PICO Question
Among adults and children who are in cardiac arrest in any setting (P), does any specific rate for external chest compressions (I), compared with a compression rate of about 100/min (C), change survival with favorable neurologic outcome; survival to hospital discharge; bystander CPR rates; time to first shock; time to first compressions; CPR quality (O)?

Evidence Reviewers
Julie Considine; Nicolas Mpotos

Task Force Question Owner
russell.griffin@heart.org

Search Strategy
Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest.

Circulation 2005; 111(4): 428-34

Recent data highlight a vital link between well-performed cardiopulmonary resuscitation (CPR) and survival after cardiac arrest; however, the quality of CPR as actually performed by trained healthcare providers is largely unknown. We sought to measure in-hospital chest compression rates and to determine compliance with published international guidelines. We developed and validated a handheld recording device to measure chest compression rate as a surrogate for CPR quality. A prospective observational study of adult cardiac arrests was performed at 3 hospitals from April 2002 to October 2003. Resuscitations were witnessed by trained observers using a customized personal digital assistant programmed to store the exact time of each chest compression, allowing offline calculation of compression rates at serial time points. In 97 arrests, data from 813 minutes during which chest compressions were delivered were analyzed in 30-second time segments. In 36.9% of the total number of segments, compression rates were <80 compressions per minute (cpm), and 21.7% had rates <70 cpm. Higher chest compression rates were significantly correlated with initial return of spontaneous circulation (mean chest compression rates for initial survivors and nonsurvivors, 90+/−17 and 79+/−18 cpm, respectively; P=0.0033). In-hospital chest compression rates were below published resuscitation recommendations, and suboptimal compression rates in our study correlated with poor return of spontaneous circulation. CPR quality is likely a critical determinant of survival after cardiac arrest, suggesting the need for routine measurement, monitoring, and feedback systems during actual resuscitation.

Abella, Benjamin S; Alvarado, Jason P; Myklebust, Helge; Edelson, Dana P; Barry, Anne; O’Hearn, Nicholas; Vanden Hoek, Terry L; Becker, Lance B;

Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest.

JAMA 2005; 293(3): 305-10

The survival benefit of well-performed cardiopulmonary resuscitation (CPR) is well-documented, but little objective data exist regarding actual CPR quality during cardiac arrest. Recent studies have challenged the notion that CPR is uniformly performed according to established international guidelines. To measure multiple parameters of in-hospital CPR quality and to determine compliance with published American Heart Association and international guidelines. A prospective observational study of 67 patients who experienced in-hospital cardiac arrest at the University of Chicago Hospitals, Chicago, Ill, between December 11, 2002, and April 5, 2004. Using a monitor/defibrillator with novel additional sensing capabilities, the parameters of CPR quality including chest compression rate, compression depth, ventilation rate, and the fraction of arrest time without chest compressions (no-flow fraction) were recorded. Adherence to American Heart Association and international CPR guidelines.
Analysis of the first 5 minutes of each resuscitation by 30-second segments revealed that chest compression rates were less than 90/min in 28.1% of segments. Compression depth was too shallow (defined as <38 mm) for 37.4% of compressions. Ventilation rates were high, with 60.9% of segments containing a rate of more than 20/min. Additionally, the mean (SD) no-flow fraction was 0.24 (0.18). A 10-second pause each minute of arrest would yield a no-flow fraction of 0.17. A total of 27 patients (40.3%) achieved return of spontaneous circulation and 7 (10.4%) were discharged from the hospital. In this study of in-hospital cardiac arrest, the quality of multiple parameters of CPR was inconsistent and often did not meet published guideline recommendations, even when performed by well-trained hospital staff. The importance of high-quality CPR suggests the need for rescuer feedback and monitoring of CPR quality during resuscitation efforts.

Babbs, Charles F;
Relative effectiveness of interposed abdominal compression CPR: sensitivity analysis and recommended compression rates.

Interposed abdominal compression, IAC-CPR incorporates alternating chest and abdominal compressions to generate enhanced artificial circulation during cardiac arrest. The technique has been generally successful in improving blood flow and survival compared to standard CPR; however, some questions remain. To determine "why does IAC-CPR produce more apparent benefit in some subjects than in others?" and "what is the proper compression rate, given that there are actually two compressions (chest and abdomen) in each cycle?" Computer models provide a means to search for subtle effects in complex systems. The present study employs a validated 12-compartment mathematical model of the human circulation to explore the effects upon systemic perfusion pressure of changes in 35 different variables, including vascular resistances, vascular compliances, and rescuer technique. CPR with and without IAC was modeled. Computed results show that the effect of 100 mmHg abdominal compressions on systemic perfusion pressure is relatively constant (about 16 mmHg augmentation). However, the effect of chest compression depends strongly upon chest compression frequency and technique. When chest compression is less effective, as is often true in adults, the addition of IAC produces relatively dramatic augmentation (e.g. from 24 to 40 mmHg). When chest compression is more effective, the apparent augmentation with IAC is relatively less (e.g. from 60 to 76 mmHg). The optimal frequency for uninterrupted IAC-CPR is near 50 complete cycles/min with very little change in efficacy over 20-100 cycles/min. In theory, the modest increase in systemic perfusion pressure produced by IAC can make up in part for poor or ineffective chest compressions in CPR. IAC appears relatively less effective in circumstances when chest pump output is high.

Bjørshol, Conrad; Søreide, Eldar; Torsteinbø, Tor; Lexow, Kristian; Nilsen, Odd; Sunde, Kjetil;
Quality of chest compressions during 10min of single-rescuer basic life support with different compression: ventilation ratios in a manikin model.
Good quality basic life support (BLS) improves outcome during cardiac arrest. As fatigue may reduce BLS performance over time we wanted to examine the quality of chest compressions in a single-rescuer scenario during prolonged BLS with different compression:ventilation ratios (C:V ratios). Professional paramedics were asked to perform single-rescuer BLS with C:V ratios of 15:2, 30:2 and 50:2 for 10 min each in random order. A Laerdal Medical Resusci Anne Simulator with PC Skillreporting System was used for BLS quality analysis. Total number of chest compressions, compression depth and compression rate were measured and the differences between the C:V ratios were analysed with repeated measures ANOVA. For analysis of fatigue, chest compression variables for each 2-min period were analysed and compared with the first 2-min period using repeated measures ANOVA. Altogether 50 paramedics completed the study. The mean number of chest compressions increased significantly from 604 to 770 and 862 with C:V ratios of 15:2, 30:2 and 50:2, respectively. Chest compression rate was significantly higher with C:V ratio of 15:2 compared to 30:2 and 50:2 but was above 100 per minute for all three ratios. However, the mean chest compression depth did not change significantly between the different C:V ratios. The number of chest compressions did not change significantly with time for any of the three C:V ratios. Compression depth did decline after the first 2-min period for 30:2 and 50:2 as did compression rate for all three ratios. However all were above the guideline limits for the entire test period. Increasing the C:V ratio increases the number of chest compressions during 10 min of BLS. Compression depth and compression rate were within guideline recommendations for all three ratios. We found no decline in chest compression quality below guideline recommendations during 10 min of BLS with any of the three different C:V ratios.

Christenson, Jim; Andrusiek, Douglas; Everson-Stewart, Siobhan; Kudenchuk, Peter; Hostler, David; Powell, Judy; Callaway, Clifton; Bishop, Dan; Vaillancourt, Christian; Davis, Dan D; Aufderheide, Tom P TP; Idris, Ahamed A; Stiell, Ian I; Berg, Robert R; , ;


Quality cardiopulmonary resuscitation contributes to cardiac arrest survival. The proportion of time in which chest compressions are performed in each minute of cardiopulmonary resuscitation is an important modifiable aspect of quality cardiopulmonary resuscitation. We sought to estimate the effect of an increasing proportion of time spent performing chest compressions during cardiac arrest on survival to hospital discharge in patients with out-of-hospital ventricular fibrillation or pulseless ventricular tachycardia. This is a prospective observational cohort study of adult patients from the Resuscitation Outcomes Consortium Cardiac Arrest Epistry with confirmed ventricular fibrillation or ventricular tachycardia, no defibrillation before emergency medical services arrival, electronically recorded cardiopulmonary resuscitation before the first shock, and a confirmed outcome. Patients were followed up to discharge from the hospital or death. Of the 506 cases, the mean age was 64 years, 80% were male, 71% were witnessed by a bystander, 51% received bystander cardiopulmonary resuscitation, 34% occurred in a public location, and 23% survived. After adjustment for age, gender, location, bystander cardiopulmonary resuscitation, bystander witness status, and response time, the odds ratios of surviving to hospital discharge in the 2 highest categories of chest compression fraction compared with the reference category were 3.01 (95% confidence interval 1.37 to 6.58) and 2.33 (95% confidence interval 0.96 to 5.63). The estimated adjusted linear effect on odds ratio of survival for a 10% change in chest compression fraction was 1.11 (95% confidence interval 1.01 to 1.21). An increased chest compression fraction is independently predictive of better survival in patients who experience a prehospital ventricular fibrillation/tachycardia cardiac arrest.
Dorph, E; Wik, L; Steen, P A;

Effectiveness of ventilation-compression ratios 1:5 and 2:15 in simulated single rescuer paediatric resuscitation.

Resuscitation 2002; 54(3): 259-64

Current guidelines for paediatric basic life support (BLS) recommend a ventilation-compression ratio of 1:5 during child resuscitation compared with 2:15 for adults, based on the consensus that ventilation is more important in paediatric than in adult BLS. We hypothesized that the ratio 2:15 would provide the same minute ventilation as 1:5 during single-rescuer paediatric BLS due to the reduced time required to change between ventilations and compressions. Fourteen lay rescuers were trained with both ratios and thereafter performed single rescuer BLS for approximately 4 min with each of the two ratios in random order on a child-sized manikin with a built-in respiratory monitor. Quality of chest compressions was assessed by measurement of the rate, depth and position. There were no significant differences in tidal volumes or minute ventilation between the ratios. Nearly all chest compressions were within acceptable limits for depth and place with both methods, but the mean number of chest compressions per minute was 48+/−15% greater with ratio 2:15. In conclusion, there was no difference in ventilation, but nearly one and a half times as many compressions with a ratio of 2:15 than 1:5 for lay rescuers during single rescuer paediatric CPR. In order to simplify CPR training for laypersons, we recommend a 2:15 ratio for both single- and two-person, adult and paediatric layperson BLS.

Harris, L C; Kirimli, B; Safar, P;

Ventilation-cardiac compression rates and ratios in cardiopulmonary resuscitation.

Anesthesiology; 28(5): 806-13

Idris, Ahamed H; Guffey, Danielle; Aufderheide, Tom P; Brown, Siobhan; Morrison, Laurie J; Nichols, Patrick; Powell, Judy; Daya, Mohamud; Bigham, Blair L; Atkins, Dianne L; Berg, Robert; Davis, Dan; Stiell, Ian; Sopko, George; Nichol, Graham; , ;

Relationship between chest compression rates and outcomes from cardiac arrest.
Guidelines for cardiopulmonary resuscitation recommend a chest compression rate of at least 100 compressions per minute. Animal and human studies have reported that blood flow is greatest with chest compression rates near 120/min, but few have reported rates used during out-of-hospital (OOH) cardiopulmonary resuscitation or the relationship between rate and outcome. The purpose of this study was to describe chest compression rates used by emergency medical services providers to resuscitate patients with OOH cardiac arrest and to determine the relationship between chest compression rate and outcome. Included were patients aged ≥ 20 years with OOH cardiac arrest treated by emergency medical services providers participating in the Resuscitation Outcomes Consortium. Data were abstracted from monitor-defibrillator recordings during cardiopulmonary resuscitation. Multiple logistic regression analysis assessed the association between chest compression rate and outcome. From December 2005 to May 2007, 3098 patients with OOH cardiac arrest were included in this study. Mean age was 67 ± 16 years, and 8.6% survived to hospital discharge. Mean compression rate was 112 ± 19/min. A curvilinear association between chest compression rate and return of spontaneous circulation was found in cubic spline models after multivariable adjustment (P=0.012). Return of spontaneous circulation rates peaked at a compression rate of ≈ 125/min and then declined. Chest compression rate was not significantly associated with survival to hospital discharge in multivariable categorical or cubic spline models. Chest compression rate was associated with return of spontaneous circulation but not with survival to hospital discharge in OOH cardiac arrest.

Iyanaga, Masayuki; Gray, Randal; Stephens, Shannon W; Akinsanya, Olajide; Rodgers, Joel; Smyrski, Kathleen; Wang, Henry E;

Comparison of methods for the determination of cardiopulmonary resuscitation chest compression fraction.

Resuscitation 2012; 83(5): 568-71

While cardiopulmonary resuscitation (CPR) chest compression fraction (CCF) is associated with out-of-hospital cardiac arrest (OHCA) outcomes, there is no standard method for the determination of CCF. We compared nine methods for calculating CCF. We studied consecutive adult OHCA patients treated by Alabama Emergency Medical Services (EMS) agencies of the Resuscitation Outcomes Consortium (ROC) during January 1, 2010 to October 28, 2010. Paramedics used portable cardiac monitors with real-time chest compression detection technology (LifePak 12, Physio-Control, Redmond, WA). We performed both automated CCF calculation for the entire care episode as well as manual review of CPR data in 1-min epochs, defining CCF as the proportion of each treatment interval with active chest compressions. We compared the CCF values resulting from 9 calculation methods: (1) mean CCF for the entire patient care episode (automated calculation by manufacturer software), (2) mean CCF for first 3 min of patient care, (3) mean CCF for first 5 min, (4) mean CCF for first 10 min, (5) mean CCF for the entire episode except first 5 min, (6) mean CCF for last 5 min, (7) mean CCF from start to first shock, (8) mean CCF for the first half of resuscitation, and (9) mean CCF for the second half of resuscitation. We compared CCF for Methods 2-9 with Method 1 using paired t-tests with a Bonferroni-adjusted p-value of 0.006 (95% confidence intervals). Among 102 adult OHCA, patient demographics were: mean age 60.3 years (SD 20.8 years), African American 56.9%, male 63.7%, and shockable ECG rhythm 23.5%. Mean CPR duration was 728 s (95% CI: 647-809 s). Mean CCF for the 9 CCF calculation methods were: (1) 0.587%; (2) 0.526%; (3) 0.541%; (4) 0.566%; (5) 0.562%; (6) 0.597%; (7) 0.530%; (8) 0.550%; and (9) 0.590%. Compared with Method 1, Method 7 CCF (start to first shock) was slightly lower (-0.057; 99.5% CI: -0.100 to -0.014). There were no other statistically significant CCF differences (range: -0.054 to 0.013). Correlation between CCF 2-9 and CCF varied (p=0.48-0.85). CCF varies
Jones, Christopher M; Owen, Andrew; Thorne, Christopher J; Hulme, Jonathan;

Comparison of the quality of basic life support provided by rescuers trained using the 2005 or 2010 ERC guidelines.


Effective delivery of cardiopulmonary resuscitation (CPR) and prompt defibrillation following sudden cardiac arrest (SCA) is vital. Updated guidelines for adult basic life support (BLS) were published in 2010 by the European Resuscitation Council (ERC) in an effort to improve survival following SCA. There has been little assessment of the ability of rescuers to meet the standards outlined within these new guidelines. We conducted a retrospective analysis of the performance of first year healthcare students trained and assessed using either the new 2010 ERC guidelines or their 2005 predecessor, within the University of Birmingham, United Kingdom. All students were trained as lay rescuers during a standardised eight hour ERC-accredited adult BLS course. We analysed the examination records of 1091 students. Of these, 561 were trained and assessed using the old 2005 ERC guidelines and 530 using the new 2010 guidelines. A significantly greater proportion of candidates failed in the new guideline group (16.04% vs. 11.05%; p < 0.05), reflecting a significantly greater proportion of lay-rescuers performing chest compressions at too fast a rate when trained and assessed with the 2010 rather than 2005 guidelines (6.04% vs. 2.67%; p < 0.05). Error rates for other skills did not differ between guideline groups. The new ERC guidelines lead to a greater proportion of lay rescuers performing chest compressions at an erroneously fast rate and may therefore worsen BLS efficacy. Additional study is required in order to define the clinical impact of compressions performed to a greater depth and at too fast a rate.

Kern, K B; Sanders, A B; Raife, J; Milander, M M; Otto, C W; Ewy, G A;

A study of chest compression rates during cardiopulmonary resuscitation in humans. The importance of rate-directed chest compressions.


A prospective, cross-over trial was performed comparing two different rates of precordial compression using end-tidal carbon dioxide as an indicator of the efficacy of cardiopulmonary resuscitation in 23 adult patients. A second purpose of this study was to determine the effect of audio-prompted, rate-directed chest compressions on the end-tidal carbon dioxide concentrations during cardiopulmonary resuscitation. Patients with cardiac arrest received external chest compressions, initially in the usual fashion without rate direction and then with rhythmic audiotones for rate direction at either 80 compressions per minute or 120 compressions per minute. Nineteen of 23 patients had higher end-tidal carbon dioxide levels at the compression rate of 120 per minute. The mean end-tidal carbon dioxide level during compressions of 120 per minute was 15.0 +/- 1.8 mm Hg, slightly but
significantly higher than the mean level of 13.0 +/- 1.8 mm Hg at a compression rate of 80 per minute. However, end-tidal carbon dioxide levels increased rather dramatically when audiotones were used to guide the rate of chest compressions. Mean end-tidal carbon dioxide concentration was 8.7 +/- 1.2 mm Hg during standard cardiopulmonary resuscitation immediately before audio-prompted, rate-directed chest compression and increased to 14.0 +/- 1.3 mm Hg after the first 60 seconds of audible tones directing compressions. Using end-tidal carbon dioxide as an indicator of cardiopulmonary resuscitation efficacy, we conclude that audible rate guidance during chest compressions may improve cardiopulmonary resuscitation performance.

Kill, Clemens; Giesel, Matthias; Eberhart, Leopold; Geldner, Götz; Wulf, Hinnerk;

Differences in time to defibrillation and intubation between two different ventilation/compression ratios in simulated cardiac arrest.

Resuscitation 2005; 65(1): 45-8

During basic life support (BLS) by a two-rescuer-team early defibrillation and ALS procedures should be performed without interruptions of the BLS-ventilation/compression sequence. The objective of this study was to determine the impact of a ventilation/compression ratio of 5:50 versus 2:15 on the time intervals "Start BLS to first shock" and "Start BLS to intubation". Using a random cross over design 40 experienced paramedics performed a standard BLS/ALS-algorithm according to ILCOR guidelines in a manikin model with ventricular fibrillation (resusci skilreporter anne, Laerdal, Norway) performing both the 2:15 and the 5:50 ventilation/compression ratio. BLS was started with bag-valve/mask ventilation, a semi-automatic defibrillator (corpuls 08/16S) was connected with the manikin, ECG-analysis and three shocks were performed and the tracheal intubation was prepared. Ventilation/compression sequence was only interrupted during ECG-analysis and defibrillation. Expiratory volumes and number of compressions were measured. Variables were compared using paired Students t-test. In addition paramedics were interviewed about work-flow and emotional stress during the tests. The time interval "Start BLS to first shock" was 78 s (2:15-group) versus 63 s (5:50-group), p<0.0001, the time interval "Start BLS to intubation" was 183 s (2:15-group) versus 150 s (5:50-group), p<0.0001, mean ventilation volumes per minute were 4490 ml (2:15-group) versus 4370 ml (5:50-group), p>0.1, mean number of compressions were 65 min-1. (2:15-group) versus 68 min-1 (5:50-group), p>0.1. The work-flow and emotional stress was appraised by the paramedics to be significantly superior in the 5:50 ratio (p<0.0001). The ventilation/compression ratio of 5:50 compared with 2:15 during BLS with an unsecured airway reduces the time until the first defibrillation and tracheal intubation was performed without changes in ventilation volume and compressions per minute. The Paramedics stated that the 5:50 ratio improved the work-flow and reduced the emotional stress.

Ko, Patrick; Chen, Wen-Jone; Lin, Chih-Hao; Ma, Matthew; Lin, Fang-Yue;

Evaluating the quality of prehospital cardiopulmonary resuscitation by reviewing automated external defibrillator records and survival for out-of-hospital witnessed arrests.

Resuscitation 2005; 64(2): 163-9
Without an easy method to monitor the performance of prehospital cardiopulmonary resuscitation (CPR), earlier studies have not been able to assess the quality of CPR. In this study, we have used a new approach to evaluate prehospital CPR performance and the impact on outcome using data retrieved from the automatic external defibrillators (AED).

Electrocardiography (ECG) and voice records from AED data cards from 633 out-of-hospital cardiac arrests (OHCA) were reviewed. Fifty-two witnessed cardiac arrests in ventricular fibrillation (VF) requiring post-shock CPR underwent an independent, structured review by two physicians. The adequacy of prehospital CPR was defined on the basis of noticeable deflection of the ECG with chest compressions, the actual number of chest compressions delivered per minute, and the continuity of prehospital CPR at the scene and during transport. Outcome measures included return of spontaneous circulation (ROSC) and survival to hospital admission and discharge. The quality of prehospital CPR was judged as adequate in 15 (29%, 95%; CI: 18-42%) and inadequate in 37 (71%, 95%; CI: 58-82%) of the consensus. Adequate CPR performance resulted in a higher rate of ROSC at the scene (53% versus 8%, 95% CI of the difference 14-76%), and survival to hospital discharge (53% versus 8%, 95% CI of the difference 14-76%). Two reviewers agreed on whether CPR was adequate in 92.3% of cases, with a kappa of 0.82. The quality of prehospital CPR is associated with a greater likelihood of survival in witnessed VF arrests in need of post-shock CPR. The potential of widely available electrocardiography and voice records in AEDs in providing a convenient and real-time evaluation of prehospital CPR should be explored further.

PubMed ID 15680524
Observational Study
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Kramer-Johansen, Jo; Myklebust, Helge; Wik, Lars; Fellows, Bob; Svensson, Leif; Sørebo, Hallstein; Steen, Petter;
Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study.

Resuscitation 2006; 71(3): 283-92

To compare quality of CPR during out-of-hospital cardiac arrest with and without automated feedback. Consecutive adult, out-of-hospital cardiac arrests of all causes were studied. One hundred and seventy-six episodes (October 2002-October 2003) without feedback were compared to 108 episodes (October 2003-September 2004) where automatic feedback on CPR was given. Automated verbal and visual feedback was based on measured quality with a prototype defibrillator. Quality of CPR was the main outcome measure and survival was reported as specified in the protocol. Average compression depth increased from (mean +/- S.D.) 34 +/- 9 to 38 +/- 6 mm (mean difference (95% CI) 4 (2, 6), P < 0.001), and median percentage of compressions with adequate depth (38-51 mm) increased from 24% to 53% (P < 0.001, Mann-Whitney U-test) with feedback. Mean compression rate decreased from 121 +/- 18 to 109 +/- 12 min(-1) (difference -12 (-16, -9), P = 0.001). There were no changes in the mean number of ventilations per minute; 11 +/- 5 min(-1) versus 11 +/- 4 min(-1) (difference 0 (-1, 1), P = 0.8) or the fraction of time without chest compressions; 0.48 +/- 0.18 versus 0.45 +/- 0.17 (difference -0.03 (-0.08, 0.01), P = 0.08).

With intention to treat analysis 7/241 control patients were discharged alive (2.9%) versus 5/117 with feedback (4.3%) (OR 1.5 (95% CI; 0.8, 3), P = 0.2). In a logistic regression analysis of all cases, witnessed arrest (OR 4.2 (95% CI; 1.6, 11), P = 0.004) and average compression depth (per mm increase) (OR 1.05 (95% CI; 1.01, 1.09), P = 0.02) were associated with rate of hospital admission. Automatic feedback improved CPR quality in this prospective non-randomised study of out-of-hospital cardiac arrest. Increased compression depth was associated with increased short-term survival. ClinicalTrials.gov (NCT00138996), http://www.clinicaltrials.gov/.

PubMed ID 17070980
Read Abstract
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Article Source PubMed
Losert, Heidrun; Sterz, Fritz; Köhler, Klemens; Sodeck, Gottfried; Fleischhackl, Roman; Eisenburger, Philip; Kliegel, Andreas; Herkner, Harald; Myklebust, Helge; Nysaether, Jon; Laggner, Anton N;

Quality of cardiopulmonary resuscitation among highly trained staff in an emergency department setting.

Arch. Intern. Med. 2006; 166(21): 2375-80

Recent reports have highlighted the poor standard of cardiopulmonary resuscitation (CPR) achieved by health care professionals in diverse situations. We explored what can be achieved in an emergency department by highly trained permanent staff. In a prospective observational study conducted from June 1, 2002, to August 31, 2005, 80 of 213 patients requiring CPR and admitted to the emergency department of a tertiary care hospital were eligible for study participation. Owing to several logistic problems with CPR, 133 patients could not be studied. The CPR team consisted of emergency- and critical care-trained physicians with more than 10 years of acute care experience, most of whom were instructors of European Resuscitation Council courses in basic and advanced life support. A specially designed defibrillator was used to assess the quality of CPR. For 80 patients, 95 data sets were available for analysis, yielding a total of 1065 minutes of cardiac arrest time. Chest compressions were performed at a rate of 114 (95% confidence interval [CI], 112-116) per minute, resulting in a mean of 96 (95% CI, 93-99) delivered chest compressions per minute. We further observed a mean hands-off ratio of 12.7% (95% CI, 12.3%-13.1%), and the hands-off ratio was linearly associated with the duration of CPR (R(2) = 0.95; mean, 4.3% increments per 5-10 minutes; P<.001). Patients were hyperventilated with a median of 18 (interquartile range, 14-24) ventilations per minute. Highly trained professionals in an emergency department can achieve appropriate chest compression rates during CPR with a low hands-off ratio. Increased attention must be paid in all situations to the avoidance of hyperventilation.

Lyon, R; Clarke, S; Milligan, D; Clegg, G;

Resuscitation feedback and targeted education improves quality of pre-hospital resuscitation in Scotland.

Resuscitation 2012; 83(1): 70-5

Out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality and serious neurological morbidity in Europe. Recent studies have demonstrated the adverse physiological consequences of poor resuscitation technique and have shown that quality of cardiopulmonary resuscitation (CPR) is a critical determinant of outcome from OHCA. Telemetry of the defibrillator transthoracic impedance (TTI) trace can objectively measure quality of pre-hospital resuscitation. This study aims to analyse the impact of targeted resuscitation feedback and training on quality of pre-hospital resuscitation. Prospective, single centre, cohort study over 13 months (1st December 2009-31st December 2010). Baseline pre-hospital resuscitation data was gathered over a 3-month period. Modems (n=40) were fitted to defibrillators on ambulance vehicles. Following a resuscitation attempt, the event was sent via telemetry and the TTI trace analysed. Outcome measures were time spent performing chest compressions, compression rate, the interval required to deliver a defibrillator shock and use of automatic or manual cardiac rhythm analysis. Targeted resuscitation classes were introduced and all ambulance crews received feedback following a resuscitation attempt. Pre-hospital resuscitation quality pre and post intervention were compared. 111 resuscitation traces were
analysed. Mean hands-on-chest time improved significantly following feedback and targeted resuscitation training (73.0% vs 79.3%, p=0.007). There was no significant change in compression rate during the study period. There was a significant reduction in median time-to-shock interval from 20.25s (IQR 15.50-25.50s) to 13.45 s (IQR 2.25-22.00 s) (p=0.006). Automatic rhythm recognition fell from 50% to 28.6% (p=0.03) following intervention. Telemetry and analysis of the TTI trace following OHCA allows objective evaluation of the quality of pre-hospital resuscitation. Targeted resuscitation training and ambulance feedback improves the quality of pre-hospital resuscitation. Further studies are required to establish possible survival benefit from this technique. Copyright © 2011 Elsevier Ireland Ltd. All rights reserved.

Min, Mun; Yeom, Seok; Ryu, Ji; Kim, Yong; Park, Maeng; Han, Sang; Lee, Seong; Cho, Suck;

A 10-s rest improves chest compression quality during hands-only cardiopulmonary resuscitation: A prospective, randomized crossover study using a manikin model.

Resuscitation 2013; :

OBJECTIVES: This study was designed to assess changes in cardiopulmonary resuscitation (CPR) quality and rescuer fatigue when rescuers are provided with a break during continuous chest compression CPR (CCC-CPR). METHODS: The present prospective, randomized crossover study involved 63 emergency medical technician trainees. The subjects performed three different CCC-CPR methods on a manikin model. The first method was general CCC-CPR without a break (CCC), the second included a 10-s break after 200 chest compressions (10/200), and the third included a 10-s break after 100 chest compressions (10/100). All methods were performed for 10min. We counted the total number of compressions and those with appropriate depth every 1min during the 10min and measured mean compression depth from the start of chest compressions to 10min. RESULTS: The 10/100 method showed the deepest compression depth, followed by the 10/200 and CCC methods. The mean compression depth showed a significant difference after 5min had elapsed. The percentage of adequate compressions per min was calculated as the proportion of compressions with appropriate depth among total chest compressions. The percentage of adequate compressions declined over time for all methods. The 10/100 method showed the highest percentage of adequate compressions, followed by the 10/200 and CCC methods. CONCLUSION: When rescuers were provided a rest at a particular time during CCC-CPR, chest compression quality increased compared with CCC without rest. Therefore, we propose that a rescuer should be provided a rest during CCC-CPR, and specifically, we recommend a 10-s rest after 100 chest compressions.

Monsieurs, Koenraad; De Regge, Melissa; Vansteelandt, Kristof; De Smet, Jeroen; Annaert, Emmanuel; Lemoyne, Sabine; Kalmar, Alain; Calle, Paul;

Excessive chest compression rate is associated with insufficient compression depth in prehospital cardiac arrest.

Resuscitation 2012; 83(11): 1319-23
BACKGROUND AND GOAL OF STUDY: The relationship between chest compression rate and compression depth is unknown. In order to characterise this relationship, we performed an observational study in prehospital cardiac arrest patients. We hypothesised that faster compressions are associated with decreased depth. In patients undergoing prehospital cardiopulmonary resuscitation by health care professionals, chest compression rate and depth were recorded using an accelerometer (E-series monitor-defibrillator, Zoll, U.S.A.). Compression depth was compared for rates <80/min, 80-120/min and >120/min. A difference in compression depth ≥0.5 cm was considered clinically significant. Mixed models with repeated measurements of chest compression depth and rate (level 1) nested within patients (level 2) were used with compression rate as a continuous and as a categorical predictor of depth. Results are reported as means and standard error (SE). One hundred and thirty-three consecutive patients were analysed (213,409 compressions). Of all compressions 2% were <80/min, 62% between 80 and 120/min and 36% >120/min, 36% were <4 cm deep, 45% between 4 and 5 cm, 19% >5 cm. In 77 out of 133 (58%) patients a statistically significant lower depth was observed for rates >120/min compared to rates 80-120/min, in 40 out of 133 (30%) this difference was also clinically significant. The mixed models predicted that the deepest compression (4.5 cm) occurred at a rate of 86/min, with progressively lower compression depths at higher rates. Rates >145/min would result in a depth <4 cm. Predicted compression depth for rates 80-120/min was on average 4.5 cm (SE 0.06) compared to 4.1 cm (SE 0.06) for compressions >120/min (mean difference 0.4 cm, P<0.001). Age and sex of the patient had no additional effect on depth. This study showed an association between higher compression rates and lower compression depths. Avoiding excessive compression rates may lead to more compressions of sufficient depth. Copyright © 2012 Elsevier Ireland Ltd. All rights reserved.

Nishiyama, Chika; Iwami, Taku; Kawamura, Takashi; Ando, Masahiko; Yonemoto, Naohiro; Hiraide, Atsushi; Nonogi, Hiroshi;

Quality of chest compressions during continuous CPR; comparison between chest compression-only CPR and conventional CPR.

Resuscitation 2010; 81(9): 1152-5

This study aimed to compare the time-dependent deterioration of chest compressions between chest compression-only cardiopulmonary resuscitation (CPR) and conventional CPR. This study involved 106 and 107 participants randomly assigned to chest compression-only CPR training and conventional CPR training, respectively. Immediately after training, participants were asked to perform CPR for 2 min and the quality of their CPR skills were evaluated. The number of chest compressions in total and those with appropriate depth were counted every 20 s CPR period from the start of CPR. The primary outcome was the CPR quality index calculated as the proportion of chest compressions with appropriate depth among total chest compressions. The total number of chest compressions remained stable over time both in the chest compression-only and the conventional CPR groups. The CPR quality index, however, decreased from 86.6+/-25.0 to 58.2+/-36.9 in the chest compression-only CPR group from 0-20 s through 61-80 s. The reduction was greater than in the conventional CPR group (85.9+/-25.5 to 74.3+/-34.0). The difference in the CPR quality index reached statistical significance (P=0.003) at 61-80 s period. Chest compressions with appropriate depth decreased more rapidly during chest compression-only CPR than conventional CPR. We recommend that CPR providers change their roles every 1 min to maintain the quality of chest compressions during chest compression-only CPR. (UMIN-CTR C0000000321). Copyright 2010 Elsevier Ireland Ltd. All rights reserved.
Randomized Control Trial

Ødegaard, Silje; Olasveengen, Theresa; Steen, Petter Andreas; Kramer-Johansen, Jo;

Resuscitation 2009; 80(8): 843-8

Most manikin and clinical studies have found decreased quality of CPR during transport to hospital. We wanted to study quality of CPR before and during transport for out-of-hospital cardiac arrest patients and also whether quality of CPR before initiation of transport was different from the quality in patients only receiving CPR on scene. Quality of CPR was prospectively registered with a modified defibrillator for consecutive cases of out-of-hospital cardiac arrest in three ambulance services during 2002-2005. Ventilations were registered via changes in transthoracic impedance and chest compressions were measured with an extra chest compression pad placed on the patients' sternum. Paired t-tests were used to analyse quality of CPR before vs. during transport with ongoing CPR. Unpaired t-tests were used to compare CPR quality prior to transport to CPR quality in patients with CPR terminated on site. Quality of CPR did not deteriorate during transport, but as previously reported overall quality of CPR was substandard. Quality of CPR performed on site was significantly better when transport was not initiated with ongoing CPR compared to episodes with initiation of transport during CPR: fraction of time without chest compressions was 0.45 and 0.53 (p<0.001), compression depth 37 mm and 34 mm (p<0.04), and number of chest compressions per minute 61 and 56 (p=0.01), respectively. CPR quality was sub-standard both before and during transport. Early decision to transport might have negatively affected CPR quality from the early stages of resuscitation.

Olasveengen, Theresa M; Wik, Lars; Kramer-Johansen, Jo; Sunde, Kjetil; Pytte, Morten; Steen, Petter A;

Resuscitation 2007; 75(2): 260-6

To evaluate the quality of cardiopulmonary resuscitation (CPR) performed by a physician-manned ambulance, and assess whether it changed with time influenced by developing scientific evidence and guideline changes. A retrospective, observational study of all cardiac arrest patients (except trauma) older than 18 years treated between May 2003 and December 2006 by the physician-manned ambulance in Oslo. CPR quality was assessed from continuous electronic recordings from the defibrillators (LIFEPAK 12, Physio-Control or a modified Heartstart 4000, Philips Medical Systems). Ventilations were assessed from changes in transthoracic impedance, chest compressions from transthoracic impedance for LIFEPAK 12 and from an accelerometer for Heartstart 4000 (nine patients). Values are given as mean+/-S.D. and differences analysed with ANOVA and unpaired Student's t-test with Bonferroni correction. Forty-eight of 169 consecutive cases were excluded from CPR quality analysis, 47 due to missing defibrillator data and one due to a short arrest time (<1min). Hands-off intervals (fraction of time without spontaneous circulation where no chest compressions are given) were reduced from 0.18+/-0.11 in 2003 to 0.10+/-0.06 in 2006 (p=0.03). Compression and ventilation rates were significantly reduced from 122+/-12 and 16+/-3min(-1), respectively in 2003 to 111+/-10 and 12+/-3 in 2006 (p<0.0001 and p=0.001). In 2003-2004 10% were discharged alive versus 16% in 2005-2006 (p=0.3, Chi-square test). High quality CPR is achievable out-of-hospital, and the improvement with time could reflect
Ong, Marcus; Quah, Joy; Annathurai, Annitha; Noor, Noorkiah; Koh, Zhi; Tan, Kenneth; Pothiawala, Sohil; Poh, Ah; Loy, Chye; Fook-Chong, Stephanie S;

Improving the quality of cardiopulmonary resuscitation by training dedicated cardiac arrest teams incorporating a mechanical load-distributing device at the emergency department.

Resuscitation 2012; :

OBJECTIVE: Determine if implementing cardiac arrest teams trained with a 'pit-crew' protocol incorporating a load-distributing band mechanical CPR device (Autopulse™ ZOLL) improves the quality of CPR, as determined by no-flow ratio (NFR) in the first 10min of resuscitation. METHODS: A phased, prospective, non-randomized, before-after cohort evaluation. Data collection was from April 2008 to February 2011. There were 100 before and 148 after cases. Continuous video and chest compression data of all study subjects were analyzed. All non-traumatic, collapsed patients aged 18 years and above presenting to the emergency department were eligible. Primary outcome was NFR. Secondary outcomes were return of spontaneous circulation (ROSC), survival to hospital admission and neurological outcome at discharge. MAIN RESULTS: After implementation, mean total NFR for the first 5min decreased from 0.42 to 0.27 (decrease=0.15, 95% CI 0.10-0.19, p<0.005), and from 0.24 to 0.18 (decrease=0.06, 95% CI 0.01-0.11, p=0.02) for the next 5min. The mean time taken to apply Autopulse™ decreased from 208.8s to 141.6s (decrease=67.2s, 95% CI 22.3-112.1, p<0.005). The mean CPR ratio increased from 46.4% to 88.4% (increase=41.9%, 95% CI 36.9-46.9, p<0.005) and the mean total NFR for the first 10min decreased from 0.33 to 0.23 (decrease=0.10, 95% CI 0.07-0.14, p<0.005). CONCLUSION: Implementation of cardiac arrest teams was associated with a reduction in NFR in the first 10min of resuscitation. Training cardiac arrest teams in a 'pit-crew' protocol may improve the quality of CPR at the ED. Copyright © 2012 Elsevier Ireland Ltd. All rights reserved.

Sutton, Robert M; French, Benjamin; Nishisaki, Akira; Niles, Dana E; Maltese, Matthew R; Boyle, Lori; Stavland, Mette; Ellevstånn, Joar; Arbogast, Kristy B; Berg, Robert A; Nadkarni, Vinay M;

American Heart Association cardiopulmonary resuscitation quality targets are associated with improved arterial blood pressure during pediatric cardiac arrest.

Resuscitation 2013; 84(2): 168-72

To evaluate the association between cardiopulmonary resuscitation (CPR) quality and hemodynamic measurements during in-hospital pediatric cardiac arrest. We hypothesized that AHA recommended CPR rate and depth targets would be associated with systolic blood pressures≥80mmHg and diastolic blood pressures≥30mmHg. In children and adolescents <18 years of age who suffered a cardiac arrest with an invasive arterial catheter in place, a CPR monitoring defibrillator collected CPR data which was synchronized to arterial blood pressure (BP) tracings. Chest compression (CC) depths were corrected for mattress
deflection. Generalized least squares regression estimated the association between BP and CPR quality, treated as continuous variables. Mixed-effects logistic regression estimated the association between systolic BP ≥ 80 mmHg/diastolic BP ≥ 30 mmHg and the AHA targets of depth ≥ 38 mm and/or rate ≥ 100/min. Nine arrests resulted in 4156 CCs. The median mattress corrected depth was 32 mm (IQR 28-38); median rate was 111 CC/min (IQR 103-120). AHA depth was achieved in 1090/4156 (26.2%) CCs; rate in 3441 (83.7%). Systolic BP ≥ 80 mmHg was attained in 2516/4156 (60.5%) compressions; diastolic BP ≥ 30 mmHg in 2561/4156 (61.6%). A rate ≥ 100/min was associated with systolic BP ≥ 80 mmHg (OR 1.32; CI 1.04, 1.66; p = 0.02) and diastolic BP ≥ 30 mmHg (OR 2.15; CI 1.65, 2.80; p < 0.001). Exceeding both (rate ≥ 100/min and depth ≥ 38 mm) was associated with systolic BP ≥ 80 mmHg (OR 2.02; CI 1.45, 2.82; p = 0.001) and diastolic BP ≥ 30 mmHg (OR 1.48; CI 1.01, 2.15; p = 0.042). AHA quality targets (rate ≥ 100/min and depth ≥ 38 mm) were associated with systolic BPs ≥ 80 mmHg and diastolic BPs ≥ 30 mmHg during CPR in children. Copyright © 2012 Elsevier Ireland Ltd. All rights reserved.

Sutton, Robert M; Niles, Dana; Nysaether, Jon; Abella, Benjamin S; Arbogast, Kristy B; Nishisaki, Akira; Maltese, Matthew R; Donoghue, Aaron; Bishnoi, Ram; Helfaer, Mark A; Myklebust, Helge; Nadkarni, Vinay;

Quantitative analysis of CPR quality during in-hospital resuscitation of older children and adolescents.

Pediatrics 2009; 124(2): 494-9

Few data exist on pediatric cardiopulmonary resuscitation (CPR) quality. This study is the first to evaluate actual in-hospital pediatric CPR. We hypothesized that with bedside CPR training and corrective feedback, CPR quality can approach American Heart Association (AHA) targets. Using CPR recording/feedback defibrillators, quality of CPR was assessed for patients ≥ 8 years of age who suffered a cardiac arrest in the PICU or emergency department (ED). Before and during the study, a bedside CPR training program was initiated. Between October 2006 and February 2008, twenty events in 18 patients met inclusion criteria and resulted in 36749 evaluable chest compressions (CCs) during 392.3 minutes of arrest. CCs were shallow (< 38 mm or < 1.5 in) in 27.2% (9998 of 36749), with excessive residual leaning force (≥ 2500 g) in 23.4% (8611 of 36749). Segmental analysis of the first 5 minutes of the events demonstrated that shallow CCs and excessive residual leaning force were less prevalent during the first 5 minutes. AHA targets were not achieved for CC rate in 62 (43.1%) of 144 segments, CC depth in 52 (36.1%) of 144 segments, and residual leaning force in 53 (36.8%) of 144 segments. This prospective, observational study demonstrates feasibility of monitoring in-hospital pediatric CPR. Even with bedside CPR retraining and corrective audiovisual feedback, CPR quality frequently did not meet AHA targets. Importantly, no flow fraction target of 10% was achieved. Future studies should investigate novel educational methods and targeted feedback technologies.
Greater chest compression fraction (CCF, or proportion of CPR time spent providing compressions) is associated with better survival for out-of-hospital cardiac arrest (OOHCA) patients in ventricular fibrillation (VF). We evaluated the effect of CCF on return of spontaneous circulation (ROSC) in OOHCA patients with non-VF ECG rhythms in the Resuscitation Outcomes Consortium Epistry. This prospective cohort study included OOHCA patients if: not witnessed by EMS, no automated external defibrillator (AED) shock prior to EMS arrival, received >1 min of CPR with CPR process measures available, and initial non-VF rhythm. We reviewed the first 5 min of electronic CPR records following defibrillator application, measuring the proportion of compressions/min during the resuscitation. Demographics of 2103 adult patients from 10 U.S. and Canadian centers were: mean age 67.8; male 61.2%; public location 10.6%; bystander witnessed 32.9%; bystander CPR 35.4%; median interval from 911 to defibrillator turned on 8 min:27 s; initial rhythm asystole 64.0%, PEA 28.0%, other non-shockable 8.0%; median compression rate 110/min; median CCF 71%; ROSC 24.2%; survival to hospital discharge 2.0%. The estimated linear effect on adjusted odds ratio with 95% confidence interval (OR; 95%CI) of ROSC for each 10% increase in CCF was (1.05; 0.99, 1.12). Adjusted (OR; 95%CI) of ROSC for each CCF category were: 0-40% (reference group); 41-60% (1.14; 0.72, 1.81); 61-80% (1.42; 0.92, 2.20); and 81-100% (1.48; 0.94, 2.32). This is the first study to demonstrate that increased CCF among non-VF OOHCA patients is associated with a trend toward increased likelihood of ROSC. Copyright © 2011 Elsevier Ireland Ltd. All rights reserved.
Wik, Lars; Kramer-Johansen, Jo; Myklebust, Helge; Sørebø, Hallstein; Svensson, Leif; Fellows, Bob; Steen, Petter Andreas;

Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest.

**JAMA** 2005; 293(3): 299-304

Cardiopulmonary resuscitation (CPR) guidelines recommend target values for compressions, ventilations, and CPR-free intervals allowed for rhythm analysis and defibrillation. There is little information on adherence to these guidelines during advanced cardiac life support in the field. To measure the quality of out-of-hospital CPR performed by ambulance personnel, as measured by adherence to CPR guidelines. Case series of 176 adult patients with out-of-hospital cardiac arrest treated by paramedics and nurse anesthetists in Stockholm, Sweden, London, England, and Akershus, Norway, between March 2002 and October 2003. The defibrillators recorded chest compressions via a sternal pad fitted with an accelerometer and ventilations by changes in thoracic impedance between the defibrillator pads, in addition to standard event and electrocardiographic recordings. Adherence to international guidelines for CPR. Chest compressions were not given 48% (95% CI, 45%-51%) of the time without spontaneous circulation; this percentage was 38% (95% CI, 36%-41%) when subtracting the time necessary for electrocardiographic analysis and defibrillation. Combining these data with a mean compression rate of 121/min (95% CI, 118-124/min) when compressions were given resulted in a mean compression rate of 64/min (95% CI, 61-67/min). Mean compression depth was 34 mm (95% CI, 33-35 mm), 28% (95% CI, 24%-32%) of the compressions had a depth of 38 mm to 51 mm (guidelines recommendation), and the compression part of the duty cycle was 42% (95% CI, 41%-42%). A mean of 11 (95% CI, 11-12) ventilations were given per minute. Sixty-one patients (35%) had return of spontaneous circulation, and 5 of 6 patients discharged alive from the hospital had normal neurological outcomes. In this study of CPR during out-of-hospital cardiac arrest, chest compressions were not delivered half of the time, and most compressions were too shallow. Electrocardiographic analysis and defibrillation accounted for only small parts of intervals without chest compressions.

**Excluded Articles**

**Question**  Chest compression rate

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