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CARDIOPULMONARY RESUSCITATION QUALITY: WIDESPREAD VARIATION IN DATA INTERVALS USED FOR ANALYSIS

INTRODUCTION

Recently, increased emphasis has been placed on providing high quality cardiopulmonary resuscitation (CPR) to patients in cardiac arrest. Several studies have indicated a significant relationship between survival outcomes and CPR quality parameters such as chest compression depth,[1-5] rate[6] and fraction.[3, 7] However, among studies, heterogeneity exists in how CPR quality parameters are reported for individual patients and then used in analysis. In 2007, Kramer-Johansen et al.[8] authored recommendations for uniform reporting of measured quality of CPR. These recommendations proposed that CPR quality data be collected over the entire resuscitation episode. The start of an episode should coincide with the first therapeutic event after arrival at a cardiac arrest patient, including first recorded chest compression, first defibrillator rhythm analysis, or first defibrillation.[8] For studies that investigate CPR quality and survival, it was recommended that researchers use discrete measurement windows of 30 seconds or less for parameters such as compression depth to detect haemodynamic changes associated with compressions.[8] In terms of undertaking analysis in these types of studies, no recommendations were made in regards to the length of the interval that should be used for analysis, nor the minimum interval length required for inclusion.

In practice, CPR quality is recorded using devices such as the Q-CPR™ (Philips Medical) or the Real CPR Help® (ZOLL Medical Corporation). Such devices provide CPR quality summary data for an entire resuscitation episode as well as on an interval-by-interval basis; however there is variation in the proportion of episode data that is used by researchers for statistical analysis. When considering the relationship between CPR quality and survival across existing studies, some studies analysed data collected over the entire resuscitation episode[3] whereas others only included the first 5 minutes.[9, 10] Furthermore, there were variations in when the analysis interval began; in some cases it was from when CPR pads were placed on the patient's chest,[11] whereas in others it was from the first monitored compression.[6] There were also variations between studies in the minimum interval length required for analysis.

We aimed to describe the characteristics of the data analysis intervals used by papers that examined the relationship between CPR quality and survival, noting sources of heterogeneity, so as to encourage a uniform approach to data description.

METHODS

We reviewed papers that reported the association between CPR quality and cardiac arrest patient survival. The protocol for locating and selecting these papers was documented in our previous systematic review.[12] In all identified papers, CPR quality was recorded using an automated CPR quality measurement device.

From relevant papers we collected information about (1) the time interval used for analysis; (2) the event that marked the beginning of the analysis interval; and (3) the minimum amount of CPR quality data required for a case to be included in the analysed cohort. We then compared this data across papers.

RESULTS

Twenty-one studies reported on the association between CPR quality and cardiac arrest patient survival (see Table). In contrast to our systematic review,[12] we excluded one paper[13] that did not directly examine this association statistically.

Length of analysis interval

The majority of studies analysed data from the start of the resuscitation period, including six studies[5, 6, 9, 10, 14, 15] that analysed data over the first 5 minutes and two studies[2, 16] that analysed data over the first 10 minutes. Alternative analysis intervals included: up to the first 500 compressions (not including the first 5 compressions),[17] the minute interval during which the first analysis was performed in addition to all recorded minute intervals before the first analysis,[7, 18] and the first, and where available, the last complete cycle of CPR.[19] Two studies used data from the first three shocks.[11, 20] In six studies[1, 4, 21-24] it was assumed, based on other descriptions in the paper, that the authors analysed all available episode data. In one study[3] it was explicitly stated that analysis occurred over the entire episode.

Start of interval

In two studies,[6, 15] the measurement interval commenced from the first recorded compression, in two cases[2, 11] from ECG pad placement, in one study[1] from device activation and in another study[19] either from the prompt to commence CPR or, if compressions were initiated prior to this prompt, from the first compression. In the remaining cases the starting point was not explicitly specified.[3-5, 7, 9, 10, 14, 16-18, 20-24]

Minimum duration of interval

Nine out of twenty-one studies specified a minimum amount of data that had to be collected for the individual case to be included in analysis; in five studies it was at least 1 minute of data[7, 9, 16, 18, 21] while in one study[19] it was data from at least one compression cycle. Two studies required data from at least one shock[11, 20] whilst one study required at least 2 minutes of time synchronised CPR quality and end tidal carbon dioxide ($ETCO_2$) data.[24] In two studies,[2, 18] if there was more than 5 minutes of CPR provided by Emergency Medical Service (EMS) personnel prior to placement of ECG pads, the case was excluded.

DISCUSSION

Overall there was heterogeneity in how CPR quality data was collected and analysed across various studies that examined the association between CPR quality and cardiac arrest patient survival. Two thirds of studies considered data from the early portion of resuscitation; the majority using data from the first 5 minutes. One of the earliest studies[10] to do so argued that the first 5 minutes was thought to represent the best rescuer effort in terms of fatigue and also was considered the most important clinically. At the same time however this study[10] demonstrated that CPR performance, as defined by individual parameters including chest compression rate and depth, did not differ significantly throughout the episode. Several other studies demonstrated that the first five minutes of data were comparable to that for the entire episode,[15, 23, 25, 26 25 26] albeit with limited sample sizes ranging from n=20 to n=176. The use of shorter intervals in analysis allows for inclusion of more cases because it allows for inclusion of cases that do not have a complete dataset representing the entire resuscitation effort.

Kramer-Johansen et al.[8] defined the start of an episode as being "…the first therapeutic event after arrival at a patient in cardiac arrest, including first recorded chest compression, first defibrillator rhythm analysis, or first defibrillation". This definition allows for variation in local CPR protocols that may promote either a shock-first or CPR-first paradigm. In the studies that we examined, both first recorded compression and placement of ECG pads were the most common events to signify commencement of the analysis interval. We assume that in many EMS-attended resuscitations these events would occur seconds apart as most EMS protocols prioritise CPR and defibrillation above other interventions. In fifteen out of twenty-one cases however, the event signifying the start of an analysis interval was not explicitly defined.

In terms of the minimum amount of data required for analysis, the most frequently applied limit was for one minute of data. Again, by specifying such a limit, researchers can increase the number of cases available for analysis by including those that contain CPR quality measurement for only a proportion of the episode. For example, in a large study of compression depth by the Resuscitation Outcomes Consortium (ROC),[2] the authors analysed data from within the first 10 minutes of resuscitation, specifying a minimum requirement for one minute of data. However care should be taken when calculating parameters such as compression fraction to ensure that the short segment of data is truly representative of the remainder of the interval of interest, particularly if other interventions were carried out during the rescue effort that resulted in extended breaks that are not accurately captured by the short segment of data chosen for analysis. It is therefore recommended that researchers note the percentage of the total cohort made up of such short intervals, and, if indicated, perform sensitivity analyses based on their inclusion or removal.

In addition to variation observed in the intervals used for analysis, variation was also observed in the methods of analysis employed by studies, including whether CPR quality parameters were examined as continuous variables or categorically, and if so, how such categories were defined. Although there was notable heterogeneity in analysis techniques among studies, their description is beyond the scope of this short paper.

CONCLUSION

Across studies that explored the relationship between CPR quality and survival, we observed heterogeneity in the interval over which CPR quality data was analysed, the event that marked commencement of the analysis interval and the minimum amount of data required for inclusion. In order to more reliably make comparisons between studies, particularly for the purpose of answering clinical questions or formulating guideline recommendations, a standardized definition for the data analysis interval is recommended; one that maximises the amount of cases available for analysis without compromising the data's representability of the resuscitation effort.

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Table

Table: Summary of how CPR quality data was analysed across studies

No.	Study ID	Cases	Interval used for analysis of CPR quality vs. survival	Event to signify the start of the interval	Minimum amount of data required for inclusion in analysis
1	Abella 2005[11]	60	First 5 minutes	Not specified	Not specified
2	Babbs 2008[1]	695	All available episode data*	Device activation	Not specified
3	Beesems 2013[20]	199	The first and when available the last complete cycle of CPR	Prompt to “Start CPR” or, if compressions occurred before this, at the first compression	1 cycle
4	Bohn 2011[9]	300	All available episode data*	Not specified	1 minute
5	Camacho Leis 2013[22]	108	All available episode data*	Not specified	Not specified
6	Cheskes 2011[12]	815	Data from the first 3 shocks	ECG pad placement	Data for at least 1 shock
7	Cheskes 2014[21]	2006	Data from the first 3 shocks	Not specified	Data for at least 1 shock
8	Christenson 2009[7]	506	Minute interval during which first analysis performed and all recorded minute intervals before first analysis	Not specified	1 minute
9	Idris 2012[15]	3098	First 5 minutes	Not specified	Not specified
10	Idris 2015[6]	10371	First 5 minutes	First monitored compression	Not specified
11	Kramer-Johansen 2006[4]	284	All available episode data*	Not specified	Not specified
12	McInnes 2011[23]	24	All available episode data*	Not specified	Not specified[a]

13	Niles 2012[18]	35	First 500 chest compressions[b]	Not specified	Not specified
14	Sheak 2015[24]	583	All available episode data*	Not specified	Only cardiac arrest events that contained ≥ 2 minutes of time-synchronised CPR quality and $ETCO_2$ data were included
15	Stiell 2012[19]	1029	Minute interval during which first analysis performed and all recorded minute intervals before first analysis	Not specified	1 minute[c]
16	Stiell 2014[2]	9136	First 10 minutes	ECG pad placement	1 minute[c]
17	Sutton 2014[5]	87	First 5 minutes	Not specified	Not specified
18	Sutton 2015[17]	390	First 10 minutes	Not specified	1 minute
19	Vadeboncoeur 2014[3]	592	Whole resuscitation episode	Not specified	Not specified
20	Vaillancourt 2011[10]	2103	First 5 minutes	Not specified	1 minute
21	Wik 2005[16]	75	First 5 minutes	Start of first recorded chest compression	Not specified

CPR: Cardiopulmonary resuscitation; ECG: Electrocardiogram; ETCO2: End-tidal carbon dioxide

*Assumed from other information provided within the paper.

Further restrictions:

a. All CPR epochs lasting less than 30 s were excluded from analysis
b. The initial 5 chest compressions were excluded from analysis
c. Cases with >5 minutes of EMS CPR quality data before placement of AED pads were excluded.