The impact of chest compression rates on quality of chest compressions – a manikin study

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Abstract

Purpose

Chest compressions are often performed at a variable rate during cardiopulmonary resuscitation (CPR). The effect of compression rate on other chest compression quality variables (compression depth, duty-cycle, leaning, performance decay over time) is unknown. This randomised controlled cross-over manikin study examined the effect of different compression rates on the other chest compression quality variables.

Methods

Twenty healthcare professionals performed two minutes of continuous compressions on an instrumented manikin at rates of 80, 100, 120, 140 and 160min^{-1} in a random order. An electronic metronome was used to guide compression rate. Compression data were analysed by repeated measures ANOVA and are presented as mean(SD). Non-parametric data was analysed by Friedman test.

Results

At faster compression rates there were significant improvements in the number of compressions delivered (160(2) at 80min^{-1} vs. 312(13) compressions at 160min^{-1}, $P<0.001$); and compression duty-cycle (43(6)% at 80min^{-1} vs. 50(7)% at 160min^{-1}, $P<0.001$). This was at the cost of a significant reduction in compression depth (39.5(10)mm at 80min^{-1} vs. 34.5(11)mm at 160min^{-1}, $P<0.001$); and earlier decay in compression quality (median decay point 120s at 80min^{-1} vs. 40s at 160min^{-1}, $P<0.001$). Additionally not all participants achieved the target rate (100% at 80min^{-1} vs. 70% at 160min^{-1}). Rates above 120min^{-1} had the greatest impact on reducing chest compression quality.

Conclusions

For Guidelines 2005 trained rescuers, a chest compression rate of 100 to 120min^{-1} for two minutes is feasible whilst maintaining adequate chest compression quality in terms of depth, duty-cycle, leaning, and decay in compression performance. Further studies are needed to assess the impact of the Guidelines 2010 recommendation for deeper and faster chest compressions.

Background

High quality chest compressions with minimal interruption are essential for successful resuscitation following a cardiac arrest.[1,2] However the quality of chest compressions is often poor during both training and actual resuscitation attempts.[3-5] Faster chest compression rates (120 vs. 60 min^{-1}) improved immediate and 24 hour survival after ventricular fibrillation arrest in an animal study.[6] Human studies have also shown improved survival from faster compression rates. Abella and colleagues found a higher mean compression rate for in-hospital cardiac arrest patients with initial return of spontaneous circulation (ROSC) compared with no-ROSC (90±17 vs. 79±18 min^{-1}).[4] In an out-of-hospital cardiac arrest, Christenson and colleagues observed an improved survival to discharge in patients who received a higher chest compression fraction, i.e., fewer interruptions in chest compressions.[7] In this study survivors also received mean chest compression rates above 110 min^{-1}.

Over the last 50 years the recommended chest compression rate has been gradually increased. Guidelines 1986 recommended an increase in compression rate from 60 min^{-1} to between 80-100 min^{-1} in order to improve blood flow and increase the number of compressions delivered to compensate for pauses caused by rescue breathing.[8] The European Resuscitation Council (ERC) Guidelines 2005 recommended a rate of 100 min^{-1}.[9,10] The 2010 International Liaison Committee on Resuscitation (ILCOR) Consensus on Science and Treatment Recommendation stated that it is reasonable for lay rescuers and healthcare providers to perform chest compressions for adults at a rate of at least 100 min^{-1} and that there is insufficient evidence to recommend a specific upper limit for compression rate.[11] The ERC Guidelines 2010 did however recommend an upper compression rate of 120 min^{-1}.[12]

Chest compression rate is one indicator and measure of chest compression quality.[13] It is currently unknown how chest compression rate influences the other important chest compression variables that also impact outcome, i.e., compression depth, duty-cycle, leaning and the impact of compression duration by a single rescuer on decay of compression quality. The aim of this study was to measure the effect of different chest compression rates on the other compression variables when compression only CPR is performed on an instrumented manikin by rescuers trained according to 2005 CPR guidelines.

Methods

Study Design

The study was a randomised controlled crossover trial conducted in the clinical skills centre of a large urban UK hospital in February 2010. The participants consisted of doctors, nurses, medical students and student nurses trained in basic life-support (guidelines 2005) and capable of performing chest compressions. Each participant was asked to perform two minutes of continuous chest compressions at 5 different rates (80, 100, 120, 140 and 160 min^{-1}). The rates were assigned to each participant in a random order from an opaque sealed envelope. Participants were grouped into pairs to allow alternate testing with at least three minutes rest between each two-minute set of compressions (see Figure 1). Compressions were performed on a Laerdal® Resusci-Anne™ manikin (Laerdal Medical AS, Stavanger, Norway) weighted to 50kg, placed on a standard hospital bed and mattress which was adjusted to the rescuers mid-thigh height. An electronic metronome (Flash metronome, www.gieson.com) with an audible beeping tone was used to guide chest compression rate. Each participant was given identical verbal instructions “I am going to play the metronome at the designated rate, I want you to listen to it for 15 seconds then I will tell you to start compressions, compress every time you hear a beep and do not stop until I tell you to do so.”

(Insert Figure 1)

Study participants

Twenty participants from a range of healthcare backgrounds were recruited to take part in the study (doctor n=1, resuscitation officer n=2, medical students n=6, student nurses n=8 and other n=3). All participants had undergone recent Basic Life Support CPR training and participants gave verbal consent; demographic data were also collected from participants including time since last life support training, professional background and gender (8 males and 12 females).

Ethics and Regulatory Approval

The study was sponsored by Heart of England NHS Foundation Trust and approved by the Trust Research and Development department.

Quality of CPR and data collection

The manikin was connected to a computer and chest compression quality data was collected using SkillReporting software, version 2.2.1 (Resusci Anne SkillReporter, Laerdal Medical). This software was used to record: session duration, total number of compressions delivered, compression rate, depth and duty-cycle, the number of compressions with leaning (incomplete release), the number of "shallow compressions" (below 38mm) in accordance with the consensus on uniform reporting of CPR quality.[13] To measure the effect of compression rates on performance decay in the quality of compressions, rescuer's decay point was defined as the time to a 10% deterioration in chest compression depth from baseline for 5 successive chest compressions.

All of the above variables were calculated automatically except for the decay point which was calculated manually from the SkillReporter software graphics.

Statistical analysis

All data were analysed using PASW statistical software package for Windows, version 18 (SPSS, Inc, Chicago, IL). All the data was normally distributed and parametric chest compression variables were evaluated using repeated measures analysis of variance (ANOVA). Decay point was analysed using Friedman's test. Difference in proportions (number of participants showing performance decay, leaning and number unable to achieve rate) were analysed by Cochran's Q test. The number of subjects was based on data from previous studies by our group.[14] We calculated that we would need 20 participants to demonstrate a 10% difference in chest compression depth at a significance level of 0.05 and 90% power. The probability value was set at $P < 0.05$ to show significance.

Results

(***Insert Table 1)***

Total number of chest compressions

As chest compression rate increased the total number of compressions delivered over the two-minute test increased significantly. The data showed an average of 160, 200, 239, 276 and 311 compressions delivered for chest compression rates of 80, 100, 120, 140 and 160 min^{-1} respectively ($P < 0.001$).

Compression depth

For all compression rates above 80 min^{-1}, the mean compression depth was below the recommended 2005 guideline depth of 38mm. There was a significant inverse relationship between compression rate and depth ($P<0.001$) (figure 2). As compression rate increased, mean compression depth decreased, with the biggest deterioration between 100 and 120 min^{-1} (2.4mm).

(**Insert figures 2 and 3)**

Duty-cycle

The compression duty cycle is defined as the fraction (or percentage) of time that is spent compressing the chest over the total compression time.[13] As chest compression rate increased, compression duty-cycle also increased towards the recommended guideline of 50% (figure 3).[10] The data showed that there was a significant difference in the duty-cycle for compression rates faster than 100 min^{-1} (P<0.001).

Leaning

The relationship between participants leaning and compression rate was insignificant. However there was a non-significant (P= 0.066) yet noticeable trend for an increased number of participants to lean at compression rates above 100 min^{-1}. The data demonstrated 4, 6 and 7 participants leaning at rates of 120, 140 and 160 min^{-1} respectively. In addition when all compressions in which leaning occurred were expressed as a percentage of total compressions, there was a non-significant (P=0.158) trend to an increased proportion of compressions with leaning as chest compression rates increased (figure 5).

(Insert figures 4 and 5)

Performance decay point

As chest compression rate increased there was an increased number of participants reaching the decay point before two minutes (figure 4) (table 1). The median time at which performance decay in compression quality occurred was also significantly reduced with increased compression rate; decay occurred at 120, 107, 69, 40 and 39 s for rates of 80, 100, 120, 140 and 160 min^{-1} respectively (P < 0.001). In addition to decay there was a significant trend that some of the participants were unable to maintain rates faster than 120 min^{-1} for two minutes; 2 and 6 participants were unable to maintain compression rates of 140 and 160 min^{-1} respectively ($P = 0.001$).

Carry over effect

Due to the design of the study it was possible that differences in performance may be due to the order that participants performed the rates rather than the individual rates. In order to test for this potential carry over effect, compression depth and decay point were analysed in the order each test was performed. This analysis showed that there was no impact on the order each test was performed on compression depth or decay point (see supplementary data).

Discussion

Summary of main findings

A chest compression rate of 100 to 120 min^{-1} for two minutes on a manikin is feasible whilst maintaining adequate chest compression quality in terms of depth, duty-cycle, leaning, and decay in compression quality according to 2005 guidelines. Our study shows that chest compression rate is not a mutually exclusive process and changes in compression rate influence other chest compression quality variables. The advantages of increasing compression rate were; a significant increase in the duty-cycle closer to the recommended 50% and a significant increase in the number of compressions delivered each minute. However the main drawbacks to faster compression rates were; a significant decrease in compression depth, a significant decrease in the time at which decay in compression quality occurred, a trend towards increased leaning and an increase in the number of rescuers that failed to achieve the target rate.

Increasing compression depth alone has been associated with improved haemodynamics in animal studies as well as improved survival in observational studies of adult humans following in-hospital cardiac arrest.[1,15] The mean compression depth at the baseline rate of 100 min^{-1} was low in our sample, with half of our participants failing to meet the minimum 2005 recommended guideline depth of 38mm, suggesting better depth performance is required regardless of the rate. There are two possible explanations for this. Firstly many healthcare professionals fail to compensate and push deep enough when the manikin or patient is on a mattress.[3,16,17] Secondly previous studies show that using a metronome or music to guide compression rates can lead to a slight decrease in depth compared to no metronome or music.[18,19] Although the change in mean compression depth in our study from 39.5mm to 34.5mm is modest this may still be clinically important. Edelson and colleagues showed that each 5mm increase in compression depth gave almost a two-fold increase in the probability of defibrillation shock success.[1] In addition the new 2010 guidelines recommend an even greater depth of 50-60mm.[12]

Our study showed an increase in the duty-cycle at faster rates approaching the recommended 50% at a compression rate of 160 min^{-1}.[12] This may be due to the shorter time available between each compression leading to the formation of a more natural compression-release cycle. Interestingly a study by Handley and Handley found no relationship between rate and duty-cycle when rates up to a rate of 100 min^{-1} were tested.[20] However our study included higher compression rates and showed significant changes at rates more than 100 min^{-1}.

In our study, the decay-point defined as a 10% decrease in chest compression depth for 5 consecutive compressions occurred much earlier at faster compression rates with important clinical significance. This decay in chest compression quality may have been caused by rescuer fatigue but we cannot rule out other causes such as that it is harder to perceive depth of compressions after a certain time period or at faster rates. This suggests that rescuers would need to be changed more frequently than the recommended two minutes if higher compression rates are used. This would however result in more interruptions in chest compressions. In addition some of our participants were unable to achieve the faster compression rates. To enable implementation the recommended rate should be realistic and be set at a level that can be achieved by most rescuers.

Limitations

Firstly this is a manikin study so patient outcomes from using different chest compression rates were not measured. Secondly our participants were only asked to perform continuous chest compressions; we did not take into account the impact of pauses for ventilations, and procedures such as tracheal intubation. It is likely that practical procedures would be more difficult with more movement of the patient. The impact of faster rates on the ability to perform procedures with higher compression rates is unknown. Thirdly, since our study was performed, ERC Guidelines 2010 has recommended a compression depth of 5-6 cm.[12] Our data suggests that this depth recommendation will be challenging to achieve for many rescuers. Finally, chest compressions were performed without feedback from a CPR feedback / prompt device. It is possible that the deterioration in compression quality seen with progressively faster compression rates may not have occurred if a feedback / prompt device had been used. However, recent studies using this technology have found a decay in compression depth occur after about 90 seconds of continuous chest compressions during in-hospital resuscitation.[21,22]

Conclusion

For rescuers trained to Guidelines 2005 a chest compression rate of 100 to 120 min^{-1} for two minutes is feasible whilst maintaining adequate chest compression quality in terms of depth, duty-cycle, leaning, and decay in compression performance. Further studies are needed to assess the impact of the Guidelines 2010 recommendation for deeper and faster chest compressions.

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