Research Article

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Pharmacogenomics

An assessment of patient perspectives on pharmacogenomics educational materials

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Aim: Pharmacogenomics (PGx) holds potential to improve patient treatment; yet, effective patient educational materials are limited. **Materials & methods:** Using a 'think aloud' technique, we sought to understand comprehension and perceptions of a multimedia PGx results packet including a cover letter with QR code to an educational video, brochure and prototype report in the context of PGx case vignettes. **Results:** The cover letter and video components were viewed less favorably due to excess detail, complex jargon and technology challenges. Recommendations were to enhance comprehension and utility and to customize materials to each patient's medications or disease conditions. **Conclusion:** Educational materials were revised to improve comprehension and usability, and diminish concerns to better prepare patients to understand the importance of discussing test results with their provider.

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Pharmacogenomics (PGx) testing is one of the leading applications of individualized and precision medicine and has the potential to improve patient treatment by optimizing drug effectiveness, reducing adverse drug reactions and improving health outcomes. An increase in PGx testing seems imminent as over 100 medications are now labeled with PGx information and coupled with an increased development of companion diagnostics [1–4]. Importantly, this testing potentially poses some limitations and risks including the likelihood for incidental results and unsettling findings for patients that could lead to insatiable desire for more testing [1,2,5]. It is important to consider the manner in which the results are communicated to patients and to assess the comprehension of these test results. A comprehensive literature and resource review indicated that the development of educational materials does not always correspond with test development, and few patient educational materials for PGx exist [4,6,7]. The few available resources have been developed by commercial testing laboratories and may be specific PGx testing being offered by the laboratory [6]. Presently, there are many institutions, hospitals and health systems, which are striving to advance patient education in PGx testing.

PGx information is complex and can be difficult for both patients and their healthcare providers to understand. Clear presentation of PGx results, their benefits and limitations is imperative to enable informed treatment and care decisions. However, communicating PGx test results may be difficult and multiple factors such as types of test outcomes [4], patients' health literacy [4,8–10], genetic literacy [9,11,12] and other patient characteristics such as age, sex and education [10] have been reported as potentially impacting patients' ability to comprehend PGx results. For example, traditional PGx results often include medical jargon and genomic nomenclature, which may not be understandable to all patients. With increasing access to online medical records, the content of a formal PGx laboratory report may be difficult for patients to comprehend. Therefore, information in test reports and accompanying materials should be presented in ways that facilitate understanding and enhance utilization of that information [13]. To address these concerns, we conducted a qualitative evaluation of PGx educational materials

designed to inform patients about their test results and to convey the purpose, benefits and limitations of PGx testing.

Materials & methods

Study design & background

The Right Drug, Right Dose, Right Time (RIGHT) protocol was designed to recruit a large group of patients for preemptive PGx testing, to develop the electronic health record (EHR) infrastructure to deliver point-of-care clinical decision support, and to study the effects of integrating preemptive PGx testing into clinical practice on patient outcomes. The RIGHT Protocol had two phases, a pilot phase and an expansion phase. The pilot phase recruited 1013 participants and reported PGx test results into the EHR and to participants directly [14]. The study was then expanded to include an additional 10,000 participants [15]. The qualitative study described herein was conducted to assess the educational materials used in the pilot phase with the purpose of improving the patient materials for the use in the expanded phase of the study. Qualitative research is well recognized in healthcare education development and is ideally suited to understand the patient experience, to explore and clarify participant views.

One aim of the RIGHT protocol pilot study was to examine predictors of PGx literacy and assess participants' reactions to the information received. Participants in the pilot study received preemptive PGx test results and were given a survey that collected data on attitudes about the mailed result letter, educational materials, participants' beliefs about personal medication use, plans for using the results and usefulness of PGx testing [10]. This previous study found that only 26% of participants were able to somewhat understand their results. A common suggestion for improvement was to increase the use of layperson terminology in the report. Consequently, a comprehensive PGx report and additional educational materials were developed (Table 1). These materials included a cover letter introducing the concept of PGx, a video describing the test, a brochure on PGx testing and a prototype OneOme, Inc. RightMed® PGx report (OneOme LLC, MN, USA). In an effort to ensure that these materials would meet the needs of the patient population, we studied participants' perceptions through in-person interviews and focus groups to inform revisions of the educational materials.

Participant recruitment

Participants in the RIGHT study were selected from the Mayo Clinic Biobank (MO, USA) [16]. The RIGHT protocol study and this substudy were approved by the Mayo Clinic institutional review board. Full details of the setting and procedure for the larger RIGHT study have been previously reported elsewhere [10,14,17]. A purposive sampling using a criterion-based strategy was used to identify participants. Enrollment was based on predetermined criteria by the larger RIGHT protocol study. The criteria were that patients must be listed in the Mayo Clinic Biobank, must be part of the 1013 participants who provided a blood sample and informed consent and were included in the larger RIGHT protocol study and had previously indicated an interest in participating in future focus groups or interviews related to PGx. A sample of 50 participants was selected from the pool of eligible participants based on geographical location and proximity to the hospital to enable participation in focus group or in-person interview. Recruitment letters and emails were sent to potential participants explaining the purpose of the study. A total of 24 participants consented and participated. Eight of the potential participants declined participation, and 18 did not respond to our request. Participants received a $25 gift card and complimentary 2 h patient parking as an incentive for participation.

Educational materials

The educational materials presented to participants were developed based on findings from a previous study [10].

Cover letter: *Right Drug, Right Dose, Right Time – Using Genomic Data to Individualize Treatment*

The one-page, color print, 293-word cover letter provided a summary of PGx. The first paragraph thanked participants for their continued participation in the study and provided general information on PGx testing; the five genes that were tested, and explained how some drugs may work faster or slower depending on patients' 'genetic make-up.' The second paragraph directed participants to other materials included in the educational packet: a PGx brochure, a link and a scanning QR code that navigates to a 5 min educational video and the OneOme RightMed® PGx report. The QR code required participants to scan with a QR code reader on their smartphones to access the video. Alternatively, they could enter a website address to access the video. Since the purpose of this

Table 1. Details of educational materials.

Component	Format	Content	Intended use
Introductory cover letter modeled after institutional letter to patients	Single page 8.5 × 11 inch, color print	• General overview of PGx testing • Number of genes tested for patients • Reference and links to video (via QR code) and brochure limitation of PGx and a 'Do not make changes to your drugs' boldly written in the letter • One institutional logo and four departmental logos	For patients
Navigating your PGx report	**Animated video, 5 min**	• **General overview of PGx** • **What PGx is** • **A general overview of terms** • **How the report is organized** • **Risks and benefits of testing** • **Next steps for patients** • **Relevant factors to consider for PGx testing**	**For patients**
What you need to know about pharmacogenomic testing	4-page, 5.5 × 8.5 inch card, color print	• Text overview of PGx • What is PGx? • Factors impacting medication response • Reasons for PGx • How test is conducted • Cost of testing and insurance coverage • What to do with results • Limitations of test Graphics • Variation in individual response	For patients to take home and share with providers For providers to share with patients
OneOme, Inc. RightMed® PGx report (prototype results document) to be used in relation to two case vignettes	**8-page, 8.5 × 11 inch, color print**	• **General overview** • **Genotype-derived recommendations for medications: color coded in red-use with great caution, yellow-use with caution and green-use as directed** • **Genotype-derived classification-impact of genetic variants** • **Legends, genotype results and reference information** • **Specific testing performed by Mayo clinic** • **Services provided by OneOme** • **Liability claimer and references**	**For patients to take home and share with providers** **For providers to share with patients**
	Two patient scenarios printed on an index card	• General overview • Patient disease characteristics, current medications • Each scenario is presented in relation to the prototype OneOme report for patients' interpretation	To aid study participants understanding of the prototype OneOme PGx report

PGx: Pharmacogenomics; QR: Quick response.

communication was to provide patients with their PGx results, the last paragraph included the caution, 'DO NOT make any changes to your drugs *without talking to your healthcare provider or pharmacist.*' The paragraph continued to caution patients about how other factors such as sex, race and age may affect treatment and emphasized that PGx is one tool that can be used to determine the best drugs for patients. The text readability was scored at 9th grade level.

Video: *Navigating Your PGx Report*

The 'Navigating Your PGx Report' was a 5-min, animated video that provided general information for participants but was condensed for brevity to include what PGx is, how the report is organized, the risks and benefits associated with the testing, a general overview of terms, the next steps for patients and other relevant factors to consider for PGx testing. A general list of medications (that patients may or may not be taking) were grouped into three categories (red = use with great caution, yellow = use with caution and green = use as directed), and labeled with colored icons. The three categories in the video and the OneOme RightMed® PGx report were illustrated and defined as follows:

- A red stop sign indicating major gene–drug interaction: major genotype–drug interaction identified that affects the metabolism of the medication and/or indicates an elevated risk of adverse reaction or loss of efficacy;
- A yellow hazard sign indicating moderate gene interaction: moderate genotype–drug interaction identified that affects the metabolism of the medication and/or indicates an elevated risk of adverse reaction or loss of efficacy;

- A green go ahead sign indicating minimal gene–drug interaction: minimal genotype–drug interaction identified that does not significantly impact medication metabolism or predict an elevated risk of adverse reaction or loss of efficacy.

The video described other factors (e.g., age, sex and ethnicity) that may impact drug response. A OneOme RightMed® PGx sample report was shown and described.

Brochure: *What You Need to Know about Pharmacogenomic Testing*

The brochure provided summary information describing what patients need to know about PGx testing. The front page had a graphic collage and a linkage graphic connecting a DNA double helix to pharmaceutical images. Inside the brochure was a description of what PGx and genes are and how genes can influence the way people process and respond to medications. A graphic of 12 human silhouettes labeled 'Patients taking same medication' was used to illustrate how individuals' responses to the same medication may vary. The image depicted two of the silhouettes in yellow indicating 'no response,' two in red indicating 'serious side effects' and eight in green indicating 'desired response.' Additional text and a graphic listed other factors that may impact response to medications: genetics, age, sex, race/ethnicity, illness, food interactions, and so on. The third page explained why a healthcare provider may order a PGx test: to avoid serious side effects of certain medication, adjust a dose of medication or to identify the right medication for a patient. Other information included how a PGx testing is done, and information about cost variation without specific details, price and insurance coverage. Patients were directed to contact their insurance provider for cost and coverage information. The Genetic Information Nondiscrimination Act was referenced. The bottom of the right panel informed patients what to with their PGx testing results (presented in a text box). Patients were directed not to make any changes to their medication and to share their results with their healthcare provider. The back page provided a summary list about PGx results, cautioned patients to not use their PGx results to guide medication decisions for others, described limitations of PGx testing and described how other blood relatives may benefit from the results.

A prototype OneOme, Inc. RightMed® PGx report & vignettes

A prototype PGx report was presented to participants in relation to two patient scenarios. Each patient scenario described a patient's age and sex, their diagnosis and medical history, treatment and current medications. The prototype report was an eight-page document that displayed results of the five genes tested along with a list of medications arranged in color-coded groups, as previously described. The report also contained information on the test limitations, impact of genetic variants, genotype results, legends, references and information about the lab test and performing laboratory.

Data collection

Data for this study were gathered via individual and focus group interviews by GB Asiedu and A Agunwamba. Interviews explored four educational items as described in Table 1. For copyright purposes, participants' assessments of the OneOme RightMed® PGx report and PGx case vignettes are not included in this article. A 'think aloud' technique [18,19] is a standard method in cognitive interviewing and was used to elicit participants' preferences and educational needs.

Seven participants were interviewed individually by trained staff. Participants were presented with the PGx case vignette and the prototype profile of a patient to assess how they would interpret the results using patient scenarios. Participants were instructed to open an envelope containing a cover letter, prototype PGx report and PGx brochure. Participants were asked to reflect on how they would review PGx testing results. All participants reviewed the cover letter, watched the short video, reviewed the brochure and assessed the OneOme RightMed® PGx report. Focus groups followed the same pattern as the individual interviews.

Interviews lasted up to 60 min (for individual interviews) and 90 min (for focus groups). All interviews were audio recorded with full participant knowledge. Transcriptions were created with no participant identifiers. Patient demographics were collected using a Mayo Clinic Biobank database search [16].

Data analysis

Data were content analyzed using a combined inductive and deductive approach [20]. This approach allowed for *a priori* codes on the basis of the research questions and developing *de novo* codes from emergent themes. An

interviewer (GB Asiedu) first read the transcripts several times and noted thoughts and what she saw in the data for discussion with a study team. A framework using the different PGx materials (cover letter, video, brochure and report) was used for the deductive portion and then supplemented with *de novo* codes. The process included inductively identifying major themes and patterns in the data and sharing them in meetings with the study team. During these meetings, the study team sought clarification on emerging themes. For any discrepancies, the interviewer returned to the original transcripts to further assess the data and confirm or modify the themes for discussion at the next study meeting. Nvivo 11 (QSR International Pty Ltd, MA, USA), qualitative analysis software, was used for data management and to facilitate analysis.

Results

Participant demographics

A total of 24 participants (n = 17 males) participated in the study. There were two focus groups (n = 10 and n = 7) and seven individual interviews. Participants' mean age at the time of the interview was 63 years (range 52–71). The majority of participants were white (n = 19). The remaining five identified themselves as black/African–American or 'other' and one chose not to disclose race. Participants' educational attainment was as follows: graduate/professional (25%, n = 6), bachelor's degree/4-year college (38%, n = 9), some associate degree (29%, n = 7) and high school (8%, n = 2). Participants' perspectives are summarized below and sample quotes are presented in Table 2. Consistent with qualitative data description, we used the terms 'few,' 'some,' and 'most' to provide a general idea rather than specifically indicating how many participants shared perspectives on a given theme. Using the data 'sources' and 'references' features available in Nvivo when a particular theme was referenced by more than half of participants, we used the term 'most/more,' if it was referenced by less than half we used the term 'some/few.'

Participant views on the cover letter

Overall, the majority of the participants thought the cover letter was comprehensible with limited ambiguity. Few participants commented that the first paragraph of the cover letter lacked context. They viewed lack of context as having a propensity to create ambiguity which could, in turn, cause anxiety for some patients. Specifically, participants said that, not knowing what to do upfront about their results could increase their worry about interpreting the results, create ambiguity about what the results could mean and cause confusion about what changes to make to their medication. Participants wanted to be told upfront, early in the cover letter, to discuss the results with their clinician. While the cover letter contained information on what to do upon receiving test results, this information was presented at the end of the letter. Other participants thought the cover letter was too generic and could be tailored to their individual needs or disease condition. The majority of the participants noted that vocabulary terms such as 'pharmacogenomics' and 'genes' could be a concern for patients who may not be familiar with medical terms. All participants overwhelmingly expressed concern about the usability of the scanning QR code inserted in the cover letter. They commented on the technical challenge of using a QR code to navigate to a website. The location of the code (in the middle of the cover letter) was reported as dominating the content of the cover letter as it was the first thing that drew their attention.

Participants' views on video

The majority of the participants acknowledged that the video provided more information about genetic testing, but expected that clinicians should be discussing this with patients. Most of them said because patients are not medically inclined, the illustrations in the videos could escape their comprehension and they would prefer to receive such information through their healthcare provider. Participants' comments and recommendations on the video were categorized as follows: content and purpose, visuals and illustration and language and terminology. Overall, the video received the most unfavorable reviews of the materials included in the packet.

Content & purpose

About half of the participants indicated that including more text in the video would be helpful to reinforce important concepts, clearly convey the purpose of the video and to maximize understanding. For example, they suggested that more explanation for what 'metabolizers' were and its implications for a patient's medication dose would help patients understand the information. Few participants questioned the relevance of the video and indicated that they did not understand the purpose of the video.

Table 2. Assessment of pharmacogenomics educational materials: representative participant quotes.

Educational material		Illustrative quotes
Cover letter to PGx results		There's a lot of people who aren't gonna understand even though they've been around for a long time exactly what a QR code is or how to get that address… The very first thing I noticed was the QR code thinking that there's a lot of people if you were to send this out now, have no idea what it is or how to access it, or um you know how to go about doing it… It should be displayed in the bottom right with a reference to… I'm not sure why they put the QR code right in the middle… It's-it-it first thing your eye goes to is the QR code when you open the letter... It just seems odd being right in the middle and, and just the dominant thing that you look at. **[Focus Group 2]** I'm thinking if I was an elderly patient, let's see, I think pharmacogenomics might be an unfamiliar word for a lot of people, and then PGx might be just that abbreviation would be a little odd. **[Participant 3]** That first paragraph, how your genes may affect your body's response to some drugs — that's, uh, a little more complex and again not knowing what I'm thinking is the spectrum… I'm stumbling on some of these that terminology, that genetic thing, genetic makeup. What is that? I'm a man I don't do makeup. **[Participant 5]** There [is] some way to reinforce… to let them [patient] know maybe upfront we're gonna share this with you, but encourage you to take these results and visit with your healthcare provider — let them know up front because I'm sitting here scrambling thinking, *I'm gonna have to figure this out*? Oh my. And yeah I'm gonna worry. Do I need to take my medicines? Can I take it tonight? I don't see my doctor till next Thursday. That you're, you're amping up my anxiety if I get this in the mail and you're gonna get calls to the provider. **[Participant 5]**
Video	**Content and purpose**	**Some of this stuff was too much and I don't think the patient cares about seeing all the pathways, and ya know, the list of all the medications... It's too busy, and they don't need to know or want to know and they can find out or ask, but it's too much. [Participant 3]** **Now if I were watching this, I would have backed this up and started all over again cause I'm still trying to process. [Participant 5]** **Maybe I just missed it, but we never talked about the metabolizers. Like why are they talking about it? 'Cause if you're low metabolizer, you need a smaller dose than an average metabolizer, and if you're a super metabolizer you're gonna need a bigger dose because your body clears it out faster.** **[Focus Group 2]** **If the intent is to educate and these genes have a role in terms of what happens, I think you need to explain to people why you're doing this, and take them through the steps; Why they should be concerned about it, why there's these things that you shouldn't do, ones that you can do, ones that you can't do... and you have to simplify that. [Focus Group 1]**
	Visuals and illustration	Rolled a little too quick for me I thought. A little slower would have been better for me. I'm just a slow reader, that's my problem. Wasn't able to metabolize the information as fast as I should… Now, I don't think the video was intended to allow us to read that, [referring to an example PGx report been shown in the video] it was [to] tell us what we're going to see in these papers. They shouldn't [have] put it up there cause some people get hung up on reading. **[Focus Group 2]** The 3 categories have way too many things going on. It's like you don't need to show all the things that fall under the caution thing… It's just too much information. And you know… Nobody knows what the drug names are. Just fewer examples of what that is might be a visually less daunting thing to look at. Kinda like information overload. **[Focus Group 2]** That font is very difficult to read or is it just me? The color after going to black and white. There's not enough contrast… and again if I had any visual challenges… I'd be tuned out. **[Participant 5]** …There's I mean red there's — there's some colors that are just more receptive to the eye… Than others and I don't know what it is about that blue because… Its just is not as easy to read. And I think we need to make it as easy 'cause otherwise you focus on… 'What's that' and then sometimes you miss what's important because you're looking at something else. **[Participant 6]**
	Language & terminology	**It seemed to be pretty technical you know… Yeah, it's like wow. Why are they sending this to me? My doctor should be discussing this with me… But they're [patients are] not medically inclined… So laymen's terms maybe a little bit better. [Focus Group 1]** **Kinda cartoony… Starts out with a sort of friendly — oh everybody can get this and then I was surprised… They use the word metabolize... I'm not sure everybody knows what that means... It's that's not something you run into in your regular... day-to-day business… daily life or reading... So it's like this friendly cartoony deal and suddenly it metabolized... You need other terms… If you're gonna keep it happy and friendly and easy to understand, you gotta make sure you don't insert pieces in there that just make it confusing [Focus Group 1]** **I think people generally, when they get a report, they want a black and white answer, but then all the sudden you give them…you know metabolism speedometer over here and over here and then the average person's gonna go, 'well what does that mean?'... So, I think it left a little gray area there for me. [Focus Group 2]**
Brochure		Actually I think its best piece of information so far. It just really does show how your genetics make a big difference… It can make a big difference… It has pretty simple questions and answers **[Focus Group 1]** If I was interested in pharmacogenetic testing I would pick this pamphlet up. You can see what the main thing is in the pamphlet… I think that's the catcher, pharmacogenomics, just a big word to some people but if they read down below it that helps, helps clarify. **[Focus Group 2]** It has a nice feel of paper. Very futuristic looking in the background, how they blurred the medication out Mayo shield and Center for Individual Medicine… Brings your eye to that. **[Participant 1]** I love this visual… It's giving me a clearer picture… You're looking at how I respond to a medicine that I'm taking. I might have no response. I could have some bad stuff. So again, you're color coordinating… The red is the bad ones. The yellow is of concern because why take it if it's not helping. It's not doing anything. Or green it's good. It's working for me. And that different people could respond to that same medicine in different ways. **[Participant 5]** I think it's pretty easy to understand and answers the question right up front. And a couple of easy, you know, easy [to] read sentences so and a picture's worth a thousand words and that's good. **[Focus Group 2]** I think that *how is pharmacogenomics testing done* is… Almost too simplistic of a description… Yeah, I don't know how you explain, but that's like tells me absolutely nothing. I would say that the last piece, the bottom one be replicated in… the film if you're gonna use them both… Because there are some things on here, the smoking and alcohol use that is only listed here it's not in the film strip. **[Focus Group 1]**

PGx: Pharmacogenomics, QR: Quick response.

Visuals & illustration

All participants overwhelmingly expressed a desire for a video with human actors as opposed to animation as they felt that the animation format had the potential to minimize the importance of the topic being discussed. Thus, a serious topic like PGx testing ought to be portrayed with an equally serious presentation format. Some referenced a segment of the video that discussed sample results of PGx testing and said this information was presented too quickly. Others considered that the use of the symbols signifying the three color categories (red = use with great caution, yellow = use with caution and green = use as directed) was an exaggeration when placed in relative context of what the results might mean. In fact, about half of the participants thought the categories were subjective and the use of colors could be a distraction.

Language & terminology

All participants expressed concerns about the medical/technical terms such as 'metabolize,' 'metabolic status' and 'phenotype.' Participants described these terms as having the potential to pose substantial challenges to a patient's comprehension of the information being presented. According to participants, while the use of animation and infographics created an impression of friendliness and ease of comprehension, the use of medical jargon (some without explanation) seemed to have defeated the purpose for the use of animation. Thus, half of the participants said that animated illustrations should correspond to simple terms and plain language in educational presentations.

Participant views on the brochure

The brochure was the most liked among all the educational materials presented in participants' packet. All participants said the visual presentation was compelling; subtitles broke out information visually, and focused attention on the topic. The use of color, visuals and illustrations were described as appealing, and the information was presented in an easy-to-understand and a visually compelling way that reinforced the key messages presented in the brochure. Many participants expressed that the illustration about variation in individual response to medication was an 'eye-catcher' and well executed.

There were few participants who shared a disparate view on the language and terminology used in the brochure. The majority of the participants thought the explanation of what PGx is, individual response to medication, factors that impact response to medication and other content were well presented in a layperson's terms. However, few participants thought the questions and answers in the brochure were too simplistic and failed to convey detailed information about PGx testing. For example, patients wanted detailed information about how much testing could cost and whether that would affect their insurance coverage. While some commented on the use of 'pharmacogenomics' as medical jargon, they quickly noted that there was further explanation following the term, which was helpful for their understanding.

For the brochure, few participants suggested increasing the font size to make it more visible to older patients who may find it challenging to read. They also suggested that replacing text with images that list the factors impacting response to medication would make it easier to understand. The majority of the participants recommended that the information presented in the brochure be replicated in the video. Also, the background to the cover page, showing the linkage graphic of pharmaceutical images was mentioned as difficult to understand as the images appeared to be too 'technical' for participants. In order to enable usability for a diverse testing platforms and laboratories, some details about the test, such as price and insurance coverage were intentionally left out. However, participants indicated their desire for more specific information on cost and insurance coverage.

Overall, participants favored the brochure over the other materials. When asked about their overall views on the educational materials, participants stated that they would have no difficulty understanding the materials; however, they frequently referenced other patients who may not understand the materials and would look to their doctors for explanation.

Discussion

Our study aimed to conduct an initial assessment of educational materials to support the return of PGx results to patients. The educational brochure was viewed most favorably, while the cover letter and the video component were viewed less favorably. Participants provided recommendations to enhance comprehension and utilization for all materials. There was consistency among most participants on how they perceived the use of medical terminology. For instance, most participants expressed concerns that language, including the overuse of medical terms like 'metabolic status,' 'phenotype,' 'pharmacogenomics,' 'metabolizers' was too challenging to understand and should

therefore be changed. Views on the brochure did receive mixed reactions as few participants felt that the terms were too simplistic and could have included more medical descriptions to accurately describe PGx testing. There have been reports echoing findings of mixed responses regarding the use of medical jargon [7,22,23] in patient education. Even so, these reports call for developing educational materials that address the participants' concerns – specifically avoiding or minimizing the use of medical jargon, and advocating for plain language to convey information.

Patients' readability is one of the major challenges in developing educational materials of any kind [23–25], as readability can affect user comprehension. The average US resident reads at the 7th and 8th grade level [23,26,27], while the average Medicare patient reads at or below 5th grade level [28]. This has implications for patients' ability to interpret or comprehend medical terms. The education materials that were reviewed by participants in this study may be written at a reading level that is too complex for patients to comprehend. Specifically, the materials contained multisyllabic words that were not familiar to patients and therefore the materials may not be comprehensible for the intended patients. Even well-educated patients with good literacy levels may have trouble decoding medical terms. While the majority (63%) of participants in this study had at least a bachelor's degree, it should be noted that their educational level was not an indicator of readability as patients typically have reading skills that are about five grades lower than the highest attained educational grade. In fact, according to guidelines set forth by the Centers for Disease Control and Prevention (CDC) [29], the American Medical Association [30] and the US Department of Health and Human Services [31], patient reading materials should be no higher than sixth-grade reading level to optimize comprehension. It is important to have adequate and appropriate PGx testing information available to patients. However, the materials cannot be utilized effectively if it is presented in a manner that is beyond the scope and comprehension of the general patient population. Healthcare providers are reminded to be cognizant of the language used in discussing PGx test results with patients given the range of literacy levels of patients and unfamiliarity with PGx testing [4,10,21]. PGx medical terminologies like 'phenotype, genes, metabolizers, genotype, ultrarapid metabolizers' [4,10,21] have been reported to potentially impact patients' comprehension of PGx testing results [4,10], and could potentially cause adverse psychological and other behavior responses [4].

Modern technologies such as 2D bar codes (QR codes) have been used to enable quick access to patient's information [32,33]. However, there has been limited exploration of patients' perceptions toward and use of QR code for health information and educational purposes, and there exist limited case reports on the innovation of such technologies for patient education [34]. Participants in this study did not show enthusiasm for the QR code linked to the PGx educational video. While the use of QR code may be well received in other areas of healthcare, its use in patient education should be considered and studied.

Animated videos have been effectively used to deliver health information [35], however, participants in our study suggested that a live-action video may be more appropriate given the seriousness of PGx testing. With a live actor, patients may be able to better relate their own experiences and fears about the topic. In general, feedback on the PGx video recommended including human actors, using lower literacy level terminology and presenting at a slower pace. Educational videos and materials are typically recommended to be short, clear, with simple illustrations [6,36,37]. Based on the complexity of the scientific concepts and information presented in the video (within a short amount of time), it is understandable that participants in this study desired additional information to promote comprehension as echoed in other reports [6,36,37]. It is suggestive from our findings that such short videos do not adequately cover all information that patients would like. In fact, some reports [6] suggest that creating an abbreviated version of a PGx educational video to generate interest for a longer version would be receptive among patients.

In October 2018, the US FDA granted marketing authorization of the personal genome service PGx reports test to 23andMe Inc. (CA, USA) [38]. This authorization allows 23andMe to conduct direct-to-consumer PGx testing and provide information about genetic variants associated with a consumer's ability to metabolize some medications [9,38–40]. This could encourage discussions between patients and their healthcare providers about genetic testing, thereby increasing access to PGx testing. Increasing access to PGx testing will require thorough patients' understanding of the service and testing results through educational materials that are developed independent of commercial companies. Importantly, patients' understanding of their metabolic predisposition and how it impacts drug selection and dosing may result in improved medication adherence and increased satisfaction [4].

On the other hand, the approval of the 23andMe test could pose potential challenges to clinicians regarding the integration of PGx data into patients' EHR, and how to utilize the results for routine clinical care in ways that are comprehensible to patients. Studies show that patients' understanding of any genetic information is limited [6,9,10] and lays responsibility on patients receiving genetic information to be prepared upfront for understanding those results.

Reports [17,39–41] also indicate that clinician preparedness for PGx testing is not as promising as patient readiness. Thus, while healthcare providers envision a major role in the delivery of PGx testing, there is also the recognition of their lack of adequate knowledge, preparedness and experience with these tests and with addressing patients' questions [17,41,42]. There is the need to utilize participatory approaches that engage healthcare providers in creating educational resources that help patients understand what the results may mean as part of treatment and care.

Educational material revisions

The feedback gathered from participants informed revisions to the educational materials. Specifically, the video components and the associated links were eliminated. We were also able to reduce the amount of text for the cover letter from 293 to 201 words and reduced the reading level from 9th grade to an 8th grade level. The first paragraph of the revised cover letter introduce recipients to the packet materials, referencing 'a brochure that gives you more information about the study' and the 'patient's personal copy' (underlined for emphasis) of the test results. Per majority suggestions, the scanning QR code was removed. The verbiage 'Do not make any changes to your drugs' was revised to 'Do not stop taking your drugs or make any changes to them,' and this text was moved up to the second paragraph. Throughout the cover letter, medical jargon such as PGx and genetic make-up were eliminated where possible to minimize confusion and enhance clarity.

A number of changes were also made to the brochure. Since the brochure was the most preferred of the educational materials, we decided to enhance it and include more information. Many of the participants provided feedback that the font size could be larger to make it easier to read. To accommodate this change, the size of the brochure was increased to an 8.5 × 11 inch document. To simplify the imagery and to maintain the medical pharmaceutical theme, we used a blurred image depicting a science laboratory and a health professional in surgical scrubs holding a medication bottle on the cover. Additional information provided in the brochure included where to find test results including cautions to not make changes to medications, how to navigate the drug list on the OneOme RightMed® PGx report, and how patients' PGx results may be used by providers. Because our institution has implemented clinical decision support alerts to provide point-of-care recommendations during prescribing, the brochure explained that clinicians may receive an alert based on a patient's specific drug–gene interaction. In certain cases where a clinically actionable genetic variant interacts with the prescribed drug, the clinician will receive an alert with recommendations to guide prescribing medications. Additional information about how to make sense of the OneOme RightMed® PGx report was provided at the end of the right-hand panel. Patients were directed to specific pages of their PGx results for further explanation of the color category and symbols meaning of the PGx testing results. Overall, the changes made to the brochure were intended to diminish patients' concerns of not knowing what to do and attempted to provide a sense of security that the EHR system and their clinician will be supported in using PGx.

Study limitations

Some limitations of the study should be noted. Our study is limited by a small sample size as well as participants' educational status (which is above the national average for US residents), and therefore our findings may not accurately represent the view of a larger population of patients. Our study is also limited by the homogeneous nature of our population. Most of the patients that utilize the services of the hospital are non-Hispanic white, thus we could not achieve diversity from a race or ethnicity perspective. Also, our findings represent patient perspectives in a single institution, and so these findings should not be generalized to other institutions without further research. Studies that elicit perspectives of a more diverse group of stakeholders could enhance PGx educational materials.

Conclusion

Patient education will hold a key component for successful implementation and utilization of PGx testing. With the increased use of PGx in precision medicine, there is a need to promote patient comprehension of PGx test results to enhance treatment and care decisions. The need to develop effective patient education materials that can easily be comprehended by patients is critical. Future PGx educational materials need to focus on decreasing reading level and minimizing the use of medical terminology and gene nomenclature. Understandably, it may be difficult to avoid medical terms; however, more common language and simple descriptive phrases can be included to enhance comprehension. Using plain language and simpler phrases could make PGx information more accessible to patients. Continuous evaluation of PGx educational materials to meet an acceptable standard for comprehension is imperative. The evaluation and development of such materials encourage a participatory approach that engages both patients and healthcare professionals. The findings of this study suggest that there should not be a one-size

fits all approach in communicating PGx testing results to patients. Instead, a tailored approach of PGx testing information based on the individual patient's disease conditions may be needed as more and more patients seek direct-to-consumer testing and the results are not delivered directly by a clinician or a healthcare professional.

Summary points

- Pharmacogenomics (PGx) holds the potential to improve patient treatment by optimizing drug effectiveness, reducing adverse drug reactions and improving health outcomes.
- A comprehensive literature and resource review indicated that effective patient PGx educational materials are limited.
- We conducted an initial qualitative assessment of multimedia PGx educational materials to support the return of PGx testing results to patients and to help patients understand the benefits, limitations and interpretation of their PGx results.
- Using a 'think aloud' technique, we conducted focus groups and interviews with 24 participants to understand comprehension and perceptions of a multimedia PGx results packet, including a cover letter with QR code and link to an educational video; brochure about PGx testing; and prototype PGx integrated report in the context of two PGx case vignettes.
- Participant demographics were as follows: mean age at the time of the interview was 63 years (range 52–71); majority were white (n = 19); educational attainment was, graduate/professional (25%, n = 6), bachelor's degree/4-year college (38%, n = 9), some associate degree (29%, n = 7) and high school/GED (8%, n = 2).
- Participants found the educational brochure useful, however, the cover letter and the video component were viewed less favorably due to excessive detail, complex jargon and technological challenges with the QR code.
- Most participants expressed concerns that language, including the overuse of medical terms like 'metabolic status, phenotype, pharmacogenomics, metabolizers' were too challenging to understand and should therefore be changed.
- Majority (63%) of participants in this study had at least a bachelor's degree; however, their educational level was not an indicator of readability.
- Study participants did not show enthusiasm for the QR code linked to the PGx educational video for educational purposes. While the use of QR code may be well received in other areas of healthcare, its use in patient education should be considered and studied.
- Following the assessment, educational materials were revised to improve comprehension and usability, and diminish concerns to better prepare patients to understand the importance of discussing test results with their provider.

Author contributions

This manuscript was prepared in accordance with Good Publication Practice (GPP) guidelines and all contributors met International Committee of Medical Journal Editors (ICMJE) criteria for authorship. The authors are listed in order of lead and senior author, based on their contributions. All the authors made substantial contribution to the design of the work and critically reviewed and provided substantial revisions to iterative drafts, approved the final version for submission and agreed to be accountable for all aspects of the work.

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Ethical conduct of research

This study followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. The authors obtained appropriate institutional review board approval or from the Mayo Clinic IRB. In addition informed consent was obtained from all participants.

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