Medical Informatics

Developing an Educational Reminder System for a Handheld Encounter Log

Walton Sumner, II, MD; John Campbell, MD; Sarah C. Irving, MD

Background and Objectives: Medical students increasingly log patient encounters on handheld computers. Detailed patient records captured at the bedside would allow these log programs to complement medical education with automated reminders. We evaluated progress toward this goal. Methods: A series of electronic student encounter logs (ESEL) were designed to quickly record common diagnoses in a family medicine clerkship. Common diagnoses were organized in a shallow, broad-tree structure that locates many concepts with one to four taps. Third-year clerks’ ESEL records of patient problems were evaluated longitudinally and across two similar clerkships. Grading criteria were introduced to encourage attention to target problems, especially infrequently reported psychosocial issues. A pilot reminder system in ESEL-4, the latest version of the computer application program, included 17 high-specificity reminders. Students’ viewing of reminders was monitored. Results: Students recorded complex patients in ESEL-4 and entered 80% of patients during office hours. ESEL grading generated anxiety but was associated with significantly increased and plausible documentation of tobacco abuse, depression, and alcohol abuse. Students viewed titles of about 25% of generated reminders but reviewed less than 1% of reminders in detail. Conclusions: Students using ESEL-4 document plausibly complex patients, usually during office hours. Grading probably improves completeness and accuracy. Diagnosis-driven educational reminder systems are possible but do not yet capture students’ attention.

Medical students often maintain electronic patient encounter logs. In addition to monitoring activity and identifying missing experiences, data collected in a student’s log could direct bedside educational activities. That is, just as an electronic medical record can provide decision support in patient care, encounter logs could provide educational support, tailoring messages to data recorded by the student at the bedside. Such a medical education reminder system would be a distinctive product. Unlike popular but passive reference software, it would make inferences and push information to students in response to clinical data. An emphasis on learners’ needs rather than patient needs would distinguish it from typical clinical reminder systems, as shown in Table 1.

Since 1999, we have been developing an electronic student encounter log (ESEL) program with a long-term goal of supporting educational reminder systems based on detailed diagnosis lists. We initially found that medical students recorded only one problem per patient using hierarchical diagnosis lists. In a second version, students recorded more problems using a combination of checkboxes and drop lists. The study reported here assesses the effects of software changes and documentation incentives on the detail and credibility of diagnosis lists and describes student reaction to the first ESEL educational reminder system.

Methods

Subjects

Subjects for this study were 109 medical students rotating in an ambulatory care clerkship in family medicine and 80 students in an ambulatory care internal medicine clerkship. Our institutional review board approved the study methods.

ESEL Architecture

ESEL is a Palm computer application written in Satellite Forms (Thacker Network Technologies Inc.).

ESEL-4, the latest version of the program, requires the expanded memory and fast processors of handheld computers that became available in 2003.
ESEL opens to the patient list screen. For Health Insurance Portability and Accountability Act (HIPAA) compliance, the patient list is hidden until a password is entered. Family medicine clerks select from five new patient types, defined by age ranges. Students record patients’ demographics and diagnoses on a screen tailored to the selected age.

Figure 1 illustrates the program and selected screens in ESEL-4. Students use the “my info” screen to record their preceptor’s name and state, the sex and race for new patients, and to select the clerkship setting as family medicine clerkship (FMC) or internal medicine.

The patient screens automatically record a sequential numeric identifier, the default sex and race, and date of encounter. Students can edit sex, race, and date. Students can record a diagnosis by tapping a button. The button colors then invert, and the screen displays its International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code and description of the diagnosis, for instance: “530.81: Gastroesophageal reflux.” ESEL links the code, description, and status “Present” to the patient. A second tap on the same button erases the link. A third tap restores the problem with status “Chief Complaint,” eg, “530.81: CC: Gastroesophageal reflux.” A fourth tap changes the status to absent: “530.81:Absent: Gastroesophageal reflux,” indicating that the user considered the diagnosis and explicitly denies its presence. Additional taps repeat the cycle.

On most screens the student can tap an “Index” button to view a list of specialties. ESEL-4 introduced detailed specialty forms, most having distinct screens for adult diagnoses, pediatric diagnoses, and procedures. Tapping a “Done” or “OK” button displays a summary screen.

Reminder System Architecture

ESEL-4 compares patient demographics and diagnoses to predefined criteria each time it displays the patient summary screen (Figure 1). Criteria are linked to “ideas,” which are educational reminders. Ideas alert students to missing diagnoses; recent trial results or guidelines; treatment pitfalls, in which a common treatment for one diagnosis is contraindicated by another diagnosis; treatment synergies, in which one treatment addresses two or more diagnoses; and eligibility for clinical trials.

ESEL evaluates criteria using fast integer math operations on prime numbers assigned to a subset of ICD-9-CM codes. For instance, the prime number 2 might indicate diabetes, while 3 might indicate trauma and 5 pregnancy. The product of 2, 3, and 5 (30) represents trauma in a pregnant diabetic. Similar products represent lists of patient problems, sets of inclusion criteria, and lists of exclusion criteria. If a number representing inclusion criteria divides evenly into the number representing a patient’s problem list, then the patient meets all of the criteria. For instance, an idea to

<table>
<thead>
<tr>
<th>Educational Reminder System (ERS)</th>
<th>Clinical Reminder System (CRS)</th>
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<tbody>
<tr>
<td>Prepares learner for rounds, tests.</td>
<td>Improves quality of patient care</td>
</tr>
<tr>
<td>Can be independent of clinical information systems: protects patient privacy.</td>
<td>Tightly integrates diagnosis, laboratory, and pharmacy data to optimize decisions.</td>
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<td>Presents old ideas that may be new to the learner: patterns of findings, physiology: “Look for an S4 gallop associated with hypertrophic cardiomyopathy.”</td>
<td>Avoids patterns of findings and physiology except to justify a treatment recommendation.</td>
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<tr>
<td>Offers broad advice on prevention, treatment, and work-up (creating and narrowing a differential).</td>
<td>Limits advice to treatment and screening recommendations.</td>
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<td>Limits repetition of simple and familiar ideas: emphasizes novelty.</td>
<td>Presents familiar ideas routinely: “Offer a flu vaccine to this patient, indication is age &gt;65 years.”</td>
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<td>Limits low probability alerts to avoid desensitization: emphasizes specificity.</td>
<td>Presents alerts when expected value is high: emphasizes sensitivity. “Hypothyroidism is an uncommon but easily treated cause of . . .”</td>
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<td>Provides general management ideas: “If using digoxin for CHF, adjust loading and/or maintenance doses for CRI.”</td>
<td>Provides specific management ideas. “( CrCl&lt;10 ): Load digoxin 0.25 mg po, then 0.125 mg po every 6 hours x 2, . . .”</td>
</tr>
<tr>
<td>Lower legal liability.</td>
<td>Higher legal liability.</td>
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</table>

CHF—congestive heart failure
CRI—constant rate infusion
CrCl—Creatinine clearance
po—by mouth
screen for spouse abuse might have the inclusion criteria 15 (trauma and pregnancy), which divides evenly into 30. If the number representing exclusion criteria has a common denominator (other than 1) with the number representing a patient’s problem list, then the patient meets at least one exclusion criterion. For instance, an angiotension-converting enzyme (ACE) inhibitor exclusion rule might be 85. The greatest common denominator of 30 and 85 is 5, so the patient has an exclusion criterion—in this case, pregnancy.

ESEL maintains groups of ideas and displays at most one idea at a time from each group. The patient summary form posts the number of ideas found. Students can view idea titles on another screen and review an idea in detail by tapping it. ESEL suppresses ideas after a predetermined number of displays, and students can suppress familiar ideas.
ESEL-4 implemented 17 distinct groups of ideas with 48 rules. These rules anticipated that students would record one diagnosis or finding for each distinct problem.

Data Collection
From June 2000 through May 2002, our FMC loaned Palm III® and Palm m500® handheld computers with the earlier ESEL-2 program to students. From June 2002 through February 2003, the FMC loaned Palm m500® handholds with the ESEL-3 program, the next version of the program, to students. From February 2003 to September 2004, our FMC loaned Sony Clie NX60® handheld computers with ESEL-4. Students were asked to record all distinct problems as accurately as practical. Students were asked not to list differential diagnoses or related symptoms. Ambulatory internal medicine clerks also used an ESEL-4 program from September 2004 through May 2005. We recovered ESEL data at the end of each 4-week rotation. Data were summarized as student-level variables. For each student we calculated the number of patients documented and the prevalence of white, female, middle age, and geriatric patients. We used JMP 5.01a (SAS Institute, Cary, NC) for statistical analyses.

Data Entry Times
A reminder system can provide timely instruction only if students use the system while seeing patients. To quantify documentation occurring during and after office hours, we counted date- and time-stamped ESEL-4 records created after 6 am and before 6 pm, after 6 pm, and after 9 pm.

Specificity and Redundancy in ESEL Data
The ESEL reminder system offered more-relevant ideas when students recorded a high specificity list (ie, one problem for each process afflicting a patient). Students might instead enter a different diagnosis, ie, a list of alternative diagnoses that could account for a patient’s presentation. We looked for evidence of three differential diagnosis lists. “Sore throat” included streptococcal and acute pharyngitis. “URI” included streptococcal pharyngitis, acute sinusitis, acute pharyngitis, acute upper respiratory infection, and allergic rhinitis. “Headache” included tension headache and classical migraine. For each set, we divided the number of patients with multiple (potentially nonspecific) diagnoses from the set by the number of patients with any diagnoses in the set.

Students also might redundantly record a symptom and its cause. To assess redundancy, we defined a group of records “Cough” to include all patients with the symptom of cough and counted any of five explanatory diagnoses as redundant: viral infection, acute upper respiratory infection (URI), acute bronchitis, chronic bronchitis, or asthma. Conversely, we counted documentation of the symptom (cough) among patients with one of the diagnoses.

Documentation Patterns and Grading Incentives
A reminder system can provide relevant instruction only if students accurately record patient encounters in some detail. Although we cannot directly compare ESEL records to off-site medical records, statistical review of ESEL-2 data suggested that students were under-documenting patient complexity in general and common psychosocial problems in particular. Therefore in June 2002, the FMC began grading students on patterns of diagnoses reported and simultaneously deployed ESEL-3 to facilitate recording graded diagnoses.

A grading process was devised to encourage thorough documentation and to complement highly variable and subjective preceptor grades. Grading rules use demographics and comorbidities to identify a subgroup of patients at high risk for a diagnosis and another subgroup at low risk. The student receives credit for documenting the diagnosis more frequently in the high-risk group than in the low-risk group; this is the expected pattern. Rules were based on literature and validated using ESEL records from previous students. For instance, one grading rule evaluated depression documentation. The high-risk group comprised adults with type 2 diabetes, coronary artery disease, anxiety, or smoking. The low-risk group comprised adults with none of those problems. Students did not know how the rule defined risk groups but understood that recording depression and comorbid problems should generate the expected pattern. While the absolute prevalence of depression in ESEL records could vary with factors beyond students’ control, such as the pace of the office, the expected pattern of depression diagnoses should persist. Prior to deployment, we evaluated the rule with ESEL-2 records and found that the few students who spontaneously documented depression in more than 5% of patients invariably generated the expected pattern, while other students did not.

FMC students were graded on smoking, depression, and substance abuse documentation. FMC students using ESEL-2 provided a control group without documentation incentives but that also differed in ESEL interface. Ambulatory internal medicine clerks provided a control group using ESEL-4 without documentation incentives but in a different ambulatory clinical setting. For each student, we calculated the mean number of problems recorded per patient, the prevalence of adult smoking, depression in a high-risk subgroup, and substance abuse. Documentation patterns among graded FMC students using ESEL-3 and ESEL-4 were compared to both control groups using Student t tests to identify statistically similar distributions. We also constructed forward stepwise linear regression models to predict target disease prevalence as a function of
grading incentives (+/−), ESEL version (2, 3, or 4), and clerkship (FMC or internal medicine).

Reminder System Use

Finally, a reminder system can provide relevant instruction only if it correctly links ideas to patients and if students choose to view these ideas. We monitored the number of ideas that ESEL linked to patients, how often students chose to display the idea screen (see Figure 1), and how often students tapped on an idea to view its full text. We manually reviewed a small number of records to confirm that ESEL selected ideas appropriately.

Results

Data Collection

Seventy-four FMC students documented 11,839 patient encounters using ESEL-2, 24 students documented 3,270 encounters using ESEL-3, and 35 FMC students documented 5,100 encounters using ESEL-4. Eighty internal medicine students documented 5,885 patient encounters using ESEL-4. The number of patient encounters recorded (median 144), patients per day (7.2), middle-age patients (83), geriatric patients (14), white patients (92%), and female patients (60%) did not differ between ESEL versions 2, 3, and 4.

Data Entry Times

FMC students began 18% of ESEL-4 patient records after 6 pm and 5% after 9 pm. Most of these data were recorded in rapid succession, with few or no entries during office hours on the same day, suggesting that students were recording data after work. Students started 82% of patient records during plausible office hours.

Specificity and Redundancy in ESEL Data

Most problem lists showed the specificity typical of a list of working diagnosis. Documentation of more than one similar diagnosis occurred in 3% of 177 “sore throat” patients, 10% of 1,475 “URI” patients, and none of 160 “headache” patients. Redundant documentation of “cough” and a causal disease occurred in 11% of 64

Figure 2

Student Documentation of all Patient Problems and Graded Problems

Abbreviations:

2, 3, 4 Versions of the electronic student encounter log
+ Log grading
- No log grading

Box plots indicate 5th, 25th, 50th, 75th, and 95th percentiles of values. Gray dots below the graph represent the distribution of points in the box plot directly above the dot. Dots that are not connected by a dashed line are from significantly different distributions (Student t test, P ≤.05).
ESEL-4 patient records. Conversely, only seven (0.5%) of 1,315 patients with an upper respiratory disease also had the redundant symptom cough.

Documentation Patterns
The box plots in Figure 2 illustrate that graded FMC students using ESEL-3 and ESEL-4 recorded significantly more problems, tobacco abuse, depression in high-risk groups, and alcohol abuse than did FMC and internal medicine students who were not graded. Regression models of smoking, depression, and alcohol abuse prevalence incorporated grading incentive as the most significant predictor variable and the variable with the largest coefficient, followed by clerkship. ESEL version was not incorporated as a predictor variable in any model.

Reminder System Results
The ESEL-4 reminder system selected ideas for 27% of FMC patients and 30% of internal medicine patients. FMC and internal medicine students viewed 31% and 23% of idea titles but reviewed only 2% and 3% of these. In both cases, students reviewed about 0.7% of all selected ideas. Manual inspection found no inappropriately selected or suppressed ideas. One student reported confusion about an idea related to steroid use: its criteria included diseases often treated with steroids, but the student’s patient had not been treated with steroids.

Discussion
Implementing an educational reminder system on a handheld computer is currently feasible. Our results show that most students will document working diagnoses on a handheld computer during office hours, with few extraneous problem entries. Grading incentives can motivate students to document patient diagnoses thoroughly. Even a basic reminder system can identify at least one idea in about 25% of family medicine patient encounters.

Although ESEL programs enable documentation, grading was the crucial incentive required to achieve thorough documentation. Unfortunately, the grading process provoked anxiety. We are studying a process of formative feedback and grading that modestly rewards high specificity and attention to two common and easily recognized problems, obesity and smoking. We expect to use ESEL programs to document specific clinical experiences for all students. Students will receive assignments that complement their reported clinical experiences, creating a new incentive to document thoroughly. However, if students document aggressively to meet experience requirements, grading might be required to discourage over-documentation, rather than to encourage thorough documentation. Students could occasionally fabricate data without being detected by statistical reviews.

Unfortunately, this reminder system is not ready to test as an educational intervention. The remaining barrier is that students do not review ideas very often. This could reflect busy offices, confusion about the ideas, disappointment with previously viewed ideas, a human interface problem, or disinterest in automated reminders. Automatically displaying ideas would increase use and may be appropriate for urgent alerts or quality assurance questions, but too many ideas would interfere with work flow. Rewarding insights that compel students to review ideas voluntarily would be much better. Students should seek ideas that explicitly help them meet log grading criteria and experience objectives or that prepare them for standardized patient and traditional examinations.

The ESEL-4 reminder system could partially automate curricula. For instance, it could guide a student through a series of diabetes management ideas, displaying a new idea with each diabetic patient encounter. We expect to develop and test such a reminder system in the immediate future. Ultimately, we hope that students will value the reminder system’s ideas so much that they enter detailed patient data to gain clinical insight.

Corresponding Author: Address correspondence to Dr Sumner, Washington University, School of Medicine, 660 South Euclid Avenue, Box 8005, St Louis, MO 63119. wsunner@im.wustl.edu.

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