Uncovering Discrepancies in IV Vancomycin Infusion Records between Pump Logs and EHR Documentation

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Abstract

Background Infusion start time, completion time, and interruptions are the key data points needed in both area under the concentration–time curve (AUC)- and trough-based vancomycin therapeutic drug monitoring (TDM). However, little is known about the accuracy of documented times of drug infusions compared with automated recorded events in the infusion pump system. A traditional approach of direct observations of infusion practice is resource intensive and impractical to scale. We need a new methodology to leverage the infusion pump event logs to understand the prevalence of timestamp discrepancies as documented in the electronic health records (EHRs).

Objectives We aimed to analyze timestamp discrepancies between EHR documentation (the information used for clinical decision making) and pump event logs (actual administration process) for vancomycin treatment as it may lead to suboptimal data used for therapeutic decisions.

Methods We used process mining to study the conformance between pump event logs and EHR data for a single hospital in the United States from July to December 2016. An algorithm was developed to link records belonging to the same infusions. We analyzed discrepancies in infusion start time, completion time, and interruptions.

Results Of the 1,858 infusions, 19.1% had infusion start time discrepancy more than $\pm$10 minutes. Of the 487 infusion interruptions, 2.5% lasted for more than 20 minutes before the infusion resumed. 24.2% (312 of 1,287) of 1-hour infusions and 32% (114 of 359) of 2-hour infusions had over 10-minute completion time discrepancy. We believe those discrepancies are inherent part of the current EHR documentation process commonly found in hospitals, not unique to the care facility under study.

Conclusion We demonstrated pump event logs and EHR data can be utilized to study time discrepancies in infusion administration at scale. Such discrepancy should be further investigated at different hospitals to address the prevalence of the problem and improvement effort.

Keywords
- clinical documentation
- electronic health record
- process improvement
- linkage process
- workflow

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Background and Significance

Vancomycin is the most prescribed antibiotic in pediatric intensive care units (PICUs) in U.S. hospitals.[1] However, the treatment is often reported to be subtherapeutic.[2–4] Optimal vancomycin treatment is challenging to achieve due to its narrow therapeutic window and high interindividual variability. Therefore, therapeutic drug monitoring (TDM) is recommended to optimize individual treatment effect, especially for patients who receive prolonged treatment, have unstable renal function, changing physiological conditions, or higher risk of developing nephrotoxicity.[5,6]

Almost exclusively administered through intermittent IV infusion, vancomycin serum concentration is monitored over time during TDM using either the area under the concentration–time curve (AUC) estimate or trough-based pharmacokinetic (PK) model. Inaccurate timestamps of infusion administration or blood draw directly contribute to preanalytical errors in both AUC estimate and PK model, resulting in potentially wrong dosing/timing decisions and even lead to patient harm.[7,8] A recent study revealed that most vancomycin-related safety events occurred during the administration and monitoring process, resulting in medication errors including dose omission, delay, or improper dose.[9] Erroneously timed trough blood draw was significantly affecting the quality of the TDM process and solutions have been proposed to improve it.[7,10,11] However, little was known about the timing issue associated with other steps involved in IV vancomycin administration, despite that IV infusion administration is an error prone process.

Procedural and documentational deviations in IV infusion administration have been identified in an average of 16.7% of a total number of over 3,000 observed IV infusions in studies in England and the United States through direct observations.[12,13] Incorrect or missing infusion start time documentation ranges from 1 to 31% across 16 hospital trusts in England.[13] In our previous study in a single-site hospital, we also observed time discrepancies between the start times on infusion pumps and the timestamps documented in the electronic health record (EHR), the latter are used for TDM decision making.[14] In general, direct observation is effective to characterize workflows or identify process gaps in clinical settings.[12–15] However, this resource intensive method makes it challenging to implement on a larger scale. It can also be subject to bias in either data collection or interpretation as the behaviors being observed may be affected, known as the Hawthorne effect.[16,17]

As more digital devices are used in modern clinical environments, they can provide alternative sources to assess health care processes.[18,19] One such technology is the smart infusion pump system. Smart infusion pumps automatically record granular information of each infusion activity such as infusion start, pause, completion, or transition. They also record time lapse and the amount of dose infused during each segment of an infusion. One study has used smart infusion pump records to detect dose discrepancies between prescription orders and actual medication administration for nine continuous IV infusion medications.[18] Another study compared infusion administration records in the EHR with pump data linked to patients via pump serial numbers, discovering several incidences of documentational start time discrepancy for IV antimicrobial medications which could have affected the clinical dose decisions.[20] In clinical practices, clinicians rarely have access to pump data, despite the fact that it automatically records care delivered to patients in real time. Through comparing these two datasets, insights on care delivery and process improvement for IV infusion administration may be provided.

Objectives

The objective of this work was therefore to analyze timestamp discrepancies between EHR documentation (the information used for TDM decision making) and pump event logs (the true administration process) for vancomycin treatment. We primarily focus on the discrepancy in timestamps documented in both systems with regard to the same infusion, as the deviation in time may lead to suboptimal data used to make therapeutic decisions.

Methods

Vancomycin Administration and TDM Processes

Vancomycin is usually administered through secondary infusion. Nurses scanned vancomycin labels (where the administration start time entered into EHR) and patient wristband to match patients with orders. They then proceeded to enter pump settings such as infusion volume and rate before the information used for vancomycin TDM decisions and the actual infusion activity. Unlike the EHR administration timestamps entered through nurses scanning vancomycin labels, the start timestamps in the pump were recorded when nurses click 'Start' button on the pump device and activating the infusion through pump (the actual infusion start time automatically captured and recorded by the pump), which more accurately reflect the actual infusion administration that patients receive. These sequences of administration processes may be interchangeable or interrupted depending on nurses workflow.[14] Physicians or pharmacists further made TDM dose adjustment decisions based on EHR documentation unless otherwise specified. Both infusion start time and completion time were needed to make a TDM decision (details of TDM decision making were provided in **Supplementary Material S1**, available in the online version); However, only the start times were recorded in the EHR and pharmacists usually guesstimate infusion completion time based on documented start time and the predefined infusion duration (usually it is 1 or 2 hours for vancomycin). By comparing these two systems, we aimed to reconstruct the true infusion administration events and identify deviations between information used in TDM decisions (based on the EHR data) and the actual IV delivery (i.e., shown by the infusion pump data).

Process Mining Approach

Process mining utilizes event logs to gain insights about processes. It can be used to study sequences of events to

understand the standard processes and detect deviations. There are established algorithms and software used in the business field to improve processes and services. Recently, it has been applied in health care to improve clinical pathways and usually event logs from one single information system were used.[21–23] In this study, we utilized data from two record systems: event logs from the infusion pump and documented administration records from the EHR, to reconstruct the infusion events and understand discrepancies regarding IV vancomycin administration documentation.

Datasets

The datasets used for this study were from a children's hospital in the Midwest in the United States between July 1 and December 31, 2016.

We included all IV vancomycin administrations for patients who received at least one vancomycin dose in the pediatric intensive care unit and the relevant patient data in the EHR. A total of 2,576 administration records associated with 138 encounter IDs were extracted. The smart infusion pump event logs were extracted from their BD Alaris System infusion pump system for all the vancomycin infusions in the neonatal intensive care unit, PICU, and general pediatric units. It consisted of 10,471 unique infusion start records associated with 459 pump PC units (PCUs). We included all 10,471 start records in the linkage process but later excluded those without pump state coded as "completed" or "transitioned" in the series of pump logs from the time discrepancy analysis as they were deemed incomplete. Infusion "completed" indicates that the infusion was completed as programmed, whereas infusion "transitioned" indicates that the pump switched back to the primary IV line from a secondary IV line upon its completion (and, vancomycin is usually administered as a secondary infusion). The study was approved by Purdue University IRB (Protocol #1704019117).

Linking EHR Records and Pump Event Logs

Because the EHR and smart infusion pumps are not interoperable in every hospital, it is difficult to obtain infusion data with exact patient ID in both datasets. We therefore applied entity resolution principles to link such records.[24–30] A series of logs concerning an infusion process was recorded with the same infusion ID to indicate multiple pump states during the infusion, such as infusion started, restarted, paused, alarmed, completed, etc. Logs indicated infusion starts were used to link with their corresponding EHR records in the linkage process. The rest were reserved for the analysis of time discrepancies. Key EHR variables used for linking included: (1) encounter ID, (2) infusion administration time, (3) dose, and (4) patient weight. Pump variables included were: (1) infusion ID, (2) pump PCU serial number, (3) infusion start time, (4) dose, and (5) patient weight. Ideally, one unique EHR administration should link to only one unique infusion pump start record. This was the basis of our proposed algorithm for linking the same infusion of the two datasets.

►Fig. 1 describes the workflow of the linkage algorithm. The algorithm was set to only compare pump records with timestamps within ±6 hours of the EHR timestamps and doses within ±30% of the EHR doses. A similarity score for each common variable (i.e., timestamp, dose, patient weight) and a composite similarity score were computed by the Gower similarity measure for each pair of EHR and pump record.[31] A higher similarity score indicated a smaller difference between the recorded values in both datasets. We further analyzed association between records that is less likely to occur by chance by identifying doses administered through the same pump PCU, clustered in time, of the same dosing amount, and/or of similar or same patient weight. A high association suggested that a pump PCU was very likely used for the same patient throughout the treatment or within a relatively short period of time. Therefore, we determined a true linked pair of the EHR documented infusion and pump infusion start event by not only the pairwise similarity but also the number of times a PCU is associated with each encounter. That is, if the pairwise similarity of a record pair is low but the pump PCU was used for many other doses for the same encounter within a similar time window, it is likely that this pair is also a true link. Details are provided in the **Supplementary Material S1** (available in the online version). We conducted a sensitivity analysis with a series of simulated datasets to understand the linkage performance under different data quality levels by introducing discrepancies in administration timestamps, patient weights, and doses.

Analysis of Discrepancies between EHR Documentation and Pump Event Logs

All pump logs associated with each linked infusion start log with the same infusion ID were used for time discrepancy analysis. This provided us with granular information regarding all pump states during the infusion.

We defined discrepancy as the difference between EHR documentation and pump logs, as illustrated in ►Fig. 2. The impact of such discrepancy can affect clinical decisions, as the simulation of vancomycin concentration–time curve shown in ►Fig. 3.

- Start time discrepancy was defined as the difference between the timestamp in the pump start log and the EHR record. For infusions with pump state as "Infusion delayed" chronically right after the "Infusion started," the timestamp used in the discrepancy analysis was adjusted to that of "Infusion started" or "Infusion restarted" right after the "Infusion delayed," which indicates the actual start time of the infusion.
- Completion time discrepancy was defined as the difference between the timestamp of pump "completed" or "transitioned" record and the estimated infusion completion time, which is defined as the EHR administration time plus the programmed infusion duration in the pump setting.
- Infusion interruption was defined as the pump state coded "stopped," "alarm," "paused," or "delayed" in the pump log, with duration of more than 1 minute before resolution.

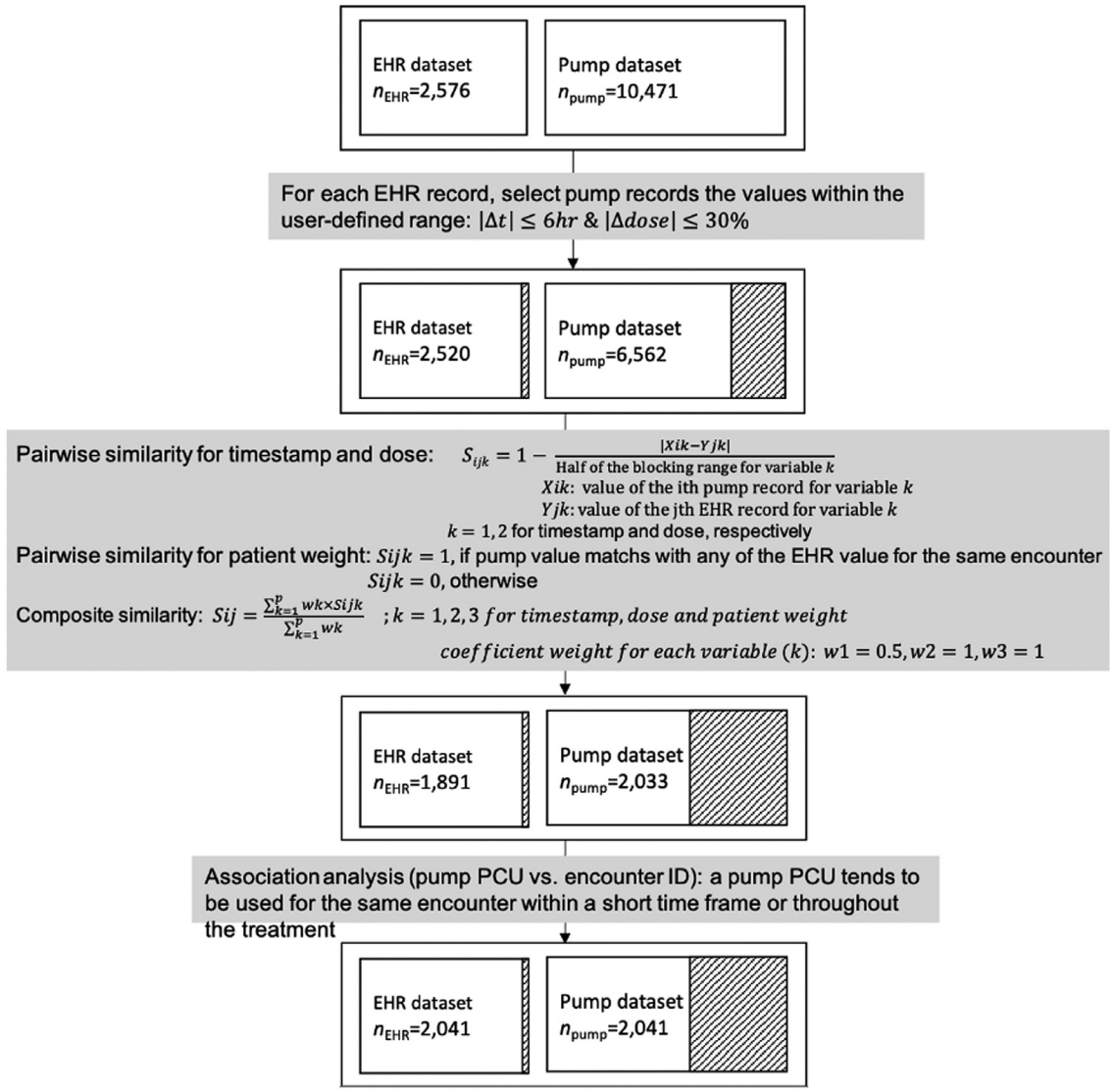
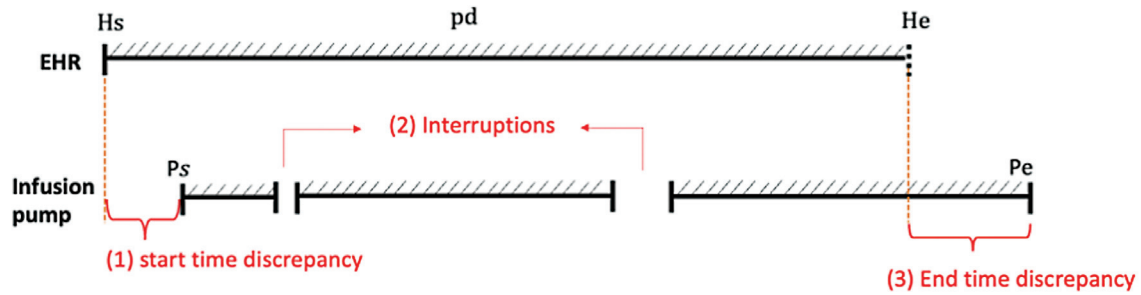


Fig. 1 Workflow of the linkage algorithm and number of records in each dataset after key steps.



Hs: manually documented administration time in the EHR
pd: predefined infusion duration
He: *estimated* infusion completion time

Ps: infusion start time recorded in the pump
Pe: infusion completion time recorded in the pump

Fig. 2 Illustration of the timestamps documented in the EHR and in the smart infusion pump. EHR, electronic health record.

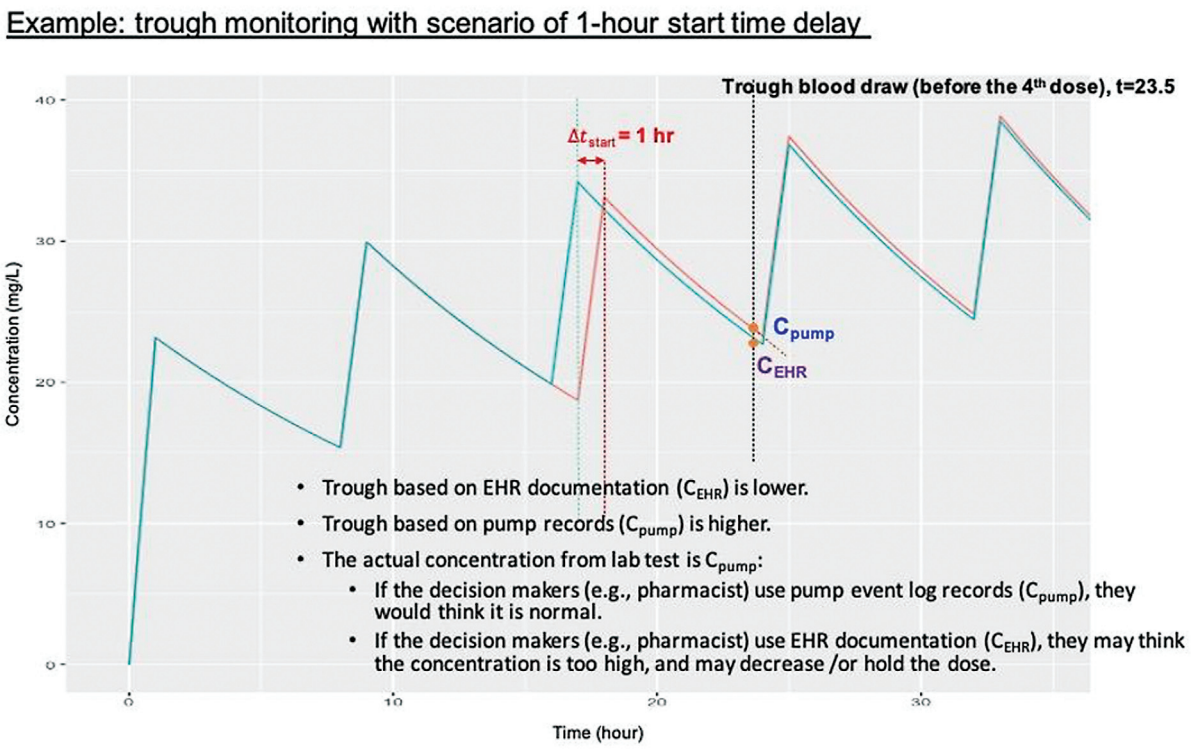


Fig. 3 A simulation of 1-hour infusion start time delay on vancomycin concentration time curve.

Results

The algorithm successfully linked 2,041 EHR records of the 2,576 records (linkage rate of 79%) with their associated pump event logs (2,041 from 10,471 pump events). Of those linked records, 183 incomplete infusions were excluded and the remaining 1,858 pairs were included for the time discrepancy analysis.

Discrepancies between EHR Documentation and Pump Event Logs

Our analysis revealed a start time discrepancy ranging from −124 to 194 minutes, which is smaller than the exclusion criteria (±6 hours) in the first step of algorithm. The median start time discrepancy is 3 minutes, with 80.9% (1,503 of 1,858) within ±10 minutes as shown in ►Fig. 4. Only 5.9% (110 of 1,858) of the pump start timestamps were the same as EHR timestamps. The majority, 68% (1,264 of 1,858) of the pump timestamps, had minor time discrepancy with either up to 10 minutes later than the EHR timestamps or earlier (6.9%, 129 of 1,858). A total of 38 (2%) pump start timestamps were more than 10 minutes earlier than the EHR timestamps, and 317 (of 1,858, 17%) pairs had pump start timestamps more than 10 minutes later.

A total of 487 infusion interruptions were identified (►Table 1). Most interruptions were resolved within 10 minutes, only 14 of them were more than 20 minutes (►Fig. 5). The data also showed that interruptions occurred randomly during an infusion (►Table 2).

We analyzed completion time discrepancy for programmed infusion duration of either 1 hour (1,287 infusions) or 2 hours (359 infusions) in the pump setting. Of the 1-hour infusions, 75.8% (975 of 1,287) had less than 10 minutes discrepancy, whereas 68% (245 of 359) of the 2-hour infusions were within the same range (►Supplementary

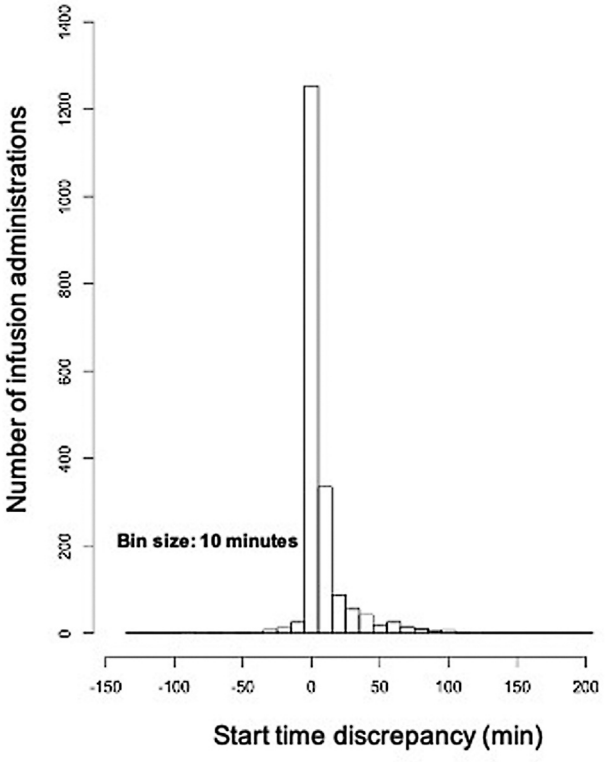


Fig. 4 Infusion start time discrepancy.

Table 1 Interruption frequency of the total 1,858 unique vancomycin administrations

Number of interruptions	Number of unique infusions (Percentage %)
0	1,371 (73.8%)
1	284 (15.3%)
2	91 (4.9%)
3	57 (3.0%)
4	21 (1.1%)
5	20 (1.1%)
6	9 (0.5%)
7	5 (0.3%)
8	2 (0.1%)
11	5 (0.3%)
18	1 (0.0%)

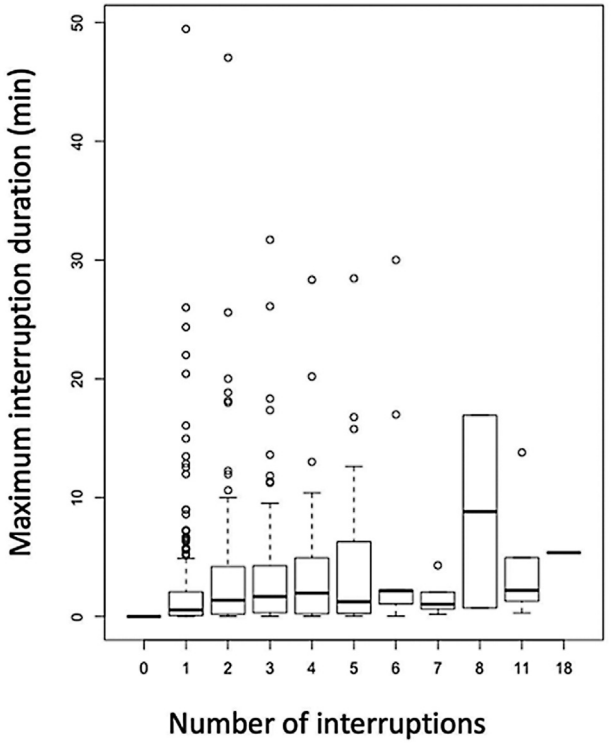


Fig. 5 Number of interruptions and the maximum duration.

Appendix A, available in the online version). It also appeared to be affected by interruptions. Only 47.1% (111 of 236) of the infusions with interruptions were completed within 10 minutes from the estimated completion times, whereas 77.2% (1250 of 1620) of the infusions without interruptions were in the same range (►Supplementary Appendix B, available in the online version).

Discussion

This research aimed to investigate the conformance between information used in vancomycin TDM decisions (EHR documentation) and the actual infusions that patients received (the pump event log), with an emphasis on events timestamps.

Discrepancy between EHR Documentation and Pump Logs and Potential Contributing Reasons

As aforementioned, following a typical administration process, several steps are involved between timestamps documented in EHR (when the nurse scans the vancomycin label on the infusion bag) and timestamps captured in the infusion pump event log (when the nurse clicked the start button on the infusion pump).[14] This may explain that 68% (1,264 of 1,858) of pump recorded start time with a delay of 10 minutes compared with the EHR documentation. Fewer pump start timestamps were earlier than the EHR timestamps (6.9%, 129 of 1,858). One possible scenario is when the patient was already on vancomycin for a period of time with a dedicated infusion line and the nurse was familiar with the patient and his/her doses. Therefore, to complete both the vancomycin trough laboratory and the drug administration tasks efficiently at once, the nurse may decide to draw the blood sample, match vancomycin label with the patient, hang and activate the new bag of vancomycin infusion on the pump before proceeding to enter administration information into the EHR. Interruptions occurred in 12.7% (236 of 1,858) of the infusions. Typically, nurses only interrupt vancomycin infusion for an urgent clinical request. For example, sometimes, a patient acutely needs a sedation

Table 2 Interruption timing for 1-h and 2-h infusions

Interruption timing (Percent into the infusion)	1-h infusion (total 1,287 infusions with 346 interruptions)		2-h infusion (total 359 infusions with 141 interruptions)	
	Time range into an infusion (min)	Number of interruptions; Percentage of the total interruptions	Time range into an infusion (min)	Number of interruptions; Percentage of the total interruptions
0–25%	0–15	476; 37%	0–30	38; 27%
25–50%	15–30	283; 22%	30–60	30; 21%
50–75%	30–45	244; 19%	60–90	32; 23%
75–100%	45–60	283; 22%	90–120	41; 29%

medication. With a limited number of infusion lines available, nurses may interrupt vancomycin to give the sedation medication through the same line. Our results in start time discrepancy were similar to that of Roydhouse et al,[20] in which the start time discrepancy for vancomycin was less than 20 minutes (range 2–293 minutes). Using a 1-month dataset of 371 vancomycin infusions, they found 9.4% of the infusions having a delay greater than 60 minutes. Our observed median start time discrepancy was 3 minutes (range −124, 194 minutes) with 10.4% of delay exceeding 60 minutes, for a total of 1,858 infusions over 6 months. These similar observations indicate potentially a common occurrence of imprecise infusion timestamps of various degrees in the EHR.

Through examining records for one-to-one matching, the algorithm also identified patterns with larger time discrepancy that may reflect issues in IV infusion administration processes which should be addressed through organizational effort. The first pattern concerned administrations of back-to-back vancomycin infusions was recorded in the pump logs and only one was documented in the EHR (►Supplementary Appendix C, available in the online version). Vancomycin is usually administered at prescribed intervals and nurses must set up the secondary infusion bag that is delivered to the patient room based on the verified order in the EHR. Therefore, it is unlikely that two doses were administered back-to-back and only one was documented in the EHR. One suspected reason could be the incorrect setup of secondary infusion for the first documented dose. In this scenario, it is possible that the roller clamp of the secondary tubing was not released successfully and thus the pump was actually drawing fluid from the primary infusion bag.[32] This can result in the actual vancomycin infusion only started 1 hour after the EHR documented timestamp, as shown in ►Supplementary Appendix C (available in the online version). Infusion delay can also be associated with discrepancy between EHR documentation and the actual infusion start time. As shown in the example in ►Supplementary Appendix D (available in the online version), the infusion only started 35 minutes after the EHR documentation. On the other hand, it can cause potential confusion if both administrations were documented in the EHR to reflect the actual situation, as shown in the example in ►Supplementary Appendix E (available in the online version).

Implications for IV Vancomycin Administration Practice and Future Research

Potential Impacts of Time Discrepancy on Clinical Decisions and Patient Safety

Erroneously timed trough concentrations can lead to incorrect vancomycin dose calculation and clinical decisions. Early drawn trough concentrations were reported in 43% of the samples in a large academic medical center study.[7] This resulted in significantly higher vancomycin concentrations (22.1 ± 11.7 mg/L vs. 15.5 ± 8.6 mg/L; p-value <0.001). Consequently, clinicians were more likely to decrease, discontinue, or hold patient's dose (25.6 vs. 21.4%, p-value$<$ 0.02).[7] Similarly, discrepancies in infusion administration documentation may lead to inaccurate information being used for TDM decisions and pose a risk on patient safety due to preanalytical error.[8] Our study shows that EHR documented timestamps do not always reflect the true infusion administration time, and many were out of the 10 minutes tolerance that clinical pharmacists typically expect based on their experience.[14] Such discrepancy can impact the quality of clinical decisions regarding treatment effect for the patient and the subsequent dose adjustment. Moreover, as illustrated in the example in ►Supplementary Appendix C (available in the online version), given the secondary infusion was not administered at the prescribed time, vancomycin concentration in the patient body may drop below the desired concentration level and result in subtherapeutic concentration. In addition, such scenario can potentially cause serious patient harm as the primary medication may be given to the patient at a rate intended for the secondary infusion.

Concerns in IV Infusion Documentation Consistency

The consistency of documentation practice should be further investigated too. The algorithm identified 35 cases with infusion delays in the beginning of the process through pump logs (as the example shown in ►Supplementary Appendix D, available in the online version), and only 10 of them had the corresponding EHR timestamps adjusted to the actual infusion start times. Inconsistent documentation practice may also cause confusion and introduce errors, as shown in ►Supplementary Appendix E (available in the online version). Two doses were documented at 22:05 p.m. and 22:40 p.m. in the EHR for the same patient. However, the pump logs indicated that the infusion was attempted to be administered at 22:06 p.m. and due to the delay, it only started at 22:40 p.m. As vancomycin is usually administered intermittently at prescribed intervals, these EHR documentations can appear to be very confusing to the pharmacists when making TDM decisions. It is unlikely that vancomycin would be administered within such short intervals (in this case, 35 minutes between 22:05 and 22:40 p.m.); additional communication effort between pharmacist and nurses may be required to resolve this confusion. This imprecision in documentation thus can increase clinician's workload, introduce errors during the communication process, potentially delay the dosing decisions, and eventually weaken clinicians' trust on the information entered in the EHR. It also raises the question of who may have the authorization to change an event timestamp that has already been entered in the EHR, and how changes or annotations can be made in the EHR that may not cause more problems. Moreover, it also raises concerns whether physicians or pharmacists who make the TDM decisions were consistently informed of the occurrences of such events.

Current and Future Vancomycin TDM Practice

The newly revised consensus vancomycin TDM guideline suggests using AUC monitoring in clinical practices.[6] AUC indicates the cumulative exposure to vancomycin for a defined time period, for example, 24 hours. Instead of one

serum concentration for trough monitoring, which is observed from our collected data, two concentrations are now required to calculate the AUC value. Even with this new approach, infusion start time and completion time are still required to estimate the AUC value, and, thus, it is of the same importance to understand the accuracy of the information documented. Nowadays, clinical decision support (CDS) tools for vancomycin TDM have been increasingly recommended to enable individualized precision dosing, and they are most likely to utilize data entered in the EHR to inform dosing decisions.[33–36] Imprecise drug administration records can thus have a great impact on optimally delivering individualized dosing. The smart infusion pump system of our dataset was not interoperable with the EHR system at the time of this study. Interoperability between these two systems has proved beneficial in reducing pump manual programming errors and increasing the accuracy of infusion dose and documented rate changes.[37,38] Clinical pharmacists also responded positively to the accuracy of infusion administration data used for clinical decisions, according to a study in an adult ICU setting.[38] This simply implies that the accuracy of infusion-related timestamps documented in the EHR can be improved if such is auto-documented in the pump and then carried over to the EHR. We foresee the value of future studies that evaluate the benefits and risks of a closed-loop system on infusion timestamps documentation and its impact on the TDM decision making process as well as the accuracy of corresponding therapeutic decisions.

Application of Process Mining

In this study, we demonstrated how multiple clinical information systems can be used to (1) understand the discrepancy between information in clinical documentation and in automated data logs, and to (2) discover unexpected behaviors in the infusion administration process or issues in documentation policy that should be addressed and improved through organizational effort. The same approach can be used to investigate such discrepancies for other antibiotics of concern with similar infusion administration processes. As more digital devices and information systems are being used for care delivery, strategies to harness useful insights from different data sources can be beneficial for improving the quality of care.

Study Strength and Limitations

This study provided an approach to review the discrepancies occurred throughout infusion administration processes at scale that may not be feasible through traditional observation methods. It also avoids potential human behavior changes during the observation that can easily compromise the quality of data (i.e., the Hawthorne effect[39]). One limitation of the study was that the data was extracted from a specific EHR and smart pump systems. Characteristics pertaining to these two electronic systems, clinical workflows, and documentation process at the study site may be unique factors of our analysis results. However, we believe this approach can be applied to study other EHR and smart pump vendor systems. Future study of a larger scale of such discrepancies in vancomycin and/or other antibiotic TDM processes can reveal more insight. Lastly, we did not have access to the clinical data beyond vancomycin administration, and thus unable to evaluate the impact of such time discrepancies on TDM decisions and patient outcomes.

Conclusion

We demonstrated the approach of utilizing the EHR infusion administration data and smart infusion pump logs to explore time discrepancies between the EHR documentation and true infusion administrations for IV vancomycin. Moreover, we discovered deviations on complying with administration and documentation policy that should inform about future organizational effort for improvement. We suggested future research efforts to advance approaches of utilizing logs from different medical systems to learn valuable insights for treatment of interests. Through identifying gaps, we cannot only improve clinical workflows but also strengthen the insights for health information systems design to better integrate with the workflows.

Clinical Relevance Statement

Clinicians are expected to make vancomycin TDM decisions and enable individualized dosing with the help of model-informed CDS tools in the future; however, time discrepancy between EHR documentation and true infusion administration was rarely discussed in the literature and it can undermine the accuracy of those models (AUC or PK), impacting clinical decisions. Despite different TDM practice models or tools used across different hospital organizations, the accuracy of EHR administration data entered through nurses' workflow is of similar documentational concern. Without a full understanding of systemic embedded errors and effective solutions developed for such discrepancies, it is uncertain that model-informed precision dosing for vancomycin using the EHR data will have the treatment effectiveness that we expect.

Multiple Choice Questions

1. When examining procedural or documentation discrepancies in intravenous infusion administration, which of the following can be used to compare with the medication administration records in the EHR?
   a. Event logs stored in the smart infusion pump system.
   b. Diagnosis in the EHR.
   c. Discharge information in the EHR.
   d. Laboratory results in the EHR.

   Correct Answer: The correct answer is option a. As mentioned in the study, smart infusion pump event logs document granular infusion information that reflect the exact infusion start time, any discontinuities during the infusion, and the exact infusion completion time. Through comparing documentations in both systems regarding the same infusion administrations for the same patient,

discrepancies between care delivery and information used for therapeutic decision making can be identified.

2. Which of the following can serve as a key variable to link infusion administration records with regards to the same infusion from the EHR and infusion pump system?
   a. The amount of medication infused.
   b. Infusion completion time.
   c. Diagnosis code.
   d. Infusion start time.

   Correct Answer: The correct answer is option d. Among these four, only infusion start time is the common attribute documented in both systems.

Protection of Human and Animal Subjects

This research was conducted in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research involving Human Subjects. All procedures were reviewed and approved by Purdue University Institutional Review Board (Protocol #1704019117).

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Conflict of Interest

None declared.

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