Visual Analytics to Enhance Personalized Healthcare Delivery

A RENCI WHITE PAPER

A data-driven approach to augment clinical decision making

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Summary

In a typical clinical setting, physicians rely on their personal experiences, and clinical recommendations and treatment guidelines developed from clinical trials in order to practice evidence-based medicine. However, in complex cases, the individual physician's experience may not be sufficient to identify the best treatment option for the patient. Additionally, clinical trials use controlled populations, thus limiting the ability to generalize results to patients in real-world situations with multiple comorbid conditions. All of these factors lead to a gap in medical care applied to an individual patient.

With the widespread adoption of Electronic Medical Record (EMR) systems to capture patient data, there is a growing need, as well as an opportunity, to leverage stored patient data in order to augment a physician's clinical decisions regarding patient care. The combination of analytical computations with interactive visual representation, referred to as Visual Analytics (VA), allows users to see, explore, and understand large amounts of information at once. In the medical domain, the Renaissance Computing Institute (RENCI), along with partner organizations, has designed a VA-framework based tool – VisualDecisionLinc (VDL) that offers an innovative approach to bridge the gap and thereby derive insight into a patient's treatment strategies. VDL works by:

1. Stratifying evidence from comparative patient cohorts into the EMR.
2. Bringing the knowledge at the physician's fingertips into a format that is easy to read and absorb.
3. Incorporating decision support features to customize the evidence in real time and deliver personalized care at the point of care.

The Challenge

An Electronic EMR is a collection of information on each and every individual patient visiting a provider facility. Typically, a wide range of data is collected which includes demographics, medical history, comorbid conditions, medications, allergies, immunizations, test results, and billing information.

The fundamental problem is that EMRs are set up to view patient visits as "transactions" in order to facilitate billing and insurance processing instead of providing quality care to reduce cost and improve patient management. Further, EMRs offer physicians limited support in the decision making process.

Additional challenges that need to be addressed to optimize EMRs to facilitate quality care include:

Information Overload: Clinicians face information overload when presented with large amount of patient data in a time-pressured clinical setting. EMRs provide access to large volumes of patient data; however, the ability of the human mind to process large amounts of data in real time is limited.

Patient Data Representation Format: Current EMR systems present patient data in a tabular format. Often, clinicians must navigate through

At a Glance

- With growing collections of patient data in Electronic Medical Records systems, clinicians have access to vast amounts of real-world patient data.
- Visual analytics, a symbiotic coupling of analytics and visualization, helps to analyze large data sets, and represent results in an easy-to-absorb format with interaction capabilities, making it simple to gather insights from data.
- The VisualDecisionLinc tool uses visual analytics as a framework to transform data into an actionable format. It aggregates health outcome evidence from similar populations to personalize care and uses visual data views to inject evidence into the clinician's workflow, which helps facilitate the decision-making process.

The Team

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multiple screens and tabs in order to find relevant patient information. In a time-limited clinical setting, it is important for a clinician to have the ability to interact with the data and quickly gain clinically relevant insights to determine different treatment options.

Alert Fatigue: EMRs provide limited decision support, mostly in the form of alerts to indicate drug-drug interaction. "Alert fatigue" is the result of too many alerts, and often the clinicians tend to simply switch off the alerts or ignore them altogether.

Gap in care: While EMRs contain vast amounts of data, there is still a gap between the patient data that is available in usable format, and data that can be applied to determining treatment options for the target patient. Access to structured EMR data offers the potential to bridge this gap, provided the data is properly leveraged.

Ideas into Action: Visual Analytics to Improve the Quality of Patient Care

While vast amounts of data are available from EMRs, it is critical to develop new methods for extracting knowledge from this data in order to optimize treatments, improve the quality of patient care, and increase the likelihood of positive patient outcomes. The solution to bridge the gap between available EMR data and improved patient care and outcomes lies in using computational methods combined with visual representations of data and data analytics. The symbiotic coupling of analytics and visualization can be achieved using Visual Analytics (VA) techniques. VA is the science of analytical reasoning facilitated by interactive visual interfaces. The visual representation of clinical data allows users to see, explore, and understand large amounts of information at once.

VA offers the best of both worlds by harnessing computational power to quickly process vast amounts of information, while maintaining the physician ability to make the ultimate decisions on treatments. Using this approach, collective intelligence obtained from the existing EMRs can be leveraged using VA techniques to provide insights into the information, thus leading to efficient decision support patient treatment.

Using Data to Personalize Patient Care

In order to test the application of VA, researchers at RENCI collaborated with Duke University researchers and worked on anonymized real-world patient data from the MindLinc EMR system, the largest de-identified, psychiatry-focused, outcome-based, data warehouse in the United States. The MindLinc EMR system stores data on patient demographics, current and past medications, side-effects, comorbidities, and other related clinical data points, including psychiatric diagnoses and therapeutic outcomes. By applying the principles of visual analysis, the RENCI team built a prototype VA tool called VisualDecisionLinc (VDL) to aid physicians in identifying strategies for patient treatment.

Working with real-world patient data from patients with Major Depressive Disorder (MDD), the researchers explored and developed innovative ways to quickly identify and stratify patient cohorts, and aggregate evidence on treatment options that work. They also identified techniques to put this knowledge at the physician's fingertips in a visual format and incorporated decision support features that customize the evidence to the physician's needs. The VA approach was designed to help overcome the density of information presented by the EMRs, and to simultaneously present the intelligence of analytics in an easily understandable format. VDL techniques were designed to be easily integrated into the workflows of different medical practices with minor adaptation. The User Interface (UI) shows information about the patient, their health outcomes resulting from various treatments in the past, as well as recommended potential treatment options that have worked for similar patient cohorts. Additionally, if a recommended treatment is selected, VDL enables the physician to gain some foresight into how the particular patient will react to the treatment choice.

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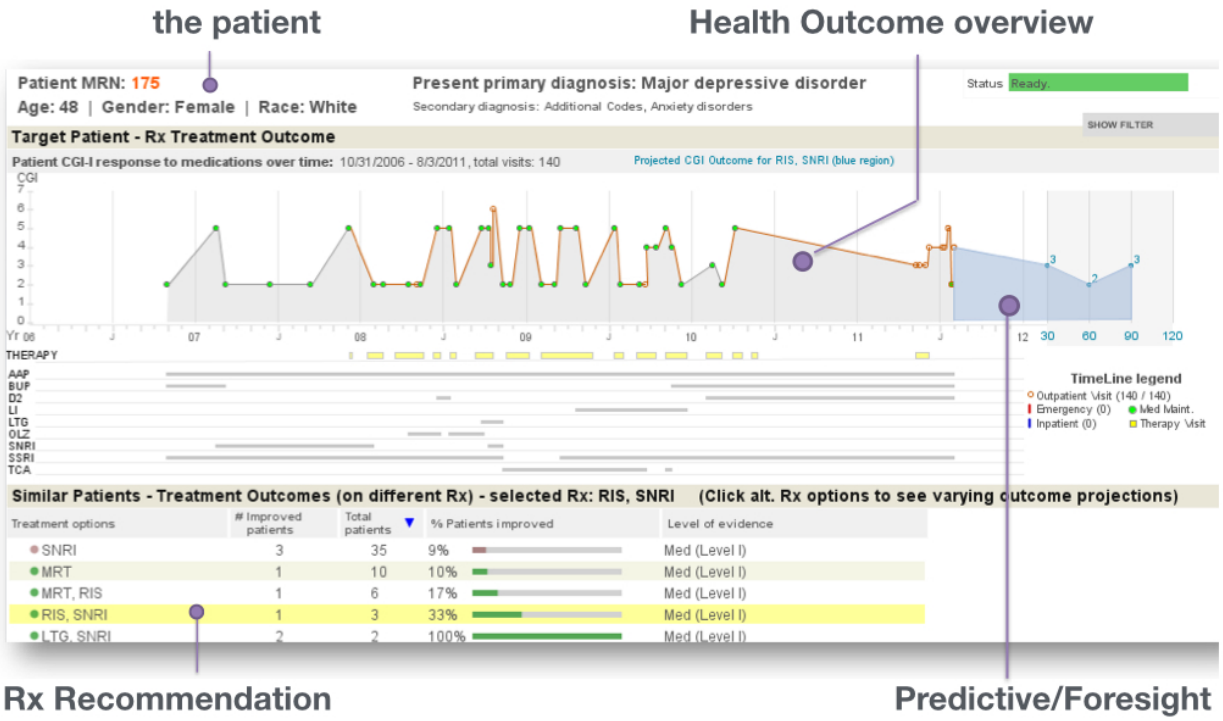

Figure 1: Figure 1: Dashboard-style visual UI with integrated and interactive data views to impact care delivery.

RENCI data infrastructure and medical informatics experts also teamed up with epilepsy experts at the UNC Chapel Hill School of Medicine, Duke University School of Medicine, and Boston Children's Hospital at Harvard University to apply visualization principles to EMR data of pediatric patients with epilepsy. The RENCI team has worked on a prototype application that allows clinicians to spot trends in the data and interact with the data to gain clinically relevant insights. The use of interactive displays augments the physician's information processing abilities by reducing information overload and facilitating the decision making process.

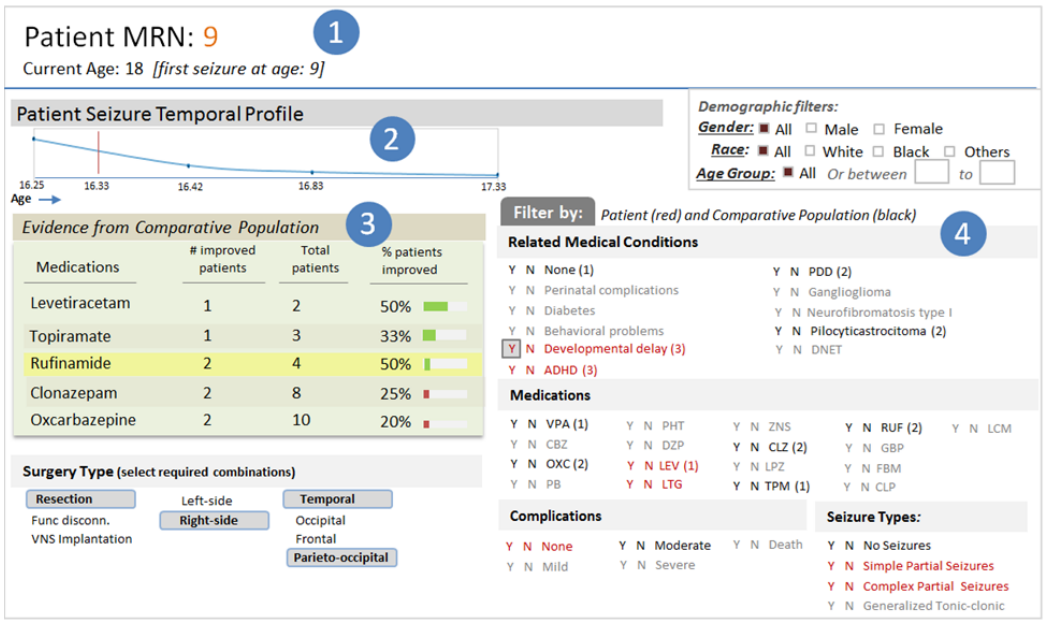

Figure 2: View showing comparative population data for use in decision support for an individual patient. Different data views are labeled. 1: Demographics for an individual patient; 2: Seizure history for an individual patient; label 3: Treatment evidence aggregated from the comparative population; 4: Data attribute level filters with yes/no (Y/N) toggles for variable selection.

Optimizing Treatment Guidelines for Care Delivery

Clinical treatment guidelines are the primary means of distributing evidence-based treatment recommendations to clinicians. Unfortunately, clinicians frequently do not adhere to these guidelines in their clinical practices for various reasons, such as the lack of patient-specific information, the absence of current information, and the difficulty of adopting the guidelines into the clinician's workflow.

A VA -based system also helps physicians map treatment guidelines to a patient's treatment history, which in turn allows the physician to easily understand what treatments have worked in the past and how they compare to the treatment guidelines developed for the condition. A visual comparison of treatment guidelines and patient history would be too time consuming without a VA system, yet it gives the physician insight into different treatment options tried over time, compares the course of the patient's treatment to the treatment guidelines and helps the physician utilize a wealth of evidence in making further treatment decisions. To demonstrate the visualization approach to clinical guidelines, the RENCI-led research team used a sample data set of patients from the MindLinc EMR and applied VA techniques to summarize the association between a patient's medical condition and the prescribed medication. Further, analytics was also used to predict the likely response of the patient to a prescribed medication. The physician interface used visual cues to indicate condition improvement or deterioration after a treatment so that that the physician was able to rapidly process the latest information on the patient's condition and decide on the best course of treatment.

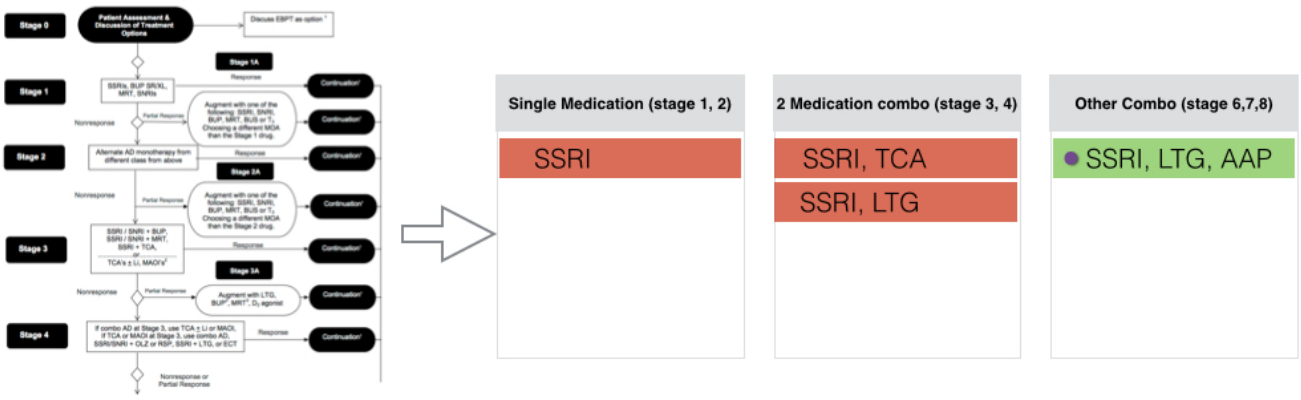

Figure 3: A compressed guideline representation for rapid absorption of treatments, and their outcome information. Red represents a bad outcome; green represents a good outcome.

Capturing Data on Mobile Devices

As more people rely on smartphone applications and other digital aids to capture and record health patterns and behavior, a wealth of data captured outside the walls of the clinical setting is becoming available. Integrating this information with the patient's EMR will provide their physicians with more information on the patient's lifestyle and habits.

For instance, clinicians who treat patients with epilepsy often see them after a medical event such as a seizure. But to effectively treat the condition, they need information about the patient's entire disease history. EMRs contain information about the frequency of seizures, drugs, dosages, side effects and hospital stays, but sifting through stacks of paper records is impractical and often impossible for busy physicians. To make patient profiles easy to access and analyze, RENCI is developing a visual dashboard that allows the clinician to view a patient profile in an easy-to-understand visual format. The dashboard includes longitudinal displays of information such as seizure events, medications, and side effects experienced. The clinician can overlay different types of data, making it easy to spot trends and find correlations between different variables, such as seizures and medications or medications and side effects.

The RENCI research team is also exploring the use of mobile and web technologies to allow patients or their family members to record details about a seizure immediately after it happens and deliver the information to the clinician before an office visit. The infrastructure will integrate outcome data reported by the patient with EMR data, and display that data on a visual dashboard in an effort to provide more holistic care. Using Visual Analytics systems will enable clinicians to view a patient's profile, overlay it with other data, and spot trends. RENCI plans to build a prototype system and test it using retrospective and prospective data by working in close collaboration with collaborators at Boston Children's Hospital, UNC Hospitals, and Duke Medical Center.

Additionally, the RENCI research team is exploring ways to leverage the mobile and web infrastructure to plug in other data points by tapping into Fitbit® data, or other devices that record exercise and other activities.

The Big Picture

EMRs contain a wealth of information, which, if leveraged properly, can be used to improve diagnoses and develop treatment plans targeted towards the needs of an individual patient. By applying Visual Analytics techniques and computational methodologies to data from EMRs, physicians receive a visual representation of the data and are able to use the collective knowledge from a comparative cohort of patients, as well as the patient's own medical history, to personalize treatments. This can lead to better treatment decisions, better treatment outcomes and an improvement in the overall quality of patient care. In addition, healthier patients who have fewer complications related to chronic conditions such as epilepsy, spend less time at clinics, in the hospital, or in the emergency room, all factors that could lower healthcare costs.

Visual Analytics Collaborations

RENCI has ongoing collaborative research ventures with various partners to test the application of Visual Analytics to EMR data in order to optimize care delivery and enhance patient care. Recent collaborations include:

- A partnership with Duke Medical Center to use the MindLinc EMR data from patients with MDD, in an effort to improve therapeutic outcomes.
- Collaborative efforts with epilepsy experts at the UNC Chapel Hill School of Medicine, Duke University School of Medicine and Boston Children's Hospital at Harvard University to apply VA principles to EMR data of pediatric patients with epilepsy.
- Cooperative efforts with Boston Children's Hospital, UNC Hospitals, and Duke Medical Center to explore the use of web technologies to integrate patient-reported outcomes with EMR data.

About RENCI

RENCI is an institute of the University of North Carolina at Chapel Hill that develops and deploys advanced technologies to enable research discoveries and practical innovations. RENCI partners with researchers, policy makers, and technology leaders to engage and solve the challenging problems that affect North Carolina, our nation and the world. The institute was launched in 2004 as a collaborative effort involving UNC Chapel Hill, Duke University and North Carolina State University. For more information, see www.renci.org.

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