A concept for a visual computer interface to make error taxonomies useful at the point of primary care

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Abstract

Evidence suggests that the quality of care delivered by the healthcare industry currently falls far short of its capabilities. Whilst most patient safety and quality improvement work to date has focused on inpatient settings, some estimates suggest that outpatient settings are equally important, with up to 200 000 avoidable deaths annually in the United States of America (USA) alone.

There is currently a need for improved error reporting and taxonomy systems that are useful at the point of care. This provides an opportunity to harness the benefits of computer visualisation to help structure and illustrate the ‘stories’ behind errors.

In this paper we present a concept for a visual taxonomy of errors, based on visual models of the healthcare system at both macrosystem and microsystem levels (previously published in this journal), and describe how this could be used to create a visual database of errors. In an alphabet test in a US context, we were able to code a sample of 20 errors from an existing error database using the visual taxonomy.

The approach is designed to capture and disseminate patient safety information in an unambiguous format that is useful to all members of the healthcare team (including the patient) at the point of care as well as at the policy-making level.

Keywords: errors, taxonomy, visualisation

Introduction

The so-called ‘quality chasm’ has been documented across the spectrum of health care. While outpatient settings have, to date, received comparatively little attention, some estimates suggest that they are at least as important as hospital settings in terms of the burden of errors and harm. There may be as many as 200 000 avoidable deaths per year attributable to ambulatory care in the USA. Primary care physicians, who
provide the vast majority of medical care, are struggling to provide the quality of care that they have been trained to provide. They are working harder under the pressures of increasing overheads, competing demands and decreasing rewards in an unpredictable environment (especially related to health insurance and malpractice).\textsuperscript{4–6} This environment inhibits efforts to improve safety and quality.

Error reporting, as part of a blame-free culture of safety, is an activity that has great potential to yield valuable insights leading to system improvement.\textsuperscript{7} Reporting systems need to be safe (that is, free from blame), easy and worthwhile.\textsuperscript{8,9} Error reports can be useful at various levels. At regional, national and international levels, the ability to collate large numbers of reports is very important as it provides the ability to generate summary statistics (protecting the confidentiality of individual reporters and institutions) that can reveal widespread systemic weaknesses that can inform policy.\textsuperscript{10} In the USA, legislation will help to protect these data from medicolegal discovery.\textsuperscript{11}

On the other hand, at the individual office level, individual physicians may perceive that generalisations made about national data, for example, do not apply to them because of their own unique circumstances (such as their patient population, their systems of care, and other local factors). In both the USA and the United Kingdom, there are calls for making quality and safety information useful at the point of care, and providing feedback on specific safety incidents.\textsuperscript{12,13}

The purpose of the work described in this paper was to develop and test a concept for a visual medical error taxonomy that can provide for both policy-level and office-level needs. Figure 1 depicts the overall concept in which error reporting at the office level is used internally for safety improvement as well as being fed seamlessly to a regional, national or international database that is used to study the epidemiology of errors and to generate alerts.

### Error taxonomies

The term 'taxonomy' originally referred to the art and science of organisation/categorisation/classification of organisms. Now this term is applied in a much wider and more general sense and is used for classifications of objects, processes and events (as well as images and networks),\textsuperscript{14} in addition to the principles underlying these classifications. Classification is performed according to a predetermined system. A good taxonomy takes into account the importance of separating elements of a group (for example, the microsystem of a particular health setting) into subgroups (such as the entities and agents and their interactions within a microsystem). Groupings should be mutually exclusive and unambiguous. A good taxonomy that can be useful at the point of care and at the policy-making level should be simple, easy to recall and easy to use.

In the context of error reports our functional definition of taxonomy is ‘Classification of reported errors with respect to healthcare domains (such as primary care office), process of care (for example, patient assessment), sub-processes (for example, history-taking), agents/entities (such as providers/doctors), interactions between agents (such as communication between doctor and patient), consequences, and severity’. This definition reflects the hierarchical relationships from

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**Figure 1** Overview of the concept for visual taxonomy and reporting
A concept for a visual computer interface for error taxonomies

the macro-level to micro-levels of the healthcare system.
Various organisations, including the US Institute of Medicine (IOM)\textsuperscript{15} and the World Health Organization (WHO)\textsuperscript{16} have recognised the need for error event taxonomy development, and a number of such taxonomies have been and are being developed to organise and classify medical error reports. The International Primary Care Patient Safety Taxonomy Steering Committee has set itself the ambitious goal of developing ‘... a primary care taxonomy for patient safety, embedded in the International Classification of Primary Care (ICPC-2) and in an episode of care structure, that can operate across settings and vendors, and that maps to other standards and data structures.’\textsuperscript{17}

Current taxonomies are essentially alphanumeric codes that are used to classify and summarise error data so as to communicate information about errors and their characteristics (including causative factors, consequences and severity), estimate frequencies and trends of various error types, and identify needs for safety improvement. Examples include the Applied Strategies for Improving Patient Safety (ASIPS) Collaborative Dimensions of Medical Outcome taxonomy,\textsuperscript{18} the American Academy of Family Physicians Taxonomy of Threats to Patient Safety in Primary Care,\textsuperscript{19,20} the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) Patient Safety Event Taxonomy,\textsuperscript{21} and the Australian Patient Safety Foundation Advanced Incident Management System.\textsuperscript{22} While such taxonomies have been used successfully in primary care, they have some limitations:

- the coding systems are complex, labour-intensive, and prone to ambiguity
- they do not readily meet the point-of-care needs of patients and health providers to understand, within their unique Microsystems, the causes, cascades and consequences of reported errors
- they do not fully capture the 'story'. By reducing an incident to a series of codes, the flavour of the event is lost. It is the 'story' that has the greatest potential to contribute to safety improvements\textsuperscript{8,23}
- they often differ in the way they define, count and track events, using different terms, data, coding methods and analysis. This contributes to ambiguity and makes it difficult to compare data that have been collected or coded using different taxonomies.

The USA is developing a National Health Information Infrastructure that, according to the IOM,\textsuperscript{15} must provide information flow across three dimensions: (1) personal health, to support individuals in their own wellness and health decision making; (2) health care providers (the office level), to ensure access to clinical decision support systems; and (3) public health (the policy level), to address and track public health concerns and health education campaigns. Use of consistent error taxonomy across these dimensions, or levels, is imperative.

Visualisation

The need for consistent and unambiguous error taxonomy and for flow of information across these levels presents an opportunity to harness the benefits of computer visualisation. Visualisation can help to structure and illustrate the 'story' of an error or event.

Visualisation is a universal tool that furnishes a natural common 'language'. For instance, it is used effectively for international road signs. It can provide:

- a fast path to fully engaging the minds of individuals and their teams
- insight into causes, cascades and consequences of errors
- a common vision for teamwork and shared understanding of the concepts, with the potential for improved outcomes
- aid for coping with the complexities, fragmentation, and decentralisation of the healthcare system\textsuperscript{7} and
- an aid for mapping across different taxonomies and data structures.\textsuperscript{24}

Applying a systems engineering/management approach, the authors have developed visual models at microsystem and macrosystem levels.\textsuperscript{25}

Macro system model

This is a high-level view of health care, with attention to transitions of care (see Figure 2). As previously described in this journal,\textsuperscript{25} care is portrayed in a cyclical fashion as a series of processes from Assessment to Plan to Implementation, Feedback, Review and back to Assessment again. These processes take place in various domains that are depicted by concentric circles starting from the patient level (circle 0) at the centre, to international health authorities such as WHO (circle n) on the outside. Office-based primary care is represented by circle 1. Depending on the system under study, circle 2 might represent the emergency room and circle 3 might represent the hospital inpatient setting, and so on. This model allows distinction between the domains that are internal as well as external to the healthcare system.
Microsystem models

These are close-up views of the system. For example, one may devise a microsystem model for a specific domain within the macrosystem, or for a specific process within a domain. These models show how the various entities/agents in the microsystem interact. The level of detail represented in a micromodel depends on the purpose for which it is used.

Figure 3 is an example of a microsystem model for the process of feedback of routine laboratory results. The diagram depicts the entities involved (doctor, patient, nurse, medical record, and so on) and the interactions that take place between them. Each interaction is shown as an arrow. Errors or safety problems can originate at any, or at multiple points within the system. Lists of errors at specific points within a microsystem can be generated through a combination of literature review and consultation with members of such microsystems. Using this approach, we have previously generated a set of 145 types and causes of errors across the range of entities/agents and their interactions in the primary care office setting.26
The macrosystem and microsystem diagrams are computerised and contain hyperlinks that facilitate hierarchical linkage between models and can be used for dynamic data links within databases. For example, any point on the microsystem model can be linked electronically to a table containing relevant data about errors that are known to occur at that point in the system, with details of frequency and consequences of these errors as well as corrective action recommended or used.

These macro- and microsystem models can provide various functions that we have described elsewhere. In this paper, we will describe how a visual taxonomy based on these models can be used to create a visual database of errors.

A visual database of errors

Table 1 shows an example of an error and how it could be coded using the aforementioned ASIPS taxonomy. Much work has been done around the globe to create databases of reported errors, coded using taxonomies of this kind. To help make the information in such databases more accessible to users, we propose that the information contained therein be represented using the visual models described above. In other words, we propose the creation of a visual taxonomy.

The proposed visual taxonomy is coded at four main levels, corresponding to the structure of the visual models:

- healthcare domain or transitions between domains
- process
- sub-process
- entity or interaction between entities.

A reported event can consist of one or more errors, together with causes and consequences. Each of these can be coded at the above four levels.

To alphatest the feasibility of this approach, we accessed a random sample of 20 events from the ASIPS database and attempted to code them using the visual taxonomy. All 20 events were successfully coded, although some minor enrichments of the existing model were required to accommodate some of the errors. In this manner a visual database was created.

<table>
<thead>
<tr>
<th>Table 1 Example event coded in ASIPS taxonomy</th>
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<tbody>
<tr>
<td><strong>Event description</strong></td>
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<tr>
<td><strong>Event coded in ASIPS Taxonomy</strong></td>
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<tr>
<td><strong>A Error types</strong></td>
</tr>
<tr>
<td>1.3.3.1</td>
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<tr>
<td>1.5.2.4</td>
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<tr>
<td><strong>B Action taken</strong></td>
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<tr>
<td>2.7</td>
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<tr>
<td><strong>C Consequences</strong></td>
</tr>
<tr>
<td>1.1.7</td>
</tr>
<tr>
<td><strong>D1 Severity of harm</strong></td>
</tr>
<tr>
<td>2.2</td>
</tr>
<tr>
<td><strong>D2 Harm</strong></td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td><strong>E Contributing factors</strong></td>
</tr>
<tr>
<td>2.5.7.4</td>
</tr>
<tr>
<td>4.1.5</td>
</tr>
<tr>
<td>6.3.9.1</td>
</tr>
<tr>
<td>7.1.5</td>
</tr>
<tr>
<td><strong>F Preventive strategies offered by reporter</strong></td>
</tr>
<tr>
<td>1.1.6.1</td>
</tr>
<tr>
<td>1.1.1</td>
</tr>
</tbody>
</table>
Figure 4 illustrates some of the screen views, showing first how a user might navigate the visual database. Starting with panel 1, at the top left-hand corner, the user selects the domain of interest, in this case the Office Domain. The user then sees this domain in more detail – the five main processes are marked around the circle and the number of events occurring in each process is shown (panel 2). We can see that among the 20 events that we coded, most occurred in either Implementation or Feedback. Supposing that the user is interested in the Feedback process, he/she now clicks on that process and is shown a list of sub-processes (panel 3). In this case, these sub-processes are various types of Feedback. Again, the frequency of events is shown; within this sample of...
A visual database, such as the one described, could be populated by importing data from existing error databases that have been coded using existing alphabetic taxonomies. In our alpha-test, we were able to manually translate a small number of events into the visual format. However, for the concept to be useful, it will be necessary to create crossmaps from these taxonomies to the visual taxonomy so that the data can be accessed in the visual format without any manual recoding. Our experience with the ASIPS taxonomy suggests that this is feasible.

In addition, it will be necessary to create visual models of other microsystems and, because of wide variations in systems used, it will be important for the models to be adaptable by users so that the approach can be used across a variety of healthcare settings and internationally. In addition, to facilitate use at the point of care, the error database should be accessible directly from within electronic medical record systems. The ability to view a macro- or microsystem diagram together with error frequency information can be very valuable in helping decision makers at various levels in the healthcare system to identify and prioritise areas for system improvement. Similarly, the ability to summarise a single event, including errors, contributing factors, and consequences, in a clear visual format, would appear to provide some advantages when compared to a list of codes (see Table 1). For example, the visual format could facilitate the sharing of information with team members and other stakeholders (including patients and families) and has the potential to enhance the understanding of events, facilitating the development of appropriate preventive strategies.

While tracking rates of errors over time or comparing rates between different institutions or regions are commonly perceived aims of error reporting systems, caution is needed in interpreting such data because of the problem of under-reporting. According to IOM estimates, only about 5% of known errors are reported. Therefore, differences in rates of errors reported over time or between institutions do not necessarily reflect true differences in rates of errors, but may merely represent differences in reporting behaviour. Similarly, and perhaps even more importantly, those errors that are reported most frequently are not necessarily the most frequent errors that occur; they are merely the ones that reporters feel more comfortable reporting. It is hoped that creating more user-friendly and intuitive reporting tools will help to increase rates of reporting so that there are more opportunities to learn. The visual approach presented in this paper also has the potential to provide a format for reporting that could, if implemented appropriately, help to facilitate the reporting process and could directly populate a visual database. Further work is needed to explore this area.

Discussion

We are proposing a novel approach, based on computerised visual models of the healthcare system, to facilitate the summarisation and dissemination of information about medical errors in primary care. The purpose is to make information about medical errors useful both at the office level and at the policymaking level. The interactive approach presented contrasts with the kind of data presentation that typically is made, of which we saw an example in Table 1.

20 events, feedback of routine lab results is the most frequent problem within Feedback. If we are interested in this sub-process, we can click on it and see the relevant microsystem model. This particular model (panel 4) describes the feedback of routine lab and radiology results. On this diagram, next to each entity and interaction, where relevant, is the number of errors that were reported involving that entity or interaction. It is important to note that this is the number of errors not events, since events often involve more than one error.

For example, if we are also interested in the feedback of STAT (that is, urgent) lab test results, we can view this microsystem’s model instead (panel 5). In this diagram it can be seen that the system for obtaining results of STAT lab results involves the lab contacting the answering service which then contacts the provider. In addition, the provider has the ability to contact the lab directly to obtain the result; they would typically do this if they did not receive the result within the expected time. Again, the error frequencies are shown next to the relevant entities and interactions. Two errors occurred in the interaction from the provider to the lab, meaning that the provider did not call the lab for the results. Clicking on this shows, in narrative form, the details of the events in which these errors occurred (on panel 6, we see only one of the events).

Finally, we can view the details of an event (in this case event no. 101) in detail in the visual form, including the error(s) that occurred, the causative factors, cascades (where relevant) and consequences. Panel 7 of Figure 4 shows that this event involved two errors. In this case, the errors were: (a) the laboratory failed to contact the answering service; and (b) as we saw earlier, the physician failed to contact the laboratory to pursue the result.

Next, we can view the contributing factors (panel 8). These are portrayed on the same diagram. As before, pointing to the highlighted area will tell the user what the contributing factor was at that point in the micro-system. Cascades of errors and consequences of errors can be visualised in the same way.
However, it should be remembered that while improved systems for reporting and dissemination of error data can be helpful, they will not succeed unless there is a simultaneous shift towards a culture of safety that encourages reporting and learning from errors and eliminates blame and punishment for errors that are due to systemic problems. It is hoped that using visual models such as those described will help to focus attention appropriately on systems and away from individual blame and thereby contribute to the development of this culture.

REFERENCES


CONFLICTS OF INTEREST

None.
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