most common errors recorded in the in-hospital setting.³⁸ Based on hazard ratio analysis, the presence of a documented error was associated with a 34.2% (95% confidence interval, 29.5-39.1) increase in relative risk of death prior to hospital discharge.³⁸ Medical students can contribute to improved patient outcome by educating themselves about signs and symptoms of impending CA (Figure),^{39,40} activation of in-hospital emergency call systems, location of AED devices and necessary equipment on each hospital floor and through prompt initiation of high-quality CPR. CPR providers should “push fast, push hard”, aiming for rates greater than 100 compressions per minute and compression depth greater than 50 mm.^{8,24} Compression quality may be improved by practicing with a metronome or automated feedback device; these have been shown to improve both pace and depth of chest compressions in medical learners.⁴¹⁻⁴⁴ Compression depth can be improved through placement of a back-board or use of a hard surface during CPR.⁸ Performing chest compressions using a stool or while kneeling has also been shown to

reduce rescuer fatigue by increasing mechanical advantage;^{34,45} however, care should be taken to avoid leaning. Frequent rotation of rescuers at prespecified intervals may also help to reduce fatigue and improve compression quality.

Pauses in CPR can be minimized by setting specific time goals for task completion (Table). Witnesses to the arrest should communicate all pertinent information succinctly upon team leader arrival. Students who have access to a dummy and wish to practice with feedback may be interested in downloading an automated feedback device to their smartphone, such as the ZOLL pocket CPR device. Though not recommended for use during real-life situations, the program is capable of giving automated feedback about compression rate and depth and may give students valuable practice by helping to improve CPR quality during simulation.

National Early Warning Score (NEWS)*							
PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

*The NEWS initiative flowed from the Royal College of Physicians' NEWS Development and Implementation Group (NEWSDIG) report, and was jointly developed and funded in collaboration with the Royal College of Physicians, Royal College of Nursing, National Outreach Forum and NHS Training for Innovation

The National Early Warning Score (NEWS) thresholds and triggers	
NEW scores	Clinical risk
0	Low
Aggregate 1 – 4	
RED score* (Individual parameter scoring 3)	Medium
Aggregate 5 – 6	
Aggregate 7 or more	High

Please see next page for explanatory text about this chart.

Figure: Sample of scoring system for physiological deterioration in-hospital. Increasing national early warning score (NEWS) is indicative of increasing risk of death, ICU admission or CA within next 24hrs.40 A level of consciousness score of A is assigned if the patient is alert. A score of V, P or U is assigned if a patient responds only to voice or pain or is unresponsive. Patients may be stratified into clinical risk categories using NEWS. Patients with an aggregate NEWS of greater than 7 or any individual parameter scoring greater than 3 are considered to be at high risk and require urgent clinical evaluation. Clinical tools like the NEWS system can help to identify high risk patients, allowing for early intervention and thus prevention of adverse events. The NEWS can be found at <http://www.rcplondon.ac.uk/resources/national-early-warning-score-news>.

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Table: Summary of Components of High-Quality CPR for Medical Learners

QUALITY INDICATOR	DESCRIPTION
1. General	<ul style="list-style-type: none"> Be aware of and monitor patients for signs and symptoms of physiological deterioration which may precede cardiac arrest (see Table 1). Know how to activate emergency response if an unconscious patient is discovered. Know location of AEDs and other required medical equipment.
2. Time to respond	<ul style="list-style-type: none"> Rapid initiation of chest compressions.
3. Chest Compression Fraction	<ul style="list-style-type: none"> Keep pauses during CPR to a minimum: <ul style="list-style-type: none"> Less than 10s for rhythm analysis and defibrillation. Less than 3s to rotate compressors. Rotate compressors regularly during necessary pauses for ventilation.
4. Chest Compression Rate	<ul style="list-style-type: none"> 100-120 per minute.
5. Chest Compression Depth	<ul style="list-style-type: none"> > 50 mm. Use a backboard or hard surface. Use a stool or kneel while performing compressions. Avoid leaning between compressions. Rotate compressors frequently to avoid fatigue.
6. Ventilation	<ul style="list-style-type: none"> Rate of < 12 breaths per minute. Avoid overinflating lungs.

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