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Quantifying medical student clinical experiences via an ICD Code Logging App

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ABSTRACT

Objectives: The logging of ICD Diagnostic, Procedure and Drug codes is one means of tracking the experience of medical students' clinical rotations. The goal is to create a web-based computer and mobile application to track the progress of trainees, monitor the effectiveness of their training locations and be a means of sampling public health status.

Materials and

Methods: We have developed a web-based app in which medical trainees make entries via a simple and quick interface optimized for both mobile devices and personal computers. For each patient interaction, users enter ICD diagnostic, procedure, and drug codes via a hierarchical or search entry interface, as well as patient demographics (age range and gender, but no personal identifiers), and free-text notes. Users and administrators can review and edit input via a series of output interfaces. The user interface and back-end database are provided via dual redundant failover Linux servers.

Results and discussion: Students master the interface in ten minutes, and thereafter complete entries in less than one minute. Five hundred-forty 3rd year VCOM students each averaged 100 entries in the first four week clinical rotation. Data accumulated in various Appalachian clinics and Central American medical mission trips has demonstrated the public health surveillance utility of the application.

Conclusion: PC and mobile apps can be used to collect medical trainee experience in real time or near real-time, quickly, and efficiently. This system has collected 75,596 entries to date, less than 2% of trainees have needed assistance to become proficient, and medical school administrators are using the various summaries to evaluate students and compare different rotation sites.

1. Introduction

There have been many attempts, some successful and therefore sustained, to develop applications to enhance the practice of medicine for clinicians and their patients [1–4]. And there have been systems developed for procedural logging, including, for example, automated trauma patient coding by physicians dating back to the 1990s [5–8]. The apps have focused on narrow, specialized sets of codes, not ICD codes, and thus lacked wide applicability and universality. Some applications, apps, have been developed specifically to enhance medical training and capture the actions of trainees [9–11]. These apps have focused on accessing a variety of medical reference materials, but have not been used for logging student activities. None of the above-mentioned systems employed universal ICD codes for the purpose of measuring medical trainee clinical performance.

Current medical school curricula do not include or only touch upon billing, diagnostic or procedural code used in the clinic, so students, even in their clinical rotation years, are not effectively trained in the use of codes that will be a significant part of their professional career as they begin their own practice. Also, the exact breadth and depth of medical student training in their clinical rotation years is not quantified; often their experiences are captured in their loosely organized hand written notes. To address these issues and others, we have created a simple, easy to use "app" that at its core captures the diagnostic and procedural experiences of medical students via the internationally accepted ICD (International Statistical Classification of Diseases and

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Related Health Problems) system, currently in version 10 (ICD-10), created and maintained by World Health Organization (WHO) [12].

The goals and utility of this system are to:

1. Quantify the diagnostic and procedural experience for each medical student, so that it becomes part of their permanent record (medical portfolio)
2. Understand the breadth, depth, and variance of clinical experiences across all rotation specialties, rotation locales (clinics, hospitals, etc.), and students
3. Use this information to refine the clinical experiences and optimize the total training experience, especially to understand how well the curriculum objectives map to actual experiences
4. Expose students to the ICD code system, so that they are prepared to use it or similar systems as part of the Electronic Medical/Health Record (EMR/EHR) systems they will be using throughout their professional life
5. Capture and monitor in real-time the public health status of the communities in the vicinity of their training locales via accumulated statistical analysis of entries captured/sampled by the students, including trend and event trigger monitoring
6. Capture the activities of specialized events, including off-shore medical mission trips and specialty fellows

2. Methods

2.1. Design

The primary goal of the "app" is to capture the day-to-day clinical experiences though ICD codes, by providing a user interface and operability that is quick, accurate, and efficient, so that students will view this as a positive, convenient tool, as opposed to a time-consuming burden. The design and implementation team consisted of experienced informaticians, app designers, clinicians and school administrators. The data captured in the app was a balance between what is needed to meet the goals of the system, and that which can be quickly and easily entered by users, so as not to over-burden them. The team, working with initial testers identified key areas, such as a simple, straightforward human interface, optimized code entry methods and clear output summaries that enable individual performance monitoring. A major constraint was to create a system that did not require HIPAA compliance, so the design captured enough meaningful patient demographics to understand the relevant diagnoses and procedures logged, without needing Personally Identifiable Information, PII.

The design of the user interface and back-end database and the hardware capabilities, including speed, internet bandwidth, and reliability were prime considerations. For universal applicability across various PC types and mobile devices it was decided that the user interface for Version 1.0 would be provided via a browser, but that the presentation and operation would be separately optimized for large (PC) and small (mobile device) screens. Key to its design was entry compatibility and speed across all display form factors. This implementation requires Internet access, so a native application will be developed as part of Version 2.0 to remove the need for continuous Internet access, something not always available in remote locations.

Version 1.0 of the logging system or app is currently implemented through a browser page that quickly and easily captures trainee (or physician) experiences via user input of ICD codes has been developed, tested and is in use. The system syncs with a SQL back-end database, allowing for the accommodation of an effectively unlimited number of users, currently over 1300 users. The user navigation flow chart is provided in Fig. 1. There are four primary ways in which users interact with the app: 1) they set their rotation type and location via the settings page; 2) they create new patient ICD log entries via the logging page; 3) the can measure their quantitative performance relative to all other medical trainees for each clinical rotation; and 4) they update and associate logged data with clinical learning experiences and build an example test bank of questions via the dashboard. The primary web page used for logging provides the user with several methods for identifying the ICD code for a given entry – a hierarchical series of drop-down menus, a keyword-based search system; a list of the "Top 25" most frequent codes seen by all trainees in each rotation; and a recent entry selection. The system collects the following information from each user (student): 1) For each patient they experience; they select/enter the ICD code that describes their diagnosis and treatment procedure; and codes for WHO listed and/or FDA approved drugs; 2) the patient gender (M/F/O) and age (in relevant increments); 3) free-text notes; 4) the clinic/hospital and rotation type as entered by the user and whether the training environment is a hospital or ambulatory; 5) their precise location (as reported by the user's device); and 6) date/time of entry (populated using the server's time). This entry page is shown in Fig. 2. Users are able to select codes which would normally be considered non-billable (indicated in red font) to allow for deliberate ambiguity when a code of greater specificity is unfamiliar to the user or when there is insufficient clinical evidence for greater specificity. No personally identifiable information (PII) is collected on patients. A PII detection system prevents entry of PII into the free-text "Notes". The system does not allow entries to contain text that include patterns of numbers typical of phone numbers and social security numbers; or proper names. A database of 85,269 proper names was constructed from the analysis of the US Census; excluding certain common words that could also be proper names (certain stop words); and excluding eponymously-named diseases; e.g. Huntington's. The intent was not to create a new Electronic Health Records (EHR) system; which would require HIPAA compliance; but could limit acceptance of such a system in our many remote sites; if it was viewed as competing with existing systems. Indeed; we kept the focus on evaluating the students so as to have acceptance by those student training sites; and not have sufficient information to compete with their own full EHR systems. The back-end database generates simple reports that enable users to track and edit their entries; and allows administrators to monitor the cumulative entries from all students; monitor trends; and trigger alerts from defined thresholds. There are also displays designed to monitor the current activities being logged (codes; date and time only) and statistics that track and graph system-wide usage which can be monitored by administrators or as public displays so that students and visitors at the medical school can get an instantaneous view of clinical activities. See Fig. 3a–c.

The servers on which the system runs are Dell PowerEdge R710 systems with dual quad-core CPUs, 64 GB of RAM, and 3.5 TB of high reliability solid state disk drives. There are two identical servers with fail-over capability, and other off-site backup and mirrored. The system runs on a standard LAMP stack and is specifically comprised of Ubuntu 16.04, Apache 2.4.18, PHP 7.0.8, and MySQL 5.7.16. Data interchange with the app's front-end interface is asynchronous to allow for rapid entry. The MySQL database captures all the user logged information, and also contains all the user access information and other information required for the various displays. The database schema is given in Fig. 4. The entire database (including entries and ICD codes) currently is 70.8 megabytes. Each new entry (including its index) on average is 0.25 kilobytes. The app uses approximately 1.2 megabytes on initial load, but with caching and mod_pagespeed optimization, subsequent loads are only 34 kilobytes. Thus, the system (and associated bandwidth to/from servers) was designed for hundreds of simultaneous queries by users, for greater than 50,000 users, following stress tests conducted using Loader [13]. The current 540 3rd year students, the most intense users, are making entries at 1 per 16 s, orders of magnitude below the average and peak performance of the system.

The current content of the system is given in Table 1. The current version of the ICD system is version 10, including both diagnostic and procedural codes, retrieved from the WHO website, and drugs downloaded from the WHO ATC website and FDA approved drugs web site.

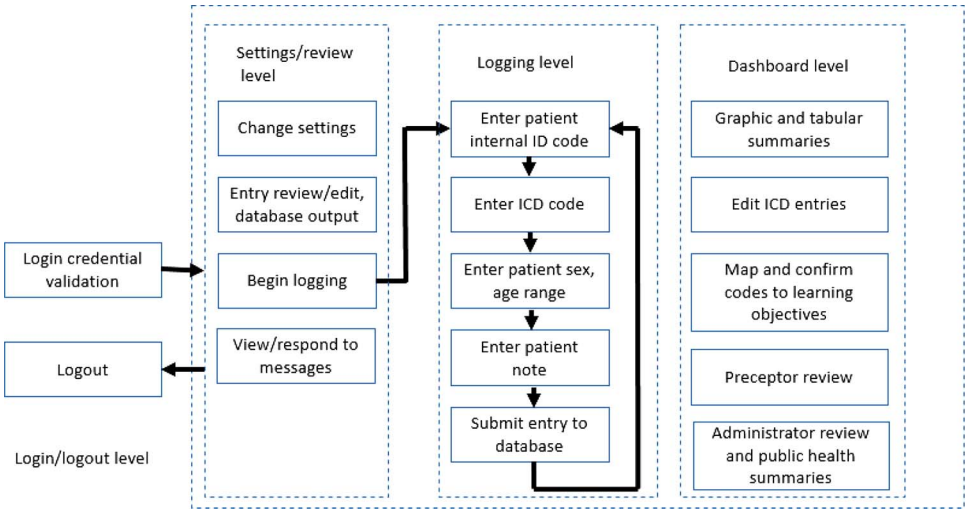

Fig. 1. Flowchart of the overall user process.

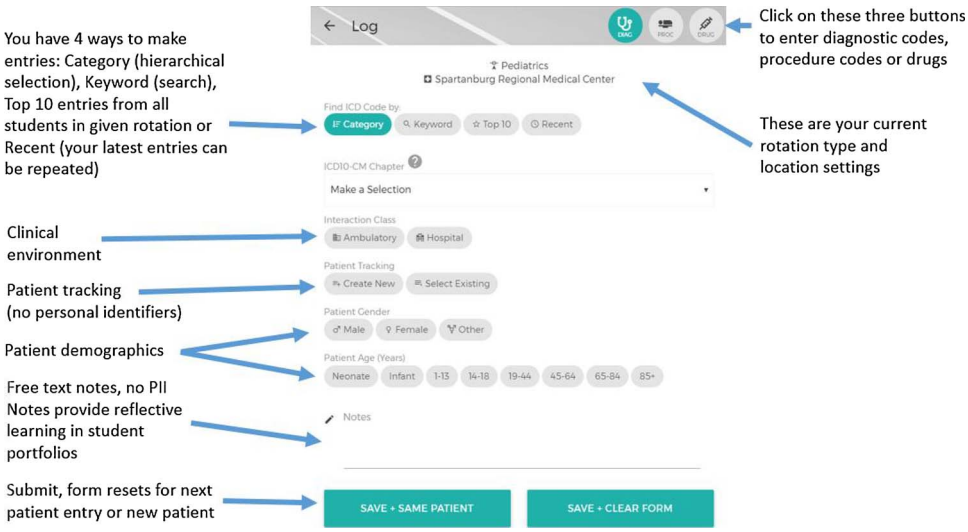

Fig. 2. The user logging entry interface.

[14,15,16] All codes are stored within the local database for maintaining referential integrity and providing detail-rich reporting functionality. At the VCOM medical school, there are over 80 recognized rotation and activity types; these activities are conducted at over 700 different locations (clinics, hospitals, etc.). There are program-specific tables which house rotation types and specific clinical locations, as well as administrative tables to maintain user entities, granular access rights, forgotten password recovery codes, etc. The keyword search procedure was implemented through use of the MySQL engine's native full-text index. The ICD descriptions were supplemented with synonyms to ease and speed finding the most specific code and enable common medical and non-medical terms to be used.

2.2. Participants

The initial beta testing of the system was carried out by ten third-year medical students who worked with the developers to report bugs and performance issues. They primarily interacted with the developers through the "support" link which allows them, and all users, to directly email developer and system support.

After the initial beta tests were complete, the system was made available to all 3rd and 4th year medical students, as well as 2nd year students on ten 1-week medical mission trips (to Central America), on a voluntary basis. Access to the ICD Logger was also provided to all VCOM faculty, administrators, affiliated clinicians, and preceptors.

As of August 1, 2017, logging for all 3rd year VCOM medical students was mandated. All students received a 30 min introductory lecture on the use of the logger system. Five hundred and forty students change rotations (and potentially sites) each four weeks. As of now, midway into their second rotation, 100% of students are logging.

A total in excess of 1200 users have logged onto the ICD Logger app.

2.3. Data analysis

Data is continuously processed and provided on a variety of displays (web pages), which we call the dashboard. Each student is provided with an interactive summary page of all their entries, which is editable, searchable, and has a variety of ranked column views. Students can also monitor their performance relative to all other students in the same rotation. Performance reports contain the number of entries made by the student and the fraction of the top 25 diagnoses, procedures and drugs which they have encountered as a measure of the breadth of clinical experience relative to all other students in a given rotation. There are also display pages for overall system use, recent entries, and other information. The full set of user entries can be exported to an Excel spreadsheet so that a variety of custom analyses can be performed by system administrators or VCOM faculty who wish to study the activities of the students during their various activities. Future data analysis displays can be implemented as needed.

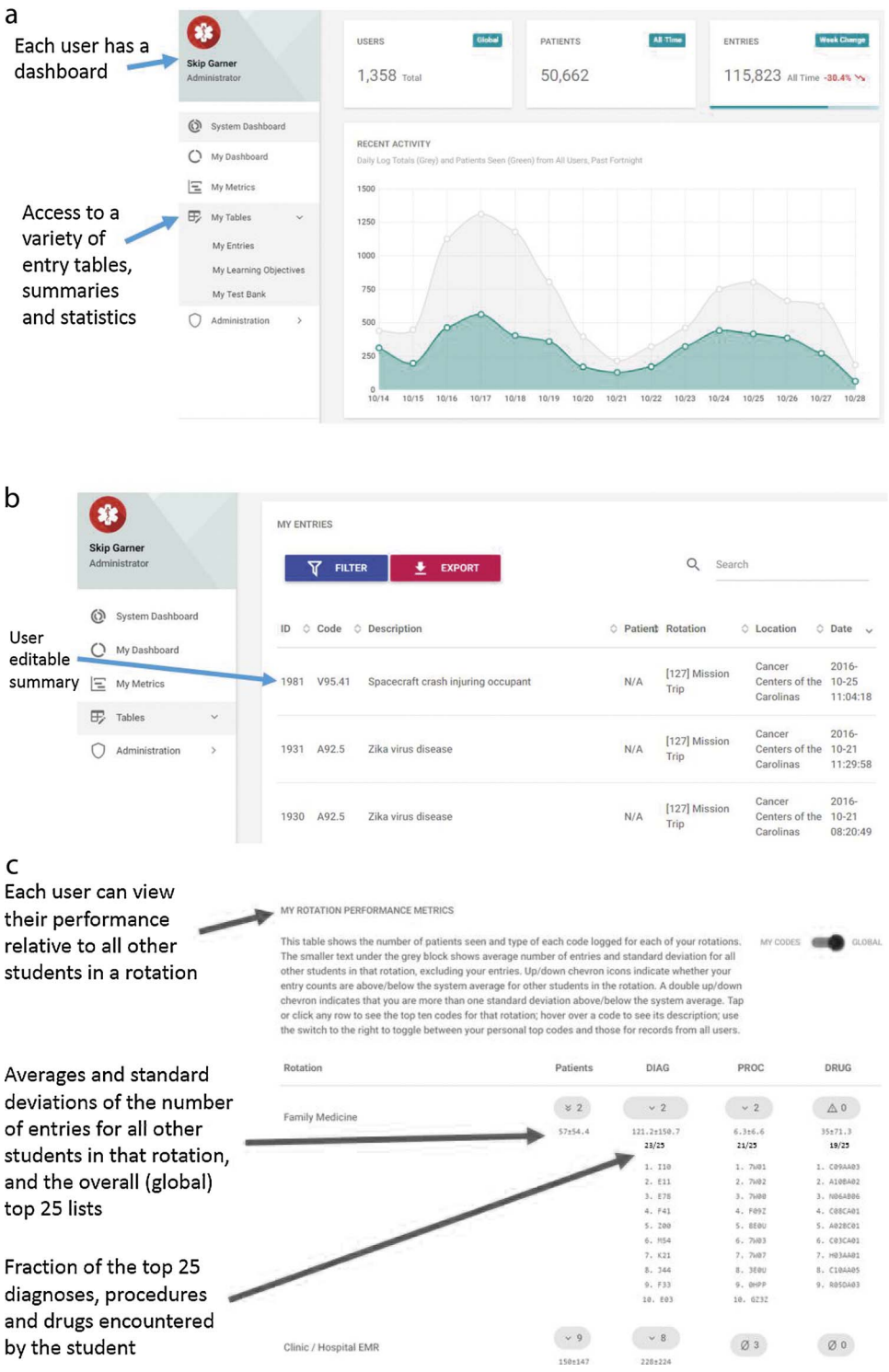

Fig. 3. a (top). The system summary dashboard. 3b (middle). The user editable summary table (with test data). 3c (bottom) Student performance metrics summary table. Metrics include counts of the number of entries as well as what fraction of the top 25 most encountered diagnoses, procedures and drugs that this student has encountered, as a measure of the breadth of their clinical exposure.

3. Results

The User Experience – During development, initial roll-out and now in regular use we have monitored user feedback to assist in optimizing the system. This was primarily done via sessions where the app is introduced to a new student group, for example typically 30 new students go on a mission trip, and then the developers work with the students for at least one hour as they begin to use the app. As reported by the student users: 1) It initially takes approximately ten minutes to master and begin logging; 2) the time required to make new log entries drops to < 1 min/entry; 3) users primarily select ICD codes using the search feature; 4) diagnostic entry selection is easier than procedure entries, especially as more specificity is required; and 5) students interact with the primary log entry page over 95% of the time, and only rarely review and edit/update entries via the dashboard interface.

The System Performance – The system has been in operation for over six months, with an uptime of > 99.9%. The highest use recorded was > 1500 entries in one hour, made by 50 concurrent users, with no change in user experience.

Use Demonstration 1 –On February 14, 2017 we engaged a team of eight 3rd year medical students to log their experiences and provide feedback to the development team. Students have completed two

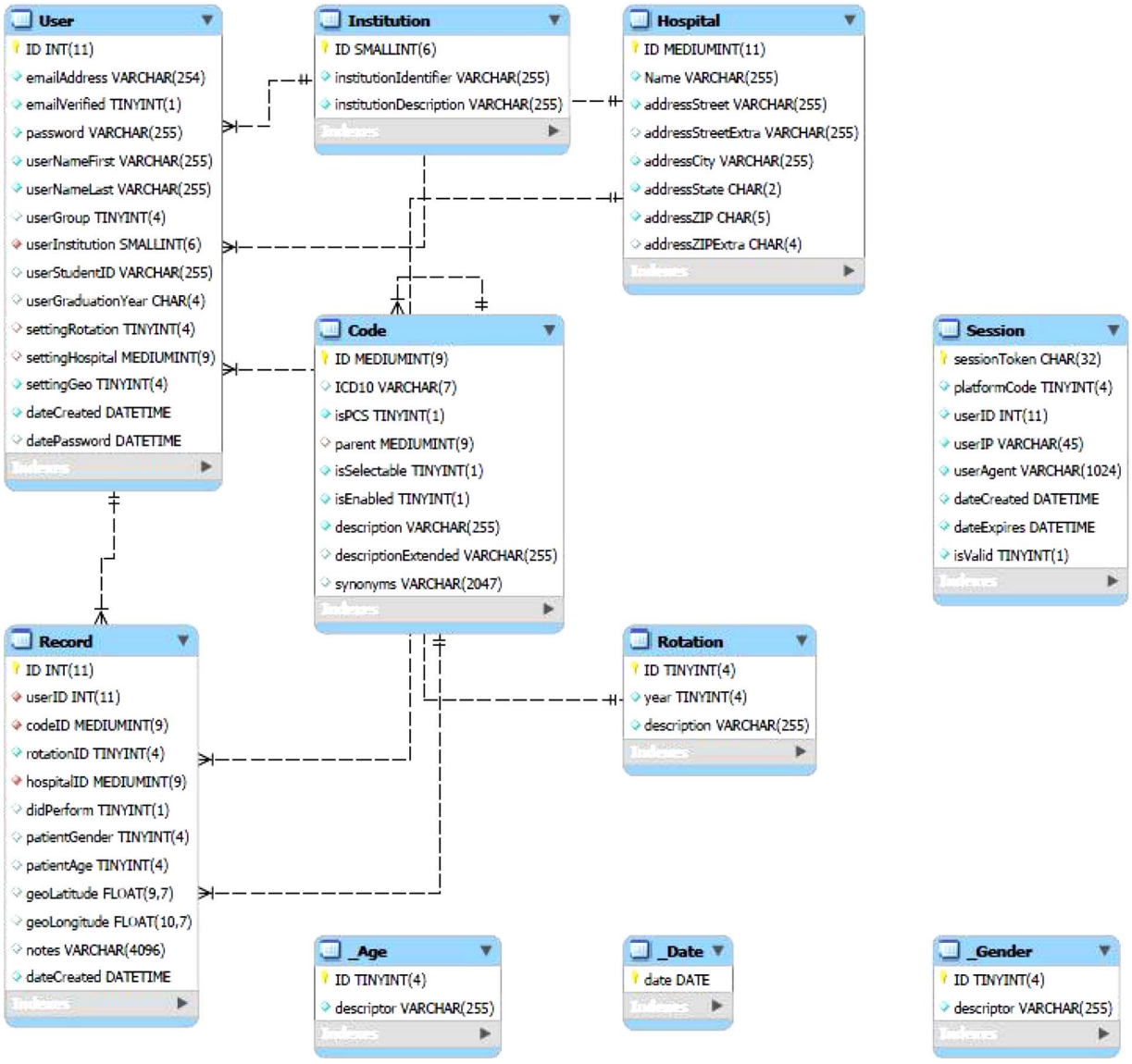

Fig. 4. Database schema.

Table 1
Content of the data tables.

ICD-10 Diagnostic Codes	44,221
ICD-10 Procedure Codes	78,705
WHO/FDA Approved Drugs	4823
Student Rotation Sites	> 700
Student Rotation Types	> 80
Learning Objectives	> 500
Student Users	> 1200
Faculty/Admin Users	> 100

clinical rotations (family medicine, internal medicine, psychiatry, geriatrics, pediatrics, etc.) of one month duration each at 13 different hospital/clinic sites. They have entered 2623 diagnostic, procedure and drug codes in the 40 days they have been in the clinic. The student entry rate varied significantly, between 97 and 916 entries, and it did not correlate with any particular type of rotation, but appears to reflect the variation in rigor among students. There were a total of 586 drug codes entered, with the most frequent being Amoxicillin, Cefdinir, Ondansetron and various forms of Acetaminophen. The most frequent diagnostic codes were (I10) essential primary hypertension, (E78x) various forms of hyperlipidemia, (E11x) various forms of Type 2 Diabetes, and (Bx) various viral infections. This sampling of diagnoses reflects the known obesity prevalence in Appalachia.

Use Demonstration 2–An additional system utility demonstration comes from 2nd year students that participate in the VCOM medical outreach trips to El Salvador, Honduras, and the Dominican Republic, where VCOM maintains a permanent local presence at its clinics [17]. There have been 10 mission trips, 7211 codes were entered by 239 student users. This has also given us insight into the Public Health potential for this app. The app has enabled us to make some fundamental observations: Females come to the clinics at twice the rate of males; the code (I10) essential primary hypertension was the most frequent, as expected given the worldwide obesity crisis. Given the socioeconomic level of the indigenous population that visit the clinics, it was not surprising to see that the next most frequent entries included were (J069) acute upper respiratory infection, (B89) unspecified parasitic disease, and (K21) gastro-esophageal reflux disease with esophagitis, for these are typically seen in first-world populations. There were a number of unique codes logged, including (A30) Leprosy, and a number of genetic or complex disorders: (Q90) Down's syndrome, (C5061) malignant breast neoplasm, and (Q66) congenital deformities of the feet, to name a few.

Initial results of 3rd year medical student logging – Medical students

while on their clinical rotations rely on handwritten notes to capture their experience, which are not standardized or searchable. On August 1, 2017 all 3rd year medical students were required to use the ICD Logger; all 4th year students could use it optionally. Students are logging between 200 entries/day (weekends) and 2500 entries/day (weekdays). All 3rd year students are currently logging. During the initial roll-out, the first four week rotation, we had less than ten students that needed assistance from our email/phone help line. This permanent, searchable, organized record is available to preceptors and college administrators to evaluate each students clinical training accomplishments.

4. Discussion

The Student Portfolio – Students have accepted the app as their primary method for capturing their clinical experiences and building their experience portfolio. 3rd year students are required to use the ICD Logger to illustrate their clinical experience, and to confirm the mandatory learning objectives that are defined by the medical school for each clinical rotation. Next year, both 3rd and 4th year students will be required to use the ICD Logger. The app, therefore also takes on a role in the formal documentation for the medical school. Preceptors now use ICD Logger information in reviewing their performance during a given rotation, and also use this information as an opportunity to engage students in reflective learning based on cases they have logged. Administrators can now evaluate the uniformity of the clinical experiences across various training sites using this data, both quantitatively (number of entries) and the considering the spectrum of different clinical cases encountered (using the top 10 list).

Extension of the “app” to future applications – This software system can be used in many ways, and would be extensible to other medical training areas (Emergency Medical Technicians, nursing, dentistry), for these other allied health professions require clinical experiences, which could be captured in the current app and its ICD-10 codes. It could also be used in other medical/non-medical areas (billing/coding training, survey taking, etc.), for it is simple and easy to use, with many options for entry. We can already see the potential as a public health monitoring/surveillance tool, for the data emerging is consistent with the general population health in the areas surveyed (Appalachia and Central America). Such a system could also be applied and used by other medical schools, of which in the US there are 180 medical schools. It could also be used in international schools, especially those that send students for their clinical experience in affiliated, but not attached, clinics.

5. Conclusion

This study showed that gathering ICD codes is an effective way to capture the diagnostic and procedural experiences of medical students in their clinical years. Initial voluntary student beta testers enabled us to release an initial version that is now in wide use by 3rd year medical students. Students, preceptors and school administrators can now better assess and quantify the performance of individual students, across different rotations and clinical sites.

Contributors

F.R. and H.R.G. contributed to the conceptualization of this project, software and experimental design, data analysis, and the writing of this manuscript. C.S. was responsible software implementation and debugging. D.S. was responsible for establishing and monitoring mission trip student users. All authors read and approved the final manuscript.

Competing interests

Authors have no competing interests.

Ethics approval

This work was conducted under IRB approval.

Provenance and peer review

Not commissioned; externally peer reviewed.

Summary Points

- We have developed a web-based app in which medical trainees can make entries into their clinical training portfolio via a simple and quick interface optimized for both mobile devices and personal computers.
- For each patient interaction, users enter ICD diagnostic, procedure, and drug codes via a hierarchical or search entry interface, as well as patient demographics (age range and gender, but no personal identifiers), and free-text notes.
- Users and administrators can review and edit input via a series of output interfaces.
- Students master the system in minutes, and then quickly enter their daily clinical activities. They can quantitatively review their entries relative to all other users.
- Data accumulated in various Appalachian clinics and Central American medical mission trips has demonstrated the public health surveillance utility of the application.

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