Differences in Documented and Actual Medication Administration Time in the Emergency Department: A Prospective, Observational, Time-Motion Study

Authors: Titus de Hond, MD[1], Bob Keuning, MD[1], Jan Jelrik Oosterheert, MD, PhD, Wietske Blom-Ham, MSN, PhD, Lisette Schoonhoven, MSN, PhD, and Karin Kaasjager, MD, PhD, Utrecht, CX

Contribution to Emergency Nursing Practice

- Early treatment improves outcomes for many patients of the emergency department. This knowledge is mainly based on retrospective time-to-treatment analyses, using the medication documentation time from the electronic health record.
- The observed medication administration time differed from the documented time in the electronic health record. This time difference was more pronounced for sicker patients. Our findings suggest that retrospective time-to-treatment studies may be prone to measurement bias.
- Our findings should be kept in mind when evaluating retrospective studies concerning time-to-treatment analyses, especially with sicker patients. In addition, future time-to-treatment studies should aim to measure actual medication administration time, instead of using retrospective data from the electronic health record.

Abstract

Introduction: Retrospective studies suggest that a rapid initiation of treatment results in a better prognosis for patients in the emergency department. There could be a difference between the actual medication administration time and the documented time in the electronic health record. In this study, the difference between the observed medication administration time and documentation time was investigated. Patient and nurse characteristics were also tested for associations with observed time differences.

Methods: In this prospective study, emergency nurses were followed by observers for a total of 3 months. Patient inclusion was divided over 2 time periods. The difference in the observed medication administration time and the corresponding electronic health record documentation time was measured. The association between patient/nurse characteristics and the difference in medication administration and documentation time was tested with a Spearman correlation or biserial correlation test.

Results: In 34 observed patients, the median difference in administration and documentation time was 6.0 minutes

Titus de Hond is Medical Doctor, Division Acute Medicine, Department of Internal Medicine, University Medical Centre Utrecht, Universiteit Utrecht, Utrecht, Netherlands. **ORCID identifier:** https://orcid.org/0000-0002-0475-9925.

Bob Keuning is Medical Doctor, Division Acute Medicine, Department of Internal Medicine, University Medical Centre Utrecht, Universiteit Utrecht, Utrecht, Netherlands.

Jan Jelrik Oosterheert is Associate Professor, Division Infectious Diseases, Department of Internal Medicine, University Medical Centre Utrecht, Universiteit Utrecht, Utrecht, Netherlands.

Wietske Blom-Ham is Nurse, Department of Emergency Care, University Medical Centre Utrecht, Universiteit Utrecht; and Nurse, Institute of Nursing Studies, University of Applied Sciences, Utrecht, Netherlands. **ORCID identifier:** https://orcid.org/0000-0002-2916-9403.

Lisette Schoonhoven is Professor of Nursing Science, Department of Public Health, Healthcare Innovation & Evaluation and Medical Humanities (PHM), Julius Center Research Program Methodology, Universiteit Utrecht, Utrecht, Netherlands. **ORCID identifier:** https://orcid.org/0000-0002-7129-3766.

Karin Kaasjager is Professor of Acute Medicine, Division Acute Medicine, Department of Internal Medicine, University Medical Centre Utrecht, Universiteit Utrecht, Utrecht, Netherlands. **ORCID identifier:** https://orcid.org/0000-0001-6958-8285.

Authors Titus de Hond and Bob Keuning contributed equally to this manuscript.

For correspondence, write: Titus de Hond, MD, Heidelberglaan 100, 3584 CX, Utrecht, Netherlands; E-mail: t.a.p.dehond@umcutrecht.nl.

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[1] de Hond and Keuning contributed equally to this manuscript.

(interquartile range 2.0-16.0). In 9 (26.5%) patients, the actual time of medication administration differed more than 15 minutes with the electronic health record documentation time. High temperature, lower saturation, oxygen-dependency, and high Modified Early Warning Score were all correlated with an increasing difference between administration and documentation times.

Discussion: A difference between administration and documentation times of medication in the emergency department may be common, especially for more acute patients. This could bias, in part, previously reported time-to-treatment measurements from retrospective research designs, which should be kept in mind when outcomes of retrospective time-to-treatment studies are evaluated.

Key words: Time and motion studies; Time-to-treatment; Emergency department; Electronic health records; Emergency nurses

Introduction

Early administration of medication in the emergency department is essential when treating life-threatening diseases such as myocardial infarction or sepsis. A delay in administration of medication could have an impact on survival.[1-4] Hence, in the case of sepsis, the Surviving Sepsis Campaign recommends administering broad-spectrum antibiotics immediately when sepsis is recognized or otherwise at least within 1 hour.[5] Nevertheless, studies in this field report door-to-antibiotics or time-to-antibiotics times ranging from 70 minutes to 166 minutes.[1,6-8] Moreover, in 2 systematic reviews, two-thirds of all patients received antibiotics in excess of 1 hour.[9,10] Treatment-focused literature on thrombolysis, asthma, analgesics, and other diseases frequently report time-to-treatment times and observe that delays in treatment are associated with worse prognosis.[11-13] There are different time intervals that can be used for evaluating time-to-treatment times, as shown in Figure 1. Studies differ in the interval used to describe time-to-treatment.[9,10,14-16] Reported medication administration delays in previous studies may not be solely explained by actual delayed administration alone (eg, owing to ED crowding). Alternative causes are likely to influence the delays in time-to-treatment as well.[14-16] Inconsistent time point measurements could be a significant factor in time-to-treatment estimates and the recommendations based on these estimates. First, most studies have retrospective designs, in which, consequently, the reported administration time of the medication is based on the time that is documented in the electronic health record (EHR). This method introduces measurement error as a risk of bias.[17,18] Approximately 53% of the research articles in emergency medicine are chart review studies.[19] Particularly for emergency departments where automatic barcode scanning or other technology for automatic EHR documentation time are not in use, there could be a difference in actual medication administration time and documentation time in the EHR by nurses. Because some studies may assume that medication documentation time is equal to medication administration time, the implications when interpreting the literature are variable. Second, different studies use different time starting points for documentation of these time periods (eg, arrival time, prescription time, or triage time), resulting in differences in reported time-to-treatment times.[9,10,20-22] By using different starting points, the studies are difficult to compare. To clarify these issues, there is a need for direct observational studies evaluating the factors contributing to a delay in the time to administering antibiotics.[15] In the currently published research literature, only 2 observational studies have reported prospective time-to-treatment measurement.[23,24] However, both studies did not actually compare medication documentation time with medication administration time. Roman et al[23] described the effects of a hospital-wide reform to improve timely delivery of antibiotics, while Miner et al[24] only investigated the effects of oral vs intravenous opioids on medication times. Furthermore, nurses in both previous studies were not blinded for the study objective. Therefore, the nurses in these studies could have behaved differently than they normally would (eg, more accurate documentation of medication), a source of bias commonly known as the Hawthorne effect.[25] Thus, a gap in the existing literature exists to determine if a difference in administration and documentation times results in biased time-to-treatment analyses. To address this gap in the published literature, the purpose of the present study was to explore differences between observed medication administration time and medication documentation time and test associations in the observed time differences with patient and nurse characteristics. As an initial and exploratory study, we hypothesized that there would be a difference between administration and documentation times and that this difference would be influenced by patient and nurse characteristics.

Methods

STUDY DESIGN AND SETTING

A prospective observational, time-motion study in the emergency department of the University Medical Center Utrecht

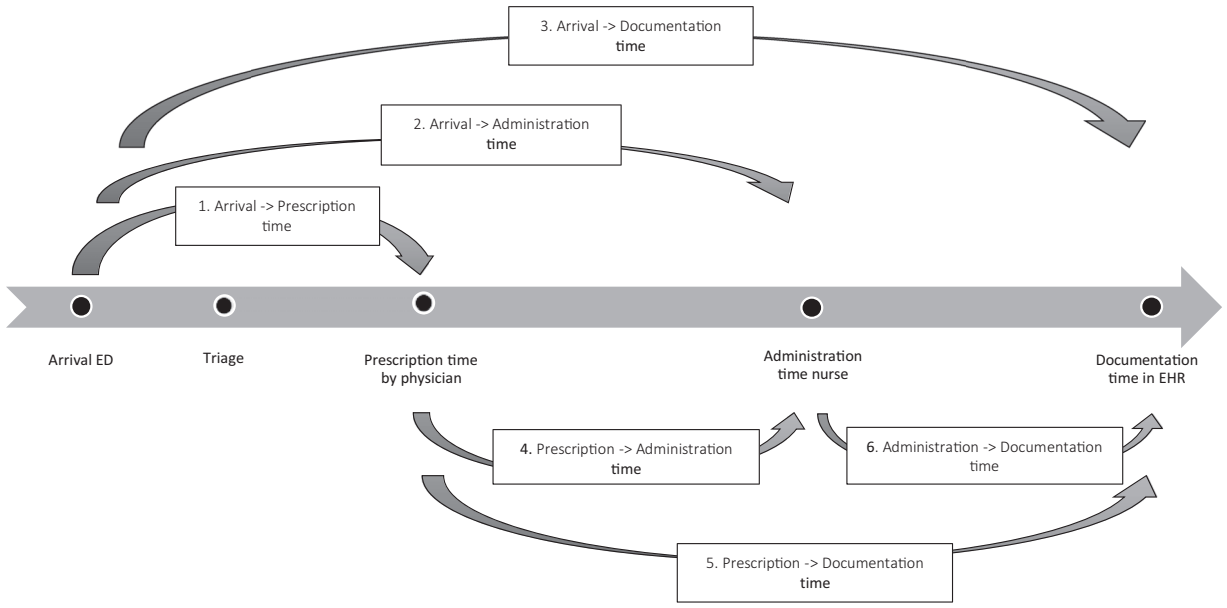

FIGURE 1

Time-to-treatment time intervals in the emergency department. Documentation time was defined as the time that was charted as given. ED, emergency department; EHR, electronic health record.

was conducted using 6 observers as data collectors. The University Medical Center Utrecht is a 1042-bed tertiary care center in the Netherlands, with more than 23 000 ED attendances per year. This emergency department was open 24/7. The study protocol was reviewed and approved by the Medical Ethics Review Committee Utrecht (reference number WAG/mb/19/038516).

POPULATION

The study population consisted of patients in the emergency department and emergency nurses. All patients in the emergency department were eligible to participate in this study if informed consent was obtained. All patients who did not agree to participate in this study were excluded. For nurses to be eligible to participate in this study, a participant must have met all of the following criteria: be a trained emergency nurse, work in the emergency department at the study site and have agreed to participate in this study. Emergency nurses who did not meet the inclusion criteria were excluded from participation in this study.

PROCEDURE

As an initial, exploratory study without intervention, no specific effect was expected. No sample size was calculated beforehand. We aimed for 100 patients for initial data and to ascertain sample sizes for future work. The initial study to ensure protocol feasibility was performed from February 2019 until March 2019. Patient case record forms were completed during this time to collect data on patient characteristics. No data were collected on nurse characteristics during this initial period. Subsequently, the full study was planned from February 2020 until April 2020, but had to be terminated prematurely in March owing to the coronavirus disease 2019 (COVID-19) pandemic.

Data collectors, trained in Good Clinical Practice,[26] shadowed and observed 1 emergency nurse during a working shift to register the several time periods. Working shifts lasted from 2 PM until 10:30 PM or 3 PM until 11:30 PM. The observed shifts in this study were all evening shifts on weekdays.Selecting evening shifts were methodologically justified as the busiest time in the emergency department.[27] Emergency nurses were instructed to continue working as they would normally do, when not being followed. To mimic real-life situations and avoid a Hawthorne effect, nurses were blinded for the study purpose. All participating nurses gave written informed consent for being shadowed without knowing the exact reason for this. In addition, all patients were asked for written informed consent to be observed by 1 of the observers.

Case record forms were used to collect the following data of all new patients who entered the emergency

department: age, sex, medical specialty, referring physician, triage color (as described in the Emergency Severity Index),[28] first vital signs, low or high care needs, arrival time, hospital admission (ward, medium care or intensive care) or discharge to home, and time of ED discharge. Furthermore, when medication was prescribed by the treating physician, the following data were documented: type of medication, route of medication administration, prescription time by the treating physician, time of actual administration of medication to the patient, and documentation time in the EHR. From the collected vital signs, the first Modified Early Warning Score (MEWS) at the emergency department was calculated. According to literature, the best cut-off value for the MEWS score to predict morbidity and mortality is 3.[29] Except for observed medication administration, if portions of the required data were not available at the moment of collection, the case record form data were supplemented within 24 hours using the EHR of the patient.

Nurse characteristics were collected through the case record forms. By means of a nurse survey, the following data were collected: number of years working experience in the emergency department, busyness of the working shift as experienced by the nurse, and number of patients during the shift. By lack of an official measurement for working shift busyness, a scale (1-10) was used. On this scale, 1 represented no busyness at all, whereas 10 was the busiest shift a nurse could imagine.

TABLE 1

Baseline characteristics of all patients in the emergency department that received medication (N = 34)

Patient characteristics	Median or n	IQR or (%)
Demographics		
Age, y, median, IQR	63.5	54.3-74.3
Female (%)	18	(52.9)
Referring physician		
General practitioner (%)	12	(35.3)
General practice center (%)	2	(5.9)
Medical specialist (%)	7	(20.5)
Own initiative (incl. ambulance) (%)	13	(38.2)
Other (%)	0	(0)
Triage color		
Blue (%)	0	(0)
Green (%)	4	(11.8)
Yellow (%)	18	(52.9)
Orange (%)	11	(32.4)
Red (%)	1	(2.9)
ED department		
Low care (%)	17	(50.0)
High care (%)	17	(50.0)
Vital signs		
Temperature,°C, median, IQR	37.2	36.8 -37.6
Heartrate/min, median, IQR	89	72-99
Systolic blood pressure, mm Hg, median, IQR	133	116-149
Diastolic blood pressure, mm Hg, median, IQR	71	65-82
Respiratory rate/min, median, IQR	18	16-24
O_2 saturation, % SpO_2, median, IQR	97	95-98
O_2 treatment (%)	7	(20.6)
Discharge to		
Home (%)	9	(26.5)
Ward (%)	18	(52.9)
Medium care (%)	2	(5.9)
Intensive care (%)	2	(5.9)
Other hospital (%)	3	(8.8)
MEWS ≥3 (%)	7	(20.6)
Admission form		
Intravenous (%)	16	(47.1)
Oral (%)	11	(32.4)
Inhalation (%)	2	(5.9)
Rectal (%)	1	(2.9)
Subcutaneous (%)	1	(2.9)
Sublingual (%)	1	(2.9)
Other (%)	2	(5.9)

IQR, interquartile range; MEWS, Modified Early Warning Score; O_2, oxygen.

PRIMARY OUTCOME

The main study end point was the difference in observed medication administration and documentation times. Documentation time was defined as the time that was charted as given. For patients who received multiple medications, the cumulative difference between administration and documentation times was calculated and divided by the total amount of prescriptions. To clarify, the mean difference for each patient was used for our analyses. Thus, the unit of analysis was per patient. An additional per medication analysis (without taking the mean) was also performed and is summarized in Supplementary Table 1. Furthermore, for all medications administered to the patients observed, the following time intervals were calculated: the ED arrival time to prescription time, ED arrival time to actual administration time, ED arrival time to documentation time, prescription time to actual administration time, prescription time to documentation time, and actual administration time to documentation time (Figure 1).

OTHER VARIABLES

Secondary outcome parameters were patient characteristics and emergency nurse characteristics associated with the aforementioned difference in actual administration and documentation time. In addition, we investigated whether this time difference was influenced by route of medication administration.

TABLE 2
Time intervals observed for all medications administered (N = 34)

Time interval	Duration in min-median	IQR	Minimum and Maximum time in min
1. Arrival to prescription time	99	38-153	Min: −45 Max: 323
2. Arrival to administration time	121	44-162	Min: 5 Max: 335
3. Arrival to documentation time	130	68-174	Min: 14 Max: 345
4. Prescription to administration time	12	6-19	Min: 2 Max: 230
5. Prescription to documentation time	16	9-32	Min: −4 Max: 230
6. Administration to documentation time	6	2-16	Min: −18 Max: 138

Min indicates minimum observed time interval and Max indicates maximum observed time interval.
IQR, interquartile range.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 25.0 (IBM Corp, Armonk, NY).[30] Medians and interquartile ranges (IQRs) were expressed for continuous variables if non-normally distributed. Otherwise means and standard-deviations were used. For categorical variables, proportions were used. To compare groups, a chi-square test was used for categorical variables, whereas a Mann-Whitney U test was used for continuous variables.

A Spearman's correlation test was used to investigate a correlation between several continuous/ordinal variables and the administration-documentation time. A correlation between dichotomous variables and the administration-documentation time was analyzed using a biserial correlation test. Data were analyzed with and without outliers.

Results

In total, 20 nurses were approached for informed consent, of whom 18 nurses (90%) were willing to participate. This resulted in the observation of 18 evening working shifts of 18 emergency nurses. During these shifts, 82 patients were treated of whom 34 patients (41.5%) received medication during their stay in the emergency department. Patients who received medication were more often admitted in the hospital (73.5% vs 45.8%, χ^2 = 6.24 P = .01) and had lower oxygen saturation levels than patients who did not receive medication (median 97% vs 98% SpO_2, U = 484.50, P = .03). Baseline characteristics of patients who received medication are shown in Table 1. Additional patient descriptions about the medical specialty referred to and the number of medications administered per patient are summarized in Supplementary Table 2.

In Table 2, the medians of the different time intervals observed in this study are shown (see Figure 1 for the conceptualization of time intervals). The median difference in administration and documentation times was 6.0 minutes (IQR 2.0-16.0). A difference between administration and documentation times of more than 15 minutes was observed for 9 (26.5%) patients. The maximum difference between administration and documentation times was 138 minutes. In 27 (79.4%), the documentation time was later than the actual administration time (median difference 5.0 minutes IQR 2.0-16.0) and in 7 (20.6%), it was earlier (median difference 2.0 minutes IQR 2.0-10.0). In 3 patients (8.8%), the door-to-treatment time based on the EHR was at least 1 hour, whereas the actual door-to-treatment time was less than 1 hour.

Figures 2 and 3 show several patient characteristics and their association with difference in actual medication administration and documentation times. High MEWS, receiving oxygen therapy, low blood oxygen saturation levels, and high body temperature were significantly associated with increasing differences in the documentation time compared with the observed administration time. For all other collected patient characteristics (sex, heart rate, respiratory rate, blood pressure, referring physician, triage color and high care needs), no association was found. In addition, the median difference between actual administration and documentation times for patients with MEWS at least 3 was significantly higher than for patients with MEWS less than 3 (median 5.0 minutes [IQR

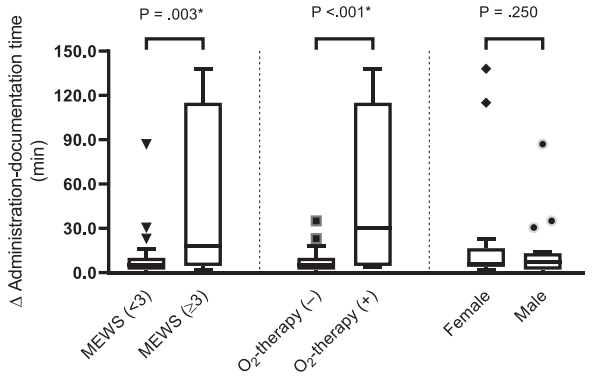

FIGURE 2

Patient characteristics and the correlation with the difference between actual administration and documentation times. Boxplots (median + IQR) are shown for MEWS, need for oxygen therapy, and sex. A MEWS ≥3 (18.0 minutes [4.5-115.0] vs 5.0 minutes [2.0-10.0]) and need for oxygen therapy (30.6 minutes [4.5-115.0] vs 5.0 minutes [2.0-10.0]) were significantly associated with an increased difference in actual medication administration and documentation times. Sex (male = 7.1 minutes [2.0-13.19] vs female = 5.5 minutes [3.88-16.5]) did not influence the difference between those times (point-biserial correlation test). IQR, interquartile range; MEWS, Modified Early Warning Score; O_2, oxygen.
*P < .05.

2.0-10.0] vs median 18.0 minutes [4.5-115.0]). No relationships were observed in the sensitivity analysis with outliers removed from the data (Supplementary Table 3 and Supplementary Figures 1 and 2).

Table 3 shows the different nurse characteristics of the nurses who participated. In 18 nurses, the median years of working experience in the emergency department was 6.0 years (IQR 3.0-15.0). Shift busyness was rated with a median of 4 (scale 1-10). The median number of patients cared for per shift was 5. There was no association between any of the nurse characteristics and differences in the administration and documentation times. This result was replicated when the outliers were removed (Supplementary Table 4).

Finally, the median difference between actual administration and documentation times was not influenced by route of medication administration (Supplementary Figure 3).

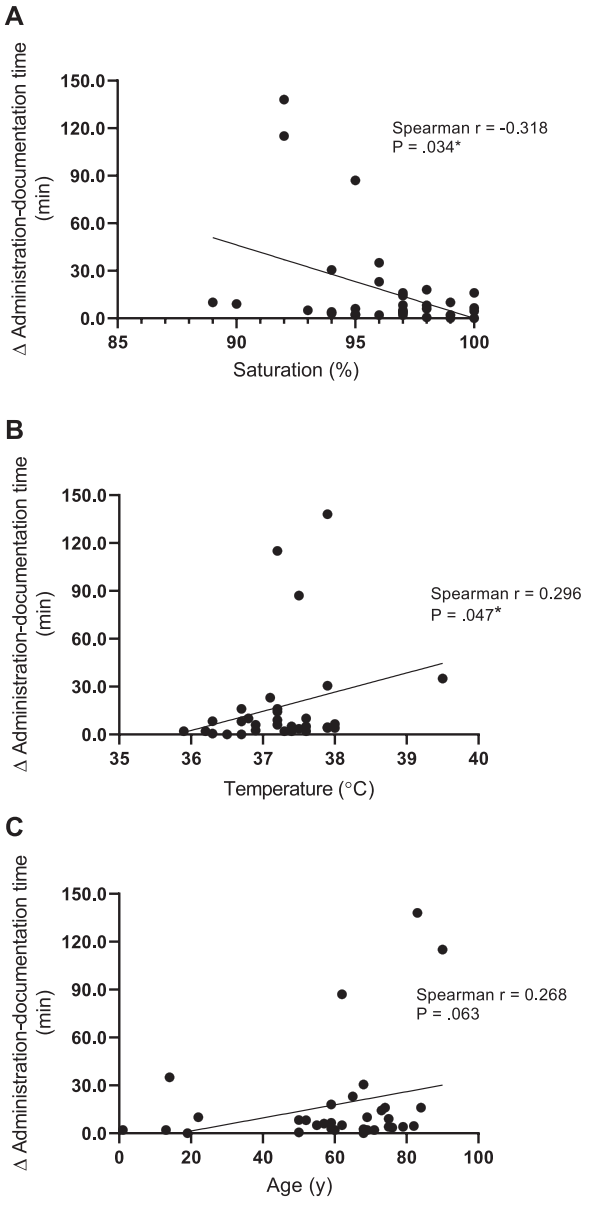

FIGURE 3

Spearman r rank correlation plots of (A) blood oxygen saturation, (B) temperature, and (C) age correlated to the difference in actual medication administration and documentation times. Saturation is significantly negatively correlated, whereas temperature is positively correlated to the difference between administration and documentation times. It shows an insignificant correlation between age and inconsistency in the administration and documentation times.
*P < .05.

Discussion

This is the first study, to our knowledge, to prospectively investigate whether there is a difference in the actual administration and documentation times of medication given in the emergency department. In half of the patients, the observed administration time of medication was more than 6 minutes discrepant with the documentation time of the medication in the EHR. Although a median difference of 6 minutes in half of the patients might not seem very high, this difference is still more than 15 minutes for 25% of the patients.

TABLE 3
Nurse characteristics and correlation with difference in administration and documentation time (n = 18)

Nurse characteristics	Median	IQR	Spearman R-coefficient	*P* value
Working experience (y)	6.0	3.0-15.0	0.05	.42
Shift busyness	4.0	3.0-8.0	0.03	.45
No. patients per shift	5.0	3.0-6.0	−0.10	.34

IQR, interquartile range.

Furthermore, there was a correlation between receiving oxygen therapy, low blood oxygen saturation levels, high body temperature, and a high MEWS (≥3) and an increasing difference between the administration and documentation times. These results may be interpreted that the care for sicker patients makes accurate documentation of the medication times more challenging. On several occasions, medication was documented in the EHR before it was administrated to the patient, indicating bias in both delayed timing and potential for the actual event not truly occurring as documented when working with retrospective collected data. Altogether, these results show a clear discrepancy between the actual medication administration and documentation times in the emergency department. Therefore, we infer that this difference introduces a risk of bias in retrospective time-to-treatment research, most pronounced in severely ill patients.[1,6–13] To further clarify the associations of the variables we tested, a multivariate model is recommended in future studies. Owing to the initial and exploratory nature of the current study with a small sample size, the multivariate model was considered beyond the scope of this article.

Our results were not replicated when outliers were removed. However, outliers are a part of clinical practice and cannot be removed from clinical operations. In a larger cohort, we anticipate outliers would still influence the results. In our cohort, most of the outliers were acutely ill (Figures 2 and 3). Since these critically ill patients have a large impact on daily practice, we intentionally included outliers in the main report of our analyses.

The currently published time-to-treatment studies focused on medications needed to treat the most acute conditions.[1,11,12] The medication prescribed to patients in our present study included a broader range of prescribed medical treatments than previously measured. For instance, we considered the administration of sodium chloride intravenously as administration of medication. Sodium chloride is used in the timely treatment of conditions, such as dehydration, in the emergency department, and its administration is documented in the EHR. The inclusion of fluids and other nonacute medications in this study could explain why the arrival to documentation time was longer in our present study than in some other studies (57.0-71.9 minutes).[1,7]

There are several ways to improve the accuracy of the documentation time in the EHR, including education for staff on existing guidelines, weekly e-mail reminders of the existing guidelines, EHR interface design changes, and standards of care for certain medical conditions or medications.[12–14,31–33] In addition to these improvements, the observed differences in this study could also be decreased by implementing better ways of monitoring the actual moment of administration of medication. For example, it is unknown if using barcoded medication administration or smart, EHR communicating intravenous systems for intravenous treatment would produce different results.[34,35] These automated methods are susceptible to nurse workarounds, such as not scanning the barcodes at all or scanning multiple medications for multiple patients at once.[36,37] These workarounds may defeat the purpose of implementing the technology, namely to reduce medication errors and adverse drug events. To counter these workarounds, these technologies should be as user friendly as possible, and further observational study as we designed is warranted to fully understand the problem and needed improvements.[38]

Methods of future time-to-treatment studies would be improved by observing actual medication administration time, instead of using retrospective data from the EHR. Studies that focus on the differences in treatment times could also focus solely on acutely ill patients, given our findings indicated that differences in the medication times of these patients were more pronounced. We recommend future studies could also combine the data on ED crowding with the observed time differences to give a more complete analysis of factors influencing medication administration and documentation differences.

Limitations

The present study, being exploratory and the first of its kind, has several limitations related to the dataset, variables, procedures, and setting. A small patient sample size of 82 patients was further decreased with only 40% of patients who received medication. The planned second study period was terminated early owing to the start of the COVID-19 pandemic. Since this termination was implemented for priority infection control preventative reasons and the hospital did not see patients with COVID-19 already at the time of termination, we do not expect that the treatment of patients with COVID-19 otherwise influenced our analysis. We did not collect data on the nurse characteristics during the initial study period. Although we acknowledge our study could lack statistical power to identify nurse characteristics influencing the administration-documentation time, the correlation coefficients were close to 0 on the data we did have available to test. Although this missing data was a limitation, prioritizing collecting and testing nurse characteristics in future study was not indicated by our results.

Our results should be interpreted with study procedure limitations in mind. Because the analysis was a combination of 2 different study time periods, it is possible that there were unmeasured differences between the first data collection period and the second. However, we were unaware of any major changes in workflow or personnel at the study site. Our results have limited generalizability as we only observed shifts in the evening and on weekdays.[27] Our results need to be interpreted in this context as compliance with guidelines may shift during the day.[39] Furthermore, owing to our study design of observing the nurses instead of the patients, actual patient medication administration could be missed if a colleague and not the observed nurse administered the medication, such as when the observed nurse was on a break. We attempted to minimize the influence of the Hawthorne effect by blinding the nurses for the actual study purpose. Nevertheless, it is possible that the nurses modified their behavior when observed by the data collectors.[25] Despite this limitation, direct observation was, to our opinion, the most optimal option to achieve the most reliable and robust results.[40]

Finally, the study setting may limit generalizability. ED crowding is a factor that influences time-to-treatment times in the emergency department.[16] In this study, we only measured nurse perception of business and did not collect objective measures of workload or crowding in the study context. No automatic devices such as barcode scanners were used by the emergency nurses in our study. Therefore, our findings are only generalizable for hospitals that work in a similar setting with manual medication documentation.

Implications for Emergency Clinical Care

The observed differences in administration and documentation times of medication in the emergency department may have several implications when evaluating the existing literature in this field and determining quality metrics of emergency care. Our results indicated that there may be substantial bias in retrospective time-to-treatment research designs using EHR data instead of observing the actual administration time. Therefore, the results of this study could explain that measurement bias is at least 1 factor in delays or longer time-to-treatment times reported in the published literature.[1,6–16] Our data show an association between the severity of the patient condition and the difference in the administration and documentation times.[9,10,14] Thus, in sepsis research and quality benchmarks, if a patient in a retrospective EHR study appears to have received medication in excess of 1 hour from arrival, our results indicated that the patient could have actually received the medication earlier.

Therefore, several recommendations can be made. Emergency nurses should consider not pre-documenting medications before they are actually given. Automated technology at the practice site is likely to increase reliability of the documented medication times but is vulnerable to workarounds. Finally, a note could be created in the EHR when documentation is delayed after administration to improve accuracy.

Conclusions

In this first of its kind, prospective, observational study, the actual administration time of medication and the documentation time in the EHR did not correspond in a significant part of the observed patients. This discrepancy should be kept in mind when evaluating retrospective studies concerning time-to-treatment analyses. Owing to the small sample size and generalizability limitations of this current study, future studies are required to advance and strengthen our findings.

Author Disclosures

Conflicts of interest: none to report.

The study protocol was reviewed and approved by the Medical Ethics Review Committee Utrecht (reference number WAG/mb/19/038516).

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jen.2021.07.002.

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