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A novel tool for patient data management in the ICU—Ensuring timely and accurate vital data exchange among ICU team members

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ABSTRACT

Objective: The coronavirus pandemic has highlighted the need to simplify data collection for critically-ill patients, particularly for physicians relocated to the ICU setting. Herein we present a simple, reproducible, and highly-customizable manual-entry tool to track ICU patients using new HIPAA-compliant Google Big Query technology for parsing large datasets. This innovative flow chart is useful and could be modified to serve the particular needs of different sub-specialists, particularly those that either rely heavily on hand-written notes or experience poor electronic medical record (EMR) penetration.
Methods: The tool was developed using a combination of three Google Enterprise features: Google Forms for data input, Google Sheets for data output, and Google Big Query for data parsing. Code was written in SQL. Sheets functions were used to transpose and filter parsed data. White and black box tests were performed to examine functionality.
Results: Our tool was successfully able to collect and output fictional patient data across all 57 data points specified by the intensivists and surgeons of Cardiovascular Department of Mt. Sinai Morningside Hospital.
Conclusion: The functional tests performed demonstrate use of the tool. Though originally conceived to simplify patient data collection for newly relocated physicians to the ICU, our tool also overcomes financial and technological barriers previously described in low-income countries that could dramatically improve patient care and provide data to power future studies in these regions. With the original code provided, implementers may adapt our tool to best meet the requirements of their clinical setting and protocols during this very challenging time.

1. Introduction

The coronavirus pandemic has changed medicine dramatically across the globe. Elective cases and non-emergency visits were and continue to be mostly canceled, leaving many physicians with substantially altered workloads. One such group is surgeons, who had their operative schedules cancelled by political and/or institutional orders and their job descriptions precipitously altered to become participants in the care of critically ill coronavirus disease 2019 (COVID-19) patients. Thus in coronavirus "hot-spots," where the high infection rates were causing critically ill patients to fill up intensive care units (ICUs) and even entire hospitals, there were fewer available healthcare workers to staff the ICUs. As a result, non-critical care physicians who do not typically work in the ICU setting were recruited to boost the ICU staff and meet the unexpected demand [1–3]. These healthcare workers with less training and experience in critical care medicine had to resort to accelerated training in respirator management and use of different critical care medication in order to provide needed care.

One significant burden on healthcare workers rapidly adapting to the ICU setting is the electronic medical record (EMR). Such difficulty is in part due to the tremendous volumes of clinical patient information presented in the EMR, especially in intensive care settings [4]. The review of this clinical information and documentation has been shown to consume vast amounts of physicians' time, [5,6] including ICU providers [7]. The EMR may also contribute to data overload, overwhelming the providers with large quantities of information that many may feel are inadequately organized [8]. Furthermore, providers report finding certain clinical data points or information more necessary than

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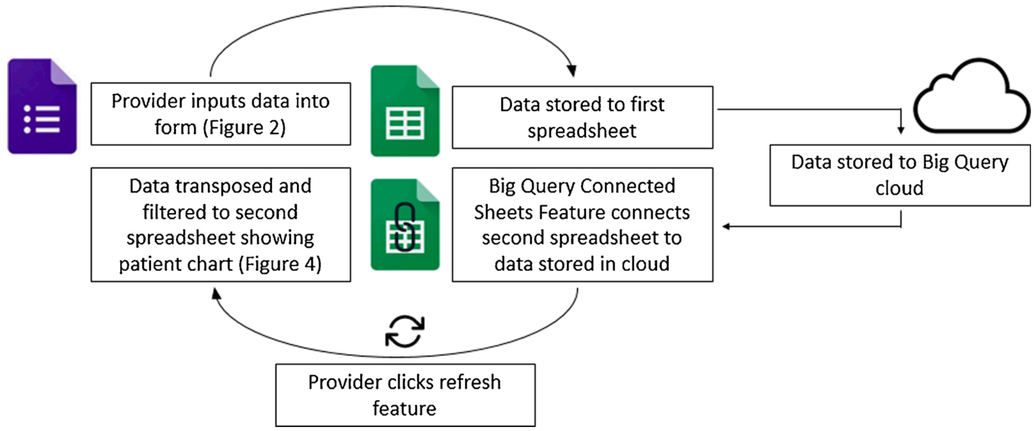

Fig. 1. Simplified illustration of how data is transferred between three *G Suite Enterprise* functionalities: Forms, Big Query, and Sheets.

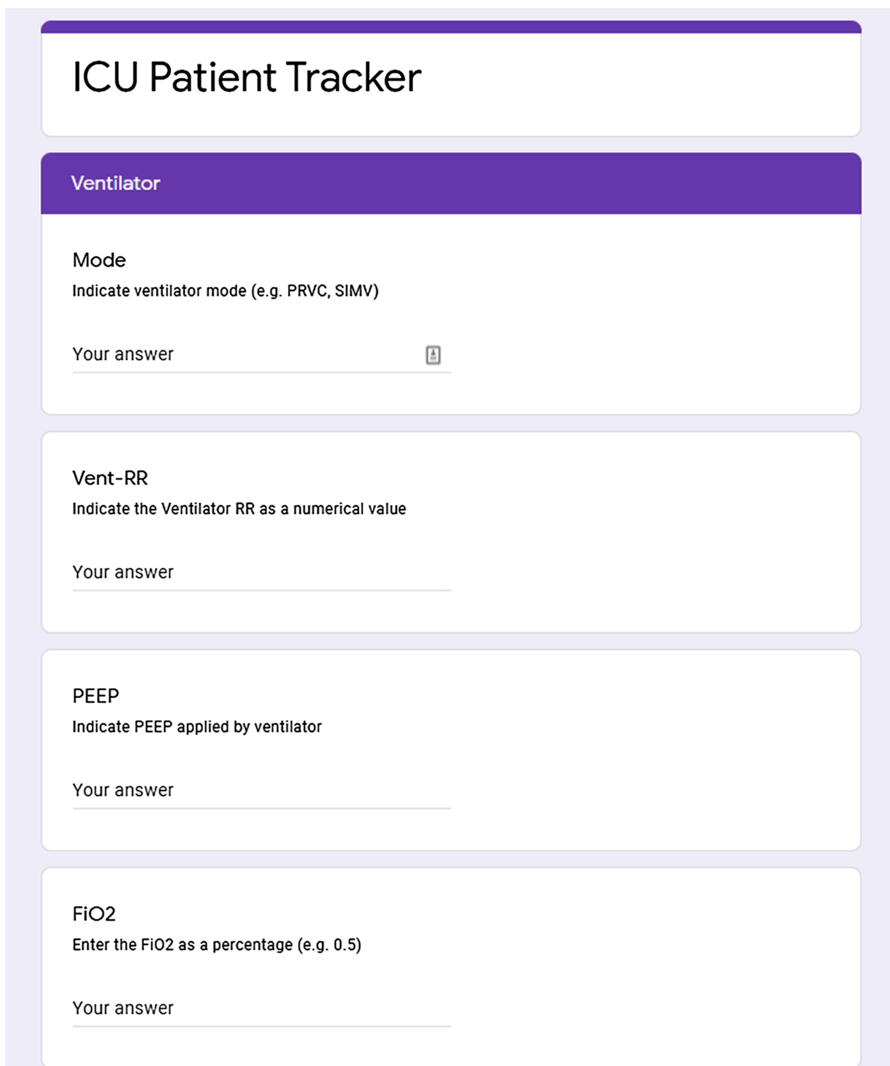

Fig. 2. Example of Google Form to Input Patient Data. This image shows only the section of the Google Form that records ventilator readings. Other sections exist for data points such as vital signs, lab results, intake and output, and more. A total of 57 data points can be recorded on our version of the Google Form. All fields in the form can be customized in the process of adapting our code to meet the protocols of specific institutions or ICUs.

others [9], indicating that providers may prefer more customized EMR experiences. These reasons highlight an opportunity to consolidate the information EMRs present to focus on what providers most value and in an organized and succinct manner. Such a need is particularly true for providers who are new to a specific ICU setting such as the case when faced with the demand of treating COVID-19 patients. These changes

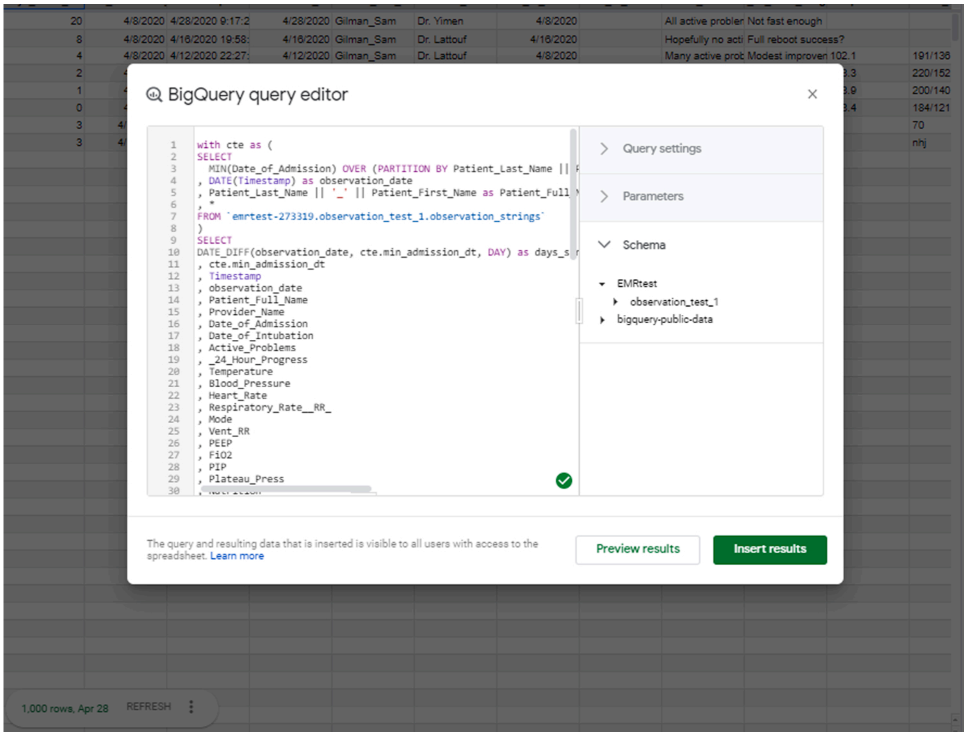

Fig. 3. Big Query Code: This figure shows a portion of the SQL query necessary to send the data from the original Google form into the cloud-based Big Query where data is stored. Please see the full source code in the Supplementary data.

would ensure that they can both quickly adapt to the ICU while also providing the best possible care.

In order to help more easily facilitate the transition of non-ICU healthcare workers to, or the transition of new team members to an established ICU system, we describe a dynamic patient chart built on HIPAA compliant Google apps available through *G Suite Enterprise*, structured to meet the needs of non-ICU trained staff, or new team members, to treat critically ill patients.

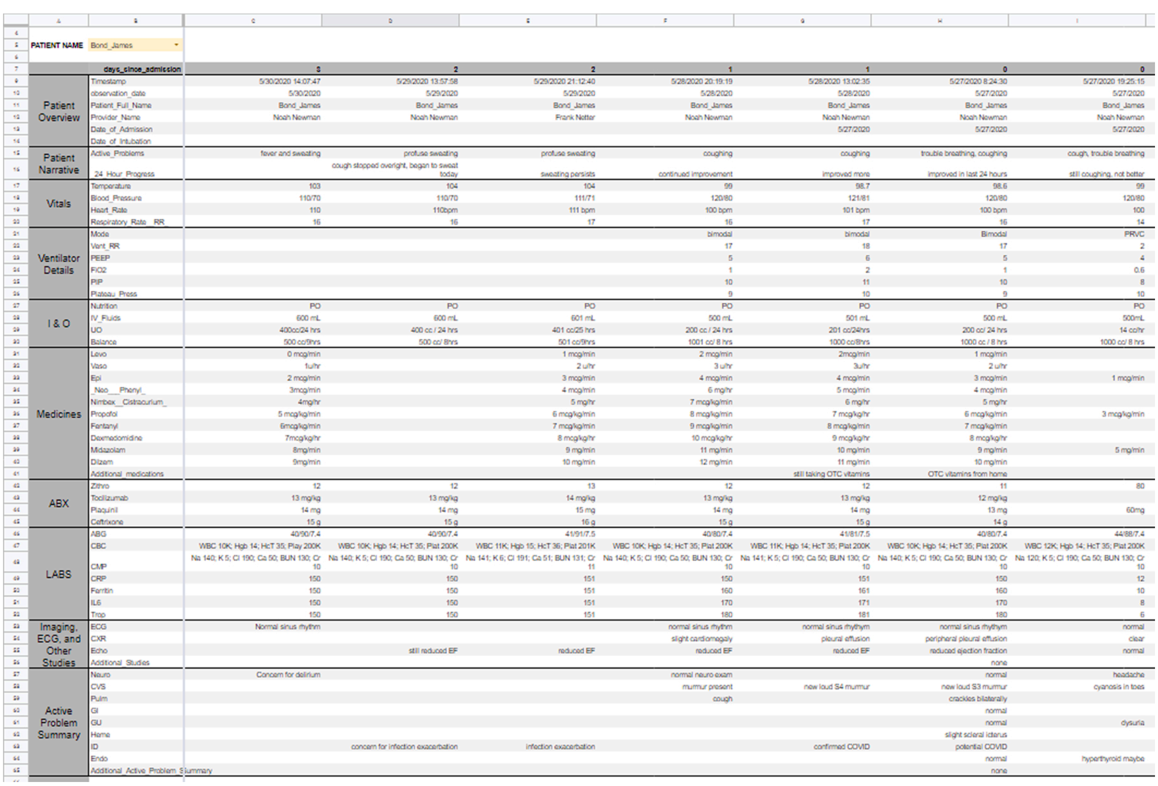

Fig. 4. Example of a Patient Chart: This chart was produced for a single fictional patient during the black box tests. This view was taken as a screenshot from a computer. Directly printing this view is also possible.

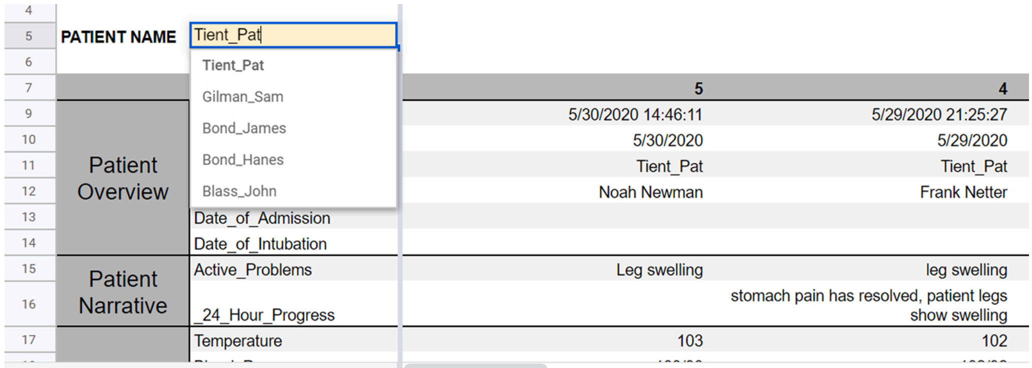

Fig. 5. Example of Patient Drop Down Menu: All individual patients are recorded in here and can be selected interchangeably.

2. Methods

This tool was developed based on flowcharts utilized in the conventional EMR using three *G Suite Enterprise* features: Google Forms, Sheets, and Big Query. The only required hardware for this tool is a device with internet connection. Providers will also need a *G Suite Enterprise* account to be set up by an administrator. Google securities including username and password protection protect the data stored, ensuring that only those with credentials through the provider's *G Suite Enterprise* Account can access the patient data. Data is automatically stored in the Google cloud after any manipulation where it is also protected.

By design, there were no restrictions on hardware or operating system used to develop the tool, and the tool can be used on either mobile devices or laptops and desktops. Google Forms was used to create and edit the fields for data input. Google Big Query was used to write SQL code for both data parsing and data transmission to the cloud. Google Sheets was used to design the patient chart where stored data was outputted. Formulas within Google Sheets were used to filter and organize the data.

Fig. 1 summarizes the data path and its relationship to the three *G Suite Enterprise* functionalities. First, providers manually enter patient data into a custom-built Google Form during daily rounds of COVID-19 ICU patients (Fig. 2). The results from each entry in the Google Form is both automatically outputted into a spreadsheet and parsed using Structured Query Language (SQL) (Fig. 3) to be stored in Google's cloud-based data warehouse called Big Query.

Next, the dynamic patient chart leverages the Big Query beta feature called Connected Sheets. Connected Sheets allows users to take a massive data set and make it available for analysis without SQL or other programming languages [10]. In other words, Connected Sheets removes row limitations and other constraints typically present in Google Sheets to present millions of rows of data from patient rounds conducted by providers in the ICU. In the present case, we enable Connected Sheets to transmit the trove of patient data housed in Big Query to this second spreadsheet that contains the patient chart template (Fig. 4).

Once the data is available to the second spreadsheet, we use transpose and filter functions to display individual patient charts. Filter functions allow a variety of providers to view each individual patient's records, as needed and simultaneously.

2.1. Cost and HIPAA compliance

Any hospital can operationalize this dynamic patient chart by purchasing Google Enterprise accounts [11] for each provider using the tool and replicating the design of the tool we present in this paper. While each of the three functionalities employed—Google Forms, Google Sheets, and Big Query—can be HIPAA compliant if the data is kept within the hospital's *G Suite Enterprise* cloud, any hospital seeking to use these tools with Personal Health Information (PHI) must sign a separate Business Associate Agreement to confirm terms of use under HIPAA [12].

2.2. Tool testing

This paper modeled functionality testing similar to da Silva et al.'s study of software development that introduced mobile applications to track nursing workloads in the ICU [13]. They utilized both white box tests and black box tests to ensure functionality.

In our study, we performed white box tests to test SQL code and Google Sheets functions, including variables, conditions, functions, and logic. We also performed black box tests by sharing a *G Suite Enterprise* account with one of the authors who did not develop the code. Over the course of three days, this author submitted fictional ICU data of three fictional patients twice daily to simulate patient rounds. The inputted and outputted data were compared to ensure correct parsing and transfer of data.

3. Results

3.1. Tool features

The designers built the Google Form to match specifications from the Mt. Sinai Morningside Hospital intensivists and surgeons of the ICU, including 57 data points requested to be tracked for each COVID-19 ICU patient on rounds. The physicians specified data points based on two criteria: data points (1) that the physicians utilized most during twice daily rounds of critically ill COVID-19 ICU patients and (2) that would transmit a comprehensive status report of these patients based on the team's physicians' collective clinical judgement. The form allows providers to record overview data, patient progress updates, vital signs, ventilator readings, intakes and outputs, medications, antibiotic names and dosages, lab values, imaging and ECG readings, and other studies, as well as notes on active problems specific to different organ systems. In our current design, all of this data is inputted manually into the aforementioned Google Form. The Google Form can be easily manipulated to include additional or fewer data points in the process of adapting our code to meet the protocols of specific institutions or ICUs.

The patient chart allows providers to view each patient's records, by day, from the newest record to the oldest. The spreadsheet presents patient data in a user-friendly interface (Fig. 4). Patient records are outputted chronologically so providers can immediately and sequentially understand patient progress. In order to toggle between patients, providers may select a different patient name or patient ID from a drop-down menu that includes each patient name (Fig. 5). Two-tier filters can be designed for large hospitals to first enable providers to select a group of providers by attending physician and then select the individual

- The coronavirus pandemic displaced many healthcare providers to intensive care units to meet the demand of incoming COVID-19 patients
- The infrastructure and IT support costs needed to establish EMRs are barriers to underserved regions adopting EMR technology
- In regions with less EMR penetration, this tool allows for low-budget cost and IT support, which is valuable both for patient care as well as data collection for future research
- Healthcare workers using this tool can manage patient information electronically with less data overload and a more intuitive use experience

patient of interest.

As long as each provider has a *G Suite Enterprise* account, the provider can digitally access their own copy of the patient chart to manage their own patients. This feature ensures that multiple providers can review the same and different patients at exactly the same time without conflict. Reviewing patient files merely requires providers to “Refresh” the query and select their patient from the drop-down menu. The patient chart interface is designed for online use on a computer or tablet, and it is also printer friendly so they can be handed to new providers during shift changes.

3.2. Tool testing

The white box tests were all positive, ensuring the code worked across a variety of input conditions. The black box tests produced 18 entries. A comparison of the inputted and outputted data for all 18 of the entries showed accurate data replication in all the correct fields, producing a 100 % success rate. These reports were then printed to ensure readable format. Additionally, two different users logged into two different *G Suite Enterprise* accounts accessed and reviewed the same and different patient charts simultaneously. This led to no errors.

4. Discussion

While the EMR has provided tremendous benefit to healthcare, it has also attracted frustration from some providers over recent years [14,15]. Such dissatisfaction with EMRs has been identified as a risk factor for physicians leaving the medical field [16]. This highlights the need to make adjustments to the current medical record.

Innovating medical records to fit physician needs is nothing new. Some of the earliest innovations for our modern EMR came in the early 20th century, when disgruntled physicians used ideas from business and industry to innovate medical records that solved problems at the time such as non-centralized storage and non-uniform notes [17–19]. However, in recent years, financial incentives have driven health IT vendors to develop EMRs with little ability for innovation and adaptation that have burdened the medical system with high IT costs and constraints [20,21]. Our tool seeks to be the opposite – provide healthcare workers as flexible, simple, and cost-effective a tool as possible to meet their immediate needs in treating COVID-19 critically ill patients.

In comparison to the conventional EMR, which one study found documented a median of 1483 clinical items over 24 h per pediatric patient receiving mechanical ventilation [4], our data collection tool records 57 data points per mechanically ventilated patient per round. Estimating that providers conduct three patient rounds daily would yield 171 data points per patient-day, only 11.5 % of the data points found in the aforementioned study. While certainly some value exists in collecting more clinical data, the pragmatism of recording and sifting through such large volumes during pandemic conditions should be strongly considered. The data points we chose for our tool focus on the need for data quality rather than quantity.

These properties also allow our tool to be shared on a global scale. Such sharing is particularly important in underserved regions of the world with less EMR penetration, yet the need to capture and exchange relevant data. Our tool, which relies on much less hardware and software than many modern EMRs, seeks to overcome barriers that low-income countries face to EMR implementation such as high implementation and maintenance costs and low computer literacy [22]. With more healthcare workers utilizing this tool, relevant data backed up to the cloud from areas that might not otherwise collect such data could be transferred to global health and funding organizations and partners, which in turn could make more informed and strategic decisions of how to fight diseases.

In order to maximize global utility of our tool, we are sharing the full Google properties we used so that others may adapt our tool. Please see the detailed technical instructions in the appendix (Supplementary File 1). In sharing our code, implementers have the ability to incorporate or remove features in order to maximize the tool’s utility for them. One future consideration is integration of automated data extraction from existing patient records to reduce labor and increase efficiency. Such a task would be highly institutionally specific because of the variations of EMRs across different institutions. Other more complex features of the modern EMR such as managing transactions and creating orders could be incorporated too; however, this comes at the cost of increasing implementation expenses and tool complexity outside our intended scope.

5. Conclusion

The coronavirus pandemic has strained medical resources on a global scale, and has required the recruitment of staff into the ICU setting who may have limited or no formal ICU training. The current EMR presents these new staff members with its own set of challenges; in addition to the challenges many of these workers face to adjusting to a new clinical environment. The pandemic has also revealed the need for affordable medical records solutions designed for the crisis. This is especially true in hospitals and regions where EMR tools are not available.

Using our design, hospitals can leverage *G Suite Enterprise* tools to track COVID-19 ICU patients at minimal cost and configuration time. From the provider standpoint, using the tool is remarkably straightforward. Future work can likely build bulk uploads between this tool and EMR record systems to ensure a single source of truth exists for each patient, though the version that we built does not yet have that functionality. Ultimately, in emergency environments that leverage rapidly retrained providers and those with minimal resources, *G Suite Enterprise* based dynamic patient charts offer healthcare workers a flexible, simple, and cost-effective way to manage patients.

Summary points

Author statement

Authors have no special considerations regarding their submission. There are no related papers by any of the authors already published or under consideration for publication. There are no previous communications with any of the editors.

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijmedinf.2020.104291.

References

[1] B. Bennet, 'It's Almost Like Learning How to Be a Doctor Again.' How One New York ICU Reinvented Itself to Treat COVID-19 Patients (Accessed 25 April 2020), TIME, 2020, https://time.com/5818835/coronavirus-doctor-new-york-icu/.
[2] S. Sengupta, With Virus Surge, Dermatologists and Orthopedists Are Drafted for the E.R. (Accessed 25 April 2020), The New York Times, 2020, https://www.nytimes.com/2020/04/03/nyregion/new-york-scoronavirus-doctors.html.
[3] M. Valerio, Mobile ICU Boot Camp Prepares New Wave of Doctors to Treat COVID-19 Patients, WUSA9. (Accessed 25 April 2020), 2020, https://www.wusa9.com/article/news/health/coronavirus/medstar-health-retrains-non-icu-physicians-step-up-treat-coronavirus-patients/65-f6c6f3d5-fa3c-47da-899e-105c3f61d47c.
[4] O. Manor-Shulman, et al., Quantifying the volume of documented clinical information in critical illness, J. Crit. Care 23 (2) (2008) 245–250.
[5] C. Sinsky, L. Colligan, L. Li, et al., Allocation of physician time in ambulatory practice: a time and motion study in 4 specialties, Ann. Intern. Med. 165 (11) (2016) 753–760, https://doi.org/10.7326/M16-0961.
[6] L. Block, R. Habicht, A.W. Wu, et al., In the wake of the 2003 and 2011 duty hours regulations, how do internal medicine interns spend their time? J. Gen. Intern. Med. 28 (8) (2013) 1042–1047, https://doi.org/10.1007/s11606-013-2376-6.
[7] P. Carayon, T.B. Wetterneck, B. Alyousef, et al., Impact of electronic health record technology on the work and workflow of physicians in the intensive care unit, Int. J. Med. Inform. 84 (8) (2015) 578–594, https://doi.org/10.1016/j.ijmedinf.2015.04.002.
[8] M.E. Nolan, R. Cartin-Ceba, P. Moreno-Franco, B. Pickering, V. Herasevich, A multisite survey study of EMR review habits, information needs, and display preferences among medical ICU clinicians evaluating new patients, Appl. Clin. Inform. 8 (4) (2017) 1197–1207, https://doi.org/10.4338/ACI-2017-04-RA-0060.
[9] M.A. Ellsworth, et al., *Clinical data needs in the neonatal intensive care unit electronic medical record.* BMC Med. Inform. Decis. Mak. 14 (2014) 92.
[10] F. Lardinois, Google Makes the Power of BigQuery Available in Sheets (Accessed 5 May 2020)., TechCrunch, 2019 https://techcrunch.com/2019/04/10/google-makes-the-power-of-bigquery-available-in-sheets/?renderMode=ie11.
[11] Choose your G Suite edition. Try it free for 14 days. Google. 2020. (Accessed 5 May 2020). https://gsuite.google.com/pricing.html.
[12] HIPAA Compliance with G Suite and Cloud Identity. Google. 2020. (Accessed 5 May 2020). https://support.google.com/a/answer/3407054?hl=en.
[13] R. da Silva, A. Baptista, R.L. Serra, D.S.F. Magalhães, Mobile application for the evaluation and planning of nursing workload in the intensive care unit, Int. J. Med. Inform. 137 (2020), 104120, https://doi.org/10.1016/j.ijmedinf.2020.104120.
[14] M.L. Graber, C. Byrne, D. Johnston, The impact of electronic health records on diagnosis, Diagnosis 4 (4) (2017) 211–223, https://doi.org/10.1515/dx-2017-0012.
[15] American EHR & the American Medical Association, Physicians Use of EHR Systems 2014, 2014. Available at: http://www.americanehr.com/research/reports/Physicians-Use-of-EHR-Systems-2014.aspx. (Accessed 10 April 2017).
[16] C.A. Sinsky, L.N. Dyrbye, C.P. West, D. Satele, M. Tutty, T.D. Shanafelt, Professional satisfaction and the career plans of US physicians, Mayo Clin. Proc. 92 (11) (2017) 1625–1635, https://doi.org/10.1016/j.mayocp.2017.08.017.
[17] Cl Camp, et al., Patient records at mayo clinic: lessons learned from the first 100 patients in Dr Henry S. Plummer's dossier model, Mayo Clin. Proc. 83 (12) (2008) 1396–1399.
[18] E.L. Siegler, The evolving medical record, Ann. Intern. Med. 153 (10) (2010) 671–677.
[19] R.F. Gillum, From papyrus to the electronic tablet: a brief history of the clinical medical record with lessons for the digital age, Am. J. Med. 126 (10) (2013) 853–857.
[20] K.D. Mandl, I.S. Kohan, Escaping the EHR trap—the future of health IT, N. Engl. J. Med. 366 (24) (2012) 2240–2242.
[21] C.S. Kruse, C. Kristof, B. Jones, E. Mitchell, A. Martinez, Barriers to electronic health record adoption: a systematic literature review, J. Med. Syst. 40 (12) (2016) 252, https://doi.org/10.1007/s10916-016-0628-9.
[22] F.F. Odekunle, R.O. Odekunle, S. Shankar, Why sub-Saharan Africa lags in electronic health record adoption and possible strategies to increase its adoption in this region, Int. J. Health Sci. 11 (4) (2017) 59–64.