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Major Article

Googling your hand hygiene data: Using Google Forms, Google Sheets, and R to collect and automate analysis of hand hygiene compliance monitoring

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Key Words:
Hand hygiene
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Shiny
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Hawthorne effect

Background: Hand hygiene is one of the most important interventions in the quest to eliminate healthcare-associated infections, and rates in healthcare facilities are markedly low. Since hand hygiene observation and feedback are critical to improve adherence, we created an easy-to-use, platform-independent hand hygiene data collection process and an automated, on-demand reporting engine.

Methods: A 3-step approach was used for this project: 1) creation of a data collection form using Google Forms, 2) transfer of data from the form to a spreadsheet using Google Spreadsheets, and 3) creation of an automated, cloud-based analytics platform for report generation using R and RStudio Shiny software.

Results: A video tutorial of all steps in the creation and use of this free tool can be found on our YouTube channel: https://www.youtube.com/watch?v=uFatMR1rXqU&t. The on-demand reporting tool can be accessed at: https://crsp.louisville.edu/shiny/handhygiene.

Conclusions: This data collection and automated analytics engine provides an easy-to-use environment for evaluating hand hygiene data; it also provides rapid feedback to healthcare workers. By reducing some of the data management workload required of the infection preventionist, more focused interventions may be instituted to increase global hand hygiene rates and reduce infection.

Hand hygiene is one of the most important interventions in the quest to eliminate healthcare-associated infections.[1,2] Since hand hygiene rates are reported to be unacceptably low and variable, interventions are needed to improve adherence.[1,3,4] A critical prerequisite to any intervention for improving hand hygiene includes observation of hand hygiene opportunities with the provision of rapid feedback.[3,5] Unfortunately, collection of hand hygiene data is cumbersome, often biased,[6,7] and can be labor intensive due to the need for multiple data collectors, data entry into an electronic format, assurance of data quality, statistical analysis, and report generation.[8] In 2010, the University of Iowa released the *iScrub* mobile application for hand hygiene data collection on an iPhone.[9] Although this application was specific to the Apple iPhone platform and relied on the user to perform statistical analysis and report generation for the data collected, it revolutionized mobile data collection for hand hygiene in the United States.

The objectives of this study were twofold: 1) to use freely available applications to develop a tool for hand hygiene data collection, while maintaining independence from a specific device or operating system; and 2) to create a free, web-based application for automated, interactive, and real-time analysis of data collected.

METHODS

A 3-step approach was used for this project: 1) create a data collection form, 2) transfer data from the form to a spreadsheet, and 3) create an automated analytics platform for report generation. Because of their usability, functionality, and interoperability, we used the following software: Google Forms (Alphabet Co., Mountain View, CA), Google Sheets, R (R Foundation for Statistical Computing, Vienna, Austria), and RStudio Shiny.[10]

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Step 1: Creation of a data collection form

First, a data collection form was created using Google Forms. The form created is linked to a specific Google user's account; to ensure data security, it is not made public. For the purposes of this example, the primary author's Google account was used. The form has 6 fields: 1) Date, 2) Time, 3) Location, 4) Individual type, 5) Moment, and 6) Compliant? A copy of our testing form is available through the corresponding author's Google Forms page.[11] A description of the data to be collected and the flexibility of the form's fields are as follows:

Date: Text input of the date of the hand hygiene observation, validated for date input.

Time: Text input of the date of the hand hygiene observation, validated for time input.

Location: A dropdown list including the various locations in which observations may occur. The user may include all locations specific to their facility. They do not have to adhere to the locations included in our testing form example.

Individual type: A dropdown list including various professions for which observations may occur. Similar to the Locations field, the user may include any professions they require.

Moment: A dropdown list including the Five Moments for Hand Hygiene as described by the World Health Organization.[12] The user may opt to include fewer or more moments or completely different options.

Compliant? A yes/no radio button indicating whether the observation was compliant or non-compliant with guidelines.

Step 2: Transfer of data to a spreadsheet

Google Forms allows for direct linking of input into a Google Form with Google Spreadsheets through the "Responses" tab on the form. After completion of the form, linkage occurs by choosing the responses tab and "View Responses in Sheets" icon. After this is completed, input into the form is automatically populated in the Google Spreadsheet of the same name. A copy of our testing spreadsheet (linked from the form indicated above) is available through the corresponding author's Google Spreadsheets page.[13] The form is currently unlinked from the spreadsheet to protect from accidental data entry into the template form. It is imperative that individuals create their own form and link to their own spreadsheet to prevent unanticipated data sharing. Once the form is created, it can be shared with users by clicking the "Share" button on the form.

Step 3: Creation of an automated analytics platform report generation

The analysis tool was built using the R software environment as the analytics engine and the Shiny application for the user interface and server actions, as described previously.[14,15] Using the R package *gsheet*,[16] the shared Google Spreadsheet URL can be pasted into the analysis engine for on-demand automated analysis and report generation. Once this is accomplished, the analysis engine pulls the data from the Google Spreadsheet and performs several functions, resulting in a final report. By clicking the "Share" button in the linked Google Spreadsheet, a link can be obtained for use in the analysis engine URL box.

Items included in the report include: 1) A statistical process control *P* chart. All points indicative of special-cause variation on the statistical process control chart are automatically marked as red dots (as opposed to black for common cause variation). It is important to note that a minimum of 25 months of data should be uploaded for a *P*-chart to be capable of detecting special-cause variation. If too few months of data are included, a chart will not be created, to protect some statistical validity. 2) A table consisting of a rolling year of monthly data with the date, numerator (number of compliant observations), denominator (total observations), and the percent compliance. And 3) a table consisting of annual aggregate compliance rates. Annual rates are automatically compared to each other using the mid-*P* exact test.

On-demand filtering and re-calculation of the chart and tables are allowed through a user interface. The interface allows for subsetting data in a date range, as well as for Individual type, Location, and Moment. This allows for a flexible evaluation of the collected data.

Data security is maintained at 3 levels: 1) the user's password-protected Google Account; 2) the firewall for the secure socket layer-protected server at our university, and 3) the software's maintenance of data only in the server's random access memory; data are automatically deleted when the browser window is closed. No data are ever stored on a local hard drive or maintained in any fashion. Regardless, basic access to Google Forms and Sheets does not provide a Health Insurance Portability and Accountability Act (HIPAA)-compliant tool for collection and storage of protected health information.

RESULTS

A video tutorial of all steps, including creating the Google Form, linking it to a Google Spreadsheet, and using the analysis engine, can be found on our YouTube channel: https://www.youtube.com/watch?v=uFatMR1rXqU&t. A screenshot of the report generated is depicted in Figure 1. The analysis tool is available at: https://crsp.louisville.edu/shiny/handhygiene. The report in Figure 1 can be recreated by pasting the Google Spreadsheets link indicated previously[13] into the "Google Sheets URL" section of the analysis tool.

DISCUSSION

In this study, we established a framework for collecting hand hygiene observations that is easy to set up and use, using freely available, platform-independent software. Furthermore, we created an automated analytics engine that provides flexible and on-demand reporting tools. All interested individuals are encouraged to set up their own Google Form/Sheet based on the criteria above. They will have unlimited, free access to the analysis tool located on the previously mentioned website.

Hand hygiene observation with feedback may be an important piece of a multimodal intervention to increase hand hygiene compliance.[2,5] As shown in a recent systematic review,[3] several studies have suggested that performance feedback may lead to lower infection and colonization rates as well, underscoring the importance of this intervention.[17-22] Moreover, since observation of hand hygiene opportunities results in only a limited snapshot of the overall hand hygiene compliance within an organization, encouraging more observation is critical.[4] By making it easy to collect hand hygiene observations on multiple devices without the need for manual data entry, and with an automated analysis tool, efforts can be focused on interventions to improve adherence.

This approach is not without limitations. First, basic access to Google Forms and Sheets does not provide a HIPAA-compliant environment for the collection and storage of protected health information. The form created for the purposes of this project does not collect identifiable data on any individual. However, many facilities are blocking access to Google services for privacy reasons. Although the data are not shared, and any links are used only within the confines of a secure server environment, as with any online

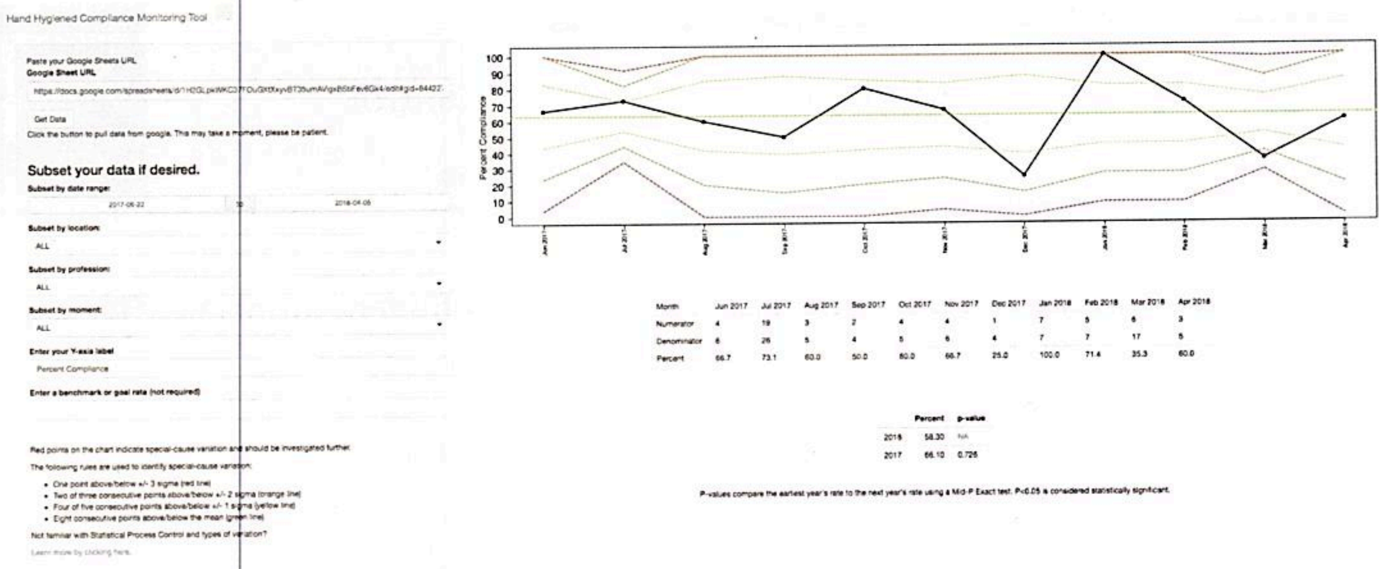

Fig 1. Automated analytics platform report located at https://crsp.louisville.edu/shiny/handhygiene.

service data breaches are possible. Even though no protected health information is collected using our approach, facilities may not wish to risk any data leaks. A second limitation is within the R environment. It is difficult to program the software with all possible approaches considered beforehand. For example, our analytics engine requires that the items in the Google Form be named exactly as described (Date, Time, Location, Individual type, Moment, and Compliant?). Changes in the text or spelling/punctuation will cause the engine to fail. This is a known issue that we will be working on into the future.

Although the field names are standardized, the elements within those fields are flexible. This is a strength of our approach, allowing nearly limitless opportunity for modifying the items within 3 variables: Location, Individual type, and Moment. For example, although the field is named Moment, if an individual does not wish to collect the Five Moments for Hand Hygiene, they can include any items within the Moment field. Any items included within that field will be available for subsetting in the analysis engine automatically.

In conclusion, this data collection and automated analytics engine provides an easy-to-use environment for evaluating hand hygiene data; it also provides rapid feedback to healthcare workers. By reducing some of the data management workload required of the infection preventionist, more focused interventions may be instituted to increase global hand hygiene rates and reduce infection.

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Major Article

Asymmetric transfer efficiencies between fomites and fingers: Impact on model parameterization

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Key Words:
Transfer efficiency
Hand hygiene
Mathematical model
Parameterization
Environmental transmission
Hospital surfaces
Healthcare-associated infections
Fomite
Acinetobacter baumannii

Background: Healthcare-associated infections (HAIs) affect millions of patients every year. Pathogen transmission via fomites and healthcare workers (HCWs) contribute to the persistence of HAIs in hospitals. A critical parameter needed to assess risk of environmental transmission is the pathogen transfer efficiency between fomites and fingers. Recent studies have shown that pathogen transfer is not symmetric. In this study,we evaluated how the commonly used assumption of symmetry in transfer efficiency changes the dynamics of pathogen movement between patients and rooms and the exposures to uncolonized patients.
Methods: We developed and analyzed a deterministic compartmental model of *Acinetobacter baumannii* describing the contact-mediated process among HCWs, patients, and the environment. We compared a system using measured asymmetrical transfer efficiency to 2 symmetrical transfer efficiency systems.
Results: Symmetric models consistently overestimated contamination levels on fomites and underestimated contamination on patients and HCWs compared to the asymmetrical model. The magnitudes of these miscalculations can exceed 100%. Regardless of the model, relative percent reductions in contamination declined after hand hygiene compliance reached approximately 60% in the large fomite scenario and 70% in the small fomite scenario.
Conclusions: This study demonstrates how healthcare facility-specific data can be used for decision-making processes. We show that the incorrect use of transfer efficiency data leads to biased effectiveness estimates for intervention strategies. More accurate exposure models are needed for more informed infection prevention strategies.

BACKGROUND

Healthcare-associated infections (HAIs) are a major concern worldwide, with an estimated 722,000 cases reported in the United States in 2011.[1] The cost of HAIs in the United States is estimated to total as much as $45 billion, with excess mortality, increased hospital stays, development of multidrug-resistant microorganisms, and overall increased healthcare costs for the patient and their families.[1,2] *Acinetobacter baumannii* (*A. baumannii*) is a gram-negative pathogen that is most commonly associated with HAIs, particularly in intensive care units, producing a variety of illnesses including pneumonia, bacteremia, wound infections, and urinary tract infections.[3] The environment[4,5] and healthcare workers (HCW)[6,7] play a significant role in the transmission of this microorganism in hospitals. Understanding the environmentally mediated transmission dynamics of pathogens such as *A. baumannii* is critical for identifying a more targeted approach to effective infection control. To study pathogen transfer through fomite contamination, we evaluated the assumption of symmetry used in estimating the transfer efficiency, which is an important parameter that describes the proportion of pathogens transferred from skin to fomite and from fomite to skin.

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