Automatic Genetic Risk Assessment Calculation Using Breast Cancer Family History Data from the EHR compared to Self-Report

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Abstract

Genetic testing is a method to assess hereditary cancer risk. However, it is under-utilized and various methods of family history intake have been evaluated in previous studies. The six-point-scale (SPS) is a validated family history screener that is used to determine eligibility for BRCA genetic counseling. We automated the calculation of the SPS score using structured family history data along with free text from the electronic health record (EHR) to detect detailed family history information of breast cancer. We extracted data for all women aged 35 to 74 who had screening mammography at Columbia University Medical Center (CUMC) from January 2015 to May 2017 (N=37,596). After we calculated SPS scores using structured and free-text EHR data, we compared the results with SPS score calculated from a baseline survey conducted for a prospective study called Know Your Risks: Assessment at Screening (KYRAS). Among 1,202 patients with EHR structured family history data, we found 1.43% had an SPS score of 6 higher which meets criteria for genetic counseling referral, while 12.05% of the survey respondents had SPS score of 6 or higher. Results show there is a need for more efficient methods to identify patients eligible for genetic counseling through EHR analysis.

Introduction

Breast cancer is the most frequently diagnosed cancer among women in U.S. with 252,710 women diagnosed in 2017.[1] Approximately 5-10% of the breast cancers are hereditary.[2] Hereditary breast and ovarian cancers (HBOC) are characterized by an increased risk for male and female breast cancers through pathogenic *BRCA* mutations.[3,4] The U.S. Preventive Services Task Force (USPSTF) recommends that women with a family history associated with an increased risk of *BRCA1* or *BRCA2* mutations undergo genetic counseling and/or testing.[5]

There are possible preventive options for high-risk patients such as mastectomy or chemoprevention.[6–8] Tamoxifen is an FDA-approved chemoprevention drug which has been shown to reduce the relative risk of invasive breast cancer by about 50% compared with placebo.[9] Other options of chemoprevention drugs, such as raloxifene and aromatase inhibitors (AIs), are available for high-risk postmenopausal women.[6,8,10] Bilateral mastectomy is another preventive strategy that reduces breast cancer risk by approximately 85-90% in female *BRCA1/2* mutation carriers.[3,8,11]

Genetic counseling[12–14] and preventive strategies[6,15,16] remain underutilized despite the known advantages. Barriers to genetic testing and counseling include lack of awareness, lack of knowledge about personal cancer risk[17], inaccuracies and inconsistencies in documentation of family history of cancer[17–20], and failure of providers and cancer specialists to obtain adequate family cancer histories in order to refer patients at risk for hereditary cancer(s) to genetic counselors.[21–23] A first step in increasing utilization of these services is to identify high-risk patients and to facilitate effective communication and discussions about the cancer risk and preventive plans between these patients and their providers.[15,24]

In order to improve provider-patient communication and the uptake of HBOC genetic counseling and testing, we developed the RealRisks online decision aid tool[25] and conducted a prospective study entitled Know Your Risks: Assessment at Screening (KYRAS)[26]. The KYRAS study recruited 3,079 women that underwent screening mammography at the Columbia University Medical Center (CUMC).

The KYRAS baseline survey evaluated genetic counseling eligibility using the six-point-scale (SPS), a validated family history screener to determine *BRCA* genetic testing eligibility based on U.S. Preventive Services Task Force guidelines (Figure 1).[27,28] When compared to other screening tools, SPS scoring had highest specificity (0.97, 95% CI 0.95-0.99) and AUROC (0.85, 95% CI 0.81-0.90) when validated at San Francisco General Hospital.[28] All evaluation measures including sensitivity were measured using another validated screening tool, Referral Screening Tool (RST)[29] as a gold standard.[28] SPS was a useful and simple tool for our recruiters to reach out to patients and administer over the phone and in person.[28] We also examined the electronic health record (EHR) structured family history of breast

cancer data along with free text notes to identify patients eligible for genetic counseling for breast cancer. Several studies have analyzed EHR data, both structured and unstructured to determine family history of diseases[30–32] and there have been previous efforts to detect patients eligible for genetic counseling[33], or to determine family history of diseases[30,31,34,35]. To our knowledge, this is the first study to detect detailed family history of breast cancer that combines the age and family member details, and to automate the calculation of a validated family history screener to determine the eligibility for genetic counseling.

Methods

The data sets we used to calculate and compare the SPS scores come from two different sources:

1) EHR family history record of breast cancer, which included structured family history data and free text notes.
2) Baseline questionnaire of the KYRAS prospective study where patients provided detailed family history for SPS score calculation.

EHR Family History Detection and SPS Calculation

The EHR data set included all women (aged 35-74) who had screening mammography at CUMC from January 2015 to May 25, 2017. From these patient records (n=37,596), we extracted patients with a breast cancer family history (n=1,398). This included both positive and negative record of breast cancer family history among patients, meaning that "yes" or "no" was documented for family history of breast cancer. Each record of positive breast cancer family history included a free-text field where providers logged further details such as family member(s) who were diagnosed, age and/or year of diagnosis, and sometimes other cancers. Using the free-text field, we calculated the SPS score to follow the logic in Table 1.

There were a few assumptions made when developing the algorithm to calculate SPS score using the EHR dataset. First, we assumed that there was no negation in the free text except for the mention of surviving family members after the diagnosis (e.g., not dead for living family member after diagnosis). Since we only looked at the free text notes for positive mentions of breast cancer family history, there was no negated mention of family history of breast cancer, in other words, if the family member was not diagnosed, they were not mentioned in the notes.

Table 1. SPS Score Point Distribution[27]

Mother with breast cancer		**Sister with breast cancer**					**Daughter with breast cancer**		**Grandmother with breast cancer**		**Aunt with breast cancer**	
Before age 50	**After age 50**	**3 or more sisters**	**2 sisters**		**1 sister**		**Before age 50**	**After age 50**	**Before age 50**	**After age 50**	**Before age 50**	**After age 50**
			Either before age 50	**Both after age 50**	**Before age 50**	**After age 50**						
4	2	6	6	4	4	2	4	2	4	2	4	2

Male family member with breast cancer	**Blood relative with ovarian cancer**	**Jewish ancestors**
6	4	4

With these assumptions, we calculated the SPS score (Table 1):

1) First, we detected family members mentioned and added 2 points per mentioned member: "grandmother", "mother", "sister", "daughter(s)", "aunt(s)". Cousins are excluded from SPS score calculation.
2) We detected mention of multiple sisters: Sisters (+2), three sisters (+4), 3 sisters (+4), multiple sisters (+2).
3) When we detected mention of "ovarian" cancer, we added 4 points.
4) We detected numbers between 15 and 50, inclusive, for age, because additional 2 additional points were assigned per family member diagnosed at or before age 50. Most of the members mentioned in this note

were year (four digit numbers such as 1990, 2000), and numbers less than 15 usually indicated the number of family members diagnosed (e.g., three sisters), or number of years un-related to the actual age of diagnosis (e.g., diagnosed 10 years ago, died 10 years ago)

5) "Jew" was detected to signal for Jewish ancestry, which added an additional 4 points. We eventually excluded because no race/ethnicity were recorded in the family history note.

6) "Brother", "uncle", "father" were detected to add 4 points, but eventually excluded because mentions of these members recorded in this field were misleading and were recorded to mention other cancers.

Following this algorithm, for a free-text note of "Mother and two sisters" had SPS score of 6 by adding 4 points for two sisters and 2 points for mother. More point distribution examples are included in Table 2. All data manipulation and analysis was performed using the computing environment R (Version 3.4.3).

Table 2. EHR SPS Score Point Distribution Examples

Points	Free Text	Member (s)/Age	Points
2	"maternal grandmother"	Grandmother/NA	+2
2	"mother"	Mother/NA	+2
4	"maternal aunt / sister died breast cancer age 80s"	Aunt/80	+2
		Sister/80	+2
6	"Mother and two sisters"	Mother/NA	+2
		2 Sisters/NA	+4

KYRAS Survey SPS Score Calculation

The KYRAS data set consisted of surveys completed by women who underwent screening mammography at the Avon Breast Imaging Center at Columbia University Medical Center (Figure 2). Inclusion criteria included women of age 18 years old or older, English or Spanish-speaking, and with no previous diagnosis of breast cancer. Those who consented and completed a baseline survey reported their family history, which was used to calculate SPS score (Figure 3). We obtained informed consent in English or Spanish, and the study was approved by Institutional Review Board at CUMC.

Results

EHR Family History Detection and SPS Calculation

Our dataset had records of 1,398 unique patients, and some patients were recorded at multiple time points and had multiple records or changes recorded from having a negative family history to a positive family history (n=24). We detected 319 out of 1,398 patients who had a positive family history of breast cancer (Table 3). Using the EHR family history data, we found 20 patients (1.43%) to be eligible for genetic counseling with an SPS score of 6 and above, 57 patients (4.08%) with score of 4, 183 patients (13.09%) with score of 2, and 0 for the rest.

Table 3. Family History of Breast Cancer Response in EHR (CDW & iNYP)

Response = Yes	Response = No	Total Unique MRN	Updated Response
319/1398	1103	1398	24

KYRAS Survey SPS Score Calculation Compared with EHR data

For the KYRAS data set (N=3,055) 368 patients (12.05%) were found to be eligible for genetic counseling with SPS score of 6 or more (Table 5). We compared this with the EHR calculated SPS score, and found 240 matching MRNs between EHR family history data and the KYRAS survey data and compared the scores. Of 52 matching MRNs with positive family history of breast cancer, 17 from the survey and 2 from the EHR scored 6 or higher and were eligible for genetic counseling. Interestingly, only one patient had an agreement in eligibility. Eleven of the matching patients

scored higher in the EHR SPS score calculation. One of these patients scored higher in EHR due to miscalculation because they logged family history of non-breast cancer and we were not able to eliminate this log to not include in the score calculation.

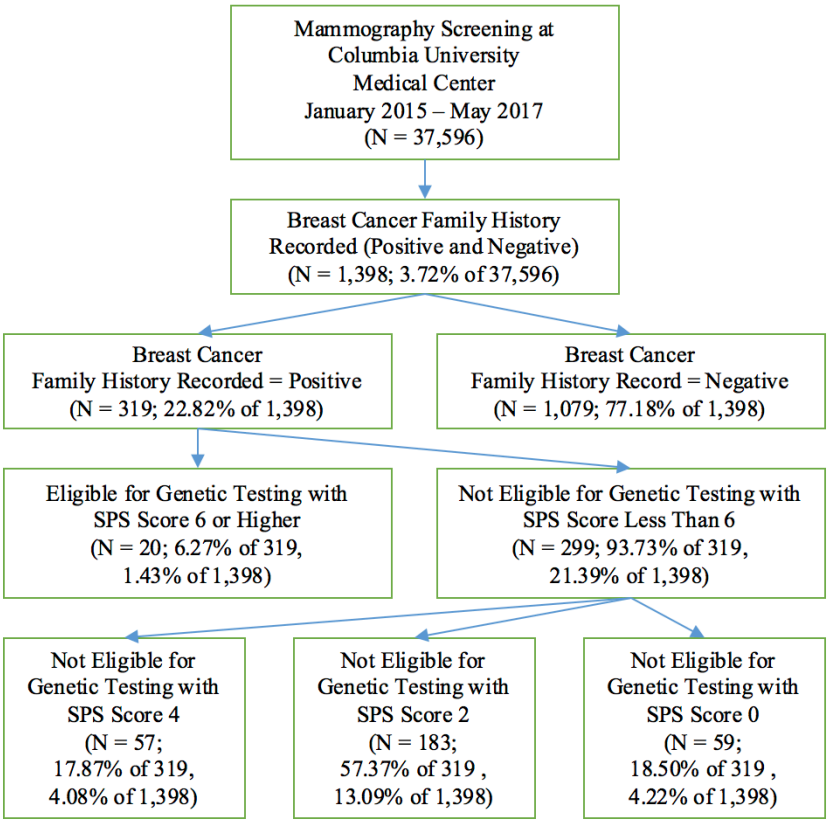

Figure 1. Flow diagram for the population who went through mammography screening and SPS score distribution for genetic counseling eligibility calculated from EHR data

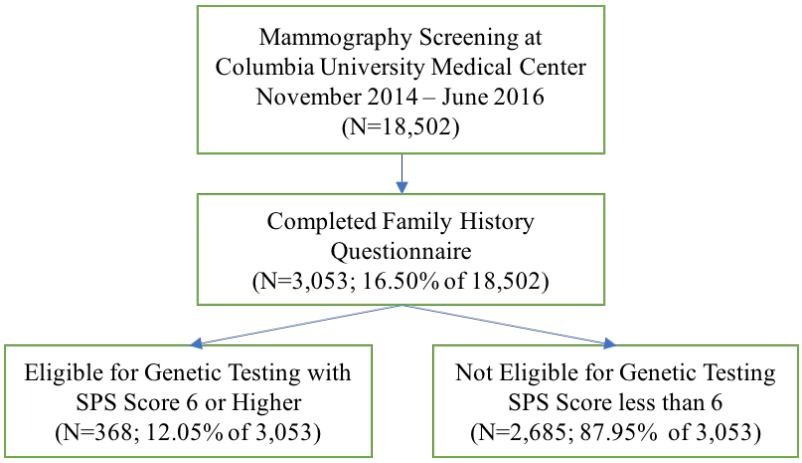

Figure 2. Flow diagram for the population approached at screening mammography for participation and completion of KYRAS survey, with responses to SPS Score Genetic Testing Eligibility (Figure 3).

1. Have you ever been told by a doctor that you have breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 1 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, were you diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
b. If yes, did you ever have cancer in both breasts? ☐ Yes ☐ No ☐ Unknown

2. Have you ever been told by a doctor that you have ovarian cancer? ☐ Yes ☐ No ☐ Unknown
Question 2 in Six-Point Scale: Yes = 6 points; No = 0 points; Unknown = 0 points

3. Do you have any Jewish blood relatives? ☐ Yes ☐ No ☐ Unknown
Question 3 in Six-Point Scale: Yes = 4 points; No = 0 points; Unknown = 0 points

4. Have any men in your family had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 4 in Six-Point Scale: Yes = 6 points; No = 0 points; Unknown = 0 points

5. Have any of your blood relatives had ovarian cancer? ☐ Yes ☐ No ☐ Unknown
Question 5 in Six-Point Scale: Yes = 4 points; No = 0 points; Unknown = 4 points

6. Has your mother had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 6 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, was she diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
Question 6 in Six-Point Scale: Yes = 4 points; No = 2 points; Unknown = 2 points

7. Do you have any sisters who have had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 7 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, how many sisters were diagnosed with breast cancer? ☐ 1 ☐ 2 ☐ 3 or more
Question 7 in Six-Point Scale: 1 = 2 points; 2 = 4 points; 3 or more = 6 points

b. If yes, was any sister diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
Question in Six-Point Scale: Yes = 4 points; No = 4 points; Unknown = 2 points

c. If yes, did any sister ever have cancer in both breasts? ☐ Yes ☐ No ☐ Unknown
If Yes, then flag

8. Do you have any daughters who have had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 8 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, how many daughters were diagnosed with breast cancer? ☐ 1 ☐ 2 ☐ 3 or more
Question 8 in Six-Point Scale: 1 = 2 points; 2 = 4 points; 3 or more = 6 points
If yes, was she diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
Question 8 in Six-Point Scale: Yes = 4 points; No = 2 points; Unknown = 2 points

b. If yes, did she ever have cancer in both breasts? ☐ Yes ☐ No ☐ Unknown
If Yes, then flag

9. Have either of your grandmothers had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 9 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, was she diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
Question 9 in Six-Point Scale: Yes = 4 points; No = 2 points; Unknown = 2 points

10. Have any of your aunts had breast cancer? ☐ Yes ☐ No ☐ Unknown
Question 10 in Six-Point Scale: No = 0 points; Unknown = 0 points

a. If yes, was she diagnosed before the age of 50? ☐ Yes ☐ No ☐ Unknown
Question 10 in Six-Point Scale: Yes = 4 points; No = 2 points; Unknown = 2 points

Six-Point Scale:
Total points = XX (If >/= 6, then eligible for referral to genetic counseling)

Figure 3. KYRAS Survey – SPS questions[27]

Table 4. SPS Score from EHR (CDW & iNYP)

Point	Number	Ratio (count/total)	Percentage among total (count/total)	Percentage Among History = Yes (count/319)
6+	20	20/1398	1.43%	6.27%
4	57	57/1398	4.08%	17.87%
2	183	183/1398	13.09%	57.37%
0	59 (family history = Yes)	59/1398	4.22%	18.50%
0	1079 (family history = No)	1079/1398	77.18%	N/A
0	1138 (family history = Yes or No)	1138/1398	81.40%	N/A

Table 5. SPS Score Distribution from KYRAS Survey

SPS Score	Number	%
0	2066	67.67%
2	304	9.96%
4	315	10.32%
6+	368	12.05%
Total Record	3053	100%

Discussion

A previous study conducted by our research team found that structured EHR family history data lacked details to calculate the SPS score.[36] In this study, we added free-text family history data to detect family members, ages of diagnosis, and family history of ovarian cancer to calculate the SPS score and eligibility for genetic counseling. While we were able to calculate the scores using some details provided through free-text, we were only able to detect 1.43% of all patients with family history record—including negative family history of breast cancer—to be eligible for genetic counseling.

Overall, while we found 1.43% patients from the EHR data set to be eligible for genetic counseling, 12.05% patients from survey were found eligible. Patients scored much lower in the EHR SPS calculation, with only one patient who was found eligible for genetic counseling both in the survey and in EHR. Among patients who scored 6 or higher from survey, four patients scored 4 in EHR (4/17; 23.53%), ten scored 2 (10/17; 58.82%), and two scored 0 (2/17; 11.76%) due to missing age information and details, or did not mention the details at the screening visit.

Family history of breast cancer is largely under-reported or reported with missing details, so it was difficult to accurately determine the eligibility for genetic screening. We found a large proportion of patients with scores of 2 and 4. By comparing the EHR scores with the survey data, we found that a large proportion of patients who scored 4, 2, or even 0 with positive breast cancer history may be eligible for genetic counseling.

Disagreement in SPS scores was mostly due to missing age of diagnosis and fewer details recorded in the EHR. For the KRYAS data set, recruiters were trained to capture all criteria needed for the SPS score calculation, while providers may have limited time and be less concerned about collecting family history information for breast cancer in an unaffected population.

There are also limitations to the survey data given that it is collected at one point in time, and not as up to date as EHR records. Methodologic or systemic collection and identification of family history recorded in the EHR would provide more up-to-date information, because the EHR maintains multiple data points for patients collected at multiple visits. Identifying family history through the SPS scoring algorithm may be improved if the structured data included age at diagnosis.[31]

For SPS score calculation using the EHR, we assumed that all family history of breast cancer was accurately logged and only recorded positive family history of breast cancer. However, we found that a few providers also documented family histories of other cancers such as colon cancer, or ovarian cancer in the free-text section of breast cancer family history. One limitation of this study is that we are missing structured data of family history of ovarian cancer for SPS calculation. However, the inaccuracy of family history documentation with mentions of ovarian cancer was helpful in SPS calculation, because family history of ovarian cancer also counts towards SPS calculation. Most other mentions of non-breast cancers in this field were noted to document that additional cancers among family members were diagnosed, for example: "Mother w/ Breast CA. Sister with h/o Colon Ca, now with Breast CA". In this case, colon cancer was mentioned because sister who has a breast cancer has a history of colon cancer as well.

Study by Polubriaginof et al. reports that, when they analyzed both structured and free-text family history data in EHR, its completeness did not meet the standards endorsed by U.S. Agency for Healthcare Research and Quality.[31] Barriers to family history data collection include clinicians' lack of time to collect the family history information[37,38], underestimation of the value of family history data[31], lack of standardized strategy for family history collection[31,39,40], and more.

For future studies, we can further expand the family history detection to look at the clinical notes to obtain details of family history breast cancer such as age of diagnosis of family members, ethnicity, and ovarian cancer history to calculate the SPS score or to develop other methods to determine detailed family history of breast cancer and other cancers. We may be able to incorporate demographic data for ethnicity or race with larger sets of breast cancer family history data. Our dataset was not large enough to detect Jewish ethnicity in the demographic data of patients with family history recorded. For alternative method to detect Jewish ethnicity, we may be able use religious information to infer that Jewish religion is linked to its ethnicity.

Conclusion

Our study identified that not only is family history of breast cancer under-recorded, but also the structure of the family history record lacks the details necessary to automatically identify the eligible patients for genetic counseling or testing. While genetic counseling eligibility for breast cancer is highly dependent on the family member's age of diagnosis of breast cancer, current EHR and clinical models lack the standardized structure to record the details systematically.[31,41] Using only structured data, it was impossible to calculate SPS score[36], but the free-text field added much more family history details such as the actual family members who were diagnosed, their age of diagnosis, their survival, and more. The survey data resulted in a higher detection of eligible patients, yet this method is expensive, time consuming, and is only usable for the research purposes since it is not maintained clinically within the EHR to be sharable inter-institutionally. There is a need to develop more efficient methods for identifying patients who are eligible for genetic counseling using EHR analysis. Moreover, develop a better structure for EHR documentation that can maximize the utilization of data from the EHR for preventive care and public health.

References

1. American Cancer Society. Cancer Facts and Figures 2017. Genes Dev. 2017;21(20):2525–38.
2. Apostolou P, Fostira F. Hereditary breast cancer: the era of new susceptibility genes. Biomed Res Int [Internet]. 2013;2013:747318. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23586058%5Cnhttp://www.ncbi.nlm.nih.gov/pmc/articles/PMC3618918/pdf/BMRI2013-747318.pdf
3. Nelson HD, Fu R, Goddard K, Mitchell JP, Okinaka-Hu L, Pappas M, et al. Risk Assessment, Genetic Counseling, and Genetic Testing for BRCA-Related Cancer: Systematic Review to Update the U.S. Preventive Services Task Force Recommendation. Risk Assessment, Genet Couns Genet Test BRCA-Related Cancer Syst Rev to Updat US Prev Serv Task Force Recomm [Internet]. 2013;(101):366. Available from: http://annals.org/article.aspx?articleid=1791501%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/24432435
4. Mavaddat N, Peock S, Frost D, Ellis S, Platte R, Fineberg E, et al. Cancer risks for BRCA1 and BRCA2 mutation carriers: Results from prospective analysis of EMBRACE. J Natl Cancer Inst. 2013;105(11):812–22.
5. Moyer VA, Services USP, Force T. Annals of Internal Medicine Clinical Guideline Risk Assessment , Genetic Counseling , and Genetic Testing for BRCA-Related Cancer in Women : U . S . Preventive Services Task Force Recommendation Statement. 2005;160(4):1–12.
6. Pruthi S, Heisey RE, Bevers TB. Chemoprevention for Breast Cancer. Ann Surg Oncol. 2015;22(10):3230–5.
7. Cuzick J, Sestak I, Forbes JF, Dowsett M, Knox J, Cawthorn S, et al. Anastrozole for prevention of breast

cancer in high-risk postmenopausal women (IBIS-II): An international, double-blind, randomised placebo-controlled trial. Lancet [Internet]. 2014;383(9922):1041–8. Available from: http://dx.doi.org/10.1016/S0140-6736(13)62292-8
8. Sismondi P, D'Alonzo M, Pecchio S, Bounous VE, Robba E, Biglia N. Chemoprevention or mastectomy for women at high risk of developing breast cancer. Maturitas [Internet]. 2015;82(3):271–3. Available from: http://dx.doi.org/10.1016/j.maturitas.2015.07.002
9. Cuzick J, Sestak I, Bonanni B, Costantino JP, Cummings S, DeCensi A, et al. Selective oestrogen receptor modulators in prevention of breast cancer: an updated meta-analysis of individual participant data. Lancet [Internet]. 2013 May 25;381(9880):1827–34. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3671272/
10. Vogel V, Costantino J, Wickerham D, Cronin WM, Cecchini R, Atkins J. Effects of Tamoxifen vs Raloxifene on the Risk of Developing Invasive Breast Cancer and Other Disease Outcomes. J Minim Invasive Gynecol [Internet]. 2006;295(23):10–2. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Effects+of+Tamoxifen+vs+Raloxifene+on+the+Risk+of+Developing+Invasive+Breast+Cancer+and+Other+Disease+Outcomes#0
11. Hartmann LC, Schaid DJ, Woods JE, Crotty TP, Myers JL, Arnold PG, et al. Efficacy of Bilateral Prophylactic Mastectomy in Women with a Family History of Breast Cancer. N Engl J Med [Internet]. 1999 Jan 14;340(2):77–84. Available from: http://dx.doi.org/10.1056/NEJM199901143400201
12. Willis AM, Smith SK, Meiser B, Ballinger ML, Thomas DM, Young MA. Sociodemographic, psychosocial and clinical factors associated with uptake of genetic counselling for hereditary cancer: a systematic review. Clin Genet. 2017;92(2):121–33.
13. Ropka ME. Uptake Rates for Breast Cancer Genetic Testing: A Systematic Review. Cancer Epidemiol Biomarkers Prev [Internet]. 2006;15(5):840–55. Available from: http://cebp.aacrjournals.org/cgi/doi/10.1158/1055-9965.EPI-05-0002
14. Shannon KM, Lubratovich ML, Finkelstein DM, Smith BL, Powell SN, Seiden M V. Model-based predictions of BRCA1/2 mutation status in breast carcinoma patients treated at an academic medical center. Cancer [Internet]. 2002;94(2):305–13. Available from: http:https://doi.org/10.1002/cncr.10223
15. Crew KD, Albain KS, Hershman DL, Unger JM, Lo SS. How do we increase uptake of tamoxifen and other anti-estrogens for breast cancer prevention? npj Breast Cancer [Internet]. 2017;3(1):20. Available from: http://www.nature.com/articles/s41523-017-0021-y
16. Peres J. Why Is Breast Cancer Chemoprevention Such a Hard Sell? JNCI J Natl Cancer Inst [Internet]. 2014 May 9;106(5):dju139. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4677265/
17. Delikurt T, Williamson GR, Anastasiadou V, Skirton H. A systematic review of factors that act as barriers to patient referral to genetic services. Eur J Hum Genet. 2015;23(6):739–45.
18. Tang EY, Trivedi MS, Kukafka R, Chung WK, David R, Respler L, et al. Population-Based Study of Attitudes toward *BRCA* Genetic Testing among Orthodox Jewish Women. Breast J [Internet]. 2016;1–5. Available from: http://doi.wiley.com/10.1111/tbj.12736
19. Mai PL, Garceau AO, Graubard BI, Dunn M, McNeel TS, Gonsalves L, et al. Confirmation of family cancer history reported in a population-based survey. J Natl Cancer Inst. 2011;103(10):788–97.
20. Wideroff L, Garceau AO, Greene MH, Dunn M, McNeel T, Mai P, et al. Coherence and completeness of population-based family cancer reports. Cancer Epidemiol Biomarkers Prev. 2010;19(3):799–810.
21. Murff HJ, Greevy RA, Syngal S. The comprehensiveness of family cancer history assessments in primary care. Community Genet. 2007;10(3):174–80.
22. Wood ME, Kadlubek P, Pham TH, Wollins DS, Lu KH, Weitzel JN, et al. Quality of cancer family history and referral for genetic counseling and testing among oncology practices: A pilot test of quality measures as part of the American Society of Clinical Oncology Quality Oncology Practice Initiative. J Clin Oncol. 2014;32(8):824–9.
23. Bell RA, McDermott H, Fancher TL, Green MJ, Day FC, Wilkes MS. Impact of a Randomized Controlled Educational Trial to Improve Physician Practice Behaviors Around Screening for Inherited Breast Cancer. J Gen Intern Med. 2015;30(3):334–41.
24. Yi H, Xiao T, Thomas PS, Aguirre AN, Smalletz C, Dimond J, et al. Barriers and Facilitators to Patient-Provider Communication When Discussing Breast Cancer Risk to Aid in the Development of Decision Support Tools. AMIA . Annu Symp proceedings AMIA Symp [Internet]. 2015;2015:1352–60. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26958276%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4765687

25. Coe AM, Ueng W, Vargas JM, David R, Vanegas A, Infante K, et al. Usability Testing of a Web-Based Decision Aid for Breast Cancer Risk Assessment Among Multi-Ethnic Women. AMIA Annu Symp Proc. 2016;411–20.
26. Wood J, Crew K, Kukafka R, Finkelstein J. A Comprehensive Informatics Framework to Increase Breast Cancer Risk Assessment and Chemoprevention in the Primary Care Setting. Proc - 2016 IEEE Int Conf Healthc Informatics, ICHI 2016. 2016;293–6.
27. Joseph G, Kaplan C, Luce J, Lee R, Stewart S, Guerra C, et al. Efficient identification and referral of low-income women at high risk for hereditary breast cancer: A practice-based approach. Public Health Genomics. 2012;15(3–4):172–80.
28. Stewart SL, Kaplan CP, Lee R, Joseph G, Karliner L, Livaudais-Toman J, et al. Validation of an efficient screening tool to identify low income women at high risk for hereditary breast cancer. Public Health Genomics [Internet]. 2016 Oct 28;19(6):342–51. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC5215008/
29. Bellcross CA, Lemke AA, Pape LS, Tess AL, Meisner LT. Evaluation of a breast/ovarian cancer genetics referral screening tool in a mammography population. Genet Med. 2009;11(11):783–9.
30. Wang Y, Wang L, Rastegar-Mojarad M, Liu S, Shen F, Liu H. Systematic Analysis of Free-Text Family History in Electronic Health Record. AMIA Summits Transl Sci Proc [Internet]. 2017 Jul 26;2017:104–13. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC5543380/
31. Polubriaginof F, Tatonetti NP, Vawdrey DK. An Assessment of Family History Information Captured in an Electronic Health Record. AMIA Annu Symp Proc [Internet]. 2015 Nov 5;2015:2035–42. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4765557/
32. Goryachev S, Kim H, Zeng-Treitler Q. Identification and extraction of family history information from clinical reports. AMIA Annu Symp Proc [Internet]. 2008;247–51. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2656021&tool=pmcentrez&rendertype=abstract
33. Moyer VA. Screening for lung cancer: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med [Internet]. 2014;160. Available from: https://doi.org/10.7326/M13-2771
34. Endevelt R, Goren I, Sela T, Shalev V. Family history intake: A challenge to personalized approaches in health promotion and disease prevention. Isr J Health Policy Res [Internet]. 2015;4(1):2–7. Available from: http://dx.doi.org/10.1186/s13584-015-0055-2
35. Bill R, Pakhomov S, Chen ES, Winden TJ, Carter EW, Melton GB. Automated Extraction of Family History Information from Clinical Notes Institute for Health Informatics , 2 College of Pharmacy , and 3 Department of Surgery ,. AMIA Annu Symp Proc 2014. 2014;1709–17.
36. McGuinness JE, Trivedi MS, Vanegas A, Colbeth H, Sandoval R, Kukafka R, et al. Decision support for family history intake to determine eligibility for BRCA testing among multiethnic women. J Clin Oncol [Internet]. 2017 May 20;35(15_suppl):1586. Available from: http://ascopubs.org/doi/abs/10.1200/JCO.2017.35.15_suppl.1586
37. Acheson LS, Wiesner GL, Zyzanski SJ, Goodwin MA, Stange KC. Family history-taking in community family practice: implications for genetic screening. Genet Med [Internet]. 2000;2(3):180–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11256663
38. Polubriaginof F, Quinnies K, Vanguri R, Yahi A, Simmerling M, Ionita-Laza I, et al. Estimate of disease heritability using 4.7 million familial relationships inferred from electronic health records. bioRxiv [Internet]. 2016;066068. Available from: http://biorxiv.org/lookup/doi/10.1101/066068
39. Tyler C V, Snyder CW. Cancer risk assessment: examining the family physician's role. J Am Board Fam Med. 2006;19(5):468–77.
40. Wilson BJ, Carroll JC, Allanson J, Little J, Etchegary H, Avard D, et al. Family History Tools in Primary Care: Does One Size Fit All? Public Health Genomics [Internet]. 2012;15(3–4):181–8. Available from: https://www.karger.com/DOI/10.1159/000336431
41. Melton GB, Raman N, Chen ES, Sarkar IN, Pakhomov S, Madoff RD. Evaluation of family history information within clinical documents and adequacy of HL7 clinical statement and clinical genomics family history models for its representation: A case report. J Am Med Informatics Assoc. 2010;17(3):337–40.