Exploring the Design and Role of Mobile Apps for Healthcare Providers to Find Teratogenic Information

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Abstract

Healthcare providers (HCPs) caring for pregnant patients often need information on drug risks to the embryo or fetus, but such complex information takes time to find and is difficult to convey on an app. In this work, we first surveyed 167 HCPs to understand their current teratogen information-seeking practices to help inform our general design goals. Using the insights gained, we then designed a prototype of a mobile app and tested it with 22 HCPs. We learned that HCP's information needs in this context can be grouped into 3 types: to understand, to decide, and to explain. Different sets of information and features may be needed to support these different needs. Further, while some HCPs had concerns about appearing unprofessional and unknowledgeable when using the app in front of patients, many did not. They noted that incorporating mobile information apps into practice improves information access, can help signal care and technology-savviness, in addition to providing an opportunity to engage and educate patients. Implications for design and additional features for reference apps for HCPs are discussed.

Introduction

Uncertainty about drug safety for pregnant women is a significant problem. Birth defects are common and affect approximately 120,000 children in the United States each year.[1] There is a high incidence of comorbidities such as diabetes, depression and autoimmune diseases in women of child bearing age. Thus, it is not surprising that nine out of 10 women are prescribed one or more drugs during pregnancy.[2] The use of prescription medications during the first trimester of pregnancy has increased more than 60% over the last three decades[2].

Healthcare providers (HCPs) who care for pregnant women are concerned about the quality and accuracy of the information that is available to their patients. If the information is inappropriately frightening, women may become unnecessarily anxious about the health of their fetuses and avoid taking a medication that actually improves the likelihood of a successful pregnancy. In extreme cases, a woman may unnecessarily terminate a normal, wanted pregnancy out of fear that an exposure may have harmed the fetus[3]. In other circumstances, a pregnant woman may have a teratogenic exposure that could have been avoided if she or her HCP had understood the hazard more fully.[2] Thus, those who care for pregnant patients need to stay abreast of current teratology information treat their patients' illnesses effectively with minimal risk to the fetus, and address their patients' concerns appropriately.

Keeping up with the constant flow of medical research can be a daunting task for any HCP because of time constraints. Mobile devices have become an indispensable tool for HCPs in the management of disease, health data sharing and patient communication. Their portability is perfectly suited to the vagaries of the clinical setting, where HCPs can access information resources at the point-of-care (or from anywhere) any time of day. Mobile devices can provide HCPs with immediate access to evidence-based information when access to personal computers is not always feasible, such as in exam rooms or visits in clinics. But would these apps be merely mobile ports of existing teratogenic risk databases? How might we leverage mobile devices to help meet the information needs of HCPs within the time constraints of a clinic visit? Further, while much prior research has examined how the use of Health IT affects patient-provider interaction[4–8], relatively little is known about how providers perceive and adapt mobile apps for information seeking in front of patients. To answer these questions, we (1) conducted an online survey of HCPs evaluating their teratology information needs and their use of mobile apps for seeking this type of information, (2) developed a prototype mobile application based on what we learned from the survey, and (3) tested our prototype by asking local HCPs to think aloud while completing four clinically-relevant tasks.

Background: Pregnancy Drug Risk Information Seeking

HCPs use a variety of resources to stay current on drug information, such as books, colleagues, the primary literature, online databases and internet search engines. Large electronic databases such as Micromedex®[9], UpToDate®[10], Epocrates®[11], and Lexicomp®[12] are used by many HCPs to obtain information about the risks associated with the use of drugs during pregnancy. These databases provide an evidence-based summary of the available literature on the teratogenic risks associated with the use of medications during pregnancy. But this

information is a subset of the broader clinical information and therefore does not always provide a comprehensive review and evaluation of the teratology studies that have been published. Moreover, the expertise of the individuals who have summarized the teratogen information for these databases is not always transparent to the consumer. These large databases are distributed on a paid subscription basis to major hospital and university libraries; so HCPs who do not have affiliations with these institutions are limited in their ability to access this information.

A few databases exist that are designed specifically for HCPs with pregnant patients (e.g. Briggs Drugs in Pregnancy and Lactation®[13], Reprotox®[14], Shepard's Catalog of Teratogenic Agents®[15], and TERIS®[16]). These databases provide an expert review and comprehensive, evidence-based summary of the fetal risks associated with the use of specific medications during pregnancy and lactation. However, most HCPs are not aware that these databases are available through some of the larger publishers, such as Lexicomp®, Micromedex®, RightAnswer.com®[17], and ToxPlanet®[18] or that they even exist.

We utilize data from the TERIS® (Teratogen Information System) database for the primary content in our app. TERIS® is a computerized, peer-reviewed database designed to assist physicians or other HCPs in assessing the fetal risks associated with exposures to drugs or chemicals in pregnant women. The database consists of a series of agent summaries, each of which is based on a thorough review of published clinical and experimental literature.

Background: The Use of Mobile Apps in the Clinical Setting

A 2012 survey by Manhattan Research suggests a high adoption rate of smartphones for US physicians: 81% of those surveyed own a smartphone, and 87% of them use a smartphone or tablet device in their workplace.[14] One of the key uses of mobile devices and apps is for reference and information gathering.

However, despite their increased usage and potential, a 2012 review paper on smartphone usage among physicians and students in medicine concludes that "very few high quality-studies exist to help us understand how to best use this technology [for physicians and students]."[20] Much of existing studies about smartphone usage in the health context focus on smartphone use for telemedicine or from the patients' perspective for self-tracking, self-care and communication with providers (e.g.,[21,22]). There are much fewer studies on HCPs' use of smartphones for decision-making in the clinical setting, and specifically there are "very limited data" on the use of reference apps by HCPs.[20]

Research on more traditional forms of technology does suggest that the use of smartphone apps for HCPs can improve the quality of care.[6,8] Studies on the use of PDAs for data management have found that PDAs facilitated the access of patient information during ward rounds.[23] A study on nursing student's use of PDAs also found that "the use of the PDAs in clinical practice enhanced communication skills and contributed to the quality of care they delivered." It both enhanced their ability and their confidence to provide clear and quality information, quickly.[4] Recent research on the use of other Health IT, such as EMR has also generally shown positive outcomes from use, especially supportive in terms of information related tasks.[20] However, one important drawback is that their use had a negative impact on patient centeredness; reducing eye-contact and losing rapport with patients.[5,8] Insights to address these drawbacks on desktop usage include improving HCP's technology skills and changing their behavioral style.[7] Others have also noted that collaborative viewing, or showing the screen to patients, can create a "common information space" to facilitate interaction between patient and doctors.[24]

Methods: Survey

We began our work by developing and deploying a survey targeted to HCPs. The goal of this survey was multi-fold. First, we sought to understand HCPs' teratogen information needs and behaviors when it comes to prescribing medication for pregnant women or counseling those who have been inadvertently exposed. In addition, we sought to explore the use and role of mobile apps for teratology information seeking by HCPs.

For the open-ended questions, three of the authors who have expertise in human-centered design and clinical teratology, analyzed the responses separately to generate category codes. They then discussed each of the responses and followed an iterative process of applying open coding and axial coding to discover relationships among emerging concepts until a consensus is reached[25].

1. Recruitment and Participants

We emailed our survey link to members enrolled in the Washington, Wyoming, Alaska, Montana and Idaho medical education network, the Washington Academy of Physician Assistants, Washington State Obstetrical Association, the Midwives' Association of Washington State, the Washington State Perinatal Regional Network, Washington State Pharmacy Association, University of Washington Department of Psychiatry and Behavioral Sciences,

MotherToBaby of Arizona, MotherToBaby Utah, and Department of Health and Emergency Medicine Services in Colorado. Initially we offered $10 gift card for completing the survey. We raised it to $20 to increase participation.

A total of 225 surveys were initiated, out of which 167 answered all the questions (74%). 115 HCPs were female (69%), and the mean age was 39 years old, with a range from 23 to 70 years of age. The mean number of years in practice was 11.5 years, with a range from 0 to 43. The HCPs' specialties included retail and clinical pharmacists (64%), physicians (13%), midwives (7%), physician assistants (6%), nurse practitioners (4%), and others (6%). The majority (63%) of pharmacists surveyed were specialty pharmacists who practice in medical settings and focus on therapy for patients with complex disease states.

Results: Survey Findings

When asked about their most recent incident where they sought teratogen information, the five most common inquiries were related to infectious (19%), psychoactive (14%), gastrointestinal (8.3%), pain (7.2%), and cold (5.3%) medication. To seek the information, the vast majority of the HCPs used online databases (86%), such as Epocrates®, Micromedex®, or UpToDate®. Others used textbooks (11%) and less frequently manufacturer's website and package inserts (2%), and other clinicians (1%).

Almost half of the HCPs surveyed expressed dissatisfaction with their recent information searches (45%). The biggest problem noted was that the resources did not provide enough information. For example, "I wasn't very happy with the online databases that I have access to. They don't give much beyond the pregnancy category." Relatedly, others noted being dissatisfied with having to access information that was spread across different sources. "There is no single, trustworthy, up to date resource for them to consult when it comes to drug use in pregnancy". Usability and speed were also other issues noted by respondents. "Didn't like the layout in Briggs/Lexicomp - class effect data were emphasized over specific agent. Also - references had conflicting data." And "info limited and not presented in easy format to understand. I think pregnancy categories should not be eliminated but refined."

1. Teratogenic Information Needs. As part of the survey, HCPs were presented with a clinical scenario about a pregnant patient who is being treated with escitalopram and is concerned about its risks on her baby. HCPs were given the TERIS database output for escitalopram and were asked about its content. We found that participants also desire to have additional information on alternative drugs, breastfeeding, dosage, maternal disease and actionable recommendations. For our prototype, we incorporated this additional information into the mobile app.

2. Usage of Mobile Apps for Drug Information. In the survey, we also asked about the use of mobile devices to search for teratogen information. About 67% (112) of our respondents have used mobile apps to find teratogen information, with the most popular app being UpToDate® (53%), followed by Epocrates® (38%).

When asked about the major limitations of existing mobile apps, 106 responded. The issues reported were similar to what they had reported with their most recent teratogen information seeking experience. The main issues (52% of responses) were related to the amount and quality of information offered in existing apps. As one respondent wrote:

> *Epocrates only gives an overall summary - no specific risks; Reprotox® can sometimes be hard to digest quickly if there's a lot of research; UpToDate® doesn't always list quality of evidence and is often the recommendation of the author based on studies, which, in my experience, don't always support the conclusions drawn.*

Many simply desired a centralized database of information across pregnancy and lactation resources that contain concise summaries in addition to more in depth information and links to primary resources.

The second set of limitations was related to usability (22%). Many of these respondents noted challenges with finding and navigating information via a small screen, and a desire to have more intuitively organized content. Others pointed out that logging into the app and having it sync and update often takes too much time. The third set of limitations had to do with access and cost (18%). Some interesting points to note are: Mobile apps are not always supported by existing practices, so they are often out-of-pocket costs for HCPs; not all apps are available on all phones; a lack of access to the internet when the information is needed.

3. Information Seeking in Front of Patients. While we were initially concerned that HCPs would not be comfortable with using mobile apps in front of patients, we found that about 60% of participants were not concerned. In fact, more than a third of the HCPs (37%) reported that their most recent teratogen search was conducted in front of patients. When asked about specific concerns with using the app in front of patients, 65 HCPs responded. For them, the primary concerns are not appearing to be professional (40%) and being perceived as

incompetent (34%). A small number (9%) also mentioned that doing so may seem like they are doing something else, such as checking personal email and some (8%) are concerned that they are not sending the right message to the patients – "Patient might feel like it's something they can do as well."

4. Survey Discussion

In general, our survey provided confirmation that an app dedicated to teratogen information would be valuable to providers. Both having a consolidated information source and disseminating this information in the form of a mobile app are useful. While there are some concerns about appearing to be unprofessional and unknowledgeable, many seem to be already incorporating the use of mobile apps into their clinical practices.

At the same time, these results offer insights on the types of information that should be included in an app, as well as indicating the need for effective information architecture and user interaction to support the often descriptive information about teratogens. Combining our survey findings with the new FDA guidelines that sought to minimize the oversimplification of teratogenic risks, we decided to focus on the following goals in design: (1) consolidate pregnancy and lactation drug information across multiple sources to create a single repository; (2) provide a concise summary and overview of teratogenic risk information without oversimplifying risks; (3) reference sources of information; (4) have an easy to use interface with navigation and search support to move between overview and detailed information; (5) provide author or editorial information to indicate the credibility and reliability of the information; and (6) provide patient education handouts.

Mobile App Prototype

After a wide exploration of ideas through sketching, followed by wireframes in increasing fidelity, we developed an interactive prototype design using Justinmind[26], a prototyping platform.

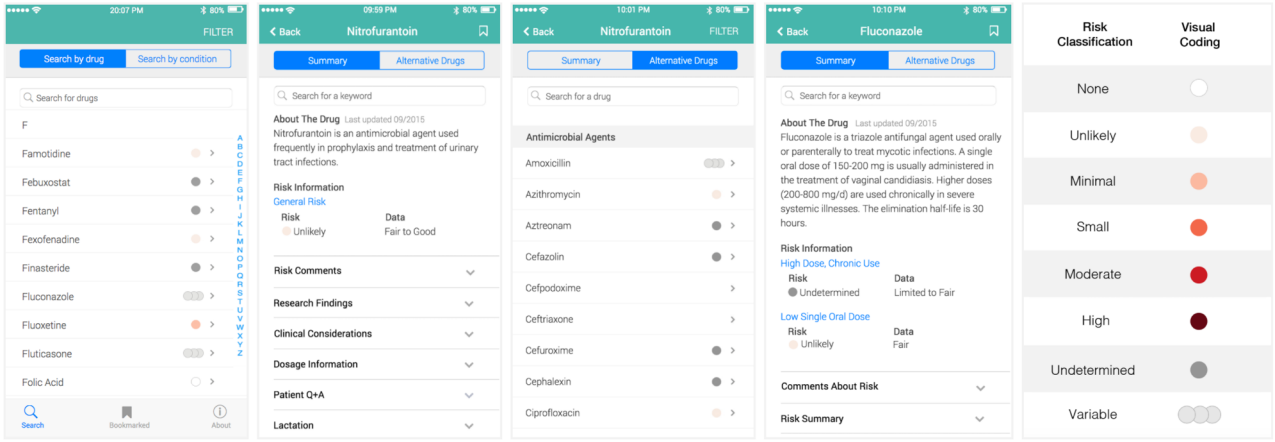

Figure 1. (a) App homepage, (b) Nitrofurantoin summary, (c) Nitrofurantoin alternative drugs list, (d) Fluconazole summary showing variable risk, (e) risk classification and visual coding.

The app's homepage shows a list of drugs with an icon denoting the teratogenic risk (Figure 1a). Users can "search by drug" through an alphabetized list of all agents, or "search by condition" through a list of maternal conditions that will lead users to an alphabetized list of agents used to treat the selected condition. The drugs can also be filtered by their risk classification; "none," "unlikely," "minimal," "small," "moderate," "high," "undetermined," and "variable."

For each drug, we used the TERIS® database for the primary teratology content in our prototype. This includes brief information About the Drug, Risk Information and Comments, Research Findings, and References. To help HCPs fully explore the risks and the benefits of treating a pregnant patient, we added a section called "Clinical Considerations." This section provided the following information (if available): Impact of disease on pregnancy; Dose adjustments in pregnancy; Drug-associated adverse maternal reactions unique to pregnancy; Fetal/neonatal adverse reactions; and Drug effects during labor and delivery. Further, using feedback from the survey, we incorporated information on breastfeeding, dosage, and a fact sheet for the patient. The individual sections use an expandable accordion design pattern to enable users to navigate to desired information quickly (see Figure 1b). To

help users assess the credibility and currency of information, we indicated when the drug information was updated right next to the "About the Drug" heading for each drug (the first line).

Another desired feature based on our surveys was for information about alternative medications that could be used to treat a particular medical condition. Thus, in our design, users can toggle between the summary or the alternative drugs screen, which features a full list of alternative agents to the current drug selected (Figure 1c).

One of the key challenges in our design is to effectively communicate the different teratogenic risk classifications used in TERIS®. The risk classifications for teratogenic effects in the children of women exposed to the agent during pregnancy range from "none," "unlikely," "minimal," "small," "moderate," to "high," and "undetermined" for agents that have an unidentified risk. For some drugs, the risk was considered to be somewhere between two ratings, e.g., drug may be assessed to have a "moderate to high" teratogenic risk if used during pregnancy.

To visually communicate these risks, we developed a color-coded system for the teratogenic risk classifications. Our final design utilizes a gradation of red circles. Red was chosen since it is commonly associated with danger. The higher the risk the more saturated the red is and the lower the risk the lighter the color. For the remaining risk classifications; "none" is represented with a white circle to symbolize no risk, "undetermined" is represented with a gray circle to symbolize unknown risk. (Figure 1e).

However, the risks for some drugs required more complex representations. For example, some of the drugs have different risk assessments depending on the nature and timing of the exposure during pregnancy, such as stage of pregnancy, dosage levels, or route of exposure. Other drugs had risks that fell between two gradations of risk (e.g., between "moderate to high"). For these, we developed a single additional symbol for "variable." Our design for "variable" is represented with three overlapping gray circles to symbolize that some drugs may have more than one risk. We thought that this single classification would be sufficient to serve its main goal, which is to notify the HCPs that the risks for this drug may be complex and they need to read further to determine if the drug's risk applies to their particular patient's exposure (Figure 1d).

Methods: User Study

We conducted a user study to evaluate our app design. The study consisted of a 30-minute usability testing of the prototype, where we observed participants performing 4 tasks using our prototype. We then followed up the usability testing with a 30-minute interview. The interview enabled us to more broadly talk about the app and its potential for integration into their practice workflow.

For the usability testing, we asked the participants to complete four tasks using our prototype. These tasks were common clinical scenarios that we developed based on the survey results. The scenarios provided detailed information, and asked participants to (1) review five antibiotics and select one that might have less risk to the fetus, (2) review evidence-based risk information for escitalopram for a pregnant patient, (3) find a list of drugs that have a high teratogenic risk and should be avoided during pregnancy, and (4) evaluate the risk and benefits of using ondansetron or an alternative medication to treat hyperemesis gravidarum. Each of the tasks took about 5 minutes to complete. During the tasks, the participants were asked to vocalize their thoughts, feelings, and opinions while interacting with the prototype (think-aloud). After each task, they were asked a few questions about the task. Upon completion of the four tasks, participants were asked to fill out a questionnaire which contained the System Usability Scale (SUS), which is a ten-item attitude Likert scale often used to assess usability.[27] The questionnaire also included questions about participants' demographics.

Throughout the study, we audio recorded the participants think-aloud sessions, as well as screen-captured their interactions with the mobile prototype. For analyses, we first had the study sessions transcribed, then we used the similar procedure in analyzing the open-ended survey responses.

1. Participants

HCPs from our survey who were local and expressed interest in participating in the app testing were contacted for the study. In addition, we contacted HCPs through the Washington State Department of Health and by word-of-mouth through some of the authors' colleagues.

Twenty-two HCPs who often worked with pregnant patients were recruited to participate in our usability study. Their ages ranged from 27-63 years. The number of years they have been in practice ranged from 1-35. Their specialties included: Family Medicine physicians (7); Naturopathic physicians/nurse practitioners/midwives (6), Medical geneticists/genetic counselors (3); Obstetricians (3); Pharmacists (2); Psychiatrist (1).

Results: User Study Findings

Overall, participants completed the tasks with ease. When asked "how easy or difficult was it to find the information you were looking for" after each task, all of the tasks had a median rating above 4 (1 is very difficult and 5 very easy). The most common reason participants gave for assigning a low score to a task was "unfamiliarity with the app". Once participants became familiar with the app they found the subsequent tasks much easier to complete. The overall SUS score of 80.8 is considered in the A level (the top 10% of SUS scores). It is important to note that participants reported that the four tasks used in the study represented commonly encountered clinical scenarios.

In terms of content provided, participants appreciated the consolidated information. "I like this [app] because the information is consolidated, and there's less noise. You're not looking at other stuff. It's focused on pregnancy." (P5). They specifically complimented us on the inclusion of lactation information, patient Q&A handout, and providing the alternative drug list. Many of them asked when the app will be available for download.

1. Three Types of Risk Information Needs

In terms of risk classification designs, participants thought the design from lighter to darker was fairly intuitive, and were able to describe what the different colors meant, after some usage:

> *Having looked at it a few times, the dark red I know means high risk, the three little bubbles I know is variable. It makes intuitive sense to me lighter to darker. I think it would just take some [time] to [get used to] it. (P3)*

However, some participants noted that the different levels of red were not memorable and sometimes hard to distinguish. Some also thought the TERIS® risk classifications were unclear since they were unable to discern the subtleties in gradations of magnitude of teratogenic risk, e.g., between "minimal" or "small." Many even specifically asked us to include the FDA Pregnancy Categories that have been discontinued by the FDA, not realizing the change in guidelines. One potential interpretation is that HCPs need more time to adjust to the TERIS® risk classifications and a clear legend or onboarding should be added to the app to help. However, we believe there is a deeper underlying issue. There is a mismatch in what we sought to design (an informational tool), and what the HCPs generally need (an easy to use decision aid). In fact, the HCPs indicated three types of risk information risks.

To Understand. One of the key goals of teratogen information seeking is to learn and understand the fetal risks associated with the use of a drug during pregnancy. Indeed, in our scenarios, some participants spent a lot of time reading through the detailed teratology information as they were completing the tasks. When asked about the amount of information presented and whether they were overwhelmed, one said: "If I'm looking it up, I want that much information" (P2).

This level of detailed understanding is often needed when HCPs are exploring drugs they have not used before or if the preliminary results from searching contradict their preconceptions or when they are counseling a pregnant patient about her chances of having an adverse pregnancy outcome.

> *If I am trying to counter what I normally do, like what's my custom and practice or If I am having a question about why I wouldn't do the things I would normally do, then I want more information than I already have. That's primarily how I would use something like this, for something that is not already in my head. (P4)*

To Decide. But to understand is not the primary use for the app. Most HCPs primarily perceived the app as a decision aid. This can be seen in how the HCPs approached our scenarios. When asked to prescribe one drug out of a list of five that poses less risk to the fetus, many participants simply started with a drug they know from experience that has a minimal risk, and stopped immediately when the app confirmed that drug's risk is minimal. They tried to base their decisions simply on the risk ratings and risk comments when possible. As one participant said:

> *As a practitioner or provider, not necessarily the pharmacist, but a doc will look at this and only want to know, is the risk information, general risk data, good. And honestly that's the bottom line. Then they'll read more if they had time. But if they're the exam room with the patient, they just want to know what's the risk, what's the data... You know, is there data, and if there's not very good data or something like that, then they'll go ahead and read more… Right there it tells me, minimal risk, good data, and I'm sold. They would be, too. (P1)*

This decision-aid view of risk visualization also helps explain why some of the participants thought the eight different types of risks were excessive, and that varying the gradient of the red was not an optimal design. With the

8-level risk ratings as offered by TERIS®, HCPs may perhaps gain more nuanced understanding for the differences in teratogenic risk across drugs. However, for the purposes of deciding what to prescribe, HCPs tended to think in terms of three distinct tiers of risk – safe, not safe and maybe safe. In which case, having three distinctive *types* of colors might be more effective (e.g., green for safe, red for not safe, and yellow for maybe safe). One HCP said: "It's almost 3 categories for me. I think of medications as ones that are safe and can be prescribed, ones that are not safe and ones that depend on the situation" (P15). Another: "In my mind, I lump minimal, unlikely, and none all together…I would clinically use them with the same frequency" (P3).

That is also how they used the outdated FDA Pregnancy Categories, which had five levels, A, B, C, D, & X. Some HCPs felt that any drug assigned an A or B category was safe to prescribe in pregnancy and others considered drugs in categories A, B, and C to be safe. For example, one HCP said "once you saw A and B, you were good to go and didn't have to fuss much. (P6)" Whereas another said "we know in our minds X means teratogenic, and then pregnancy category D…might be some harm and so have to look at risk benefits, and then ABC we'll all lump together and think it's all fine. In our heads, we think it's a quick way to separate out the drugs. (P3)"

To Explain. We also found that an important third usage of the teratogen information is to help HCPs explain their recommendations to the patients. Some of the HCPs would use the information in the app directly to corroborate what they are saying to the patients. "[Using it] demonstrates to the patients how I approach a scenario as a clinician and make lifestyle changes to benefit their health in general. It also helps to validate what I'm saying and not that I'm just saying stuff" (P14).

At the same time, HCPs also talked about the need to translate the information to terms that patients can understand. The detailed information provided can help the HCPs understand the teratogenic risks associated with the drugs themselves, but patients have a difficult time weighing the risks with the benefits when the risks are uncertain or the data are difficult to apply to their particular circumstances. For example, when HCPs saw "odds ratio" presented in the app, they wondered: "what's a number that I can translate to a patient so they can understand" (P3). They also talked about the benefit of having clear descriptions of risk ratings as it "gives a little bit of language when you are explaining to a patient" (P4).

2. Benefits and Challenges of Mobile Information Apps in Clinical Settings

Another question we sought to answer in this work is whether a mobile app can provide additional value to providers over existing databases that are accessible through desktops. Through our study, we found a number of potential benefits to having teratogen information on an app.

Access. Prior research has found that the use of personal digital assistants (PDAs) can improve information access for HCPs.[6] Similarly, when asked about potential uses, HCPs conveyed that having the information on the app enabled more flexibility in use. One example is using it during in-home visits. "I attend out of hospital births and do in-home visits. Which is another reason that [having] many of these tools not on a laptop is helpful" (P4). HCPs also talked about using the app as they moved between rooms at the hospital since it can easily fit in their pockets.

Another set of benefits related to access is the speed and efficiency of use. Many HCPs indicated preferences for using the app for information seeking even when other machines were within access. They argued that the app will be faster to use without having to move in and out of other applications already running on the other machines. It also helps keep the different machines and their tasks separate, e.g., keeping the desktop dedicated to EMR.

> *It all comes down to speed and efficiency. If a question comes up while in a room with a patient, I have to be able to quickly access [the information]. I am just such an app person. I am just much more inclined to use an app than a website. (P3)*

> *I have my EMR, schedule, and my email going; a lot of time I'll open a separate function on my phone so I don't have my EMR shut down. Also, because I have my phone, apps are pretty easy to use on it. (P4)*

Technology Savviness. Another potential benefit of using a mobile app for information seeking is that it can demonstrate technology-savviness. As one HCP said: "I used to worry that they are going to think I'm not smart enough. Now I think patients will think you are more tech savvy if you're able to show them where your data sourcing is and [is] current" (P3). And as another pointed out, "Using an app looks better than having to get the textbook out" (P8). However, there are a couple of important caveats to note. One is that this perception of technology-savviness may depend on the patient population. As P3 also mentions, it may also be because in the area where she practices the patients are generally technology savvy and the patients have themselves adopted the use of

mobile devices and apps. Second, the perception of being technology savvy is likely to depend on the HCPs' technology use skills. As another mentioned:

> *I think my only objection to looking for stuff in front of the patient is not knowing whether I am going to have a hard time finding something. If I feel like it is going to be a challenge to find something, I am not going to do it in the room. I don't want them to see me struggling looking for the information. (P10)*

Opportunity to Teach. Another potential benefit of using the mobile app for teratogen information is that it provides HCPs an additional opportunity to engage the patients and to teach them. As suggested in prior work[24], engaging patients in the information search process can be valuable and is being practiced.

> *The process can also enable HCPs to provide insights about credibility of information and help improve literacy: "I like to show patients where to get reputable information. I like to show them 'where I'm looking up the information.' I show them how to navigate the site and find relevant information." (P13)*

There are pros and cons, however, with the use of mobile devices for cooperative information search. The benefit is that it is easy to just turn the phone around or give it to the patients so they can look at it ("Yeah I just pick it up and show it to them," P4). However, compared to the computer, the small screen size makes it harder for both to look at the information together.

Demonstration of Care. Based on our survey results, it seems that some of the HCPs are concerned about using mobile apps in front of patients because they may be perceived as not being competent. However, some HCPs think that doing so may actually help demonstrate that they care. That they would take the additional step and time to look up something:

> *When you stop and when you are looking up something, the patients are very interested that their doctor cares enough. I don't think it shows a weakness that you don't know the answer to the newest drug. They look at it positively saying "the doctor is looking up something specific to me. He cares about me." (P6)*

> *I'm usually transparent. I would like to be sure I'm giving the right dose, so I am going to look it up. I haven't gotten complaints where they thought "their provider is an idiot he doesn't know anything." I think it's saying I care. I want to do it right; I want to provide the right dose. No one's ever complained about that. Safety first. (P7)*

Discussion

In this work, we present a design of a mobile teratogen-related information app for HCPs. We sought to address several key challenges with disseminating the information. We designed our app to consolidate different information types that are currently sought for by HCPs but spread out across different resources, as identified through our initial survey. Further, we examined the feasibility of displaying this information on mobile devices, where screen real estate is limited. We organized the in-depth information into expandable sections, and provided meta-level information about when the information on the app was last updated, in addition to editorial information. Through our study, we found that HCPs were able to complete a number of common tasks using our app and did so with ease. They also found the information presented to be valuable. However, we also uncovered challenges and opportunities in designing an app to convey health risk information, and the use of the mobile apps in the clinical setting.

1. The Three Different Needs for Risk Information and Implications for Design

With our design, we focused on supporting HCPs' need to understand a drug's potential for teratogenicity, particularly in situations where a pregnant patient has already been exposed to a medication and wants to know the likelihood that her baby will be born with a birth defect. We consolidated as much information as possible into the app, and chose a systematic approach for assessing risk that is fine-grained; one that offers 8 gradations of risk in addition to providing information about the data quality. The risk assessment is followed by a succinct narrative that describes and interprets the scientific evidence. Our app did well to support this need to understand.

However, what we found was that HCPs primarily need the app to help them make decisions about prescribing a medication during pregnancy. Given their constrained time, they often just want enough information to decide: safe, unsafe, or maybe safe. In other words, how they want to use the app and the risk ratings, is exactly what the FDA hoped to move away from when they discontinued the Pregnancy Categories. Thus, one of the challenges in using mobile technology to assess potential teratogenicity of a medication is how to compress a large body of complex (and often conflicting) data for quick decision aid without sacrificing critical aspects of the risk-benefit discussion. In fact, we believe this is a critical design challenge that generalizes to risk communication in the health domain.

One possible solution is to prepare interpretative statements for those agents that have substantial and/or conflicting evidence. This executive summary would include the risk ratings, dominant research findings, the context (dose, stage of pregnancy, etc.) for these findings (if known), recommendations for use during pregnancy, and preferred alternative drugs, if any. Topic-specific links would enable HCPs to quickly select the content most closely-related to their patient's situation. HCPs also discussed factors other than risk that they would like to include in the app to support decision making, such as the costs of drugs and whether the drug is available over the counter.

Finally, we cannot overlook the importance of designing the app to help HCPs better explain risk to patients. In our design, we have included handouts that HCPs can print out to patients and they all appreciated that. Additional features such as being able to directly email portions of the information on the app to patients, or printing it out are also desired. But we also found that designing the information presentation to help HCPs translate the information to patients is valuable and needs to be considered in apps like these.

2. Successful Point-of-Care Integration of Teratogen Information into Clinical Workflows in Healthcare

Another goal of this work is explore the use of mobile apps for teratogen information in the clinical context. Our findings suggest several ways that the mobile app can be utilized and benefit patient-doctor interaction. Its use can provide HCPs access to information when they are away from other technology access. But even when they are in proximity of other technologies, using the app for information search might be quicker and minimize interference with other tasks. Aside from access, the app can also be used to demonstrate to patients that they care and that they are aware and proficient with new technologies. Further, its use in front of patients also provides HCPs an opportunity to engage and teach patients. As information becomes more accessible to patients, using the apps in front of patients enables HCPs to teach effective information seeking practices.

However, as we have found in our survey, a large number of HCPs have been slow to adapt the use of mobile apps in their practices and expressed concerns about appearing to be distracted or unknowledgeable. We believe part of the reason for the difference in perceptions about mobile app usage in the clinical practice is that HCPs work with different patient populations. Some work with patients where the mobile apps are highly adopted. Patients may expect their providers to be technology proficient and adopt a multitude of mobile-based tools. In addition, patients may also be accustomed to the use of mobile apps for general information seeking in their daily experiences and are less likely to perceive it negatively. Another reason for underutilization of mobile apps by HCPs may be the lack of wireless capability in some clinical settings.

But like general Health IT usage[7,24], we believe there are general strategies that can be employed to make the integration of mobile information seeking by providers in a clinical setting to be more successful. If HCPs can clearly communicate what they are doing and why they are doing it, there is no reason why the app usage needs to be perceived as negative (or any more negative than if the HCPs were to use any other resources). Further, effective engagement of patients in the process will decrease misperceptions from patients that apps are being used for personal reasons in addition to providing additional opportunities for HCPs to educate the patients.

Conclusion

In this work, we present an exploration of a mobile app prototype to support teratogen information seeking. Aside from the prototype itself, this work also contributes to the ongoing question of how to effectively present pregnancy drug risk information. Our results suggest that part of the challenge stems from the complexity and uniqueness of teratogen risk information and the different information needs of the providers – need to understand, to decide, and to explain. We suggest different features to support these three types of information needs. In addition, our findings also advance our understanding of the potential role of mobile health information apps in HCPs' practices. Access to this type of information through mobile devices enables flexible uses (e.g., on the go), is quick and limits dependency on desktops that usually already have EMR and other applications running. Further, using apps in front of the patients may lead to potential benefits such as signaling physician care and tech-savviness, in addition to having additional opportunities to engage and educate patients. These insights can help facilitate designing for mobile apps for HCPs during provider-patient interactions.

Acknowledgement

This study was supported through SBIR Grant 1R43DD001127-01 awarded by the Centers for Disease Control & Prevention in an effort to improve medication safety for pregnant women. The authors are grateful to the HCPs who generously gave their time to participate in our study. We thank Margaret Adam, Amy Bauer, Angela Chien, Debra Doyle, Ira Kantrowitz-Gordon, Theresa O'Young, Mary Puttmann-Kostecka, Bat-Sheva Stein and WWAMI for

their help in recruiting HCPs for the study. We would also like to thank Jina Huh, Yunan Chen, Richard Boyce, and Wanda Pratt for their feedback on this work.

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