Physicians' Attitudes About Multiplex Tumor Genomic Testing

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ABSTRACT

Purpose

Although predictive multiplex somatic genomic tests hold the potential to transform care by identifying targetable alterations in multiple cancer genes, little is known about how physicians will use such tests in practice.

Participants and Methods

Before the initiation of enterprise-wide multiplex testing at a major cancer center, we surveyed all clinically active adult cancer physicians to assess their current use of somatic testing, their attitudes about multiplex testing, and their genomic confidence.

Results

A total of 160 physicians participated (response rate, 61%): 57% were medical oncologists; 29%, surgeons; 14% radiation oncologists; 37%, women; and 83%, research principal investigators. Twenty-two percent of physicians reported low confidence in their genomic knowledge. Eighteen percent of physicians anticipated testing patients infrequently ($\leq 10\%$), whereas 25% anticipate testing most patients ($\geq 90\%$). Higher genomic confidence was associated with wanting to test a majority of patients (adjusted odds ratio [OR], 6.09; 95% CI, 2.1 to 17.5) and anticipating using actionable (adjusted OR, 2.46; 95% CI, 1.2 to 5.2) or potentially actionable (adjusted OR, 2.89; 95% CI, 1.1 to 7.9) test results to inform treatment recommendations. Forty-two percent of physicians endorsed disclosure of uncertain genomic findings to patients.

Conclusion

Physicians at a tertiary-care National Cancer Institute–designated comprehensive cancer center varied considerably in how they planned to incorporate predictive multiplex somatic genomic tests into practice and in their attitudes about the disclosure of genomic information of uncertain significance. Given that many physicians reported low genomic confidence, evidence-based guidelines and enhanced physician genomic education efforts may be needed to ensure that genomically guided cancer care is adequately delivered.

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INTRODUCTION

Over the past 20 years we have seen dramatic advances in the treatment of cancer through the combined use of predictive somatic genetic testing and genomically targeted therapies.¹ Prominent examples of this approach include erlotinib for *EGFR*-mutant lung cancer² and vemurafenib for *BRAF* V600E-mutant melanoma.³ As genomic technologies become more accurate and less expensive,⁴ we will see increasing numbers of predictive multiplex tests (ie, tests that analyze tens to hundreds of cancer-related genes) marketed for clinical use. Despite the fact that multiplex tests are commercially available, little is known about how they are used in clinical practice.

Although there is a substantial body of literature related to the use of germline cancer susceptibility testing, far less is known about how physicians use somatic tests. Recent work has shown that there may be increasing rates of adoption of somatic predictive and risk recurrence testing⁵⁻⁷ and that patients report a high willingness to undergo testing.⁸⁻¹⁰ In addition, several physician factors have been associated with higher reported use of cancer genetic tests, including medical specialty, prior use of cancer-related genetic testing, and higher reported confidence in making genetic recommendations.¹¹⁻¹³

The launch of the Profile research study at Dana-Farber Cancer Institute (DFCI)/Brigham and Women's Hospital (BWH) provides a unique

Table 1. Tiers of Somatic Profiling Test Results

Tier	Description
Introduction	OncoMap test results will be tiered into three categories by disease center leaders and Personalized Cancer Medicine Partnership Executive Committee
One	Genomic variants proven to be clinically relevant (eg, validated, FDA approved, and/or actionable)
Two	Potentially actionable genomic variants (eg, nonvalidated or non-FDA approved but potentially actionable)
Three	All other genomic variants that do not fall under tier one or two
Abbreviation: FDA, US Food and Drug Administration.	

opportunity to study physician adoption of multiplex testing. In the first iteration of Profile, all patients with cancer are offered OncoMap, a test for 471 alterations in 41 cancer-related genes. Profile results are tiered based on clinical utility (Table 1). Whereas tier-one and -two results can be returned to the patient's provider with patient consent, the protocol prohibits disclosure of alterations of uncertain significance (tier three). To better assess physicians' use of somatic testing and characterize the context into which multiplex testing was being introduced, we conducted a baseline survey at the initiation of the Profile study. We hypothesized that medical oncologists, physicians with high genomic confidence, and those reporting high baseline testing would be more likely to want testing for their patients and anticipate disclosing test results to patients. Because genomically targeted therapies are most commonly prescribed by medical oncologists, we also hypothesized that medical oncologists would be more likely to intend to use results to inform treatment recommendations. The data presented here represent the first phase of a longitudinal study of physician adoption of multiplex testing at our institutions.

PARTICIPANTS AND METHODS

Population

Our sampling frame included all faculty members who provide clinical care to adult patients with cancer at DFCI/BWH. We recruited participants from September 19, 2011, to January 25, 2012. The study was approved by the DFCI Institutional Review Board.

Survey Instrument

The survey instrument (Data Supplement) contained questions related to use of genetic testing before the introduction of Profile (baseline genomic testing), anticipated impact of testing, and sociodemographic and practice characteristics. We queried participants about their behavioral intentions by asking them to estimate: (1) the percentage of patients for whom they would want testing; (2) how often they would disclose results to patients; (3) how often they would use results to inform treatment recommendations; (4) the terms that they would use to describe multiplex testing to patients; and (5) where they would seek information to learn more about test results. We asked participants open-ended questions about the types of patients whom they would or would not test. We assessed attitudes about test-result disclosure by asking whether physicians should discuss different types of results with patients and about disclosure policies by asking how much they agreed or disagreed with the decision to prohibit the return of tier-three alterations. We created a genomic confidence scale by combining three questions on physicians' confidence in their: (1) knowledge about genomics; (2) ability to explain genomic concepts to patients; and (3) ability to make treatment recommendations based on genomic information.

The survey was pilot tested with medical oncologists, radiation oncologists, and surgeons. On the basis of their feedback, the survey was refined and finalized. The survey took approximately 10 minutes and was administered online via REDCap (version 4.13.10; Vanderbilt University, Nashville, TN).¹⁴

Study Procedures

S.W.G. sent all potentially eligible physicians an electronic letter that contained study details and a survey link. Electronic reminders were sent to nonresponders 2 and 4 weeks after the initial contact. A third e-mail was sent to nonresponders by B.J.R., chair of the Profile Steering Committee. S.W.G. then called all nonresponders. Participants were not offered incentives.

Statistical Analyses

Our primary aims were to determine whether participant characteristics were associated with wanting testing for most patients ($\geq 75\%$ of patients), anticipating disclosing test results, reporting that test results would inform treatment recommendations, and agreeing with the policy to prohibit disclosure of tier-three results (often or routinely). We used multiple [logistic regression analyses](#) to examine associations between our predictor and outcome variables while controlling for potential confounders. All hypothesis testing was based on two-tailed tests with a *P* value of less than .05. With respect to assessing the impact of missing data, we first performed complete case analyses. Then, in [sensitivity analyses](#), we addressed missing data through the missing indicator method and through multiple imputation.¹⁵ The genomic confidence scale had an α of 0.86. Open-ended questions were coded to identify themes in response. All statistical analyses were conducted using STATA software (version 12; STATA, College Station, TX).

RESULTS

Sample Characteristics, Baseline Testing, and Genomic Confidence

Of the 276 physicians who were contacted, 13 were ineligible and 160 completed the survey for a response rate of 61%.¹⁶ Sample characteristics and self-reported baseline testing are summarized in Table 2. Participants reported that before the introduction of Profile, they ordered tumor genomic testing for an average of 24% of patients (range, 0% to 100%). Participants most commonly ordered *KRAS* (25%), *EGFR* (24%), *BRAF* (24%), *C-KIT* (13%), *BRC-ABL* (13%), and *JAK2* (9%) testing. Many participants were not very confident or not confident at all in their knowledge of genomics (22%), ability to explain genomic concepts to patients (14%), and ability to make treatment recommendations based on genomic data (26%; Fig 1). The average score on the genomic confidence scale was 3, corresponding to a response of somewhat confident. After controlling for potential confounders, high genomic confidence was associated with being a medical oncologist, being a researcher, and high baseline test use (Appendix Table A1, online only).

Anticipated Test-Related Behavior and Attitudes About Disclosure and Impact

Participants varied widely in how they anticipated using multiplex testing in practice. Eighteen percent of physicians anticipated testing patients infrequently ($\leq 10\%$), whereas 25% anticipated testing most patients ($\geq 90\%$; range, 0% to 100%; Fig 2). We identified themes related to physicians' predictions about patients whom they would and would not test (Appendix Table A2, online only). Participants' test-related intentions are shown in Appendix Figures A1 and A2 (online only). Although participants were more likely to endorse disclosure of actionable or potentially actionable results, $> 40\%$ of physicians endorsed disclosure of uncertain genomic findings (Figs

Table 2. Participant Characteristics (N = 160)

Characteristic	Participants
Years since medical school, %	
0 to 10	27
11 to 20	36
21 to 30	23
31 to 40	11
> 40	3
Female sex, %	37
Type of physician, %	
Surgical specialist	29
Medical oncologist	57
Radiation oncologist	14
Research principal investigator, %*	
Clinical trials	50
Translational science	33
Basic science	21
Outcomes	21
Other	2
Not principal investigator	17
No. of new patients each month	
Mean	12.5
SD	10.0
Percentage of patients recommended for phase one	
Mean	16.9
SD	19.5
Professional effort, %	
Patient care	
Mean	50.0
SD	26.3
Research	
Mean	35.5
SD	27.4
Teaching	
Mean	11.8
SD	12.5
Administration	
Mean	12.8
SD	15.2
Baseline genomic testing, %	
Mean	24.3
SD	29.2

Abbreviation: SD, standard deviation.

*Percentages do not add up to 100 because some participants are principal investigators in more than one area.

3A and 3B). Thirty-nine percent of participants somewhat or strongly disagreed with the policy of prohibiting the return of tier-three alterations (Appendix Fig A3, online only).

Participants reported that they would use a variety of terms to describe testing to patients, including tumor testing (77%), molecular testing (72%), tumor profiling (66%), genetic testing (62%), and biomarker testing (41%). On open-ended questioning, participants identified an additional 28 terms that they would use, including tumor fingerprinting, treatment target testing, molecular biology testing, scanning for actionable mutations, and personalized therapy testing. Participants reported that they would use multiple information sources to learn more about OncoMap results (Appendix Table A3, online only).

A majority of participants reported that OncoMap testing would somewhat or greatly increase patients' treatment options (73%), prog-

Fig 1. Physicians' genomic confidence.

nostic information (62%), and satisfaction (80%); the time required to discuss treatment options with patients (73%); and research opportunities (> 90%). Eighty percent of participants thought that OncoMap testing would increase their professional satisfaction. Twenty-two percent of physicians anticipated that OncoMap would increase their clinical uncertainty.

Unadjusted associations between participants' characteristics and outcomes are listed in Appendix Table A4 (online only). After controlling for potential confounders, higher genomic confidence was associated with wanting to test a majority of patients, being likely to disclose tier-one results, anticipating using results to inform treatment recommendations, and disagreeing with the policy of prohibiting return of tier-three results (Table 3). Physicians who reported higher baseline genomic testing were more likely to report that they would disclose tier-two results. Medical oncologists were less likely to report that they would disclose tier-two results and to believe that tier-two results would help inform treatment recommendations as compared with other physicians. High genomic confidence was also associated with the belief that physicians should disclose wild-type and altered tier-one and -two results (data not shown).

Fig 2. Percent of patients for whom physicians anticipated wanting OncoMap testing.

Fig 3. Percentage of physicians who believed that (A) genomic alterations and (B) wild-type results should be discussed with patients (by tier).

No variable had > 10% missing data. In sensitivity analyses, effect estimates were similar when comparing the complete case analysis, missing indicators approach, and multiple imputation. Appendix Table A5 (online only) summarizes baseline testing, genomic confidence, and outcomes, stratified by specialist and adoption style, to demonstrate similarities and differences across different physician subpopulations.

DISCUSSION

Before the introduction of enterprise-wide predictive multiplex somatic genomic testing at our institutions, we surveyed adult cancer physicians and found that a sizeable minority of physicians had low levels of genomic confidence. We also found that there was variability in how physicians planned to use multiplex testing and in physicians' attitudes about the disclosure of genomic information of uncertain significance.

Our finding that physicians' had varying degrees of genomic confidence is consistent with prior studies. In the setting of cancer susceptibility testing, studies have shown that 50% of oncologists felt qualified to provide genetic counseling¹² and that only 30% to 52% of specialists (eg, surgeons, oncologists) were moderately or very confident in their cancer genomic knowledge.¹³ Although our genomic confidence measure is novel, we found that high confidence was

associated with being a medical oncologist, being a researcher, and high baseline testing. These associations provide evidence of construct validity, because this group of physicians may have more experience using genetically guided treatments, and therefore be more knowledgeable about genomics, than other physicians. The fact that there was considerable variation in genomic confidence among our physicians may not be surprising when one considers that genomic data are highly uncertain in nature.^{17,18} Areas of uncertainty include the role that specific variants play in disease pathogenesis, the magnitude of effect associated with alterations, and the clinical utility of genomic information.¹⁹ Our data also suggest that physicians' genomic confidence may play a critical role in clinical decision making, because genomic confidence was one of the strongest predictors of physicians' attitudes about and anticipated use of testing. Our findings are consistent with prior work that demonstrated an association between physicians feeling qualified to recommend genetic testing and use of cancer susceptibility tests.¹¹ One potential explanation for our findings is that greater confidence in one's abilities to understand and use genomic information may increase a physician's sense of self-efficacy, which is an important predictor of behavior.²⁰

We found a high degree of variation in how physicians used somatic testing in practice. Differential use of baseline testing and attitudes about future testing might be explained, in part, by the fact that our providers are highly subspecialized. Somatic genomic testing is not standard of care for most patients with cancer, and physicians' attitudes about the value of testing might vary given that the clinical utility of predictive genomic information varies by clinical context. For example, the benefit of somatic testing may be evident to physicians who care for patients with advanced lung adenocarcinoma but could be less evident to physicians who care for patients with early-stage bladder cancer. Counter to our hypothesis, however, was the finding that physicians' baseline use of testing was associated with wanting testing for most patients in univariable, but not multivariable, models. Possible explanations for this finding include the facts that we had a relatively small sample size and that baseline testing was correlated with genomic confidence.

Our results also demonstrate that there is considerable variation in physicians' attitudes about test result disclosure. For example, 23% of physicians said that they would rarely or sometimes disclose tier-one results, a finding that was higher than expected given that tier-one results are by definition clinically relevant. Predictors of nondisclosure of tier-one results included lower genomic confidence and lower reported baseline testing (data not shown). Additionally, there were no consensus beliefs on the appropriateness of disclosure of tier-two or -three results. Physicians with higher levels of genomic confidence were more likely to endorse tier-one and -two test result disclosure, again suggesting that genomic confidence is an important predictor of physician attitudes. Our finding that physicians had differing views on disclosure is consistent with the fact that there is an ongoing national debate related to the return of genomic findings to patients and research participants.²¹⁻²⁴ Additional research on patients' preferences for the return of genomic information and on the impact of test result disclosure will be needed to guide return-of-result policies going forward.

This study also highlights the fact that there is significant variation in the language that physicians plan to use to describe multiplex testing. It is important that we critically evaluate the language that is

Table 3. Logistic Regression Models for Survey Results

Variable	Want Testing		Likely to Disclose Tier-One Results		Likely to Disclose Tier-Two Results		Likely to Use Tier-One Results to Inform Treatment Recommendations		Likely to Use Tier-Two Results to Inform Treatment Recommendations		Agree With Policy to Prohibit Return of Tier-Three Results	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Years since medical school	1.13	0.89 to 1.44	1.13	0.88 to 1.46	1.10	0.89 to 1.35	1.06	0.86 to 1.30	1.19	0.92 to 1.55	1.26*	1.01 to 1.59
Sex (female v male)	1.72	0.59 to 5.01	1.14	0.44 to 2.93	0.78	0.33 to 1.85	1.71	0.71 to 4.09	0.75	0.21 to 2.72	2.15	0.85 to 5.48
Type of physician (v surgical specialist)												
Medical oncologist	1.05	0.28 to 3.90	1.24	0.36 to 4.22	0.24*	0.08 to 0.74	0.67	0.23 to 1.96	0.16*	0.04 to 0.66	1.01	0.33 to 3.15
Radiation oncologist	0.98	0.18 to 5.44	2.24	0.52 to 9.68	0.64	0.17 to 2.37	1.95	0.51 to 7.43	0.97	0.19 to 5.10	0.68	0.16 to 2.85
Researcher	0.52	0.11 to 2.59	0.73	0.18 to 3.02	0.74	0.22 to 2.51	0.56	0.16 to 1.94	0.74	0.16 to 3.35	3.31	0.83 to 13.14
No. of new patients each month	1.08	1.01 to 1.15	0.99	0.94 to 1.05	0.98	0.94 to 1.03	1.00	0.95 to 1.05	0.98	0.92 to 1.05	0.98	0.93 to 1.03
Percentage of patients tested at baseline	1.02	1.00 to 1.03	1.02	0.99 to 1.04	1.02*	1.00 to 1.04	1.01	0.99 to 1.02	1.00	0.98 to 1.03	0.99	0.98 to 1.01
Percentage of patients recommended for phase one	1.02	1.00 to 1.05	1.01	0.97 to 1.04	1.00	0.97 to 1.02	1.01	0.99 to 1.04	1.00	0.96 to 1.03	0.99	0.97 to 1.02
Confidence in genomics	6.09†	2.12 to 17.50	2.14*	1.06 to 4.31	1.66	0.85 to 3.22	2.46*	1.18 to 5.16	2.89*	1.06 to 7.93	0.38*	0.18 to 0.84

Abbreviation: OR, odds ratio.

* $P < .05$.† $P < .001$.

used to describe cancer genetic testing, because prior work has demonstrated that message framing can be a determinant of physicians' willingness to test²⁵ and that patients may misunderstand the implications of somatic testing.⁸ To determine how best to describe somatic testing to patients, we need to study the way in which message framing influences patients' attitudes. Without language standardization, we run the risk of increasing patient confusion and decreasing test acceptance.

Additionally, we found that many surgeons and radiation oncologists had ordered tumor genomic testing before the introduction of Profile. Although we detected some differences in our outcomes by specialty, we also found that medical oncologists, surgeons, and radiation oncologists anticipated using OncoMap in similar ways. One explanation for these findings is that DFCI/BWH physicians may have more experience with genomic testing and genomically guided clinical trials than physicians in other practice settings. In addition, surgeons and radiation oncologists at DFCI/BWH might be more likely to use genomic information in making treatment recommendations because medical decisions are often made in multidisciplinary clinics with input from all specialties. For example, decisions about neoadjuvant chemotherapy/radiation therapy or surgery may be different for patients with *EGFR*-positive lung cancer who are eligible for targeted-therapy clinical trials versus patients who are *EGFR* negative. Counter to our hypothesis, medical oncologists were less likely than other physicians to say that they would use tier-two results to inform treatment recommendations. A possible explanation for this finding may be that medical oncologists are more aware than other physicians of the fact that the use of tier-two findings in treatment planning is limited to small patient populations.

Finally, the fact that we found significant variation in genomic confidence among physicians at a major cancer center speaks to the urgent need to understand how genomic confidence varies across different physician populations and whether genetic education programs are needed. One might argue that providers at an academic cancer center would be expected to have higher levels of genomic confidence than other providers. Given that we found a sizable minority of our providers had low levels of genomic confidence and that confidence among our physicians might be considered a best-case scenario, one would hypothesize that the potential for confusion over test use and for missed testing opportunities might be greater in other settings. A recent report from the Secretary's Advisory Committee on Genetics, Health, and Society concluded that many health care professionals lack basic genetic knowledge, that there is a shortage of genetic professionals, and that inadequate provider education may significantly limit the appropriate integration of genetics into patient care.²⁶ Given the rapid evolution of genetic technologies, innovations in provider education may be needed to help cancer physicians integrate genomic data into medical decision making.²⁷

Our study has a number of limitations. Although our study represents a population-based sample of adult cancer providers at a major cancer center, our findings may not be generalizable to nonacademic physicians or to decision making related to commercial testing. Our study may also be limited by nonresponse bias. Nonresponse bias was somewhat mitigated by our high response rate—a rate comparable to similar physician surveys.^{13,28,29} In addition, we assessed physicians' genomic confidence with a novel unvalidated measure. Although genomic confidence may be conceptualized in numerous

ways, we asked participants about their confidence related to specific skills as opposed to asking about their confidence in the benefits of multiplex testing more generally. Other groups have used self-assessed measures relating to feeling qualified or unqualified to recommend cancer genetic testing^{11,12} and confidence in personal knowledge of genetics.¹³ We decided against using an objective knowledge measure, because we received feedback during pilot testing that physicians might not complete the survey if they felt as if they were being tested. Additionally, we asked physicians about their behavioral intentions, and it is possible that intentions may not predict actual behavior. Finally, we assessed outcomes using single-item unvalidated measures, and it is possible that our relatively small sample size may have limited our ability to detect significant effects.

In summary, we found that there is little consensus on how physicians plan to use somatic predictive multiplex genetic testing in practice or in their attitudes about test result disclosure. Our data also suggest that genomic confidence may be highly variable among cancer physicians and that genomic confidence might be an important factor in test adoption decisions. These data suggest the value of evidence-based guidelines to help physicians determine when genomic testing is indicated and renewed efforts in physician genomic education and decision support. Finally, a concerted effort is needed to ensure that physicians present information about predictive multiplex tests to patients in a way that enhances patient understanding and increases patients' test acceptance. It is only through further study and a nuanced understanding of the physician-related factors that contribute to variations in genomic cancer care that we will be able to design and implement interventions promoting the appropriate adoption of these innovative technologies.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Although all authors completed the disclosure declaration, the following author(s) and/or an author's immediate family member(s) indicated a financial or other interest that is relevant to the subject matter under consideration in this article. Certain relationships marked with a "U" are those for which no compensation was received; those relationships marked with a "C" were compensated. For a detailed description of the disclosure categories, or for more information about ASCO's conflict of interest policy, please refer to the Author Disclosure Declaration and the Disclosures of Potential Conflicts of Interest section in Information for Contributors.

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GLOSSARY TERMS

Genomics: The scientific discipline in which multiple genes, gene products, or regions of the genome are analyzed via large-scale, high-throughput molecular approaches directed to DNA and RNA. This definition is a deviation from that of the original term, which meant an analysis of the whole genome.

Logistic regression analysis: A multivariable regression model in which the log of the odds of a time-fixed outcome event (eg, 30-day mortality) or other binary outcome is related to a linear equation.

Sensitivity analyses: Analyses that evaluate the impact of missing data and possible differences in interval assessments.

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Appendix

Table A1. Multivariable Logistic Regression for Predictors of High Genomic Confidence*

Variable	OR	95% CI	P
Years since medical school	0.95	0.74 to 1.23	.72
Sex (female v male)	0.57	0.20 to 1.61	.29
Type of physician (v surgical specialist)			
Medical oncologist	4.88	1.37 to 17.41	.01
Radiation oncologist	0.44	0.11 to 1.71	.24
Researcher	5.02	1.28 to 19.69	.02
No. of new patients each month	1.00	0.95 to 1.06	.92
Percentage of patients tested at baseline	1.03	1.00 to 1.05	.047
Percentage of patients recommended for phase one	1.01	0.97 to 1.05	.66

Abbreviation: OR, odds ratio.

*Defined as score ≥ 3 .

Table A2. Themes Related to Physicians' Predictions About Patients Whom They Would and Would Not Test

Theme	Physicians (%)	Examples
Patients to Be Tested (n = 112)		
Cancer type	54	Lung, mesothelioma, thymoma, breast, colon, pancreatic, esophageal, ovarian, endometrial, melanoma, prostate, GIST, glioma, meningioma, pituitary, sarcoma, ALL, AML, NHL, MM, MDS, unknown primary, rare tumor types
Cancer stage	29	Stage IV, high-risk stage III, recurrent disease
Absolute responses	16	Test all patients, test as many patients as possible, test all patients receiving active treatment, test all patients at diagnosis, test all phase one patients, test all patients if test is free
Tumor characteristics	14	Chemotherapy refractory, rapid progression, histology (eg, squamous), deep melanoma
Testing informs treatment	10	Clinical trial enrollment, risk stratification, choice of therapy
Patient characteristics	7	Young patients, patients interested in clinical trials or research, well-educated patients, nonsmokers, patients with family history of cancer, those with multiple malignancies, those at risk for second malignancy
Genomic status	7	ER- and HER2-positive, triple-negative breast cancer, cases of MEN-1, need to evaluate for <i>P13KCA</i> , <i>KRAS</i> , and <i>BRAD</i> mutations, known negative for routinely tested mutations, normal-karyotype hematologic diseases
Other	5	Patients needed to establish database for correlating tumor genetics to treatment response in situations of proven clinical benefit; patients will want testing to guide decision making
Patients Not to Be Tested (n = 53)		
Cancer stage	42	Early-stage tumors, stage I/II
Cancer type	40	Bladder, prostate, testicular, sarcoma, DCIS or LCIS, ovarian, vulvar, cervical, AML, hematologic malignancies, benign tumors
Patient characteristics	32	Patients receiving palliative or supportive care, patients who are debilitated or have poor performance status
Absolute responses	8	Most patients do not need testing, will not test any of my patients, will not test inpatients
Tumor characteristics/genomic status	6	Low-risk cancers, curable tumors, early recurrence, low-grade tumors, high-grade tumors, ER- and HER2-positive tumors or histology (eg, squamous cell), AML with low blast count
When does not inform treatment	6	Patients who discontinue treatment, patients eligible for clinical trials, patients undergoing long-term follow-up
Other	9	Patients who do not have enough tissue, patients with low probability of genomic abnormalities, second opinions, few or no relevant or actionable genes for my patients, patients who do not consent

Abbreviations: ALL, acute lymphoblastic leukemia; AML, acute myeloid leukemia; DCIS, ductal carcinoma in situ; ER, estrogen receptor; GIST, GI stromal tumor; HER2, human epidermal growth factor receptor 2; LCIS, lobular carcinoma in situ; MDS, myelodysplastic syndrome; MEN-1, multiple endocrine neoplasia type 1; MM, multiple myeloma; NHL, non-Hodgkin lymphoma.

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Table A3. Oncologists' Likelihood of Using Various Information Sources to Learn More About Test Results

Information Source	Very Unlikely (%)	Somewhat Unlikely (%)	Somewhat Likely (%)	Very Likely (%)
Colleagues in disease center	0	3	25	72
Colleagues at institution outside disease center	4	18	39	39
National/international experts outside institution	14	32	36	18
Medical literature	1	2	26	70
Foundation/government Web sites	12	28	35	24
Evidence-based synthesized Web sites	6	23	32	39
Institution Web site	4	11	41	44

Table A4. Unadjusted Associations Between Participant Characteristics and Survey Results

Variable	Want Testing		Likely to Disclose Tier-One Results		Likely to Disclose Tier-Two Results		Likely to Use Tier-One Results to Inform Treatment Recommendations		Likely to Use Tier-Two Results to Inform Treatment Recommendations		Agree With Policy to Prohibit Return of Tier-Three Results	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Years since medical school	1.04	0.88 to 1.22	1.11	0.91 to 1.35	1.03	0.88 to 1.21	1.05	0.89 to 1.23	1.16	0.94 to 1.43	1.10	0.93 to 1.31
Sex (female v male)	0.83	0.40 to 1.72	0.73	0.34 to 1.59	0.75	0.38 to 1.48	1.06	0.54 to 2.09	0.50	0.19 to 1.34	2.09*	1.01 to 4.36
Type of physician (v surgical specialist)												
Medical oncologist	1.97	0.93 to 4.18	1.63	0.71 to 3.71	0.60	0.29 to 1.22	0.96	0.47 to 1.96	0.58	0.23 to 1.46	0.75	0.36 to 1.58
Radiation oncologist	0.55	0.17 to 1.77	1.46	0.45 to 4.77	0.54	0.19 to 1.50	1.05	0.38 to 2.87	0.78	0.21 to 2.83	1.18	0.36 to 1.58
Researcher	1.31	0.55 to 3.13	0.91	0.34 to 2.45	0.60	0.26 to 1.38	0.76	0.33 to 1.74	0.67	0.24 to 1.85	0.80	0.33 to 1.95
No. of new patients each month	1.01	0.98 to 1.05	1.00	0.96 to 1.04	0.99	0.96 to 1.02	0.99	0.96 to 1.02	1.01	0.97 to 1.05	1.02	0.98 to 1.05
Percentage of patients tested at baseline	1.03†	1.01 to 1.04	1.02*	1.01 to 1.04	1.02‡	1.01 to 1.03	1.01	1.00 to 1.02	1.01	1.00 to 1.03	0.99*	0.97 to 1.00
Percentage of patients recommended for phase one	1.03‡	1.01 to 1.05	1.02	0.99 to 1.04	1.01	1.00 to 1.03	1.02*	1.00 to 1.04	1.02	1.00 to 1.04	0.99	0.97 to 1.00
Confidence in genomics	3.26†	1.84 to 5.77	2.00‡	1.22 to 3.26	1.54	0.98 to 2.41	1.70*	1.06 to 2.72	1.95	0.99 to 3.85	0.44‡	0.26 to 0.75

Abbreviation: OR, odds ratio.

* $P < .05$.† $P < .001$.‡ $P < .01$.

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Table A5. Baseline Testing, Confidence in Genomics, and Outcomes Stratified by Specialist and Adoption Style

Result	Surgical Specialist		Medical Oncologist		Radiation Oncologist		Exact <i>P</i>	Late Adopter*		Early Adopter†		Exact <i>P</i>
	No.	%	No.	%	No.	%		No.	%	No.	%	
Percentage of patients tested at baseline							< .001					—
0	16	36	13	17	15	71		44	38	0	0	
1 to 20	17	39	23	29	5	24		45	39	0	0	
21 to 50	5	11	20	25	1	5		26	23	0	0	
> 50	6	14	23	29	0	0		0	0	29	100	
High confidence in genomics							< .001					.001
< 3	25	54	10	11	10	61		42	37	2	7	
≥ 3	21	46	81	89	9	39		73	63	27	93	
Want testing							.03					.001
No	28	64	39	47	16	76		68	63	8	29	
Yes	16	36	44	53	5	24		40	37	20	71	
Likely to disclose tier-one results							.52					.13
No	13	29	18	20	5	22		29	25	3	10	
Yes	32	71	72	80	18	78		85	75	26	90	
Likely to disclose tier-two results							.33					.02
No	21	46	52	58	14	61		69	61	10	34	
Yes	25	54	37	42	9	39		45	39	19	66	
Likely to use tier-one results to inform treatment recommendations							1.00					.15
No	24	53	49	54	12	52		65	58	12	41	
Yes	21	47	41	46	11	48		48	42	17	59	
Likely to use tier-two results to inform treatment recommendations							.50					.26
No	35	78	78	86	18	82		97	86	22	76	
Yes	10	22	13	14	4	18		16	14	7	24	
Agree with policy to prohibit return of tier-three results							.64					.38
No	16	36	36	42	7	32		42	38	13	48	
Yes	29	64	49	58	15	68		69	62	14	52	

*Late adopter defined as physician who tested ≤ 50 patients in 12 months before OncoMap.

†Early adopter defined as physician who tested > 50 patients in 12 months before OncoMap.

Fig A1. Percentage of physicians who intended to view OncoMap test results.

Fig A2. Percentage of physicians who intended to (A) disclose OncoMap test results and (B) use OncoMap test results to inform treatment recommendations (by tier).

Fig A3. Physicians' agreement with institutional policy to prohibit return of tier-three results to patients.