

FOCUS ON CARDIAC ARREST

A FAILED ATTEMPT TO IMPROVE QUALITY OF OUT-OF-HOSPITAL CPR THROUGH PERFORMANCE EVALUATION

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ABSTRACT

Introduction. Quality of CPR performed by professionals has been reported to be substandard even with automated corrective feedback. Our hypothesis was that providing CPR performance evaluation (CPR-PE) to three ambulance services would facilitate local education and implementation of CPR guidelines and, consequently, improve CPR quality. **Methods:** Quality of CPR in 85 consecutive cases of adult out-of-hospital cardiac arrests after CPR-PE was compared to 39 cases prior to CPR-PE. Real-time automated verbal and visual feedback on CPR performance was given in all cases. No general implementation strategy was provided because the sites were expected to use the CPR-PEs in development of local strategies. Because the strategies were expected to vary, the sites were analyzed separately. **Results:** No significant improvement was seen in quality of CPR after CPR-PE. No

chest compressions were given 40% of the time before versus 41% after CPR-PE. The median (95% confidence interval) percentage of chest compressions within the recommended depth range (38–51 mm) was 35% (27–57) before versus 51% (42–60) after CPR-PE ($p = 0.12$). In site-specific analysis, chest compressions within guideline depth increased from 31% to 61% after CPR-PE ($p = 0.05$) in one site. **Conclusions:** Overall our attempt to improve CPR-quality was unsuccessful. Quality improvement likely requires a full range of implementation strategies to change current attitudes and practices. **Key words:** heart arrest, cardiopulmonary resuscitation; advanced cardiac life support; ambulances; emergency medical services; guideline adherence.

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INTRODUCTION

It is well established that chest compressions and ventilations given during cardiopulmonary resuscitation (CPR) increase survival after cardiac arrest,¹ and that quality of CPR influences outcome.^{2–4} It was recently shown that quality of CPR performed by professionals in both out-of-hospital⁵ and in-hospital settings⁶ does not adhere to recommended guidelines. Automated feedback from a defibrillator based on its measurements of CPR performance has been suggested as a means to improve CPR quality as consistently found in manikin studies,^{7–9} but only modest improvements have been reported in clinical studies.^{10,11} Development of new strategies for improving CPR quality is therefore needed.

Increasing knowledge and changing current attitudes through training and education are necessary for successful implementation of any new practice. The development of a prototype defibrillator capable of measuring and recording quality of CPR^{5,6} made it possible to provide real-time feedback on performance data to the individual rescuers.^{10,11} Having a method for recording quality of CPR makes it possible to report back performance data to CPR providers off-line for use in quality evaluation and improvement and to objectively

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evaluate strategies to improve CPR quality in a group of performers. Our hypothesis was that providing site-specific CPR performance evaluation (CPR-PE) from the previous phases of this study^{5,10} to the three participating ambulance services would facilitate local, tailored education, and implementation of CPR guidelines and, consequently, improve CPR quality.

METHODS

Because this was an add-on phase of a prospective study of CPR quality performed by ambulance personnel, the general material and methods, including detailed descriptions of the equipment used, have been presented in detail in previous reports,^{5,10,12} and the present description is therefore less detailed.

The study was performed in three ambulance services: London (England), Stockholm (Sweden), and Akershus (Norway) and was approved by the respective regional ethics committees. Informed consent for inclusion in the study was waived as decided by these committees in accordance with paragraph 26 in the Helsinki Declaration.¹³ In this prospective study registered at ClinicalTrials.gov (NCT00138996), patients older than 18 years suffering from out-of-hospital cardiac arrests of all causes were included.

From October 2004 until the CE approval for the experimental defibrillators expired in June 2005, data were gathered for observations on depth-force relationships in chest compressions.¹² During this period, we wanted to see if the improvement seen with the introduction of automated feedback¹⁰ could be further improved if local awareness of the results was highlighted. Initiation of the study coincided with the publication of the results from the first phase of the study at the European Resuscitation Council meeting in Budapest in September 2004, at which all head instructors and local coordinators from the respective sites attended. After the meeting, each ambulance service arranged meetings with the local CPR instructors where site-specific details on performance were presented and potential for improvements discussed by one or two of the head investigators. This CPR performance based evaluation (CPR-PE) was the only planned central intervention for the study, and it was our intention that the site-specific information would increase knowledge and change current attitudes and training. Developing implementation strategies for local CPR quality improvement were left at the discretion of the local instructors but included addition of the information into retraining and recertification of the crews that fall. Thus, all data were gathered 0–8 months after retraining with the new information. Because the strategies were expected to vary, the sites were also analyzed separately.

Parallel to the add-on phase, as part of a separate study protocol and serving as a control group illustrating achievable CPR quality, identical equipment was

used and data collected between January 2005 and April 2006 from the physician-manned ambulance in Oslo, Norway (manned by two paramedics and one anesthesiologist), all well informed about the results from study phase one.

Data from each episode included scanned patient report forms and locally adapted Utstein style forms. ECG, accelerometer, and transthoracic impedance signals, time and events were registered and collected from the defibrillator as previously reported.^{5,10,12} In the present study, special attention was given to time without compressions (No Flow Time [NFT], No-flow ratio [NFR] and chest compression depth). NFR is defined as NFT divided by total time segment without spontaneous circulation. Adjusted no-flow ratio (NFRadj) is the fraction of no-flow time to time without spontaneous circulation but allowing for time for rhythm analysis, shock delivery, and pulse check if appropriate.⁵

The annual statistics and demographic data for the three emergency medical service systems were described previously.⁵ Statistical calculations were performed by using MATLAB, a spreadsheet program (Excel 2002, Microsoft Corp, Redmond, WA, USA) or a statistical software package (SPSS 12.0, SPSS Inc., Chicago, IL, USA). Quality and outcome measures from this add-on-CPR-PE phase of the study were compared with the results from the second half of the second phase of the study, thus, cases with identical feedback as in the present add-on-phase. P-values for differences not equal to 0 were obtained from two-sided independent samples *t*-test, except for percentages of compressions with depth 38–51 mm, too deep, and too shallow before and after CPR-PE in which a Mann-Whitney U-test was used. Ten different quality variables were tested with no correction for possible alpha error included in the statistical analysis. A power analysis based on the results from the 39 episodes previously gathered revealed that to detect a meaningful reduction in NFR from 0.40 ± 0.16 to 0.30 with an alpha of 0.05 and a power of 0.8, we needed 43 cases in this study. Similarly, to detect a change in chest compression depth from 36 ± 7 mm to 40 mm, 65 subjects were needed.

RESULTS

Ninety-nine episodes were collected between October 2004 and June 2005. For analysis of CPR quality, 14 cases were excluded; five due to failure to use the compression sensor, five due to inadequate or missing data transfer, and four due to other technical problems leading to substandard signal quality. Quality of CPR for the 85 (86%) remaining cases were compared with the results for the pre-CPR-PE period. From the 44 patients in the pre-CPR-PE period who had received identical feedback on CPR quality immediately before the CPR-PE, five patients were excluded from quality assessment; two due to failure to use the compression sensor

TABLE 1. Demographic and Utstein Characteristics Before and After CPR Performance Evaluation (CPR-PE)

| | All Sites | |
|----------------------------|---------------|--------------|
| | Before CPR-PE | After CPR-PE |
| Number of episodes | 44 | 99 |
| Age (years) | 70 ± 16 | 67 ± 16 |
| Males (%) | 33 (75) | 65 (66) |
| Usable episodes (%) | 39 (89) | 85 (86) |
| Site (% of usable): Site A | 17 (44) | 30 (35) |
| Site B | 8 (21) | 27 (32) |
| Site C | 14 (36) | 28 (33) |
| Ambulance-witnessed (%) | 4 (9) | 6 (6) |
| Bystander-witnessed (%) | 29 (66) | 55 (56) |
| Bystander-CPR (%) | 18 (41) | 39 (39) |
| Response time (min) | 7 (6, 8) | 7 (6, 8) |
| Outcome | | |
| Admitted alive | 7 (16) | 13 (13) |
| Discharged alive | 2 (5) | 2 (2) |

All variables give a number (percentages in parenthesis) except age (mean ± SD), response times (mean with 95% CI), and shocks per episode (median with 95% CI). Ambulance personnel-witnessed cases are not included in bystander-witnessed and bystander-CPR, and response time calculations.

and three due to other technical difficulties, leaving 39 (87%) cases for CPR quality analysis.¹⁰ Because of sub-optimal signal quality, ventilation count could only be determined in 37 of 39 (95%) before and in 77 of 85 (91%) after CPR-PE, respectively.

The distribution of site inclusions was different before and after CPR-PE with a relative decrease in inclusions from site A, an increase from site B, and little change from site C (Table 1). There were no significant differences in any other demographic or Utstein characteristics between the periods before and after CPR-PE (Table 1). This also applies to each site analyzed separately (data not shown).

There were no significant differences between the periods before and after CPR-PE in any of the CPR quality components analyzed (Table 2). The higher proportion of compressions within the recommended range of depth after CPR-PE only approached statistical significance ($p = 0.12$).

When quality of CPR was analyzed separately for each site, the results from site A appeared distinctly different from sites B and C. Results from site A are therefore presented separately from B and C, which are presented together (Table 3). At site A there was an increase from 31% to 62% ($p = 0.05$) of compressions within guidelines limits after CPR-PE with no change for sites B and C (Table 3). There was no change in the fraction of time without chest compressions at any of the sites whether or not adjusted for the time required in the guidelines for defibrillation and patient checks. However, there was a mean absolute difference of 20% in NFR at site A compared to site B and C (95% CI: 13%, 27%, $p < 0.0001$).

There was no difference in the rate of admission or overall survival before and after CPR-PE (Table 1). Seven (16%) patients were admitted to hospital before and 13 (13%) after CPR-PE, with odds ratio 0.8 (95% CI: 0.3: 2.2, $p = 0.66$). Only two patients were discharged alive both before and after CPR-PE, representing 5% and 2%, respectively ($p = 0.42$ using Fisher's exact test).

In the 11 cases treated by the physician-manned ambulance in Oslo between January 2005 and April 2006, 12 ± 2 ventilations and 93 ± 18 compressions were given per minute with a mean compression rate of $106 \pm 6 \text{ min}^{-1}$. NFR was 0.08 ± 0.06 and mean compression depth $44 \pm 6 \text{ mm}$, with 78% of the compressions within the recommended range of depth (38–51 mm).

DISCUSSION

Our hypothesis that providing information on specific CPR quality problems to the training teams of the different ambulance services would facilitate local education and improve CPR quality, could not be confirmed. Overall, no significant improvements were found even without corrections for possible statistical alpha errors due to the parallel analysis of ten different quality factors. For the only factor found to be improved, doubling of chest compressions within the recommended range

TABLE 2. Performance of CPR with Automated Feedback Before and After CPR Performance Evaluation (CPR-PE)

| | Before CPR-PE (n = 39) | After CPR-PE (n = 85) | Difference mean (95% CI) | P-value |
|---|------------------------|-----------------------|--------------------------|---------|
| No flow | | | | |
| No flow ratio | 0.40 ± 0.16 | 0.41 ± 0.18 | 0.01 (−0.06, 0.07) | 0.83 |
| Adjusted no flow ratio | 0.33 ± 0.14 | 0.33 ± 0.16 | 0.00 (−0.06, 0.06) | 0.99 |
| Compressions | | | | |
| Compressions per min (min^{-1}) | 69 ± 21 | 68 ± 24 | 0 (−15, 1) | 0.83 |
| Compression rate (min^{-1}) | 108 ± 13 | 110 ± 10 | 1 (−3, 6) | 0.53 |
| Compression depth (mm) | 36 ± 7 | 37 ± 7 | 1 (−2, 3) | 0.56 |
| Depth 38–51 mm (%) | 35 (27,57) | 51 (42,60) | | 0.12 |
| Too deep (>51 mm) (%) | 0 (0,1) | 1 (0,3) | | 0.40 |
| Too shallow (<38 mm) (%) | 51 (32,69) | 40 (30,53) | | 0.22 |
| Compression part of duty cycle (%) | 42 ± 4 | 42 ± 4 | 0 (−0.01, 0.02) | 0.65 |
| Ventilations per minute (min^{-1}) | 11 ± 4 | 10 ± 4 | −2 (−3, 0) | 0.30 |

Values given as mean ± SD, mean difference with 95% confidence interval (CI) except for percentages of compressions with depth 38–51 mm, too deep, and too shallow, which are given as median values with 95% CI.

TABLE 3. Performance of CPR with Automated Feedback Before and After CPR Performance Evaluation (CPR-PE)

| | Site A | | | Site B + C | | |
|--|------------------------|-----------------------|---------|------------------------|-----------------------|---------|
| | Before CPR-PE (n = 17) | After CPR-PE (n = 30) | P-value | Before CPR-PE (n = 22) | After CPR-PE (n = 55) | P-value |
| No flow | | | | | | |
| No flow ratio | 0.29 ± 0.13 | 0.28 ± 0.13 | 0.80 | 0.49 ± 0.12 | 0.48 ± 0.16 | 0.80 |
| Adjusted no flow ratio | 0.23 ± 0.12 | 0.22 ± 0.13 | 0.85 | 0.43 ± 0.10 | 0.39 ± 0.14 | 0.59 |
| Compressions | | | | | | |
| Compressions per min (min ⁻¹) | 82 ± 18 | 83 ± 26 | 0.88 | 58 ± 17 | 60 ± 18 | 0.69 |
| Compression rate (min ⁻¹) | 106 ± 9 | 109 ± 8 | 0.38 | 110 ± 16 | 110 ± 11 | 0.89 |
| Compression depth (mm) | 36 ± 8 | 39 ± 6 | 0.11 | 37 ± 7 | 36 ± 7 | 0.68 |
| Depth 38–51 mm (%) | 31 (5,55) | 62(36,75) | 0.05 | 44 (27,59) | 48 (36,58) | 0.69 |
| Too deep (>51 mm) (%) | 0 (0,0) | 1 (0,8) | 0.07 | 1 (0,5) | 1 (0,3) | 0.59 |
| Too shallow (<38 mm) (%) | 66(32,95) | 30(15,49) | 0.06 | 47 (24,72) | 49 (32,62) | 0.98 |
| Compression part of duty cycle (%) | 43 ± 3 | 43 ± 4 | 0.59 | 41 ± 4 | 41 ± 4 | 0.69 |
| Ventilations per minute (min ⁻¹) | 12 ± 4 | 10 ± 4 | 0.14 | 10 ± 3 | 9 ± 4 | 0.19 |

Values given as mean ± SD and differences with 95% confidence interval (CI), except for percentages of compressions with depth 38–51 mm, too deep, too shallow, and with incomplete release, which are given as median values with 95% CI.

in site A, an alpha error cannot be excluded with $p = 0.05$, and CPR was still not performed according to recommended guidelines.^{14,15}

These findings pose some immediate questions. Do the 2000 guidelines assume unrealistic capabilities from the CPR-provider, as suggested in an editorial by Ewy and Sanders?¹⁶ Was the effort to improve quality of CPR inadequate because the CPR-PEs did not improve the CPR training? Were general rules for implementation not followed? What can be learned from this effort at quality improvement for others to have a better chance of improving quality of CPR?

A recent study from Odegaard et al. highlights the first question.¹⁷ They found that ambulance personnel from two of the present study sites were physically capable of consistently giving guideline-quality CPR, even on a chest mimicking the stiffest chests found clinically.¹⁷ Obviously, the clinical cardiac arrest scenario is different than training and testing on a manikin model. However, the CPR quality documented for the physician-manned ambulance in Oslo and similarly reported in highly trained staff from the emergency department setting in Austria¹⁸ indicates that guideline-quality CPR is achievable also in real patients. Having experienced physicians with interest in resuscitation research as a part of the resuscitation team, as was the case both in our physician-manned ambulance and in the emergency department setting in Austria,¹⁸ presumably adds significant knowledge and enthusiasm to the resuscitation team, consequently improving CPR quality.

It therefore seems reasonable to assume that there were other non-physical barriers to guideline compliance. Simply presenting the performance evaluation to the CPR-instructors with emphasis on areas in need of improvement at the respective sites was clearly insufficient to improve their CPR quality. Leaving the sole responsibility of developing an implementation strategy to the respective CPR instructors

gave little control over how the information was used.

Choice of implementation strategy is crucial when setting out to improve quality of any treatment or service. Evidence-based medicine is increasingly emphasized, but much less attention is given to evidence-based implementation. Knowing how to best treat an illness is of little practical importance if caregivers do not comply with evidence-based treatment. There is a growing number of studies indicating limited success in encouraging health care workers to implement the necessary changes.^{19–21} Rogers defines this process as: "...the spread of a new idea from its source of invention or creation to its ultimate users or adopters".²²

There are several different models for implementation strategies, based on similar principles.^{22–24} One suggested model is the "Precede-Proceed model," emphasizing predisposing factors (knowledge and attitudes in target group), enabling factors (capacity, resources, availability of service), and reinforcing factors (opinions, behavior of others).^{20,23,25,26} It is documented in systematic reviews that strategies that take all three levels into account are the most successful.^{27,28}

Regarding "predisposing factors," a questionnaire answered by ambulance personnel after completion of the CPR-PE phase, gives important information on their level of knowledge and especially their attitudes.¹⁸ For example, the CPR-PEs at all sites included information that most compressions given were too shallow. This new knowledge failed to increase compression depth significantly in two sites, and when asked after study completion, many paramedics still believed that guideline-depth compressions would often cause severe injury and could therefore not be justified. The majority relied on their personal sense of correct depth and/or force.¹⁷ This finding indicates that the local implementation strategies did not address the underlying barriers and therefore could not convey sufficient understanding of the basis for the CPR

guidelines. An initial assessment of theoretical knowledge and attitudes in addition to the practical performance might have enabled us to identify knowledge gaps that could have been addressed in the quality improvement strategy.

Were there sufficient “enabling factors”? It is important to have a simple protocol to ensure guideline adherence. Failure to reduce hands-off intervals may support the growing consensus that the 2000 ALS guidelines^{14,15} were too complex.^{16,29} When compared to the physician-manned ambulance, which uses identical equipment and is rarely assisted by another ambulance during cardiac arrest in contrast to the other ambulances studied, shortage of personnel or equipment cannot explain the deviation from guideline recommendations. The survey mentioned above¹⁷ indicated that procedures such as intubation and establishing intravenous access were prioritized when arriving at the patient, leading to discontinuation of chest compressions.¹⁷ Rather than indicating lack of personnel or equipment (enabling factors), this again suggests lack of knowledge when incorrectly prioritizing advanced procedures instead of chest compressions (predisposing factor).

What about “reinforcing factors”? Participating personnel have to believe in the changes suggested in order for them to “buy into” the project. One reinforcing factor is a local champion chairing the process.³⁰ In a study investigating beta-blocker use after myocardial infarction, hospitals with successful implementation of this recommended treatment were all characterized by strong physician leadership advocating beta-blocker use, together with shared goals for improvement, administrative support and use of credible data feedback.³¹ Consequently, if continuous interest and strong leadership are absent, no improvements can be expected. Site A, the only site to show an improvement, had medical advisors with a general interest in resuscitation and quality of CPR and continuous interaction with the researchers of this study. Being able to discuss the findings from previous stages of this study in detail and question their importance in informal discussions might have been invaluable both for developing a local implementation strategy and for ensuring that the paramedics actually changed current attitudes and practices. It is worth noting that site A also had much less time without chest compressions than the other two sites, of which only a small fraction can be explained by the manual mode defibrillation at site A.^{32,33} Another reinforcing factor exclusive to site A was significant media attention given to the results from the baseline period before the present study period was started. This may have had an additional psychological effect in site A and underlines the importance of opinions and behaviors of others. This observation is supported by Rogers, who states that the awareness and knowledge of an in-

novation can be made most efficiently through mass media.²²

Having an evaluation method is essential in any quality improvement effort. Using quality measurements as reinforcing factors by reporting progress to participating personnel has been suggested to be a part of a successful approach when implementing evidence-based strategies in clinical care.^{31,34} Although available, no such progress information was given to any of the sites during the study. This finding illustrates our failure as medical researchers to think of quality improvement as a continuous process. We are accustomed to finishing collecting data before we analyze them and share the information instead of using hermeneutic research principles; making use of the information appearing as the project develops and feeding it back into the system.

Any of the above reinforcing factors will most likely require repeated efforts and substantial time. This was clearly demonstrated at a regional trauma center in Virginia, where a standardized evidence-based protocol for treatment of brain injury was implemented. The compliance rate was only 50% during the first year, but it increased to 85% during the following year by repeating educational seminars, repeatedly citing the evidence, and allowing for debate.³⁵

Whether the change to 2005 guidelines in itself improves quality of CPR remains to be seen. The change from 15 to 30 compressions per two ventilations in unintubated patients and the recommendation of immediate chest compressions after single defibrillation attempts should decrease hands-off time, but most of the hands-off time in the present study cannot be explained by these factors. There is no change in the guidelines that should improve chest compression depth except for increased emphasis on the importance of quality of CPR, and the present study indicates that increased knowledge of quality problems is not enough to improve performance.

CONCLUSION

Quality of CPR was not improved probably because of an inadequate implementation strategy. Bringing about changes in established practice likely requires a well-thought-through implementation plan, addressing current barriers and giving sufficient time for repeated performance evaluations documenting progress. The presence of committed and respected leaders focusing on areas in need of improvement is also believed to be important. As evidence-based medicine is increasingly demanded, more research is needed to give evidence-based implementation strategies.

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