American Journal of Infection Control ■■ (2016) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Process control charts in infection prevention: Make it simple to make it happen

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Key Words:
Quality improvement
Health care-associated infection
Surveillance

Background: Quality improvement is central to Infection Prevention and Control (IPC) programs. Challenges may occur when applying quality improvement methodologies like process control charts, often due to the limited exposure of typical IPs. Because of this, our team created an open-source database with a process control chart generator for IPC programs. The objectives of this report are to outline the development of the application and demonstrate application using simulated data.

Methods: We used Research Electronic Data Capture (REDCap Consortium, Vanderbilt University, Nashville, TN), R (R Foundation for Statistical Computing, Vienna, Austria), and R Studio Shiny (R Foundation for Statistical Computing) to create an open source data collection system with automated process control chart generation. We used simulated data to test and visualize both in-control and out-of-control processes for commonly used metrics in IPC programs.

Results: The R code for implementing the control charts and Shiny application can be found on our Web site (https://github.com/ul-research-support/spcapp). Screen captures of the workflow and simulated data indicating both common cause and special cause variation are provided.

Conclusions: Process control charts can be easily developed based on individual facility needs using freely available software. Through providing our work free to all interested parties, we hope that others will be able to harness the power and ease of use of the application for improving the quality of care and patient safety in their facilities.

Quality improvement is central to Infection Prevention and Control (IPC) programs. Nearly all activities of an Infection Preventionist (IP) can be defined as quality or performance improvement. Indeed, many IPs also have direct roles as quality improvement personnel or their department is part of a larger quality/performance improvement department.[1] IPs are likely to be well versed in use of a traditional quality improvement framework such as Deming's plan–do–study–act.[2] Surveillance for health care-associated infections is done to determine rates of disease that can be expected given the activities occurring in a facility. This is a step in the plan phase of a quality improvement project. If any particular rate is considered too high, interventions may be instituted to reduce the burden of disease; that is, the do phase of the project. Once the intervention is established, it is necessary to evaluate its effectiveness; that is, the study phase. Finally, the act phase includes developing policies and procedures to ensure the new process is applied consistently and appropriately. This simple example outlines the continuous quality improvement cycle of an IPC program.

In the area of quality improvement, statistical process control is an important methodology for monitoring performance and processes.[3,4] In fact, The Joint Commission suggests their use for monitoring processes related to patient safety metrics.[5] Challenges may occur when applying these statistical quality improvement methodologies to a particular process, often due to

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Conflict of interest: None to report.

TLW, SPF, RMC, and JAR contributed to the design of the protocol. TLW, SPF, AKP, BEG, WAM, RRK, BEG, and KAB contributed to computer programming. TLW, SPF, WAM, RMC, KAB, and JAR had primary writing responsibilities. TLW and KAB were responsible for video recording and editing. All authors provided a critical review of the manuscript and approved the final version.

0196-6553/
http://dx.doi.org/10.1016/j.ajic.2016.09.021

the limited exposure of typical IPs to these statistical methodologies. Furthermore, software available to easily create process control charts can be cost-prohibitive for an IPC department, or can be difficult to obtain and install due to local information technology security policies. Moreover, the majority of US hospitals are small, fewer than 200 beds, and resources supporting quality improvement and IPC departments may be limited.[6]

Due to the difficulties outlined above, our team decided to create an open source database with an accompanying automated process control chart generator for IPC programs. The objectives of this report are to provide an overview of the creation and workflow of the application while describing each of the software packages used, to provide the data dictionary and computer program used to build the application so others can implement the application at their facilities or build onto the program, and to provide evidence of the functionality of the application using simulated data.

METHODS

To develop this application, we used 3 open source software packages: Research Electronic Data Capture (REDCap Consortium, Vanderbilt University, Nashville, TN),[7] R (R Foundation for Statistical Computing, Vienna, Austria), and R Studio Shiny (R Studio Inc. Boston, MA).[8] Our approach in building the application and the workflow for its use are outlined below its use are outlined below in Figure 1.

REDCap

REDCap is an electronic data capture software package that was developed and is maintained by Vanderbilt University. It can be installed locally or on a server for multiple users. Our REDCap database is housed on a secure cloud-based server and is composed of several data collection forms. Separate forms are used for the following items: dates (eg, month in which data were collected), facility (eg, name of facility or facilities providing data), and events to monitor (eg, hand hygiene compliance or *Clostridium difficile* infections). The options for the facility and processes are preloaded into the system and are activated for users upon request. REDCap Data Access Groups (DAGs) are used to ensure confidentiality of records and house unique users in each facility. REDCap restricts access to all data so that users in specific DAGs can only access records that have been created by users in that DAG. This restriction is also applied to reports and exported data sets. Data collection forms can be uniquely set for each DAG through user role settings, so that facilities are only tracking data of interest. Data are exported from REDCap using its Application Programming Interface (API), facilitating automated subsetting of data for each facility upon data export or visualization. The data collected can be dynamically changed as facilities add or delete items of interest to monitor. For example, it is simple to add or delete any compliance measure or infection to be monitored through the REDCap Web interface or data dictionary, particularly because all measures

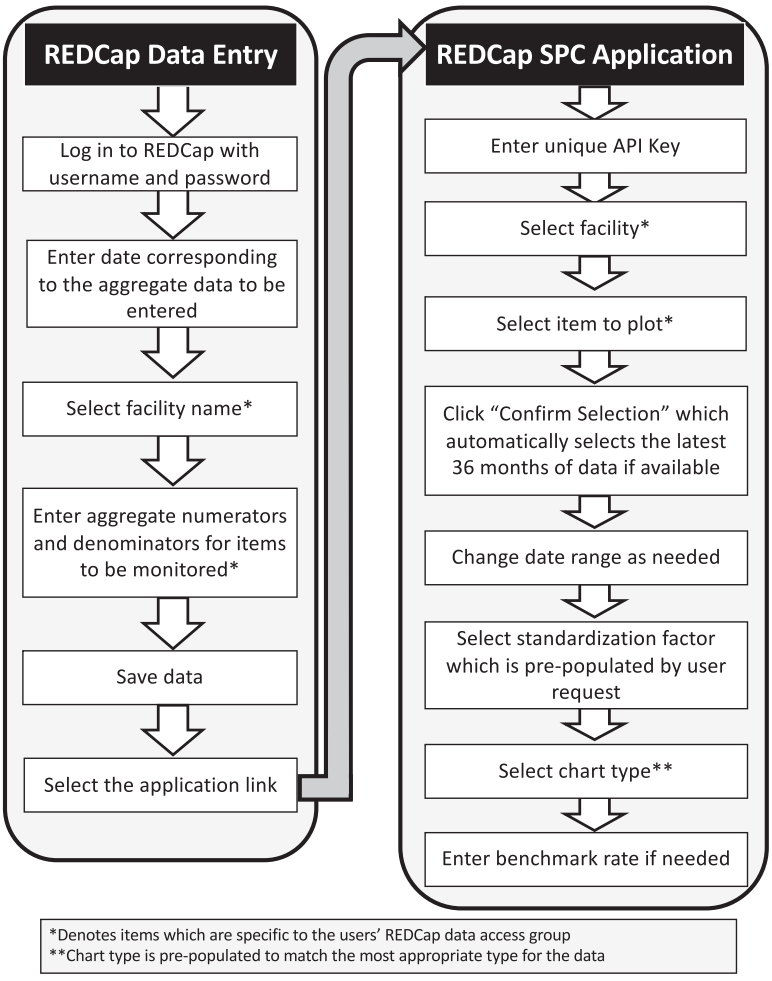

Fig 1. Workflow for data entry and process control chart creation. *Items that are specific to a user's REDCap data access group. **Chart type is prepopulated to match the most appropriate type for the data. *REDcap*, Research Electronic Data Capture (REDCap Consortium, Vanderbilt University, Nashville, TN).