Improving the Quality of Acute Stroke Care through Interactive Visualization of Registry Data

Noreen Kamal, Sheelagh Carpendale, Mona Hosseinikhani, and Michael D. Hill

Abstract—Time is critical in the treatment of ischemic stroke patients. This is particularly true for the rapid administration of clot-busting drug after arrival at hospital. In a provincial project in Alberta, Canada, we aim to achieve a median time of 30 minutes from arrival at hospital to the administration of the drug across all 18 hospitals that administer the drug in the province. We aim to study various interactive visualizations including augmented versions of event sequences with interactions that include aggregations, alignment, filtering and ranking to better understand delays in delivering the clot-busting drug upon arrival in the hospital. We will compare these visualizations to standard quality improvement visualization of statistical process control charts.

Index Terms—Event sequences, health registry, electronic health records, stroke, health quality improvement

1 BACKGROUND OF MEDICAL PROBLEM

The burden due to stroke is significant, as the leading cause of disability and the third leading cause of death [1]. We know that treating patients more efficiently can reduce mortality and disability due to stroke, and therefore, the mantra time is brain [2,3] has become ubiquitous. One of the most critical steps in treating acute ischemic stroke patients is the rapid administration of tissue plasminogen activator (tPA) to open a blocked artery in the brain. The treatment window from time of onset is 4.5 hours [4] in most guidelines [5,6], yet there is rapidly declining benefit as time elapses. A 1997 NINDS Symposium and the subsequent Brain Attack Coalition [7] set the standard of 60 minute door-to-needle (DTN) time [8], which is the time from when a patient arrives in the hospital to when tPA is administered. This was arbitrary but designed to provide a useful metric. It has now been incorporated into both national guidelines and accreditation standards [9,10,11]. Yet in Canada only 34% of patient received tPA within 60 minutes of arrival [12] and results from the US Get With The Guidelines data show that only 26.6% of patients received tPA within 60 minutes in the US [13]. We know that we can do better, as a site in Finland was able to achieve a median DTN of 20 minutes [14].

The quicker that blood flow is restored in ischemic stroke, the better the outcomes [15,16]. For each 15-minute reduction in delay, there is an estimated 4% improvement in good clinical outcomes. [16] The number of neurons that are lost in a middle cerebral artery stroke has been quantified to be 1.9 million per minute or 114 million neurons every hour, which translates to 3.6 years in accelerated aging [3].

2 PROCESS FOR DELIVERING tPA

There are several steps involved from the patients’ arrival (and prior to arrival) to the delivery of tPA. Although the process is variable at different hospital depending on their protocols and internal processes, there are several steps that need to be completed prior to the administration of tPA. These steps include:

- Establishing if symptom onset occurred less than 4.5 hours prior to presentation
- Ensuring that the patient is not currently on Warfarin or other anti-coagulant drug
- Completing a neurological exam to better understand deficits
- Ensure that the non-contrast CT shows no evidence of hemorrhage and (ideally) that a CT angiogram shows that there is a blocked artery (confirming diagnosis of an ischemic stroke)
- Ensure that the blood pressure is within set limits

Figure 1 shows an example process flow diagram for the delivery of tPA. There are some steps in this current process that do not add value and can be further improved to deliver tPA more time-efficiently. However, the process includes various events such as EMS pre-notification (patch), arrival at ED, stroke team assessment, CT scan, blood pressure management, and administration of tPA. There are other aspects that are not event-based or part of the DTN timeline that are based on the patients’ clinical history such as use of anti-coagulants.

3 BACKGROUND OF PROJECT

In the province of Alberta, we are striving to achieve median DTN time of 30 minutes (95th percentile 60 minutes). This will ensure that most patients will receive tPA within 60 minutes of arrival. This will be done as part of a 5-year project called QuICR (Quality Improvement and Clinical Research). Alberta is the 4th most populous province in Canada with a population of 4 million, and an area of 661,848 km², which is comparable to the size of Texas or France. There are 18 hospitals in Alberta that administer tPA.

As part of the QuICR project, a provincial stroke registry will be developed. The stroke registry will link to Alberta’s provincial electronic health records to fill in data automatically that pertain to stroke care; additionally, the registry will include all brain images and other data that will be entered proactively across the province.

The quality improvement project will use the Institute for Healthcare Improvement’s Breakthrough Series Collaborative methodology [17] to make improvements across the hospitals. This Improvement Collaborative is a structured approach of alternating face-to-face meetings and on-site action periods that use the Model for Improvement, which is based on the Plan-Study-Do-Act improvement cycle [18]. We plan to study various interactive visualizations to understand which ones lead to improvements in DTN time across the province. Interactive visualization can support performance awareness, pattern discovery, monitoring, and exploration of DTN performance to support the interdisciplinary team to make changes that will lead to improvement in DTN time.
Interactive visualizations and visual analytics have been touted as having the potential to improve healthcare [19]. There has been significant work done in visualization of temporal health data. As early as 1994, time-based patient summaries on a common scale (high, normal, low) of various clinical indicators were being proposed for visualizing individual patient records [20]. Along the same lines, LifeLines was used to visualize patient records temporally as events along a timeline, which was shown to be beneficial over tabular views [21].

The previously mentioned works have been incorporated to visualizing multiple records using event sequences for discovering patterns in the data. LifeLines2 investigated features such as align, filter and rank to assist with pattern discovery [22]. Event sequences were further developed for large datasets through the incorporation of aggregation of records in LifeFlow, where the width of the bar indicated the number of records with a particular sequence as shown in Figure 2 (top) [23]. Similar simplification was used in EventFlow to obtain an understanding of large dataset through aggregation as shown in Figure 2 (bottom) [24]. All of these examples have been applied to clinical datasets or healthcare operations data, and user studies found that the interactive visualizations were helpful and easy to use. These encouraging results provide impetus for our work to develop interactive visualizations that will lead to improvements in DTN performance across the province of Alberta.

These event sequence visualizations make sense for understanding delays in DTN time, which can assist hospital to make improvements. However, we also need to consider the following:

- How will non-event based information and imaging be incorporated into the visualization?
Can the visualizations be easily understood by various health and medical professionals involved in the acute care of patients?

Can the visualization be used to understand variability in care?

How can the users be allowed to add quality improvement events into the visualizations?

We contrast these event-based visualizations with the current standard for displaying data for quality improvements: statistical process control (SPC) chart. These visualizations have been shown to assist health professionals improve quality of care [25].

Through the QuICR project we hope to design various interactive visualizations of DTN time. These designs will include quality improvement elements such as changes that have been implemented by the hospital, variability in care, and potential causes of variability.

We anticipate that one of the designs will be an augmented version of the event sequence visualization that include interactions based on non-event-based clinical data and imaging data. User studies will be conducted to validate which visualizations (including SPC charts) promote the greatest understanding of:

- Discovery of the causes of delays in the current process
- Understanding if changes that teams are trailing at the hospital are leading to improvements
- Understand the variability in care and if they are reducing previous variability
- Allow for the greatest improvements to be made

The long-term aim of this project is to use the visualization in different settings within stroke and TIA (transient ischemic attack) and eventually in other medical areas.

REFERENCES


