Assessing Text Characteristics of Electronic Discharge Summaries and their Implications for Patient Readability

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Abstract
A Discharge Summary provides critical information to patients for managing their post-discharge care. This study analyzes the characteristics of a corpus of Electronic Discharge Summaries (EDSs) with respect to content and readability of its sections in terms of text length and grade level complexity, use of abbreviations and noun phrase complexity based on the Open Access Consumer Health Vocabulary. We find that the Advice to Patient section has acceptable readability but is brief, and does not tend to lengthen in proportion to the Clinical Management section of the EDS. Conversely, the Clinical Management section, while acceptable by traditional readability measures, has a higher density of abbreviations than Advice to Patient and considerable density of noun phrases that are unlikely to be understood by consumers. If patients are intended to be a primary audience of the EDS, then efforts should be made to improve readability for ordinary health consumers.

Keywords: electronic discharge summary, consumer vocabulary, consumer health informatics, abbreviations, readability.

1 Introduction
The healthcare system serving the 1.5M residents of the Auckland metropolitan area is largely electronic, both in the public hospital environment and in community based General Practice. Hospital discharge summaries are authored online by a health professional and transmitted to General Practice via HL7 messages. The patient is given a hard copy printout.

A Discharge Summary is usually created by a health professional for a number of audience including patients and their families to provide a snapshot of a patient’s condition at the time of discharge (Barretto, Chu et al. 2006) and to provide a post-discharge framework of care for a patient (Walraven 1999). It usually includes a synopsis of care provided along with the advice of ongoing management of clinical condition, appropriate use of medications, relevant laboratory results and required follow-up.

Consumers play an important role in managing their own care, especially post-discharge (Maloney and Weiss 2008), hence the availability of easily understandable discharge information becomes critical. Engel et al (Engel KG, Heisler M et al. 2008 Jul) emphasize that the patients should understand “both” the care that they received and their discharge instructions.

While many patients have access to their discharge summaries, some studies (Heng, Tham et al. 2007; Clarke, Friedman et al.) have raised the comprehension issues of discharge instructions by patients with respect to ineffective care (Clarke, Friedman et al.), and lower compliance rates (Enguidanos and Rosen 1997). According to Makaryus et al (Makaryus and Friedman 2005), better understanding of diagnosis and treatment plans helps in enhancing patients’ education and compliance, therefore reducing the likelihood of hospital readmission.

To disseminate the discharge summary information optimally, it is necessary that the written information provided is clear, free from errors and sources of confusion and, importantly, it must be easy to read and comprehend. While, a significant number of patients have low literary and/or health literacy levels (Zeng-Treitler, Goryachev et al. 2007), language is recognized as a factor affecting compliance rates of discharge instructions (Enguidanos and Rosen 1997). Clarke et al (Clarke, Friedman et al. Jan 2005) identifies the vocabulary and medical terminologies employed by electronic discharge summaries (EDSs) as key factors affecting
their comprehension. In addition, it has been observed that the use of abbreviations causes "severe shortcoming" in the clinical data of EDS and serves to confuse the communication between providers and patients (Walsh and Gurwitz 2008).

Keeping in view of the comprehension issues of discharge instructions by the patients and language employed by EDSs, we have embarked on a project to produce more readable EDS contents through interactive computer-based support, both at the authoring and in the reading of discharge summaries. As a first phase in this research, we are conducting analysis of current EDS content in terms of the text characteristics, associated readability, use of abbreviations and language familiarity. Herein we present findings from measurements on a corpus of EDS text.

2 Readability Evaluation of Health Information

Readability of a text, is usually expressed as grade level and refers to the ease with which it can be read (Zakaluk and Samuels 1988). However, standard measures of readability are insufficient to evaluate the difficulty of medical texts (Rosemblat, Logan et al. 2006; Kim, Goryachev et al. 2007; Zeng-Treitler, Kim et al. 2007). Rosembalt et al identified the 'vocabulary' as one of the factor that need to be considered in readability of medical text (Rosemblat, Logan et al. 2006).

Many researchers have used common readability metrics and medical terminologies to examine the difficulty level of medical text for a lay reader. In 2006, Elhadad (Elhadad 2006) presented a method for health consumers to automatically predict difficult terms in medical literature. Also in 2006, Leory et al. (Leroy, Eryilmaz et al. 2006) analysed and compared the text characteristics of easy and difficult WebMD documents, patient education material and patient blogs. In a follow-up study (Leroy, Helmreich et al. 2008) Leory and colleagues analysed and compared the text characteristics of disease specific web contents, Medline and patients blogs. Furthermore, in 2007, Zeng et al (Zeng-Treitler, Kim et al. 2007) showed that Electronic Health Records (EHRs), consumer health materials, and scientific journal articles display many syntactic and semantic aspects that are not taken into account by existing readability measurements.

Previous research in health information readability has focused on consumer health materials, research articles and EHRs, but not assessment of readability issues in EDSs. In light of known patient comprehension difficulties (Engel, Heisler et al. 2008), text analysis of EDS contents may provide additional valuable information about consumer readability issues. The objective of this study, therefore, is to assess the factors that affect the patient’s comprehension of EDS contents. This research is an important step in directing future efforts to identify and intervene on readability issues of EDSs to overcome patient comprehension deficits.

3 Materials

We collected 200 de-identified randomly selected hard copies of EDSs from the clinical data repository of a metropolitan District Health Board managing two public hospitals: North Shore Hospital and Waitakere Hospital (Auckland, New Zealand) with yearly presentations of around 43,000 and 24,000 patients, respectively. The sample data was collected from a total of 62,674 EDSs generated during the period of June 2007 to July 2008. We retrieved 50 EDSs each from Emergency, Medicine, Surgery and Older Adult Health Services departments as hardcopy printouts (as it proved most expedient to perform de-identification by literally cutting identifying information from the page!). The sample data, once transferred to the research cite, was then transformed back to electronic format for automatic analysis. For this purpose we scanned the EDSs using OCR (optical character recognition) software included with the Hewlett-Packard ScanJet 2200c scanner. The scanned EDSs were then checked manually by the first author and errors in the scanned output corrected to reconcile to the hardcopy printout (most errors were in the lists of Medications and laboratory investigation results, with narrative text observed to scan with near-perfect accuracy).

The EDSs contains sections including diagnoses, admission reason, clinical management, discharge medications, follow up, procedures, allergies and adverse reactions and relevant laboratory results, as well as an advice to patient section. All sections have a combination of complete sentences and bulleted text except for diagnoses and discharge medications, which have bulleted text only. For purposes of readability analysis, we consider the combined text of six key sections of the EDS documents, as per Table 1. These sections represent the most important information that the consumers might be expected to understand.

4 Methods

In this section we describe in detail the three measures we used to assess the text difficulty and our natural language processing techniques adapted for measuring the text characteristics of EDS contents. We first present our strategy of measuring readability scores. We then describe our process to extract abbreviations from text. Finally, we present the
method of identifying difficult words or phrases in the text.

4.1 Readability Score
The readability score for the all the key sections in our corpus was measured with the use of the Flesch–Kincaid readability scale (grade-level range, 0 to 12) using Microsoft Word (Zakuluk and Samuels 1988). The intuition behind Flesch-Kincaid formula is that it is the most common metric for readability evaluation that represents the minimum school grade the reader should have completed to understand a document.

The formula is based on counts such as the number of syllables per word and the number of words per sentence. In addition, we also calculated total number of characters, words and sentences to measure the syntactic features of the text. We also calculated the average word length (i.e. number of characters per word) and the average sentence length (i.e., number of words per sentence). All bulleted texts were considered to be a sentence. Distribution of word count of advice to patient and clinical management section was also calculated.

4.2 Abbreviations
We used three methods to extract abbreviations from EDS text. First we extracted the list of abbreviations defined in SNOMED CT 2008 version. The SNOMED CT which contains 311,000 unique concepts and their synonyms is a comprehensive source for medical terms, including clinical abbreviations. The terminology file in SNOMED CT “sct descriptions” contains information associated with clinical terms, such as the unique concept identifier and source vocabulary. To extract abbreviations from source vocabulary we used the method reported by Liu (Liu, Lussier et al. 2001) of using a space-delimited hyphen in terms as a marker of an abbreviation and its expansion. For example, the abbreviation “DM” is extracted from the SNOMED CT term DM - Diabetes mellitus.

Second, as we are processing DS data collected from WDHB, we also used a list of locally approved abbreviation (supplied by the District Health Board) and integrated them into Abbreviation Lexicon.

For abbreviation detection, we used GATE - General Architecture of Text Engineering (Cunningham, Maynard et al. July 2002). GATE is an open source well-established suite for developing natural language processing application. Some of the basic modules of GATE are Tokenizer, Gazetteer and JAPE (Cunningham, Maynard et al. 2000). The Tokenizer splits texts into simple tokens, the Gazetteer matches phrases to named entities in a given list, and distinguishes lowerscases and uppcercases. The JAPE grammars can be used to code a pattern-matching algorithm.

The key sections (Diagnoses, Clinical Management, Medications, Follow Up, Advice to Patient and Allergies and Adverse Reactions) in each document in the corpus were processed by GATE to calculate number of abbreviations. Figure 1 illustrated the complete named entities extraction process in EDS text. The GATE operational model of abbreviation recognition is shown in Figure 1(a). The text splits into words by the GATE Tokenizer. We considered a word to be any token that does not contain punctuation symbols. For the use of abbreviation analysis, we used GATE Gazetteer. We built new Gazetteer list for our Abbreviation Lexicon, which consist of SNOMED CT and WDHB approved abbreviations. Finally, a JAPE grammar was written to extract all ‘unknown abbreviations’ in the text. The definition of ‘unknown abbreviation’ is an all-capital-letters word having length of one to seven characters and not falling into either of SNOMED CT or approved abbreviations.

For analyzing abbreviations in Clinical Management and Advice to Patient sections, a JAPE grammar was written to extract abbreviations in the Noun Phrases of these sections. These sections provide information about in-hospital and post-discharge care to the patient in free text form. Our hypothesis is that Noun Phrases comprise the most meaningful content in such text and have a higher percentage of abbreviations and difficult words, as compared to other parts of speech, making the entire content difficult to assimilate. Noun Phrase chunker in GATE is an implementation of the Ramshaw and Marcus transformational learning-based noun phrase chunker (Ramshaw and Marcus 1995) . This module uses the set of rules and the lexicon to group Part of Speech tagged words, generated by GATE Part of Speech Tagger, into the noun phrases.

For the use of abbreviations in Noun Phrases, we extracted abbreviations used in the Noun Phrases of the Clinical Management and Advice to Patient sections. Figure 1(b) shows the GATE operational model of recognizing abbreviations in Noun Phrases. The text was grouped into words by the Noun Phrase chunker. To identify abbreviations in Noun Phrases we used the abbreviation Gazetteer list as described above. Finally a JAPE grammar is written to extract all components of noun phrase that recognized as abbreviations.

4.3 Open Access Consumer Health Vocabulary
Open Access Collaborative’s Consumer Health Vocabulary (Zeng and Tse 2006) (CHV) link
technical terms or jargon used by health care professionals ("myocardial infarction") with consumer health specific words and phrases ("heart attack"). Each term in CHV has three associated familiarity scores: a frequency-based term score (calculated by a support-vector machine model based on term occurrence frequency in several health text corpora), a context-based term score (calculated based on term co-occurrence patterns in a health-specific query log data), and a context-based concept score (calculated on the basis of concept co-occurrences in medical literature and log data as well as semantic relations in medical vocabularies). The term scores reflect the string-level difficulty to estimate the likelihood the term will be recognized by an average consumer. The concept score estimates the concept-level difficulty for consumers. The scores range between 0 and 1, with a score of 0.8 to 1.0 representing "likely", 0.5 to 0.8 “somewhat likely” and below 0.5 “not likely” for a term to be familiar to a consumer (Keselman, Tse et al. 2007).

For term familiarity analysis, we extracted CHV terms used in the Noun Phrases of the Clinical Management and Advice to Patient sections. The GATE operational model of CHV term recognition is illustrated in Figure 1(c). The text was grouped into words by the Noun Phrase chunker. To identify CHV terms in Noun Phrases we built a new Gazetteer list for CHV terms. Finally a JAPE grammar is written to extract all components of noun phrase that mapped to terms defined in the CHV.

To calculate the level of understanding of these free text sections by consumers, we use CHV term and concept familiarity scores to gauge the semantic complexity of the contents. Some extracted CHV terms did not have scores assigned (indicated as a -1); while analyzing scores of CHV terms in noun phrases, these missing score terms were excluded.

5 Results

5.1 Readability Scores

The text characteristics of the EDS sections are reported Table 1. On the level of text unit length, the total word count differs radically; the Clinical Management section has 8 times the word count of the Advice to Patient section. The Advice to Patient section uses longer sentences as compared to other sections. The shorter sentence length of the Diagnoses and Allergies and Adverse Reactions texts are largely due to incomplete sentences and use of abbreviations (see section 4.2).

On the readability grade level, we found that Flesch-Kincaid Grade Level scores vary in different
sections. Advice to Patient requires a grade level of above 6th grade while the Diagnoses and Follow-up requires a grade level that is above 12th grade.

The word count of the Advice to Patient section with respect to Clinical Management and the whole EDS is shown as scatter plots in Figures 2 and 3. Linear regression was used to model length of Advice to Patient; although somewhat influenced by outlier data, the regression (shown as the square of the correlation coefficient - $R^2$) with a value of 0.0084 in Figure 2 and 0.034 in Figure 3 gives a clear indication of only a very weak association.

<table>
<thead>
<tr>
<th>Section of Discharge Summary</th>
<th>Total Words</th>
<th>Words per Sentence</th>
<th>Characters per Word</th>
<th>Flesch-Kincaid Grade Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnoses</td>
<td>4079</td>
<td>4.3</td>
<td>5.9</td>
<td>12.3</td>
</tr>
<tr>
<td>Clinical Management</td>
<td>40090</td>
<td>8.9</td>
<td>4.9</td>
<td>8.9</td>
</tr>
<tr>
<td>Medications</td>
<td>9953</td>
<td>10.0</td>
<td>4.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Follow Up</td>
<td>2148</td>
<td>10.4</td>
<td>6.4</td>
<td>12.3</td>
</tr>
<tr>
<td>Advice to Patient</td>
<td>4719</td>
<td>12.3</td>
<td>4.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Allergies and Adverse Reactions</td>
<td>345</td>
<td>1.7</td>
<td>5.7</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Table 1. Readability statistics of the EDS Corpus

5.2 Abbreviations

The percentage of abbreviations used in EDS sections are reported in Figure 4. The bar-graph shows that Allergies and Adverse Reactions have the highest percentage of abbreviations followed by Medications and Diagnoses sections. In the Clinical Management almost 8% of words were abbreviations. In the Advice to Patient almost 4% of words were abbreviations (almost 50% lower).
The distribution of number of abbreviations in Noun Phrases of the Advice to Patient section and Clinical Management is shown in as scatter plots in Figures 5 and 6 respectively. The $R^2$ for abbreviation count in Clinical Management section (Figure 5) has a value of 0.6681, which shows the strong association between the variables. While the $R^2$ value of 0.3607 in Figure 6 indicating a weak association of abbreviations count in Noun Phrases of Advice to Patient text.
5.3 Consumer Health Vocabulary Scores

Three CHV scores in Noun Phrases of Clinical Management and Advice to Patient sections are reported in Figure 7 and 8 respectively. Greater number of Noun Phrases in Clinical Management has lower scores than Advice to Patient in all three CHV measures. The percentage of CHV terms in Clinical Management having frequency-based, context-based and concept-based terms scores < 0.5 are 27%, 10%, and 27%, respectively. In contrast, the Advice to Patient percentage of CHV terms having frequency-based, context-based and concept-based terms scores < 0.5 are 10%, 4%, and 18%, respectively.

6 Discussion:

Although discharge summaries are primarily written for health professionals, health consumers access their contents for self-care; but comprehension of discharge instructions and readability for the consumer audience has been recognized as problematic. Our analyses indicate that the Advice to Patient section of the EDS, while written at an approachable grade level and low abbreviation density, is a very brief component of the total document. More concerning, the length of the section is largely uncorrelated to the length of the Clinical Management section or the total length of the EDS. The results suggest that Advice to Patient does not provide complete information about the condition, treatment plan and medication side effects to patients but, rather, readable ‘stock phrases.’ For example, in 31 of the EDSs the only advice for the patient was a single sentence advising them to see their GP for any medical concern. Therefore, for optimal post-discharge care, patients will in fact have to look outside of the Advice to Patient section in the present EDS documents to find all the information they might need.

The Clinical Management section, which provides a summary of diagnosis and treatment plan, unsurprisingly, exhibits characteristics making its content difficult to understand by a lay person, which aligns with similar findings based on characteristics of EHR reports (Zeng-Treitler, Kim et al. 2007). The Clinical Management section has more than twice the abbreviation density of Advice to Patients and a much higher frequency of terms that are unlikely to be understood by the consumer based on the Open Access Consumer Health Vocabulary (Zeng and Tse 2006).

It is assumed that after discharge from hospital patients will be transferred to the care of a general practitioner. Thus, patient understanding of the entire Discharge Summary contents is probably not the most important factor in the discharge care plan. However, to improve the post-discharge self care it is an integral component.

Our results indicate a need to improve the readability of EDS documents for patients. In the first instance, there should be improved emphasis and training of hospital staff with respect to the importance of addressing the consumer audience in the EDS. However, we also see an opportunity for computer-based support to play an important role in improving readability for the health consumer.

A first opportunity comes with electronic decision support at the time of EDS authoring. The authoring environment could provide interactive feedback on CHV scores of terms used, unknown or low readability abbreviations, and correlation of length of Advice to Patient to other key sections of the document. Secondly, we live in an increasingly electronic consumer environment where many health consumers (e.g., as is the case presently for Kaiser Permanente patients) access a wide range of provider information and services online (Zhou, Garrido et al. 2007). If the EDS is presented online, then there is potential to provide a degree of support for less readable terms through hypertext, both with links to consumer health resources and through the ability to direct a question to the primary care physician, the EDS author or another source of support.

A key limitation of the present analysis is that it is purely a computational one utilizing statistical and automated term matching characteristics of the data. A further analysis of a sample from the present corpus is under way involving the professional judgment of physicians and medical records staff as feedback on the suitability and completeness of the EDS sections. Consulting the consumers themselves is a further important step for this research program. Another limitation is the use of a single District Health Board as the source for our sample, in that the specific policies and software infrastructure of this jurisdiction limit the ability to generalize the findings.

7 Conclusion

This study analyzed the characteristics of a corpus of Electronic Discharge Summaries (EDSs) with an eye to the readability for health consumers. We examined content and readability of its sections in terms of text length and grade level complexity, use of abbreviations and noun phrase complexity based on the Open Access Consumer Health Vocabulary. We find that the Advice to Patient section has acceptable readability but is brief, and does not tend to lengthen in proportion to the Clinical Management section of the EDS, suggesting that consumers will need to look outside of the Advice to Patient section for information they need.

The Clinical Management section, while acceptable by traditional readability measures such as Flesch-Kincaid Grade Level, has a higher density of abbreviations than Advice to Patient and considerable density of noun phrases that are unlikely to be understood by consumers. If patients are intended to be a primary audience of the EDS, then efforts should be made to improve readability for ordinary health consumers. Such efforts should include improved training of staff to focus on the needs of patients as an audience, but should also be leveraging the potential of software to aid readability both at the EDS authoring and reading stages.

8 Acknowledgments

This work was supported by a Higher Education Commission, Pakistan scholarship. The research protocol was approved by the University of Auckland Human Participants Ethics Committee under protocol number...
2008/221 and by the Waitemata District Health Board Knowledge Centre.

9 References


