



When minutes count—the fallacy of accurate time documentation during in-hospital resuscitation[☆]

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Abstract

The purpose of this study is to examine the commonly held assumption that time is measured and documented accurately during resuscitation from cardiac arrest in the hospital.

Methods: A two-pronged approach was used to evaluate the accuracy of time documentation and measurement. First, two existing databases—the National Registry of Cardiopulmonary Resuscitation (NRCPR) and a 240-bed hospital's repository of cardiac arrest records—were evaluated for completeness and accuracy of documentation on resuscitation records of times required for calculating the Utstein gold-standard process intervals—recognition of pulselessness to starting cardiopulmonary resuscitation (CPR), delivery of first defibrillation shock, successful intubation, and epinephrine (adrenaline) administration. Second, nurses from a 900-bed hospital were interviewed to determine timepieces used during resuscitations, and timepieces were assessed for coherence and precision.

Results: From the NRCPR database that included 10,689 pulseless cardiac arrests submitted by 176 hospitals, time data for calculating the Utstein intervals were missing for 10.9% of the interventions; negative intervals were calculated for 4%. From 232 consecutive resuscitation records from the 240-bed hospital, 85 records were identified from non-monitored units with staff who provided only CPR. Defibrillation, intubation and epinephrine administration were delayed until after arrival of advanced life support (ALS) responders; unlikely intervals of 0 min from event recognition to these ALS interventions were calculated for 11.5%. Sixty-seven nurses from the 900-bed hospital were interviewed; when documenting information during resuscitations, 21 (31.3%) reported using only patient room clocks, 30 (44.8%) only their watches, and 16 (23.9%) several timepieces. In all in-patient units in the same hospital, 241 timepieces (nurses' and physicians' watches, clocks in patient rooms, defibrillator clocks, central station monitors, and nursing station clocks) were compared to atomic time. The mean absolute time difference from atomic clock was 2.83 min (S.D. ± 5.9 min), median 1.88 min, and range 52.1 min slow to 72.85 min fast. There was no difference among timepieces ($P = 0.35$).

Conclusions: Missing time data, negative calculated Utstein gold-standard process intervals, unlikely intervals of 0 min from arrest recognition to ALS interventions in units with CPR providers only, use of multiple timepieces for recording time data during the same event, and wide variation in coherence and precision of timepieces bring into question the ability to use time intervals to evaluate resuscitation practice in the hospital. Practitioners, researchers and manufacturers of resuscitation equipment must come together to create a method to collect and document accurately essential resuscitation time elements. Our ability to enhance the resuscitation process and improve patient outcomes requires that this be done.

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1. Introduction

The cornerstone of resuscitation guideline development and ongoing process improvement activities is the gathering of complete and accurate information regarding events that occur in response to cardiac arrests [1–3]. The Utstein guidelines for reporting in-hospital resuscitation and the American Heart Association's National Registry of Cardiopulmonary Resuscitation (NRCPR), an in-hospital event registry, have identified four "gold-standard" cardiopulmonary resuscitation (CPR) interventions and process intervals that affect outcome and should be determined for all cardiac arrests [2,3]. These gold-standard intervals following recognition of pulselessness are: starting CPR within 1 min, delivering the first defibrillation shock within 3 min when ventricular fibrillation or pulseless ventricular tachycardia is the initial rhythm, intubating successfully within 5 min, and administering the first dose of intravenous or intraosseous epinephrine (adrenaline) within 5 min.

Implicit in these calculated intervals is the requirement to measure and document accurately the times of recognition of pulselessness, interventions and patient responses [2]. Actual variances from these gold-standard intervals should serve as a motivator to analyze critically internal systems and processes with the intent of improving resuscitation performance and outcome [3]. The purpose of this study is to examine the commonly held assumption that time is measured and documented accurately during CPR in the hospital setting.

2. Materials and methods

A two-pronged approach was used to address the issues of accuracy of time documentation and measurement. First, from two existing databases of in-hospital resuscitations—one from several hospitals in the American Heart Association's National Registry of Cardiopulmonary Resuscitation [3], the other from a single hospital—we evaluated the completeness and accuracy of documentation of interventions and times on resuscitation records. Second, in another hospital, we determined the timepieces used by nurses for documentation, and we assessed the coherence and precision of timepieces.

2.1. Completeness and accuracy of time data

2.1.1. Determining unusable time intervals

We reviewed records submitted by participants to the NRCPR for completeness and accuracy of time data. The NRCPR is an American Heart Association-sponsored, prospective, multi-site, observational study of in-hospital resuscitation [3]. Each hospital participating in NRCPR has a specially trained research coordinator who abstracts data from resuscitation records and patient medical records retrospectively. This data is transmitted to an NRCPR central data repository that facilitates data management and validation,

and provides hospitals with quarterly summaries of reports and comparisons of data from individual sites and groups.

From the NRCPR database, we reviewed data on 10,689 pulseless cardiac arrest events submitted by 176 hospitals over a 2-year period between 1 January 2000 and 31 December 2001. We calculated the gold-standard process intervals for patients who received chest compression, attempted defibrillation (when ventricular fibrillation or pulseless ventricular tachycardia was the initial rhythm), intravenous/intraosseous epinephrine, or endotracheal intubation. We determined the number of intervals from arrest recognition to intervention that could not be calculated because of missing time data, the number of negative calculated intervals (negative intervals), and the combined number of intervals that were not "usable" defined by either missing time data or negative intervals.

2.1.2. Determining time intervals of 0 min

Intervention times are usually documented in minutes only; therefore, when the documented intervention time is the same as event recognition time, the calculated interval equals 0 min. This interval of 0 min indicates that the intervention was performed within less than 1 min following recognition of the event.

In units in which patients are not monitored and where staff provide CPR only, the advanced life support (ALS) interventions of defibrillation, intubation and administration of epinephrine are provided solely by the ALS team after arrival at the unit. Intervals of 0 min from arrest recognition to these three ALS interventions would be unlikely. Because the NRCPR dataset from multiple hospitals does not include information about whether staff on each unit provide only CPR and not ALS, we could not identify in the NRCPR dataset the Utstein gold-standard intervals [2,3] of 0 min from records from units staffed with CPR providers only. For this evaluation we chose records from a single 240-bed, medical school-affiliated hospital where we knew the resuscitation response capability of each unit. We reviewed 232 consecutive resuscitation records from a 6-year period retrospectively between October 1993 and June 1998 from non-critical care areas, and identified 85 records from units staffed with CPR providers only. When times were documented in these records we calculated the gold-standard intervals and determined the frequency of time intervals of 0 min for each.

2.2. Timepieces used and coherence and precision of timepieces

In a 900-bed, urban academic medical center, we determined both the timepieces the nurses used for documentation during resuscitation, and the coherence and precision of those timepieces.

2.2.1. Timepiece used during resuscitation

Using a written survey distributed during ALS and basic life support courses, we surveyed a convenience sample of 67

nurses who had recorded data on resuscitation records. These nurses were asked to identify which types of timepieces they used for documentation during actual resuscitation events.

2.2.2. Coherence and precision of timepieces

We made unannounced visits over a 3-day period to 44 in-patient nursing units that included all medical/surgical units, intensive care units, and labor-and-delivery suites. Following the methods described by Cordell et al. [4], times to the second from a convenience sample of 241 timepieces (nurses' and physicians' watches, patient room clocks, defibrillator clocks, central station monitors and nursing station clocks) were recorded. When recording time from analog watches and clocks, the second hand was allowed to sweep to 12 in order to eliminate the difficulty in reading seconds. When recording from digital timepieces, seconds were included; when seconds were not available, the time that the minute first began was recorded.

At the same moment that time was recorded from each timepiece, the time on the standardized digital timepiece, a new digital watch that included seconds, was also recorded. The standardized watch was set to the time recorded on a radio-controlled clock using signals from the National Institute of Standard's U.S. Atomic Clock in Fort Collins, Colorado (atomic clock). The day before the multiple time sources were evaluated, the time on the standardized digital watch was checked every 1–2 h over a 12-h period with the atomic clock; there was no drift and the standardized watch remained accurate to the second. On each day that timepieces were evaluated, the standardized digital watch was checked with the atomic clock both before and after the time measurements; again there was no drift and the standardized watch remained accurate. The time recorded from each timepiece was compared to the time on the standardized digital watch; differences were calculated to the second. For calculation of means and medians, the absolute values of the time differences were used (all negative intervals were converted to positive) to avoid problem of negative (slow) and positive (fast) times canceling each other out.

Data were analyzed using descriptive statistics (mean \pm S.D., median, and range), two-tailed independent samples *t*-test for differences between two means, and one-way analysis of variance for evaluating differences among groups. Results were considered significant if $P \leq 0.05$.

3. Results

3.1. Completeness and accuracy of time data

3.1.1. Determining unusable time intervals

For the 10,689 events, there were a total of 26,888 interventions of chest compression, defibrillation, intubation and epinephrine administration. The calculated time intervals from arrest recognition to intervention were usable for only 22,884 (85.1%) interventions, and not usable because of missing time data or negative intervals for 4009 (14.9%) interventions. Times were missing for 2923 (10.9%) interventions and negative intervals were calculated for 1086 (4%). The breakdown for usable and unusable intervals due to missing times and negative intervals for each event is displayed in Table 1.

3.1.2. Determining time intervals of 0 min

There were 85 records identified from non-monitored units with staff who provided only CPR. Unlikely calculated intervals of 0 min from arrest recognition to defibrillation, intubation and epinephrine administration that were provided after arrival on the unit by ALS responders were calculated for 11.5%. The identified time intervals of 0 min for each intervention are displayed in Table 2.

3.2. Timepieces used and coherence and precision of timepieces

3.2.1. Timepieces used during resuscitation

Of the 67 nurses surveyed, 21 (31.3%) reported using only patient room clocks for recording times during resuscitation, 30 (44.8%) reported using only their watches, and 16 (23.9%) reported using one of several sources including patient room clocks, their watches, the defibrillator clocks and the emergency timers in patient rooms.

3.2.2. Coherence and precision of timepieces

A total of 241 timepieces from seven time sources were evaluated and compared to atomic time. The mean absolute difference from atomic time was 2.83 min (S.D. \pm 5.9 min) and the median absolute difference was 1.88 min. The range was 52.1 min slow (a defibrillator clock) to 72.85 min fast (a patient room analog clock). Excluding these two outliers, the mean absolute difference for the remaining 239 timepieces

Table 1
Unusable calculated gold-standard time intervals in the NRCPR database

Gold-standard interval	Number of events	Time intervals not usable	
		Missing times	Intervals negative
Recognition of pulselessness to start of CPR	10141	1218 (12)	440 (4.3)
Recognition of pulselessness to first attempted defibrillation	2528	180 (7.1)	35 (1.4)
Recognition of pulselessness to first successful intubation	5539	774 (14)	11 (0.2)
Recognition of pulselessness to first iv/io epinephrine	8680	751 (9)	600 (6.9)

The values given in parentheses are percentages; iv/io: intravenous or intraosseous.

Table 2
Calculated gold-standard intervals of 0 min^a in units where staff provided only CPR

Gold-standard interval	Times available to calculate intervals	Intervals of 0 min ^a
Recognition of pulselessness to start of CPR	68	50 (73.5)
Recognition of pulselessness to first attempted defibrillation	7	3 (43)
Recognition of pulselessness to first successful intubation	55	2 (3.6)
Recognition of pulselessness to first iv/io epinephrine	69	10 (14.5)

The values given in parentheses are percentages; iv/io: intravenous or intraosseous.

^a Times documented in minutes only; an interval of 0 min is equivalent to less than 1 min.

Table 3
Variations from atomic time for nurses' watches, defibrillator clocks and patient room clocks that may be used for time recording during resuscitation

Timepieces	Number	Mean \pm S.D.* (min)	Median (min)	Range (min)	Slow	Fast	Exact
Nurses' watches	73	2.40 \pm 2.35	1.97	-11.3 to +10.63	31 (42)	42 (57.5)	0
Defibrillator clocks	30	4.58 \pm 9.20	2.54	-52.1 to +7.5	16 (53.3)	13 (43.3)	1 (3.3)
Patient room clocks	66	3.11 \pm 8.84	1.86	-3.17 to +72.85	16 (24.2)	50 (75.8)	0

The values given in parentheses are percentages; S.D.: standard deviation; -: slow; +: fast.

* $P=0.35$ (ANOVA).

was 2.33 min (S.D. \pm 2.03 min) and the median absolute difference was 1.87 min, with a range of 11.3 min slow to 11.8 min fast (see Fig. 1). Compared to atomic time, 73.4% of time sources varied by 1 min or more, 28.2% by 3 min or more, and 10% by 5 min or more. Ninety-one (37.8%) were slow and 149 (61.8%) were fast. The page-operator digital clock was 4.77 min fast. Only once out of 241 measurements (defibrillator clock) was any timepiece accurate to the second.

Of the 241 timepieces, 195 (81%) were analog and 46 digital (19%). There was no difference in the mean absolute difference between analog and digital timepieces (2.60 min versus 3.86 min, respectively; $P=0.30$). Table 3 displays the variations from atomic time for nurses' watches, defibrillator clocks and patient room clocks, the timepieces the nurses reported that they used for time recording during resuscitation. There was no significant difference among the three timepieces ($P=0.35$). Sixty-three (37.3%) of the 169 were slow, 105 (62.1%) were fast; only 1 timepiece was exact overall (0.6%).

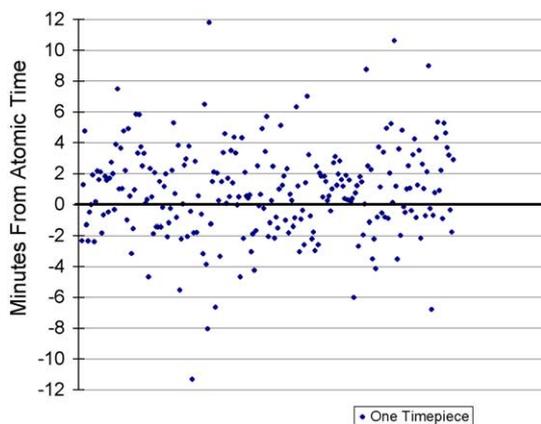


Fig. 1. Coherence and precision of 241 timepieces—deviations from atomic time. Zero represents actual atomic time.

4. Discussion

These data demonstrate substantial problems regarding the completeness and accuracy of time documentation for in-hospital resuscitations. Many data points were not documented. Some calculated intervals were unreasonable or impossible. Finally, we found that nurses might use several timepieces during resuscitation, and that there was substantial variation in the coherence and precision of commonly used timepieces.

We identified missing time data elements in 10.9% of the records. The gold-standard intervals cannot be calculated if time data are missing. In addition, many of the time intervals were unreasonable or impossible. Time intervals from recognition of the arrest to initiating CPR can be 0 min (i.e. less than 1 min) in areas with on-site CPR-trained personnel. However, intervals of 0 min from recognition of the arrest to the first attempted defibrillation, recognition to successful intubation, and recognition to administration of epinephrine are only possible in a unit staffed with ALS providers. In these units with only CPR-trained personnel, the intervals of 0 min for advanced life support interventions are improbable because the interventions could not be provided before arrival of the responding ALS resuscitation team. Negative intervals between recognition and interventions are impossible.

We found that more than one time source might be used for documentation of time; and timepieces in the hospital are unsynchronized, often differ substantially from atomic time, and there is a wide variability of times displayed. Intervals calculated from data points obtained from more than one timepiece used for documentation during an event can result in unreasonable 0 min and negative time intervals. These findings suggest that during resuscitation documentation of time may be inaccurate.

There are several challenges to accurate documentation of time during resuscitation. In the hospital, cardiac arrest situations are highly stressful events [5–8]. The discovery of

the patient in cardiac arrest often initiates a flurry of chaotic activity [5]. Nurses' experiences have been described as frightening, scary, overwhelming, frustrating, or stressful [6–8]. First priorities are initiating CPR and obtaining resuscitation equipment, not documentation. The resuscitation record usually arrives with the resuscitation equipment, and the staff member who documents the event on the record may arrive several minutes after the pulseless patient was discovered and the resuscitation initiated.

In one study, 49% of 199 nurses reported discomfort with documentation and this discomfort was reduced to only 36% of 89 nurses after mock emergency call training [9]. The time that the event was recognized and CPR started may be estimated, or documented after the fact when someone else is completing the form; but perception of time is often distorted by the stress of the event. Wong et al. asked 47 nurses and physicians during a period of routine work to estimate time by saying when 5 min had elapsed without making reference to clocks or watches. Their ability to estimate a 5-min interval accurately was poor. Estimates ranged from 1 min 46 s to 8 min 41 s [10].

The use of multiple unsynchronized timepieces adds to the problem. Brown et al. reported that nurses were eager to hand off their tasks to another during an event [9]. The person who discovers the event might use a watch or the wall clock for time of recognition, whereas each person who subsequently is responsible for documentation might use one or more different watches or clocks. Finally, there is the possibility that the time was determined accurately, but incorrectly written on the record or omitted entirely.

Unlike the hospital setting, problems with accurate time documentation are well known in the pre-hospital environment [4,11–14]. In 1991, Becker et al. published a study in which 39% of the Chicago emergency medical services (EMS) cases reviewed had time discrepancies [11]. The authors report that a number of cases contained time data that indicated EMS had been called even before the patient had collapsed. Recognizing the impossibility that the events

occurred in the manner documented, the authors call for the development of methods to more accurately document time.

In 1992, Cordell et al. point out considerable variation in documentation of time in one EMS system [4]. This study examines the differences among 152 time sources in an emergency medical system when compared to time from the atomic clock. They report a range of 12 min 34 s slower to 7 min 7 s faster than standard time—a potential for variance as great as 19 min 41 s.

In 1998, noting that erroneous time documentation of emergency treatment caused by variation in the accuracy of timepieces has profound medical, medico-legal, and research consequences, Ornato et al. confirm the variation of critical timepiece settings in an urban emergency care system [12]. The authors implemented a prospective program to improve time synchronization of 393 timepieces used by firefighters, paramedics, emergency physicians and nurses. Before a one-time synchronization of the 393 timepieces to atomic time, the mean error between the devices was 2.0 min. One month after the synchronization, the mean error had improved to 0.9 min. The effect of a one-time synchronization event, however, was found to be short-lived. After 4 months, the mean variation had returned to 1.7 min. Once again, the authors call for the development of strategies to address the critical issue of accurate time documentation.

Lerner et al. compare atomic time with the time on timepieces used by 23 ambulance, fire and police dispatch centers. Time differences ranged from –551 to 117 s. They conclude this time difference may be clinically significant for time-dependent research, quality improvement tasks, or medial legal reviews when multiple timepieces are used [13].

Spaite et al. report a model for EMS systems by in-field observation of specific time intervals in pre-hospital care. However, the problems demonstrated with time documentation confounds the ability to use these intervals for systems comparisons [14].

Table 4

Types and capabilities of devices used for recording times of event onset, interventions and patient responses during resuscitation

Type of device	Can show actual event onset time	Can show event recognition time	Can show intervention and patient response times	Provides accurate interval calculations (if same device is used throughout resuscitation)	Can be synchronized to atomic clock
Bedside rhythm strip	Yes	Yes	Yes	Yes	Yes
Room clock	No	Yes	Yes	Yes	Yes
Watch on person recognizing arrest	No	Yes	Yes	Yes	Yes
Defibrillator clock	No	No	Yes	Yes	Yes
Emergency timer on wall in patient room	No	Yes	Yes	Yes	NA
Crash cart clock/timer	No	No	Yes	Yes	Yes
Electronic resuscitation record	No (yes, if synchronized to bedside monitor)	No	Yes	Yes	Yes

NA: not applicable.

There are several types of devices that are used in the hospital for recording times of event onset, interventions and patient responses during resuscitation. The devices and their capabilities for recording time accurately are summarized in Table 4.

A problem remains, however. In the unmonitored, unwitnessed arrest, the actual time of onset of the arrest cannot currently be determined. Only in the monitored or witnessed arrest can actual onset time be known. Current gold-standard target intervals that are specified in Utstein guidelines [2] are calculated from *recognition* of the arrest. Time of recognition may not be the time of arrest onset for the unmonitored and unwitnessed patient. The time before arrest recognition may confound outcome, even if the recognition-to-intervention interval is short.

In Guidelines 2000, the recommended 3-min interval from recognition to defibrillation was based on pre-hospital *witnessed* arrests [1,15,16]. A mechanism is needed to identify arrest onset (true zero time) for all in-hospital arrests, monitored, witnessed, unmonitored and unwitnessed. An expensive solution is to provide ECG monitoring for all patients. Other options should be explored. Nevertheless, even for patients with unknown time before recognition of arrest, the intervals from event recognition to intervention for not only defibrillation, but also the other gold-standard intervals can still be used as targets to measure process. Processes can be modified as needed to meet the targets.

5. Conclusions

The Utstein guidelines imply that clock accuracy and synchronization can be a major problem in resuscitation research [2]. Although this problem has been identified in several pre-hospital studies, we have confirmed that inaccurate time measurement and documentation occur during in-hospital resuscitation as well.

In the high stress situation of resuscitation following cardiac arrest when times are not documented at all, when times are estimated or recorded retrospectively, or when multiple unsynchronized timepieces are used, subsequent interval calculations will be invalid. Facilities need to have accurate measurement of their gold-standard time intervals. Further, they must validate them as reasonably reflective of actual practice. This will allow them to focus on process improvement activities if actual intervals do not meet gold-standard targets.

It is now time for practitioners, researchers, and manufacturers of resuscitation equipment to come together to create a usable method to collect and report essential resuscitation time elements accurately. Our ability to enhance the resuscitation process and improve patient outcomes requires that this be done. Minutes *do* count!

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