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Scope, Completeness, and Accuracy of Drug Information in Wikipedia

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Abstract and Introduction

Abstract

Background: With the advent of Web 2.0 technologies, user-edited online resources such as Wikipedia are increasingly tapped for information. However, there is little research on the quality of health information found in Wikipedia.
Objective: To compare the scope, completeness, and accuracy of drug information in Wikipedia with that of a free, online, traditionally edited database (Medscape Drug Reference [MDR]).
Methods: Wikipedia and MDR were assessed on 8 categories of drug information. Questions were constructed and answers were verified with authoritative resources. Wikipedia and MDR were evaluated according to scope (breadth of coverage) and completeness. Accuracy was tracked by factual errors and errors of omission. Descriptive statistics were used to summarize the components. Fisher's exact test was used to compare scope and paired Student's *t*-test was used to compare current results in Wikipedia with entries 90 days prior to the current access.
Results: Wikipedia was able to answer significantly fewer drug information questions (40.0%) compared with MDR (82.5%; $p < 0.001$). Wikipedia performed poorly regarding information on dosing, with a score of 0% versus the MDR score of 90.0%. Answers found in Wikipedia were 76.0% complete, while MDR provided answers that were 95.5% complete; overall, Wikipedia answers were less complete than those in Medscape ($p < 0.001$). No factual errors were found in Wikipedia, whereas 4 answers in Medscape conflicted with the answer key; errors of omission were higher in Wikipedia (n = 48) than in MDR (n = 14). There was a marked improvement in Wikipedia over time, as current entries were superior to those 90 days prior ($p = 0.024$).
Conclusions: Wikipedia has a more narrow scope, is less complete, and has more errors of omission than the comparator database. Wikipedia may be a useful point of engagement for consumers, but is not authoritative and should only be a supplemental source of drug information.

Introduction

Of the 80% of adults in the US who use the Internet to look for health-related information, 37% focus their search on prescription or over-the counter (OTC) drugs.[1] A number of studies have characterized the manner in which consumers search the Internet for health-related information.[2-4] One study in particular demonstrated that consumers search the Internet using suboptimal techniques, with one participant reporting that he thought the first 10 results returned were the only ones available.[4] Since Google is the search engine of choice for many consumers,[3] it is not uncommon for a Wikipedia entry to be the first returned result (eg, http://en.wikipedia.org/wiki/Rifampicin, as of November 5, 2008); this underscores the fact that Wikipedia is a frequently accessed resource by consumers seeking health information on the Web. Due to a "perfect storm" combining the rise of Web 2.0 technologies and a desire by patients to take a more active role in managing their health, user-edited online resources such as Wikipedia are increasingly being tapped as informational resources.[5]

Wikipedia is an extensive (>10 million articles), multilingual (253 languages), free online resource (www.wikipedia.org).

As a user-edited site, it allows anyone to write, edit, discuss, and track changes to an article. In the Wikipedia entry for "Wikipedia," it states that the database "is a project that attempts to summarize all human knowledge," and the accumulation of that knowledge is done by tapping into the global network of the Internet.[6] Wikipedia is one of the most popular destinations on the Internet and recently was ranked as the ninth most visited Web site of the top 1,000,000 tracked by Compete.com.[7] Based on the frequency with which consumers are purposefully turning to or unintentionally reaching Wikipedia as a source of drug information, healthcare practitioners (ie, physicians, pharmacists, nurses) need to consider the impact that this resource could have on the behavior of and interactions with their patients. This is particularly true with respect to drug information, as it has been demonstrated that when information about drugs is in written form, it can impact patients' attitudes and behaviors.[3,8] Healthcare practitioners should be prepared to counsel patients about reputable sources for medical and pharmaceutical information on the Internet and would be well served to have some insight as to the suitability of this frequently consulted source.

Moreover, consultation of Wikipedia for drug information is not limited to the general public. Alarmingly, its content is being cited as an authoritative source more frequently by students in the healthcare professions.[9,10] Wikipedia links have also recently been included in the abstract of an article in the *International Journal of Cardiology* and thus similarly appear in MEDLINE.[11] Concerns raised by Taylor-Mendes[9] about using Wikipedia as a reference reflect the fact that: (1) many articles are written anonymously, (2) many contributors are students still studying the very topics about which they write, (3) some Wikipedia authors self-identify as "pre-hospital care workers," and (4) anyone can purposefully add misinformation (eg, political humorist Stephen Colbert prompted viewers to change a Wikipedia entry on elephants to incorrectly read that their population in Africa had tripled over the last 6 months).[12] Perhaps even more telling is that Wikipedia founder Jimmy Wales has stated that students and researchers should not cite Wikipedia as a source because of the high error rate.[13] The issue of entry modification with more serious consequences has come under scrutiny as well, as evidenced by the implication that several pharmaceutical companies have edited their own drug entries in Wikipedia to minimize associated safety issues.[14] Despite all of these concerns, conceptual support for the Wikipedia model exists in certain corners.[15,16]

The question remains: Is Wikipedia a dangerous source, an inconsistent source, an authoritative source, or, as other studies have found, a mostly accurate but incomplete source? The first study that attempted to use peer review to address this question compared the science content for 42 entries between Wikipedia and *Encyclopedia Britannica*.[17] The study found an average of 4 inaccuracies in Wikipedia per entry versus an average of 3 in *Encyclopedia Britannica*. The most problematic Wikipedia entry contained 19 inaccuracies of varying significance. Another study compared 25 biographical entries in Wikipedia against Microsoft's Encarta and the American National Biography Online (ANBO), which is produced by professional historians.[18] On average, ANBO was the most complete, followed by Wikipedia, then Encarta. The investigator was also surprised to find only 4 "clear-cut, factual" errors in the 25 Wikipedia entries reviewed. In one of the few attempts to evaluate the quality of health information on Wikipedia, Nicholson[19] undertook a similar effort in 2006. The study found that Wikipedia fared poorly with regard to completeness, but that 100% of the information elements covered by Wikipedia were deemed to be either mostly or entirely correct. Nicholson's recommendation in light of Wikipedia's low completeness scores was that "consumers should use this information source with caution." Finally, a study by Devgan et al.,[20] published in 2007, examined Wikipedia's entries for the most commonly performed inpatient procedures in the US and similarly concluded that, "Wikipedia is an accurate though often incomplete medical reference." They also found a correlation between an entry's quality and how often it was edited.

No study to date has attempted to evaluate the scope, completeness, and accuracy of Wikipedia for content that one-third of all Internet health-seekers search for: information on medications. Additionally, no previous study has attempted to determine whether any measured differences were statistically significant. In this study, we aimed to assess the scope, completeness, and accuracy of drug information contained in Wikipedia.

Methods

Comparator Selection

To evaluate the quality and completeness of the drug information contained in Wikipedia, a comparator database was necessary. To be considered for this study, the comparator database had to be a freely accessible general drug information database that had been previously evaluated and found to be broad in both scope and depth of drug information that was gathered from authoritative references. The database also had to be edited in a traditional,

non-open, non-wiki model through a peer-review process or by an editorial board. Medscape Drug Reference (MDR) was determined to meet these qualifications and was thus chosen as the comparator database.[21]

Category and Question Construction

Eight essential categories of drug information recognized as clinically important to patient safety and care were used: administration, adverse drug events, contraindications, dosage, drug interactions, indications, mechanism of action, and use in pregnancy and lactation. Eighty question and answer pairs, based on commonly used and potentially dangerous drugs, were written and divided evenly among the 8 categories. The questions covered diverse topics such as inpatient and outpatient care, non-Food and Drug Administration (FDA)-approved indications, novel medications, and recently approved dosage changes. Answers were verified with gold standard and authoritative references used in general practice in the US, not including the comparator database. A sample of drug information questions used for the evaluation is provided in Table 1 .

Evaluation of Current Wikipedia and Medscape Drug Reference Monographs

Due to the dynamic nature of Wikipedia entries, the evaluation was conducted on entries centered on March 12, 2008, to capture temporally related data. Both Wikipedia and MDR were evaluated using the question list for the scope (presence of an answer) and the completeness of the information provided. If an answer was present, a score of 1 was assigned; conversely, if an answer was absent, a score of zero was given and it was also classified as an error of omission. Factually erroneous answers (ie, those that conflicted with the answer key) were also counted and characterized.

Completeness was assessed using a 3-point scale, with 3 being the most complete and 1 being the least complete. Only questions that scored a 1 for scope received a score for completeness. In instances where a question had a 1-part answer (eg, What is the risk of using amphotericin B with gentamicin? nephrotoxicity), a score of 3 was assigned if the answer was present. If a question had a 2-part answer (eg, What is the dose of ciprofloxacin for postexposure prophylaxis for inhalation anthrax? 500 mg orally every 12 hours for 60 days or 400 mg intravenously every 12 hours for 60 days), and both parts were present, a score of 3 was designated, and if only one part was found, a score of 2 was given.

Finally, for questions that had 3 or more parts to their answers (eg, What hematologic effects are associated with methotrexate? anemia, aplastic anemia, pancytopenia, leukopenia, neutropenia, and/or thrombocytopenia), a score of 3 was assigned if all parts were present; a score of 2 was assigned if multiple, but incomplete corresponding elements were present; and a score of 1 was assigned if only one element was present.

Evaluation of Previous Wikipedia Entries

In addition to the evaluation of the current drug monographs for Wikipedia and MDR, an assessment was conducted on a previous version of the same Wikipedia entry to evaluate change over time in scope and completeness. By using the history link and the "compare selected versions" function available on the Wikipedia entries, the page version that corresponded closest to 90 days prior to the current entry was also assessed, using the same question list. The page version permanent link for both the current and prior versions evaluated was documented.

Statistics

Descriptive statistics were used to summarize the components and are presented as frequencies, percentages, and means. For comparisons between the current Wikipedia page version and MDR, Fisher's exact test was used to compare scope between databases and unpaired Student's t-test was used to compare completeness. Additionally, paired Student's *t*-test was used to compare current and previous page version Wikipedia results for scope and completeness.

Results

Scope

The current page version of Wikipedia was able to answer significantly fewer (40.0%) of the total number of drug information questions compared with MDR (82.5%; $p < 0.001$). Wikipedia was able to answer more questions in the

indication category (60.0%) than was MDR (50.0%) and tied MDR in the scope score for the mechanism of action category (80.0%). However, Wikipedia was unable to answer any questions on dosage, versus the MDR score of 90.0%. Full results for scope scores for the current page version evaluations of Wikipedia and MDR are shown in Table 2 .

Completeness

Answers in Wikipedia were significantly less complete compared with those of MDR ($p < 0.001$). The answers that Wikipedia was able to provide were only 76.0% complete, while MDR was able to provide answers that were 95.5% complete. Wikipedia did not outscore MDR in completeness for any of the drug information categories. Full results for completeness scores for the current page version evaluation of Wikipedia and MDR are shown in Table 3 .

Accuracy

No factually inaccurate answers were provided by Wikipedia, whereas 4 answers in MDR conflicted with the answer key. Three of those errors occurred in the indication category and one occurred in the pregnancy and lactation category. Two errors were due to lack of timely updates for newly approved FDA indications, and 2 errors occurred because the database provided conflicting information in different sections of the monograph. Fourteen errors of omission were recorded for MDR and 48 errors of omission were noted with Wikipedia. Errors of omission in Wikipedia that would most directly impact patient safety included contraindications (n = 7), pregnancy and lactation (n = 7), drug interactions (n = 6), and adverse drug reactions (n = 5). An overview of each factual error in MDR is provided in Table 4 .

Current versus Prior Wikipedia Entries

There was marked improvement in the quality of drug information in Wikipedia over time, as current entries were superior in scope to those 90 days prior ($p = 0.024$). Scope scores between current and prior Wikipedia evaluations were 40.0% and 33.8%, respectively. While comparisons between scope scores of current and prior page versions revealed significant improvement ($p = 0.024$), comparisons between completeness scores revealed a nonsignificant deterioration ($p = 0.77$). Prior page version overall completeness scored 76.5%, while current versions scored 76.0%.

Discussion

Principal Findings

We used manufacturer-provided product information and other authoritative sources as performance standards (eg, *United States Pharmacopeia Drug Information*, Volume I, for off-label uses). With these sources, our comparison of general online drug information content between a popular user-edited Web site (ie, Wikipedia) and a traditionally edited pharmacy practice-specific Web site (ie, MDR) found that, while Wikipedia provided factually accurate drug information, it was incomplete, much more likely to contain errors of omission, and thus, of more limited scope than the information available in MDR.

This study is the first to quantitatively assess the scope, completeness, and accuracy of drug information in Wikipedia. Eight essential categories of drug information were assessed, enabling a broad yet detailed look at an important emerging online resource compared with established traditional and authoritative references.

Limitations

The version of Wikipedia evaluated and MDR are English-language resources, which limits generalization to specific audiences and countries. Also, the questions used to evaluate MDR and Wikipedia are a finite subset of a much larger set of drug information questions. While this subset was designed to be diverse in topics, it is possible that an alternative array of questions may yield slightly different results. However, because of the large disparity that we found between the performances of the databases in terms of scope, completeness, and accuracy, it is unlikely that the results would vary significantly with a different series of evaluative questions.

Results in Context: Possible Explanations and Implications for Clinicians and Policy Makers

The proliferation of online health resources over the past decade has changed the experience of health for many

consumers, actively engaging them in looking for health information.[1] Written information on medicines influences consumers' attitudes toward and use of medications.[3] Thus, the use of online drug information resources has the potential to contribute positively to consumers' management of their own health. In the coming years, it will be particularly important to have more informed and health-literate consumers, considering, among other factors, the increasing prevalence of chronic diseases requiring medical management, as well as the growth of online prescription and OTC medication commerce.

The attractiveness of user-edited sites is evident: they are often trusted more due to their social networking aspect.[22] That is, they are characterized as self-correcting via a phenomenon called the "wisdom of the masses"[23] and may be perceived to be edited by altruistic "peers" who improve the content with each edit.[24] This trust may spill over to health and drug information, where it might be misplaced, given that commercial considerations can drive content and increase the risk of abuse. It has been suggested that health professionals may wish to take a more active role in Wikipedia[20] should they be concerned about the quality of entries; whether busy health professionals are likely to do so remains an open question. Healthcare professionals may be more inclined to invest their time in wikis that have oversight and formal contributions by fellow practitioners. such as RxWiki (www.rxwiki.com), PubDrug (http://smbrower.com/mediawiki/index.php/Main_Page), and MediPedia (www.medipedia.com).

An important drawback of user-edited sites is that free and anonymous editing potentially allows amateur or erroneous entries, fraudulent material, or conflict of interest (whether by inclusion or omission) to go unnoticed or unchallenged. In particular, the increasing use of nonvalidated resources is thought to pose a risk for consumers who rely primarily or solely on user-edited Web sites for health, medical, or pharmaceutical information.

The issue of errors of omission has been largely ignored in previous studies, which have focused exclusively on factual errors.[17-20] The fact that pharmaceutical companies have been caught deleting negative information on user-edited sites attests to the significant commercial interests at stake and the risk of relying on these resources where such a conflict of interest exists.[14] The danger is that the potentially negative impact of errors of omission could get lost in the message that has been frequently conveyed, which is that Wikipedia is incomplete but factually accurate. For example, if consumers consult only Wikipedia to learn whether there is an interaction between a medication that they are currently taking and one that they are considering taking, the omitted information about a drug interaction could contribute to an avoidable medication misadventure. This type of scenario may be of increasing likelihood, as the same group of 18- to 44-year-old individuals who consult resources like Wikipedia has recently been identified as the most likely to borrow and share prescription drugs without medical oversight or disclosure.[25]

Unanswered Questions

User-edited sites may have an advantage over traditionally edited sites in that they may respond more rapidly to the more dynamic aspects of drug information (eg, new indications, medication recalls, or market withdrawals by the FDA) since they are not driven by a peer-review and editing process. The lack of a more responsive procedure for updating content on traditional sites can mean a delay in the inclusion of timely information, as was evidenced by the errors of omission in MDR for recently approved indications. However, it can also lead to a potential loss of quality in the data presented due to uninformed or less knowledgeable contributors. As yet, there are no standards or studies in this area and this aspect deserves further investigation.[26]

The proliferation of quality initiatives in the form of checklists, instruments, tools, rating schemes, codes of ethics, seals, and accreditation over the past decade reflects the concern of consumers and health professionals over quality when it comes to online health content.[27-30] These quality control measures have had limited success in practical terms, as they are largely unenforceable, unscalable, and variable in their application. It remains open as to whether traditional quality indicators remain relevant or whether they need to be reexamined, as well as whether consumer evaluation of quality needs to be reassessed in the Web 2.0 context.

Today's Web 2.0 environment requires that consumers learn a new set of skills and behaviors that include media literacy, health literacy, and ethical behavior online. Consumer search and appraisal skills are highly variable, but most adult online health consumers are not passive recipients of health information. They shop around, compare, and consider what peers are saying; in addition, many use information from the Web as a starting point for more information.[31,32] There may be particular risk for persons, including youth, who are first using Wikipedia to obtain information on drugs and then ordering these drugs on e-commerce sites. Youth behavior in this new online context requires further research.

Conclusions

This study suggests that Wikipedia may be a useful point of engagement for consumers looking for drug information, but that it should be supplementary to, rather than the sole source of, drug information. This is due, in part, to our findings that Wikipedia has a more narrow scope, is less complete, and has more errors of omission versus the comparator database. Consumers relying on incomplete entries for drug information risk being ill-informed with respect to important safety features such as adverse drug events, contraindications, drug interactions, and use in pregnancy. These errors of omission may prove to be a substantial and largely hidden danger associated with exclusive use of user-edited drug information sources.

Alternatively, user-edited sites may serve as an effective means of disseminating drug information and are promising as a means of more actively involving consumers in their own care. However, health professionals should not use user-edited sites as authoritative sources in their clinical practice, nor should they recommend them to patients without knowing the limitations and providing sufficient additional information and counsel. If these sites are recommended, it should be in the form of a permanent link pointing to the specific recommended version of an entry. Finally, the issues raised in Web 2.0 are not novel, nor are the approaches; consumer education, watchful editors, alert health professionals, and ethical online behavior remain, as ever, the foundation for the safety of Internet health information.

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Table 1. Sample of Questions Used in Evaluation

What is the incidence of cough with Micardis?
Doxycycline is an alternative choice for treatment of infections due to *Listeria monocytogenes* in what circumstance?
Can Avandia be initiated in a patient with NYHA class III heart failure?
How does tacrine work in the treatment of Alzheimer's disease?
Do vasectomized males taking thalidomide need to use barrier contraception?
What is the dose of fosamprenavir in a treatment-naïve patient with severe hepatic impairment (Child-Pugh score between 10 and 12)?

NYHA = New York Heart Association.

Table 2. Scope Scores by Drug Information Category

Question Category	Questions, n	Wikipedia, n	MDR, n
Administration	10	3	9
Adverse drug events	10	5	8
Contraindications	10	3	8
Dosage	10	0	9
Drug interactions	10	4	10
Indications	10	6	5
Mechanism of action	10	8	8

Pregnancy/lactation	10	3	9
Total	80 (100%)	32 (40.0)	66 (82.5)

MDR = Medscape Drug Reference.

Table 3. Completeness Scores by Drug Information Category

Question Category	Questions, n	Wikipedia, %	MDR, %
Administration	10	88.9	96.3
Adverse drug events	10	80.0	100.0
Contraindications	10	77.8	95.8
Dosage	10	0.0	100.0
Drug interactions	10	75.0	96.7
Indications	10	66.7	86.7
Mechanism of action	10	75.0	100.0
Pregnancy/lactation	10	77.8	85.2
Total	80 (100%)	76.0	95.5

MDR = Medscape Drug Reference.

Table 4. Overview of Erroneous Answers in Medscape Drug Reference

Question	Drug Information Category	Source Used to Verify Answer	Answer Used in Evaluation	Summary of Erroneous Answers
What are the approved indications for Abilify?	indication	manufacturer package insert	treatment of schizophrenia in adults and adolescents (13-17 y),	drug monograph states that safety and efficacy have not been established in pts. <18 y of age changes to the approved indication list were approved by the FDA in February 2008; these changes had not been updated
			treatment of acute manic or mixed episodes associated with bipolar I disorder in adults and children >10 y old	

			adjunctive treatment of major depressive disorder in adults	
What are the FDA-approved indications for Tysabri?	indication	manufacturer package insert	treatment of multiple sclerosis and Crohn's disease	brief overview lists Crohn's disease as an approved use, but the detailed monograph states, "Although safety and efficacy have not been established, natalizumab has been investigated for the treatment of Crohn's disease" and indicates it as an unlabeled use changes to the approved indication list were approved by the FDA in January 2008; these changes had not been updated
What is the only FDA-approved indication for Natrecor?	indication	manufacturer package insert	intravenous treatment of acutely decompen-sated CHF in pts. who have dyspnea at rest or with minimal activity	brief overview states the indications are "overt cardiac failure, uncompensated chronic heart failure," and the full monograph states that the indications are "treatment of pts. with acutely decompensated congestive heart failure (CHF) who have dyspnea at rest or with minimal activity"
Can a breast-feeding mother safely use Indocin?	pregnancy/lactation	manufacturer package insert	no, it is excreted in breast milk	full monograph states correct answer. "Indomethacin is distributed into milk. Indomethacin should not be used in nursing women"; brief monograph contradicts full monograph, stating: "Lactation precaution: American Academy of Pediatrics (AAP) considers drug compatible with breast-feeding"

CHF = congestive heart failure; FDA = Food and Drug Administration.

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