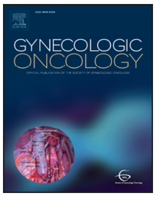
Gynecologic Oncology 153 (2019) 100–107

Contents lists available at ScienceDirect

Gynecologic Oncology

journal homepage: www.elsevier.com/locate/ygyno



A patient-centered mobile health application to motivate use of genetic counseling among women with ovarian cancer: A pilot randomized controlled trial

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HIGHLIGHTS

- Women randomized to the intervention had greater knowledge of hereditary cancer and genetic counseling.
- Women receiving the intervention were more likely to talk with their family about genetic counseling.
- Women demonstrated greater self-efficacy in making a genetic counseling appointment.
- Participants in both the intervention and control groups reported high utilization of genetic counseling services.

ARTICLE INFO

Article history:
Received 4 October 2018
Received in revised form 17 January 2019
Accepted 22 January 2019
Available online 1 February 2019

Keywords:
Ovarian cancer
Genetic counseling
Communication
Mobile application
BRCA

ABSTRACT

Objective. Despite current guidelines recommending women with ovarian cancer receive genetic risk evaluation by a genetic counselor, utilization has historically been low. We sought to assess the feasibility and effectiveness of a week-long mobile Application for Genetic Information on Cancer (mAGIC) intervention aimed to persuade women with ovarian cancer to pursue genetic counseling.

Methods. The mobile application intervention was based on the Fogg Behavior Model, and consisted of three parts: (1) identifying barriers, (2) developing motivators, and (3) providing triggers to action. The Health Belief Model was used to guide content development. We conducted a prospective, randomized, controlled pilot trial among 104 untested women with a history of epithelial ovarian, primary peritoneal or fallopian tube cancer with the primary objective of increasing uptake of cancer genetic counseling services.

Results. Utilization of cancer genetic counseling services improved in both study arms over historical controls, however there was no statistically significant difference between them (intervention: 54.5% versus control: 38.6%; $p = 0.14$). However, compared to controls, women randomized to the mAGIC intervention demonstrated greater knowledge of hereditary cancer (0–10 scale; 9.4 ± 1.0 vs. 7.1 ± 1.5; $p < 0.0001$), which persisted for at least three months. Additionally, 96% of women in the intervention group reported they had talked with their family about genetic counseling compared to 77% in the control group ($p = 0.01$).

Conclusions. The mAGIC intervention did not result in increased uptake of genetic counseling, however it provided significant secondary benefits, including increased participants' knowledge about hereditary ovarian cancer, self-efficacy, and their reported communication with family members.

ClinicalTrials.gov Identifier: NCT02877862

1. Introduction

Ovarian cancer accounts for more deaths than any other gynecologic malignancy. Up to 20% can be attributed to hereditary cancer syndromes including hereditary breast and ovarian cancer syndrome (*BRCA1* or *BRCA2* gene mutations) and Lynch syndrome [1–4]. In 1996,

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https://doi.org/10.1016/j.ygyno.2019.01.019

the American Society of Clinical Oncology (ASCO) issued its first statement recommending oncologists refer all women with invasive ovarian cancer, high-grade epithelial tumors, or any serous tumor for genetic testing [5]. In October 2014, the Society of Gynecologic Oncology (SGO) released a Clinical Practice Statement encouraging the medical community to offer genetic counseling and testing to all women with ovarian, fallopian tube and peritoneal carcinoma [6]. Given the absence of effective screening, the improved prognosis with early detection, and possible prevention strategies (such as ovarian suppression with oral contraceptives and risk-reducing prophylactic surgery) early identification of at-risk patients is crucial to optimizing outcomes.

Genetic counselors educate patients about cancer genetics and genetic risks as well as facilitate genetic testing as appropriate. Most guidelines continue to recommend genetic counseling precede testing. This is highly relevant given the complexity of hereditary cancer syndromes, and errors in medical management and genetic testing which have been reported when appropriate genetic counseling was not performed [7]. Despite these recommendations, cancer genetic counseling uptake has historically been low [6,8,9]. Our group found that only 19% of epithelial ovarian cancer patients were referred for genetic counseling (2004–2006) despite recommendations that all patients be referred [10]. Referral rates improved, albeit modestly, to 30% after introduction of an automated referral within the electronic medical record [11]. Worse, even when referrals are made, significant barriers to testing persist, including: suboptimal timing of provider referral, fear of insurance discrimination, cost, emotional distress, unknown benefit, additional time commitment, lack of knowledge about genetic counseling or testing, discouragement of family members, and personal fear [12,13]. Provider reported barriers include limited knowledge about hereditary cancer and lack of awareness of availability of genetic services [14,15].

Mobile health (mHealth) strategies are emerging as a direct and effective medium to support chronic disease management [16], including as means to change health behaviors in cancer care [17,18]. Advances in technology, pervasive use of mobile phones, and willingness to use these for health interventions now enable patients to be directly informed about healthcare recommendations [19]. While web-based cancer risk assessment tools are available, we are unaware of any other mHealth interventions promoting use of genetic services among women with ovarian cancer. To study the potential of a mHelath strategy to effect improvements in genetic counseling service uptake, a multi-disciplined study team developed and tested the **m**obile **A**pplication for **G**enetic **I**nformation on **C**ancer (mAGIC) intervention to provide education and increase utilization of genetic counseling services among women with ovarian cancer.

We hypothesized that participants randomized to the mAGIC intervention, compared to the control group, would have 1) greater uptake of genetic counseling services; 2) greater self-efficacy in making a genetic counseling appointment; 3) be more likely to communicate with family members about hereditary cancer risk; and 4) increased knowledge of ovarian cancer and hereditary cancer risks. Further, we hypothesized that participants in the intervention group would report high acceptance of and satisfaction with the intervention.

2. Methods

The research was approved by both the University of Minnesota Institutional Review Board and the US Army Medical Research and Material Command Office of Research Protections, in accordance with the Department of Defense Ovarian Cancer Research Program funding (A-18144).

2.1. Intervention development

A series of focus groups among women diagnosed with ovarian cancer were conducted to inform the design and content of the mAGIC intervention. Details are provided in a previously published manuscript [20]. Briefly, the focus groups included both women with ovarian cancer who had and had not previously attended genetic counseling. Topics covered included their understanding of genetic counseling, perceived positives and negatives, preferences for receiving health information, and familiarity with mobile phone technology.

Following completion of the focus groups, an iterative process was used to create a mobile application with a seven-day program to persuade women to change their attitudes and behaviors about genetic counseling. We used continual input from the study team and a Community Advisory Board consisting of women with ovarian cancer, an oncology nurse, a gynecologic oncologist and breast oncologist. Core intervention components consisted of daily messaging and videos presenting varied content to engage participants, including information about genetic counseling and testing, personal health, cancer genetics, self-care, and ways to prepare for a genetic counseling appointment.

We adopted the Fogg Behavioral Model of Mobile Persuasion [21] as our main theoretical guide in designing the mAGIC intervention. Using Fogg's model, we promoted use of the app and uptake of genetic counseling by customizing motivational messages, providing positive feedback, incorporating video and graphics to enhance messaging, offering messages at opportune times designated by the user, building user self-confidence through positively encouraging their repetitive use of the app (daily for seven days), delivering quality information (e.g., current, relevant) and providing multiple triggers (e.g., prompts, cues).

We incorporated the Health Belief Model as an ancillary intervention theory to address the concept of self-efficacy [22]. Self-efficacy represents the *confidence* to undertake a behavior to achieve a desired outcome, and represents a central determinant of health behavior change models [22] and a critical concept in chronic disease management [23]. Written and video messages focused on increasing participants' self-efficacy by emphasizing their ability to change a situation, e.g., seek genetic counseling or talk with family, and effectively manage their emotional reactions. To encourage buy-in, messages were personalized using a participant's name and when possible, tailored to a specific participant's answers to questions embedded in each lesson. Research using printed materials and cell phone messaging provides evidence of the effectiveness of tailoring health behavior change messages and its crucial role in informing interventions [24,25].

We followed a four-step process to develop the educational materials associated with the intervention. First, we outlined the topics to be included on each of the seven days based on barriers identified from the focus group and identified appropriate placement of informative videos (Table 1). Next, we focused on message creation. Our goal was to create a user-friendly, tailored, positive, interactive educational experience requiring a moderate level of engagement. We structured each day in an analogous manner for consistency, aiming to improve ease of use and to engage the user. This included a daily welcome message, introduction to the topic of the day, 2–3 interactive and educational questions, 1–2 videos, and a summary with key messages. Lead study team members, in consultation with the Community Advisory Board, outlined and developed content for each day and presented it to the full study team. Subsequently, messages were refined and limited in length and frequency, with the goal of 10–15 short messages per day, requiring an estimated 10 min per day. Finally, eight 1–2 min videos were produced in which healthcare providers, patients, and family members of those affected by ovarian cancer discussed issues relevant to the topic of the day. The sum duration of the seven-day application/intervention was approximately 70–90 min.

The mAGIC intervention was created as an iOS (Apple) application only due to budget constraints. Focus groups and Community Advisory Board members stressed the importance of a clean, simple and easy-to-use app. Use of a large font size, a colorful interface and a positive overall tone were emphasized. Design elements and graphics were used to

Table 1
mAGIC intervention educational topics by day.

Day 1: genetic counseling	• Define genetic counseling for hereditary cancer • Recommendations for women with ovarian cancer
Day 2: genetic testing	• Define genetic counseling and describe genes linked to ovarian cancer • Benefits of meeting with a genetic counselor before genetic testing • Explanation of anti-discrimination laws and genetic testing
Day 3: cancer genetics and personal health	• Explain hereditary causes of cancer • Personal risk of another cancer depending on gene mutations • Treatment options to decrease likelihood of another cancer
Day 4: cancer genetics and my family	• Benefits of speaking with family about genetic counseling/testing and cancer screening • Usefulness of genetic counseling even if adopted or do not have medical history • Gene mutations in men and how they can be affected by cancer
Day 5: taking care of yourself	• Discussion of worry and other common concerns about genetic counseling and/or testing • Benefits of knowing results for self and extended family • Describe how self-care can improve health and provide options
Day 6: preparing for a genetic counseling appointment	• Practical tips and reminders before first appointment • Discussion of insurance and costs for genetic counseling and testing • Phone number for appointment
Day 7: summary	• Review of key points during the seven-day intervention • Summary quiz

highlight messaging, add interactivity, and improve user experience (see examples screenshot in Fig. 1).

Initial usability testing of the mAGIC intervention was performed using standard methodology prior to implementing the randomized trial [26]. Fifteen participants, including Community Advisory Board members, women with ovarian cancer and healthcare providers (including gynecologic oncology nurses, social worker, psychologist, and cancer genetic counselors) reviewed the content using a think-aloud protocol, in which reviewers voiced their intentions and thought processes during a 60–90 min individual meeting with a study investigator. This information was shared with the team for final intervention refinement.

2.2. Study population and recruitment strategy

Following development, we conducted a pilot randomized controlled trial (RCT) to test the effectiveness of the mAGIC intervention in improving uptake of genetic counseling services in women with ovarian cancer.

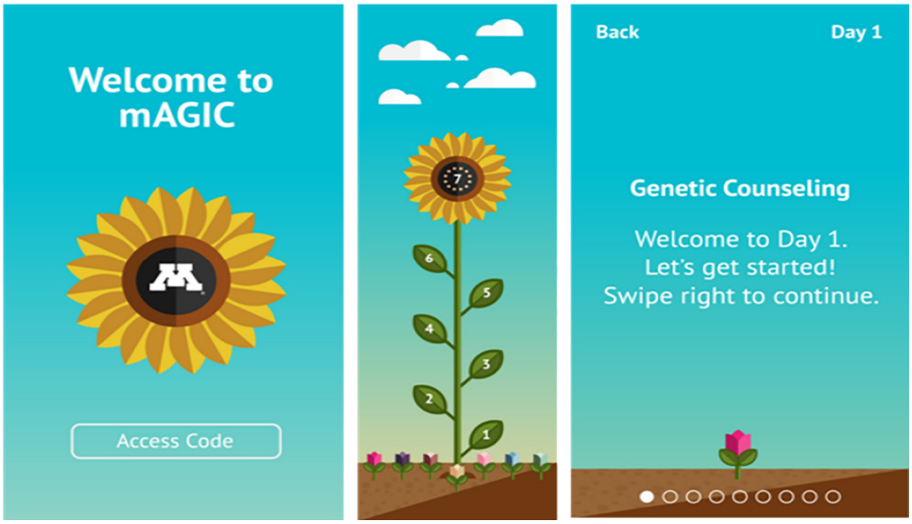
Women with a diagnosis of epithelial ovarian, primary peritoneal or fallopian tube cancer who had not previously received or scheduled genetic counseling or testing related to cancer were recruited from the Gynecologic Cancer Clinic at the University of Minnesota-Fairview Medical Center between February 2016 and October 2017. Survey and medical record data collection continued through January 2018. Eligible participants were 18 years old or older, able to read and write in English and had no known major psychiatric or neurological diagnosis. Participants without an appropriate mobile device were supplied with an iPad for the intervention period.

Eligible participants were approached by the study coordinator at the time of a regularly scheduled cancer care clinic visit, provided information about the study and invited to participate. Participants provided written informed consent to participate in the study and to allow for review of their electronic medical records. Participants received a small financial incentive ($20) at the start of the study and again after completing the three month follow-up survey.

2.3. Study design

Patients were randomized 1:1 to either the intervention or a usual care control group. Randomization was computer generated block randomization with variable block sizes. The randomization allocation was concealed in identical, opaque, sequentially-numbered, sealed envelopes that were opened at enrollment.

Following usual care, all participants received a pamphlet on hereditary cancer risk and genetic counseling at the time of study entry and were provided with information on both the genetic counseling services in the clinic along with other genetic counselors throughout the state for patients who preferred appointments near their home. Those randomized to the intervention group underwent a training session with the patient health navigator (study staff member) on mAGIC application use. During this training session, the application was downloaded and installed for them and they were shown how to open the application, view messages, reply to questions, and view videos using a training module in the application. The participants also were instructed to contact the patient health navigator with questions or trouble with usage of the application during the study.



Welcome to mAGIC

Genetic Counseling

Welcome to Day 1.
Let's get started!
Swipe right to continue.

Fig. 1. Example screenshots of the mAGIC intervention.

Regardless of randomization assignment, participants received a phone call from the patient health navigator one week following enrollment to complete a short phone survey. Three months following study entry, all participants were mailed a follow-up paper survey.

The planned enrollment was 104 participants, anticipating an 80% retention rate, which would yield a final sample size of 82 participants. A sample size of 82 (41 in each arm) would achieve 80% power to detect a difference between 15% of women in the control group attending genetic counseling during the 3-month study period compared to 45% of women in the intervention group attending genetic counseling as statistically significant with a significance level of 0.05, using a Fisher's Exact test.

2.4. Measures

Demographics, including age, race/ethnicity, education, income, marital status, and mobile phone experience were collected at baseline for all participants.

2.4.1. Primary outcome

The primary outcome measure was actual and planned utilization of genetic counseling services during the 3-month study period. Participants responded ‘yes’ or ‘no’ at the 3-month post intervention to a single survey question: Have you made an appointment for genetic counseling in the past three months? In a secondary analysis, these data were supplemented using the electronic medical record for all participants one-year post-randomization, including those who did not return the survey.

2.4.2. Secondary outcomes

Three secondary outcomes were evaluated, including: confidence (self-efficacy) in making an appointment for genetic counseling, discussion of genetic counseling with family, and knowledge about hereditary cancer. Confidence in making an appointment for genetic counseling was measured on a Likert-type scale from 0 to 100, with participants reporting a number along the scale, with descriptive anchors at 0, 50 and 100 of ‘not-at-all confident’, ‘moderately confident’, and ‘totally confident’, respectively. Discussion with family (communication) was assessed using a single self-report item: “I have talked with my family about genetic counseling” (yes/no).

Knowledge was measured using a 10-item quiz based on a previously developed measure focusing on hereditary breast cancer [27] (see Supplemental Table 1). The original knowledge questions were modified to include ovarian cancer for the purposes of this study. These knowledge question items were chosen so that the results of this study can be compared to the previous literature measuring hereditary cancer knowledge. A total knowledge score was created by summing the number of correct answers on two multiple choice and eight true/false questions resulting scores from 0 to 10. These measures were collected at baseline and during both the 1-week phone and 3-month paper surveys.

2.4.3. Usability and acceptability

Thirteen items were developed for the study to identify satisfaction with attributes of the intervention. This measure was completed only at the time of the post-intervention 3-month survey among those randomized to the mAGIC intervention. Items included delivery method (mobile phone), graphics, videos, ease of use, quality of content, amount of information presented, knowledge about genetic counseling, tone of messages, interactivity, relevancy of information, length of daily messaging and overall satisfaction. All items were answered using a 4-point Likert scale (very satisfied, somewhat satisfied, somewhat dissatisfied, very dissatisfied) and summarized separately. In addition, two questions asked whether participants would recommend the mAGIC intervention to other women with ovarian cancer and whether they would share it with family or friends (yes/no). Finally, one open-ended question was included asking participants if they had any recommendations for changes to the intervention.

2.5. Statistical methods

Patient demographics and clinical information were descriptively summarized and compared by randomization group using Chi-squared tests and Fisher's Exact tests as appropriate for categorical data, and two-sample two-sided *t*-tests for continuous data. To address the primary outcome, the proportion of participants randomized to each group (intervention vs. control) who self-reported a scheduled appointment with genetic counseling at the time of the 3-month survey were compared following an intention-to-treat analysis using a Chi-squared test. Comparisons of reported discussions with family members were conducted using a Chi-squared test. The total knowledge scores and confidence in making a genetic counseling appointment (self-efficacy) were compared between randomization groups using two-sided two-sample *t*-tests assuming unequal variance. Satisfaction with the intervention was summarized using descriptive statistics. Missing data were minimal; if an item was missing for an individual, that individual was excluded for that item only. Data were analyzed using SAS 9.4 (Cary, NC) and p-values < 0.05 were considered statistically significant.

3. Results

3.1. Study participants

A total of 127 women with no genetic counseling appointment noted in the electronic medical record were approached to participate in the study. Of them, 104 (81.9%) consented to participate and completed the baseline survey, 94 (90.4%) completed the 1-week telephone survey, and 91 (87.5%) completed the 3-month survey (Fig. 2).

Demographic and clinical data for participants are detailed in Table 2. Participants were primarily white, non-Hispanic, older, and had at least some college education. Most were newly diagnosed with advanced stage ovarian cancer. There were no statistically significant differences in demographic or clinical characteristics between randomization groups.

The majority of participants owned a mobile phone (97.1%) and over three-quarters reported using it several times per day. More than 80% reported using their phone for calls and texting and approximately half reported using mobile applications and games.

3.2. Primary outcome: genetic counseling appointment

The primary endpoint for this trial was self-report of a genetic counseling appointment within 3 months of study entry. Per study eligibility, all participants had not previously attended a genetic counseling appointment at baseline. While genetic counseling utilization reported at 3 months was higher among those randomized to the intervention compared to the control group (54.5% vs. 38.6%), this difference was not statistically significant ($p = 0.14$). When we expanded our review beyond the 3-month study period, the majority of participants in both groups had documented genetic counseling appointments; 75.5% in the intervention group and 68.6% in the control group had documented or self-reported genetic counseling visits within 1-year of study entry ($p = 0.44$).

3.3. Confidence and communication with family members

Participants randomized to the intervention group reported statistically significantly greater confidence in making an appointment for genetic counseling at the 3-month survey ($N = 44$, 87 ± 27 vs. $N = 37$, 71 ± 38; $p = 0.04$). Participants in the intervention group were also statistically significantly more likely to self-report talking with their family about genetic counseling (96% vs. 77%, $p = 0.01$). The majority of

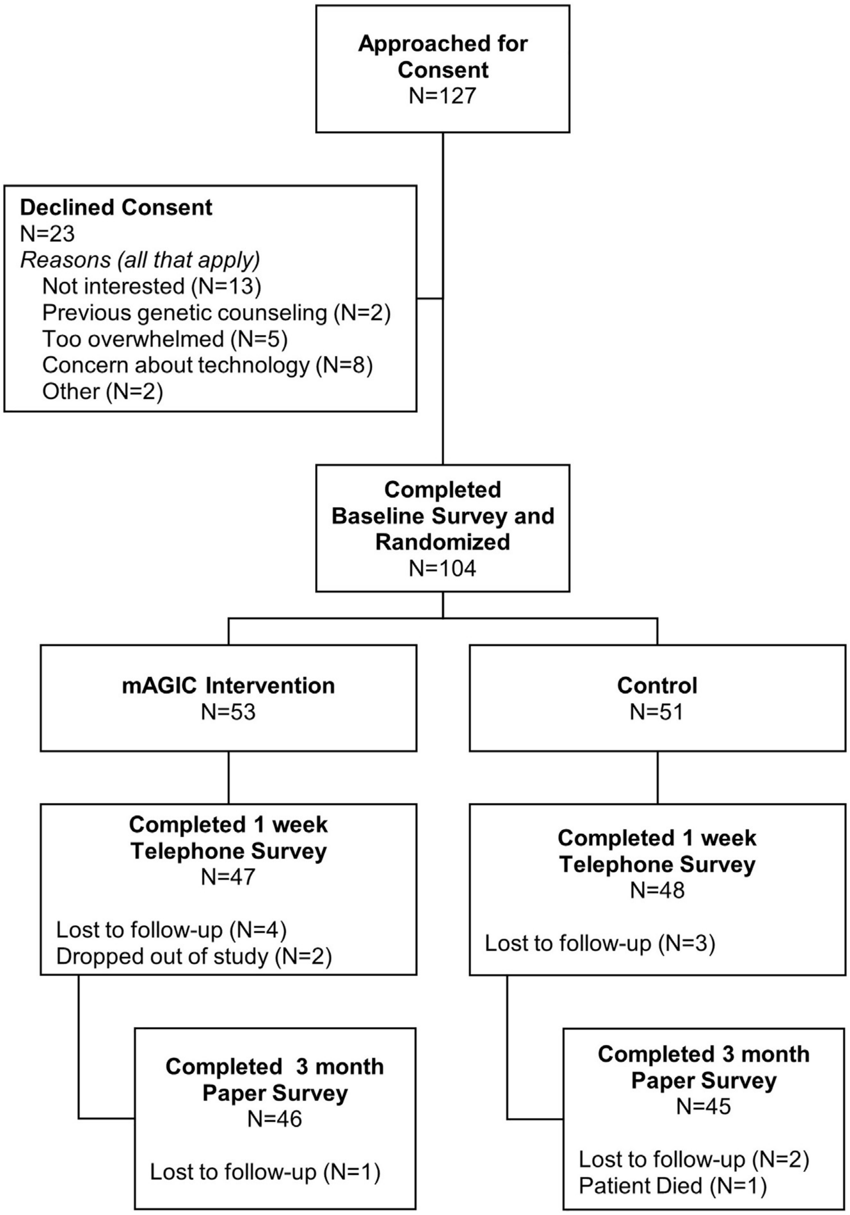


Fig. 2. CONSORT diagram. Enrollment and randomization of study participants.

patients in both intervention and control groups who reported discussing genetic counseling with their families reported that either their family encouraged genetic counseling (38.1% and 29.4%, respectively) or supported whatever decision the patient thought best (54.8% and 58.8%, respectively).

3.4. Knowledge

Participants randomized to the intervention group scored significantly higher on the knowledge quiz than those randomized to the control group following the 1-week intervention period ($N = 47$, 9.4 ± 1.0 vs. $N = 48$, 7.1 ± 1.5; $p < 0.0001$, Fig. 3), and this persisted at the 3-month survey ($N = 45$, 9.0 ± 1.3 vs. $N = 45$, 7.7 ± 1.7; $p < 0.0001$). The majority of participants had genetic counseling appointments scheduled at a time beyond completion of their 3 month survey; only 23.9% of intervention participants and 17.8% of control participants had completed their genetic counseling appointment prior to the 3 month survey ($p = 0.47$). This likely would have increased the knowledge scores at 3 months but was not differential between the randomization groups.

3.5. Usability and acceptability

More than 80% of participants were 'very satisfied' with each of the following items: mobile phone delivery method, graphics, videos, ease of use, content quality, amount of information presented, interactivity, tone and length of messages. All but one (98%) would recommend the intervention to others with ovarian cancer and most (89%) would share the application with family or friends. Recommendations for changes included using more inclusive/gender-neutral language, providing more information about basic biology and genes, and adding a video of a younger patient with ovarian cancer.

4. Discussion

We found that women randomized to the mAGIC intervention increased their hereditary cancer and genetic counseling knowledge, more often communicated information about genetic risk with family and were more confident about making an appointment. The mAGIC intervention did not significantly improve uptake of genetic counseling; both groups had relatively high uptake rates after participating in the study.

Genetic counseling uptake rates in our overall clinic population were accelerating at the onset of this study. It is likely the increase in uptake from our pre-intervention baseline blunted the effect of our intervention. Over the approximately 5-year time period between our two studies, multiple pertinent, well documented health-related social developments and medical initiatives occurred undoubtedly promoting an acceleration of referrals before and during our intervention. In 2013, Angelina Jolie revealed she was a carrier of the *BRCA1* gene, proceeded to undergo a prophylactic mastectomy, and two years later, announced that she had a prophylactic oophorectomy. In ensuing years, the “Angelina Jolie Effect” was described, with studies reporting Jolie's announcement generated a surge in genetic counseling referrals for breast/ovarian cancer with peak increases of up to 285% [28]. In 2017, immediately before the initiation of this study, the SGO released the Clinical Practice Statement encouraging the medical community to offer genetic counseling and testing to all women with ovarian, fallopian tube and peritoneal carcinoma [6]. Therefore, at the time of our intervention, clinical providers recently had been educated and encouraged to refer all eligible gynecologic oncology patients for genetic counseling. Additional developments impacting genetic counseling uptake at the time of but independent from this study was the FDA approval of poly adenosine diphosphate-ribose polymerase (PARP) inhibitors for treatment of ovarian cancer patients with germline *BRCA* mutations. Finally, the type of patients who agree to participate in a genetic counseling intervention study may be more likely than the general patient population to attend a genetic counseling appointment and it is possible the usual care information pamphlet received in a study context was sufficient to promote genetic counseling.

Self-reported intra-familial communication was significantly higher among participants assigned to the mAGIC intervention, suggesting the intervention changed communication of health-related information. While secondary uptake was not measured in this study, it is crucial to the success of genetics-based intervention/prevention strategies.

We were encouraged by observed improvements in patient confidence in making a genetic counseling appointment, i.e. self-efficacy. We promoted self-efficacy for making a genetic counseling appointment by educating, encouraging, and/or facilitating success in making an appointment. Rising cancer survival rates and health policy initiatives promoting the delivery of patient-centered care suggest self-

Table 2
Participant demographic and clinical characteristics.

Variable	mAGIC intervention N = 53		Control N = 51		
	N	Mean (SD)	N	Mean (SD)	p-Value
Age, years	53	60.9 (10.7)	51	62.0 (12.0)	0.63
	N	%	N	%	p-Value
Race					0.70
White, Non-Hispanic	48	90.6	45	88.2	
Other	5	9.4	6	11.8	
Highest education					0.84
Did not graduate high school	1	1.9	0	0.0	
High school graduate	10	18.9	9	18.0	
Some college/technical school	15	28.3	16	32.0	
College graduate	21	39.6	21	42.0	
Professional school	6	11.3	4	8.0	
Current employment					0.20
Yes – full time	24	45.3	14	27.5	
Yes – part time	4	7.6	8	15.7	
No	8	15.1	7	13.7	
Retired	17	32.1	22	43.1	
Marital status					0.11
Single	7	13.2	7	13.7	
Married/partnered	38	71.7	30	58.8	
Divorced	3	5.7	11	21.6	
Widowed	5	9.4	3	5.9	
Biological children					0.99
No	16	30.8	15	30.6	
Yes	36	69.2	34	69.4	
Missing	*1*		*2*		
Cancer diagnosis					0.94
Fallopian tube	4	7.6	3	5.9	
Ovarian	44	83.0	43	84.3	
Primary peritoneal	5	9.4	5	9.8	
Disease stage					0.38
Stage I	12	22.6	7	13.7	
Stage II	2	3.8	6	11.8	
Stage III	26	49.1	29	56.9	
Stage IV	11	20.8	8	15.7	
Recurrent	2	3.8	1	2.0	
Current disease status					0.97
Newly diagnosed	41	77.4	38	74.5	
Remission	8	15.1	8	15.7	
First recurrence	2	3.8	3	5.9	
Multiply recurrent	2	3.8	2	3.9	
History of other cancer					0.09
No	48	92.3	40	80.0	
Yes	4	7.7	10	20.0	
Missing	*1*		*1*		

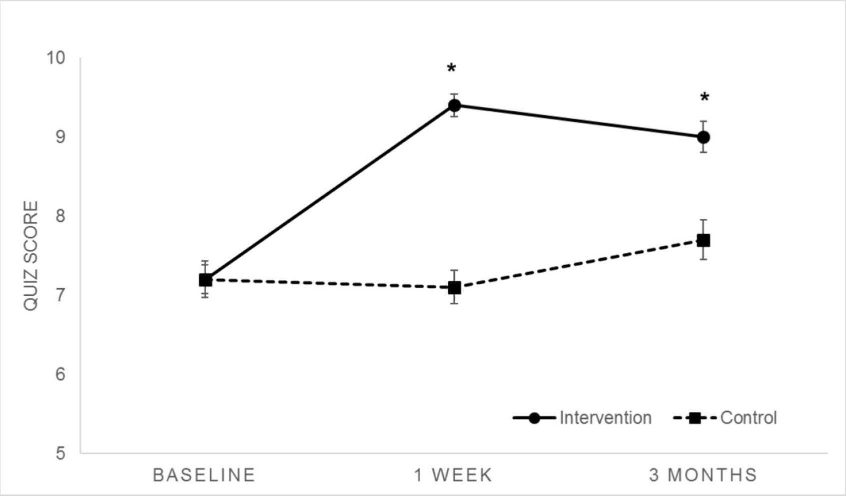


Fig. 3. Knowledge of genetic counseling and testing for hereditary ovarian cancer over the intervention period by randomization group. Means ± standard errors are presented. Total quiz score, sum of correct responses to 10 items (0−10). Asterisk indicates p-value < 0.0001 for comparison between intervention and control groups.

efficacy will have an ongoing and important role in managing the myriad of tasks associated with promoting cancer survival. Our results indicate mobile applications represent a useful and efficient tool to increase survivors' confidence to manage these tasks.

Lastly, using the intervention increased knowledge about hereditary cancer and cancer genetic counseling. Cancer knowledge has been linked to patients' increased ability to understand and talk about cancer-related topics, their likelihood to contribute to decision-making and their ability to more capably provide informed consent [29]. Increasing the accessibility of health information is one of the key intervention strategies used by phone-based interventions [25].

Education of cancer patients via mobile applications to improve health behaviors [30–32] has been developing rapidly. With the recent publication of SOLO 1 [33] the landscape of when women should be tested for BRCA1/2 has changed dramatically. Future mHealth applications will need to respond to new developments regarding how to test for hereditary cancers and how to best treat ovarian cancer. As data evolve regarding testing for somatic versus germline mutations in determining who might best be served by PARP inhibitors, timely education of patients is critical. Educating women and their families as to the differences in germline and somatic testing and what the results mean to them and their treatment and prevention options is paramount for informed decision making. As recommendations are changing so quickly, software developers will need to be able to meet the demands of rapidly changing guidelines in future mobile applications.

To date, breast cancer patients have been most often targeted. In our study, nearly all participants had mobile phones and many had previously used applications. Therefore, access and experience were not limitations. The experience with this study suggests mHealth technology emphasizing behavior change(s) is feasible and acceptable to older women with an aggressive chronic disease.

This study has a number of notable limitations. It was conducted at a single academic gynecologic cancer clinic in the Midwest which treats predominately women who are white, educated, and insured. While women with ovarian cancer were included as stakeholders in the application design and usability testing, whether the intervention would be as effective in other populations in unknown. Further, family communication about inherited risk is complex, with both emotional and informational components [34]. We used a self-report measure of discussions with family members which does not adequately address this complexity. Understanding patients' feelings about informing relatives about genetic counseling, their anticipated reactions, family rules and patterns, and finding the right time and level of disclosure, are some of the many themes that were beyond the scope of this intervention [35] but may have impeded making a genetic counseling appointment and/or cascade testing.

The next step in this line of research will be to modify the intervention to improve uptake of genetic counseling services among women with ovarian cancer and their family members when appropriate. Given the explosion of data on use of both germline and somatic testing to identify those at highest risk for a hereditary cancer and those who may benefit most from a PARP inhibitor, mHealth products must have the ability to be easily tailored to specific populations and be able to be updated with the latest content by reliable sources. This functionality is mandatory for our revised app which will be tested in a larger clinical trial and will be necessary to expand this intervention to additional cancer populations, such as breast and colon, and to men.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ygyno.2019.01.019.

Conflict of interest statement

The authors have no conflicts of interest to report.

Author contributions

RI Vogel: Study design, intervention development, statistical analysis, data interpretation, manuscript writing and revision.

K Niendorf: Study concept, study design, intervention development, data interpretation, manuscript writing and revision.

S Petzel: Study design, intervention development, data interpretation, manuscript writing and revision.

H Lee: Intervention development, recruitment, data collection, manuscript revision.

D Teoh: Intervention development, data interpretation, manuscript revision.

A Blaes: Intervention development, data interpretation, manuscript revision.

P Argenta: Recruitment, manuscript revision.

C Rivard: Recruitment, manuscript revision.

B Winterhoff: Recruitment, manuscript revision.

HY Lee: Study concept, study design, intervention development, data interpretation, manuscript revision.

Geller MA: Study concept, study design, intervention development, study supervision, recruitment, data interpretation, manuscript revision.

Acknowledgments

This work was funded by the Department of Defense Ovarian Cancer Research Program [A-18144].

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