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Vascular Access Tracking System: a Web-Based Clinical Tracking Tool for Identifying Catheter Related Blood Stream Infections in Interventional Radiology Placed Central Venous Catheters

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Abstract Vascular access is invaluable in the treatment of hospitalized patients. Central venous catheters provide a durable and long-term solution while saving patients from repeated needle sticks for peripheral IVs and blood draws. The initial catheter placement procedure and long-term catheter usage place patients at risk for infection. The goal of this project was to develop a system to track and evaluate central line-associated blood stream infections related to interventional radiology placement of central venous catheters. A customized web-based clinical database was developed via open-source tools to provide a dashboard for data mining and analysis of the catheter placement and infection information. Preliminary results were gathered over a 4-month period confirming the utility of the system. The tools and methodology employed to develop the vascular access tracking system could be easily tailored to other clinical scenarios to assist in quality control and improvement programs.

Keywords Data collection · Data mining · Medical informatics applications · Reporting · Software design · Workflow re-engineering

Background

Central venous access is an important tool in the treatment of critically ill patients. In the USA, over 15 million catheter days/year are recorded in the intensive care unit alone [1]. Placement of a central venous catheter (CVC) is a basic skill for nearly every medical specialty; however, it is not without risk. Complication rates during catheter placement are reported as high as 15–33 % [2, 3]. Even after successful placement, having an indwelling CVC puts patients at risk for central line-associated bloodstream infections (CLABSI). Each year in the USA, central venous catheters cause an estimated 80,000 catheter-related blood stream infections in intensive care units (ICUs) [4]. A total of 250,000 cases of blood stream infections have been estimated to occur annually if entire hospitals are assessed and, as a result, up to 62,000 deaths among patients in hospitals [5].

National quality improvement efforts have been directed towards decreasing the incidence of CLABSI and have succeeded in reducing the number of ICU patients suffering a central line infection by 63 % between 2001 and 2009 [6]. To continue this trend, hospital quality improvement programs must continually monitor placement and outcomes among all medical specialties that routinely place central lines to identify and correct problems rapidly.

Clinical informatics tools can facilitate clinical outcome tracking after central line placement. At our institution, catheter placements are recorded in the electronic medical record; however, the system lacks the capability to easily search for recently placed catheters or differentiate lines placed by different hospital departments. Variability in the coding of interventional procedures, limited search capabilities, and lack of a workflow for documenting follow-up precluded the use of the radiology information system (RIS) or picture archiving and communication system (PACS).

The pre-existing system for tracking each central line placed by interventional radiology consisted of an Excel (Microsoft, Redmond, WA) spreadsheet on a single office computer. The spreadsheet contained patient info, date of

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placement, and follow-up information at 30 days after placement. This method relied on the manual effort of a single medical assistant to perform all documentation of line placements, determine when follow-up was needed and when follow-up was completed. The data was incomplete and not standardized, making automated analysis impossible. A dedicated online tool called the venous access tracking system was created to standardize data entry, allow documentation by multiple users simultaneously, automatically populate the list of patients needing follow-up, and provide basic analysis tools to examine the data.

Methods

As part of a quality improvement initiative, the institutional review board (IRB) determined that this project is not a research involving human subjects, and IRB review and approval was not required. An interventional radiology fellow and a medical assistant were responsible for entry of central venous catheter placement data and follow-up information into the web application during the pilot deployment and testing phase. A companion Excel spreadsheet was maintained with the patient name and medical record number (MRN) along with identical procedural and follow-up data to gauge data validity and integrity. The spreadsheet was saved on a secure departmental network storage drive in compliance with institutional protocols. A key was used to link each application record with a spreadsheet entry for follow-up purposes. The application was hosted on a departmental workstation. Future deployment on a dedicated institutional virtual server will allow for the storage of protected health information (PHI); however, the costs associated with creation and maintenance were considered too high for the prototype and testing phase.

For ease of accessibility throughout the hospital, offices, and clinics, a web-based approach was chosen as all institutional workstations have access to a web-browser. The development packages were chosen for several reasons including cost, ease-of-use, extensive online support, and developer familiarity. The components chosen (Node.JS, MongoDB, Bootstrap) are all free and open source software [7–9]. Node.JS enables client and server construction using JavaScript as the sole programming language, unifying development. JavaScript is a simple but powerful web-based programming language that is supported in all modern web-browsers and offers an extensive online support community and open-source libraries enabling a variety of complex features. MongoDB, a document-oriented database, was chosen to store the patient and follow-up information as the inherent formatting of database entries in JavaScript Object Notation (JSON) simplified the server-side coding for database administration and querying. Finally, client-side webpage development was facilitated by Bootstrap, a collection of hypertext markup language (HTML) and cascading style sheet (CSS) tools for creating uniform streamlined user interfaces.

The structure of the application is depicted in Fig. 1. The server contains the database and data processing engine. The client-side web interface consists of web forms for data entry, database queries, and data analysis display. Authentication was implemented to ensure data confidentiality. The data model for each procedure and follow-up information is shown in Fig. 2. The client and server communicate through a custom application-programming interface (API), opening the possibility for future applications to make use of the database and the information it contains.

The webpage interface allows any authenticated user to enter the information for a newly placed line. The system automatically recognizes when 30 days have elapsed from time of catheter placement and displays the record in the "Pending Follow-Up" queue. Following departmental protocol, a user performing patient follow-up would then conduct a chart review and contact the patient directly to determine if he/she had developed any signs or symptoms of an infection or had documentation of an infection in the interval. If the patient is unreachable or the follow-up is incomplete, the attempt is documented and the record remains in the "Pending Follow-Up" queue. Once follow-up has been completed, the record is removed from the "Pending Follow-Up" list but remains easily accessible under the "Browse Registry" tab (Fig. 3a–e).

Records in the database are searchable and may be browsed entry-by-entry or queried by date of placement, type of line, side, site, and follow-up results. The system also provides a dashboard consisting of high-level analysis of the database for infection rates over time, by catheter type, and by site and side of placement (Fig. 3f).

Results

The venous access tracking system (VATS) was deployed on a pilot basis over a 4-month period (July 2014–October 2014). A total of 186 central venous catheters were placed by the interventional radiology service during the pilot period and entered into the database. Manual comparison was made between the VATS database and companion spreadsheet. No discrepancy or loss of data was identified, and the application remained operational and online throughout the trial period. Catheter-related infections were defined as the presence of infectious symptoms or positive blood cultures between placement and follow-up at 30 days. Fourteen possible central line-associated bloodstream infections were identified during follow-up.

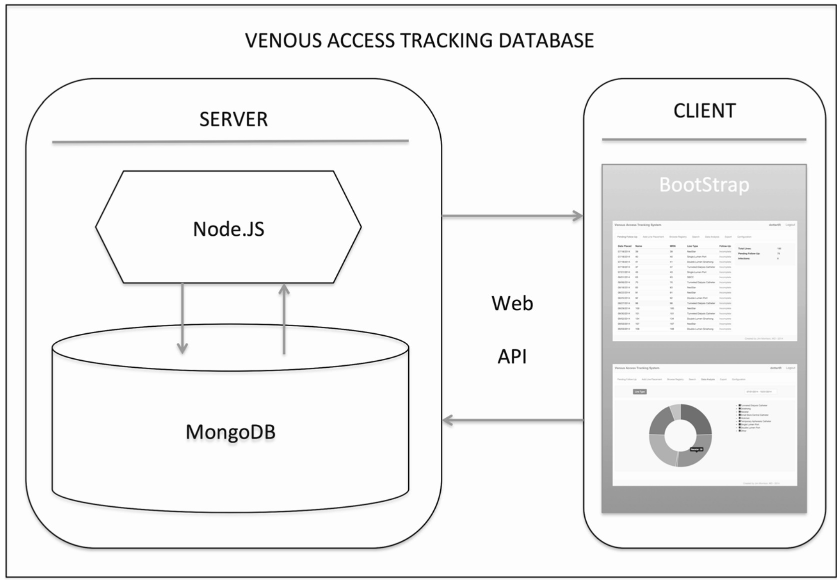

Fig. 1 High-level structural diagram of how the application components interact with one another

Discussion

Central line-associated bloodstream infections remain a quality improvement priority for decreasing hospital-related morbidity and mortality. Retrospective analysis of catheter-related clinical follow-up information has typically involved extensive chart review, which is time-consuming, difficult, and often incomplete. The ability to automatically collect and analyze this type of procedural information is not otherwise available at our institution, either through the electronic medical record (EMR) or the RIS. Using a prospective custom built database containing relevant procedural information and obtaining follow-up information at defined intervals can provide a valuable resource for examining a difficult to measure problem.

Trial implementation of our venous access tracking system demonstrated the feasibility and utility of quantifying the number and type of venous access procedures being performed within the department as well as the associated infection information at 30 days follow-up. The application successfully provided a simple to use interface with reliable data storage and real-time analysis using open-source tools.

The availability of open-source software, libraries, and large user support community has lowered the barrier for rapid development of useful and powerful clinical informatics tools. The design and coding of the VATS took

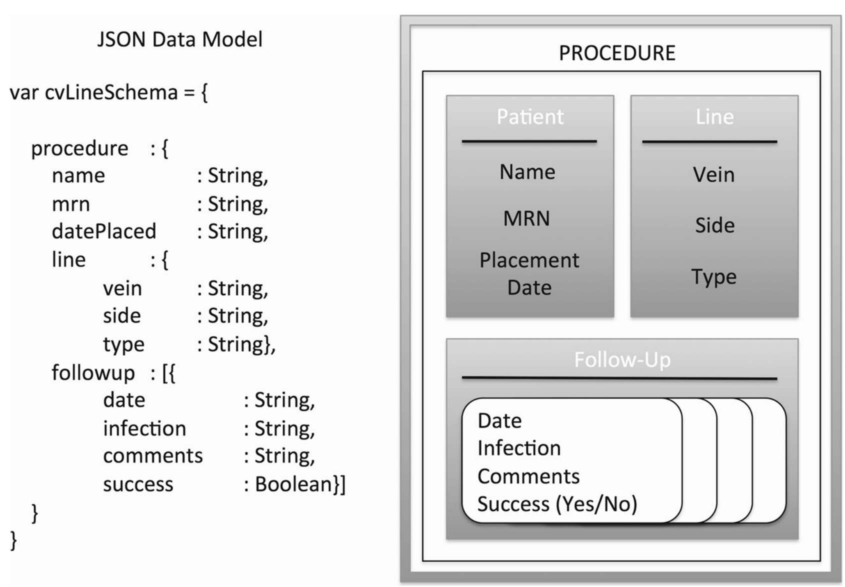

Fig. 2 Data model for each catheter placement and subsequent follow-up

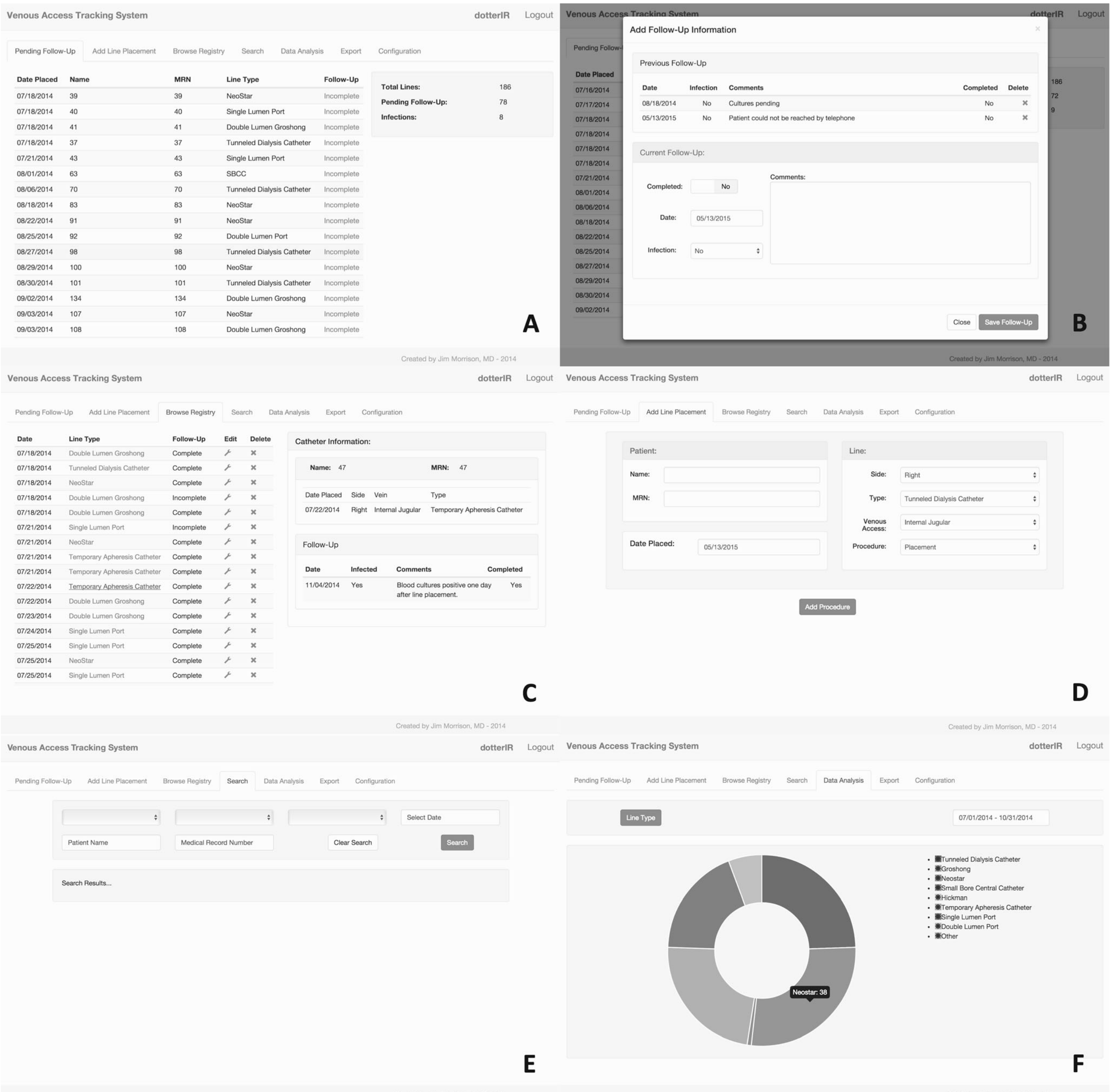

Fig. 3 Screenshots of the application in use showing **a** the pending follow-up queue, **b** addition of follow-up information, **c** browsing the entire registry, **d** documenting a new catheter placement, **e** search of the registry, and **f** data analysis looking the types of catheters placed over a defined time period

less than 120 h total; the majority of which was performed over an initial 72-h period with development of the core documentation and storage functions. The remaining development time was used for refinements and the addition of search and analysis functions. While the VATS was designed to track infectious complications after central venous catheter insertion, the underlying technology could be easily tailored to track a wide variety of clinical scenarios. The use of a representational state transfer (REST) API in the Node.JS client-server interface also allows for future integration with other web-enabled interfaces.

Society of Interventional Radiology (SIR) reporting standards for central venous access classifies "early complications" as those occurring within 30 days of the procedure [10]. However, infection control protocols at our institution associate bloodstream or catheter-related infections with the catheter placement procedure only if it occurs within 10 days of placement. The 30-day follow-up period resulted in the identification of infections or infectious symptoms not related to the initial catheter placement procedure. Our institutional protocol for identification of CLABSI also includes a patient questionnaire assessing for signs/symptoms of infection after placement. The authors became aware of the institutional protocol after the termination of the pilot period and plan to incorporate these changes into the next version of the VATS application.

Limitations of the VATS application are related to its custom design and development. Changes and additions to the application must be made at a developer level and depend upon a user with coding expertise and a familiarity with the codebase. Commercial alternatives exist, both proprietary (Access, Microsoft, Redmond, WA) and open-source (Base, Apache Software Foundation, Forest Hill, MD), that provide the database infrastructure and user interface tools necessary to develop a similar system, although still require a developer with familiarity of the platform to build and maintain such a system. In addition, some commercial EMR software packages are capable of registering or tracking medical implants; however, use of these systems and data-mining/reporting are dependent upon the institutional support for these functions.

Future goals for this application are integration with both the radiology reporting system and EMR. Queries of recently dictated procedure reports could be used to automatically detect and record information on newly placed catheters. Integration with the EMR could facilitate identification of infections (i.e., positive blood cultures) and automate clinical documentation in the patient's chart after follow-up has been performed.

Conclusion

Central venous access catheters are a significant source of patient morbidity and mortality. Quality improvement programs have demonstrated substantial decrease in infection rates over the last decade. To continue this trend, clinical tracking utilities such as the VATS are needed for prospective monitoring of patient outcomes. Open-source tools enable the rapid design and implementation of instruments such as the VATS that can facilitate data collection and reporting, and ultimately, giving clinicians timely feedback to positively affect patient care.

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