A Generic Method to Monitor Completeness and Speed of Medical Documentation Processes*

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Summary
Background: Physicians dedicate approximately a quarter of daily work to documentation. Completeness and speed of medical documentation processes are important parameters, because they can affect quality of healthcare.
Objectives: A generic method to monitor these quality parameters is proposed and its utility is demonstrated in two examples.
Methods: Based on a generic event-driven process chain of a medical documentation process, completeness functions for created and finalized documents (available versus required documents by time) are defined. The 95%-quantile of process time is applied as performance indicator of documentation speed. A plotting function for these parameters is provided: completeness and speed of medical documentation (CSMD)-plot. Open source code and a sample data set are available in the Supplement.
Results: This methodology is applied to analyze the effect of an electronic dictation system on discharge letter documents. CSMD-plot detects significant differences regarding speed and completeness of the process before and after implementation of electronic dictation; in addition, it pinpoints differences regarding these quality parameters in documentation processes between different clinical departments. In a second example, CSMD-plot is used to analyze follow-up documentation of a clinical trial. Due to its generic design, CSMD-plots can be applied to other medical documentation processes such as order-entry processes.
Conclusions: Monitoring of completeness and speed of medical documentation is feasible and can provide quantitative information on these processes.

1. Introduction
Physicians dedicate a major proportion of their daily work to medical documentation. There is evidence that clinical doctors, especially interns, spend on average approximately a quarter of daily work for this task [1–3]. Completeness and speed of documentation are relevant for quality of medical care, for instance to support outpatient therapy based on timely discharge letters.

Medical documentation is commonly organized as a multi-stage process, i.e. a document is initiated at a certain point in time and then processed until a final version is released. For example, a draft of a discharge letter is being dictated by a resident. The secretary transcribes this document. After approval by the resident, an attending physician reviews and signs it, eventually there’s another review cycle with the chairman of the department until the final document is released.

A similar example refers to documentation in a clinical trial: the study nurse fills in a case report form (CRF), the study physician reviews it, a data monitor checks all items and generates queries until each CRF can be finalized.

A third example would be the order-entry process for a diagnostic procedure like computer tomography: a nurse prepares an order document, a physician signs it, a radiologist reviews this order and conducts the diagnostic procedure, then a diagnostic report is being created, reviewed within the radiology department and final-ized – similar like a discharge letter.

These three quite different examples of medical documentation processes share a common feature: A medical document for a specific patient is created at a certain point in time and then processed until a final document is released.

In practice, these documentation processes can be implemented in many different ways. For instance, documentation can be paper-based, mixed paper-based and electronic, or purely electronic. Different documentation tasks can be assigned to dedicated documentation staff, nurses and physicians. To identify the most efficient implementation of a specific documentation process and to monitor its performance over time, quantitative methods to compare different approaches are needed.

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In the following sections we focus on completeness and speed as quality parameters of documentation processes [4].

2. Objectives

A generic method to monitor speed and completeness of medical documentation processes is presented. It is applied to different real-world examples. Sample data and open source code are provided in the Supplement to make it available in other clinical settings.

3. Methods

3.1 Event-driven Process Chain (EPC)

Figure 1 presents a high-level overview of a medical documentation process using EPC notation [5]. The starting point of the process needs to be defined depending on the scope of the process analysis. For instance, the initial event could be patient discharge or, alternatively, creation of a specific document like patient discharge letter. The function “data acquisition and review of patient document” depends on the specific application domain. It can be performed several times involving different persons and systems. The result of the documentation process is a final document, which is released to its recipients.

3.2 Completeness of Medical Documentation Process

\( n(t) \) denotes the number of available patient documents (either created or finalized) at time \( t \). \( n_0 \) denotes the number of documents that should be available according to some given medical process standard. In this setting we define completeness of a medical documentation process at time \( t \) as \( c(t) = \frac{n(t)}{n_0} \).

\( c_1(t) \) denotes completeness of created documents, \( c_2(t) \) denotes completeness of finalized documents.

Example: Hospital X discharged 200 patients in one month. Discharge letters should be available for every patient (= process standard), therefore \( n_0 = 200 \). Ten days after patient discharge \( (t = 10 \text{ days}) \) finalized discharge letters for 195 patients are available in the hospital information system \( (n(t) = 195) \), resulting in a completeness of finalized documents \( c_2(10 \text{ days}) = \frac{195}{200} = 0.975 \).

3.3 Speed of Medical Documentation Process

\( t_1(d) \) denotes the point in time where the documentation process for document \( d \) is started. \( t_2(d) \) denotes the point in time where \( d \) is finalized. Therefore, \( \Delta t(d) = t_2(d) - t_1(d) \) indicates the process time for this document.

In this setting, we define the speed of a medical documentation process for time interval \( T \) as \( s(T) = 95\%-\text{quantile} (\Delta t(d)) \) for all documents \( d \), which should be available for time interval \( T \) according to some given medical process standard.

Example: Hospital X discharged 200 patients in July 2010 \( (T = [1 \text{ July 2010}; 31 \text{ July 2010}]) \). For each patient a discharge letter should be finalized (= process standard). Ninety-five percent of these discharge letters were finalized within five days after creation of the document, therefore documentation speed \( s(\text{July 2010}) = 5 \text{ days} \).

3.4 Completeness and Speed of Medical Documentation-plot (CSMD-plot)

Based upon these definitions of completeness and speed for a medical documentation process, we implemented a plotting function (CSMD-plot) in R (version 2.9.0 [6]). This function requires creation and finalization time for each document as input. Points in time are provided relative to a reference point \( (t = 0) \), which needs to be defined for each documentation process. For instance, the day of patient discharge is a suitable reference point when analyzing discharge letters. This input for CSMD-plot can be provided by automated data extraction from documentation systems or by manual data collection.

CSMD-plot provides completeness for created \( (c_1(t)) \) and finalized \( (c_2(t)) \) documents versus time as well as speed of the documentation process \( (s(T)) \).

4. Results

4.1 Example 1: Analysis of Discharge Letters

We applied this methodology to analyze the effect of an electronic dictation system (EDS) on the discharge letter documentation process in the university hospital of Münster, Germany, a tertiary care referral center with approximately 1400 beds. With this system (MBS-easy 4.5 from Nuance® Inc.) physicians can dictate discharge letters electronically and send audio files to a central service department. Secretaries transcribe these files and send them back to clinical users. In our setting there was a shortage of local secretaries, therefore the hypothesis was that an EDS would improve

![Fig. 1](https://example.com/fig1.png)

Generic event-driven process chain (EPC) of medical documentation. Hexagons represent events, the rounded rectangle stands for a function.
We applied chi-squared test and Mann-Whitney-U-Test to compare completeness and speed of documentation between control group (discharge letters before EDS) and intervention group (intervention: implementation of EDS).

Figure 2 presents the EPC of this example. "Patient document" from Figure 1 is instantiated by "dictation document", "data acquisition" by "transcription". Figure 3 presents CSMD-plots for a department before (a) and after (b) implementation of EDS. Letter completeness at day 0 (= discharge day) raised from 3% to 21% (p < 0.0001), at day 10 from 6% to 79% (p < 0.0001). Before implementation of EDS, this department stored most of their letters only on paper and not in the HIS. In addition, the speed of the documentation process was improved: before implementation of the EDS it took 9.12 days until 95% of letters were completed, after EDS implementation 4.47 days (p = 0.0009).

Figure 4 presents frequency distributions of time to document creation and time to document finalization for the same data like Figure 3. The big differences completeness and speed of discharge letter documentation.

To analyze completeness and speed of the discharge letter documentation process, we implemented a data report in our hospital information system (HIS) using the report generator of ORBIS® from Agfa Healthcare [7]. This report provides a pseudonymized list of all patient cases who were discharged during a certain time interval. For each case two timestamps are provided: creation of the letter and its finalization (null values are given for missing data).
regarding completeness (6% versus 79% on day 10 after patient discharge) before and after implementation of EDS are not directly visible using frequency distributions, because information about missing cases is omitted.

Figure 5 presents CSMD-plots for a different department before and after implementation of EDS. Again, this method shows that completeness of discharge letters at day 0 and day 10 as well as speed of finalization of letters was improved. In contrast to Figure 3, this department already had a relatively high completeness before start of EDS. Interestingly, it can be seen in Figure 5 that letter writing starts for quite a few cases several days before patient discharge.
4.2 Example 2: Clinical Trial Documentation

To demonstrate the generic properties of CSMD-plot, we present an example from clinical trials: analysis of processing time for case report forms (CRFs). Figure 6 presents the EPC for this example. The shift between upper and lower line indicates the process time from creation to finalization of CRFs. There are several possible reasons for 20% missing CRFs: Patients can be lost-to-follow-up during a trial or a subset of included patients did not yet reach this follow-up time point. In any case, CSMD-plot can provide combined information about speed and completeness of the CRF documentation process.

5. Discussion

The proposed method enables to monitor completeness of medical documents, which is relevant for efficiency of medical processes and even patient safety, because medical errors can be caused by missing documents. However, the literature regarding routine monitoring of completeness in HIS environments is quite limited.

Most commercial HIS provide reporting capabilities, therefore it should be possible to extract the data needed for CSMD-plots in other environments. In principle, these plots can also be generated from manually collected data, but automated data extraction is preferable because of the high data volume. We provide open source code of CSMD-plot and sample data (Supplement) to facilitate its use in other settings.

At present, paper-based documentation still plays an important role in hospitals, even when a fully implemented electronic healthcare record (EHR) is available [8]. Completeness of electronic document...
tation in HIS can vary substantially even within the same institution; we provided two quite extreme examples in Figures 3 and 5. For successful EHR implementation and – more specifically – clinical decision support systems (CDSs) complete documentation is important [9]. Monitoring of relevant HIS documents can reveal heterogeneities and time trends in documentation [10].

The second aspect of our analysis, which is equally important, addresses speed of the documentation process. Based on the generic EPC model of Figure 1, we assess time of two events: creation and finalization of the document. This approach can provide new insights into the documentation process – for instance, it becomes evident in Figure 5 that the letter writing process starts several days before patient discharge for a relevant proportion of cases. We propose to use a 95%-quantile of the time difference between creation and finalization of a document as performance indicator. In addition to this indicator, the slope of CSMD-plot (steep or flat completeness curves) provides information about speed of the process.

However, why do we propose three different measures, i.e. documentation speed, completeness of created and completeness of finalized documents? Documentation speed (time from creation to finalization of a document) alone can be misleading, for instance a lazy doctor can start creation of the discharge letter weeks after discharge of the patient, but finalize the discharge letter soon. He has an excellent speed, but his discharge letter is far too late. In a real world setting, there are finalized documents, created but not finalized documents and completely missing documents. The proportion of missing documents can be substantial (Fig. 3), for example because a central documentation system is not used by some employees. To capture information about creation, finalization, missing documents and time course within the documentation process, analysis of completeness regarding created and finalized documents can provide additional insights.

We applied our method in two different examples: analysis of discharge letters and CRFs. Completeness and speed are relevant for many medical documentation processes. CSMD-plots could be used to compare documentation processes at different trial sites or to assess quantitatively effects of various interventions – such as user training, additional personnel or new documentation software.

In principle, this method can also be applied to analyze any order-entry process with defined events for start (creation of order form) and end (release of result). In a review of computerized physician order entry (CPOE) systems, ten areas of impact assessment and 39 indicators to measure impact of CPOE were identified [11]. Several of these parameters could be assessed quantitatively by our method: In particular analysis of process speed (turnaround times: time from order to result, from order to diagnosis, from order to treatment change, from availability of critical result until time critical condition resolved) as well as completeness in compliance with guidelines (% of patients who require a test that actually have the test, rate of physician compliance with suggested corollary orders). In a CPOE setting, CSMD-plot can provide more information than “average turnaround time for test X is five hours”, because it shows distribution of process time and completeness of available results. From our perspective, the aspect of complete documentation is sometimes not considered appropriately in analysis of turnaround times. In general, completeness cannot be taken for granted (example 1, Fig. 3).

Computer-generated documents are increasing in clinical settings, for example due to new medical devices. On the other hand, comprehensive EHRs are still very rare: According to a current survey only 1.5% of U.S. hospitals provide such systems on all units [12]. Currently, many hospitals work with a mixture of paper-based documentation and electronic documentation in departmental as well as central systems.

From our point of view, medical documentation processes should be monitored to avoid risks for the patient by incomplete or delayed records. It would be very interesting to see if similar results like in our electronic dictation example could be obtained in other clinical settings.

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