



Title: Biomarker Testing (Including Liquid Biopsy) for Targeted Treatment and Immunotherapy in Breast Cancer

Related Policies:	<ul style="list-style-type: none"> • <i>Genetic Testing for BRCA1 or BRCA2 for Hereditary Breast/Ovarian Cancer Syndrome and Other High-Risk Cancers</i> • <i>Comprehensive Genomic Profiling for Selecting Targeted Cancer Therapies</i> • <i>Circulating Tumor DNA and Circulating Tumor Cells for Cancer Management (Liquid Biopsy)</i> • <i>Assays of Genetic Expression in Tumor Tissue as a Technique to Determine Prognosis in Patients with Breast Cancer</i>
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Professional

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Populations	Interventions	Comparators	Outcomes
Individuals: <ul style="list-style-type: none"> • With hormone receptor-positive, 	Interventions of interest are:	Comparators of interest are:	Relevant outcomes include: <ul style="list-style-type: none"> • Overall survival

Populations	Interventions	Comparators	Outcomes
<p>HER2 negative advanced or metastatic breast cancer</p>	<ul style="list-style-type: none"> • <i>PIK3CA</i> gene testing to select targeted treatment 	<ul style="list-style-type: none"> • Standard treatment without <i>PIK3CA</i> Gene Testing 	<ul style="list-style-type: none"> • Disease-specific survival • Test validity • Quality of life • Treatment-related morbidity
<p>Individuals:</p> <ul style="list-style-type: none"> • With locally advanced or metastatic breast cancer who are being considered for immunotherapy 	<p>Interventions of interest are:</p> <ul style="list-style-type: none"> • <i>NTRK</i> gene fusion testing to select targeted treatment 	<p>Comparators of interest are:</p> <ul style="list-style-type: none"> • Standard treatment without <i>NTRK</i> gene fusion testing 	<p>Relevant outcomes include:</p> <ul style="list-style-type: none"> • Overall survival • Disease-specific survival • Test validity • Quality of life • Treatment-related morbidity
<p>Individuals:</p> <ul style="list-style-type: none"> • With hormone receptor-negative/HER2-negative (triple negative) recurrent, metastatic or unresectable breast cancer who are being considered for immunotherapy 	<p>Interventions of interest are:</p> <ul style="list-style-type: none"> • PD-L1 testing 	<p>Comparators of interest are:</p> <ul style="list-style-type: none"> • Standard treatment without PD-L1 testing 	<p>Relevant outcomes include:</p> <ul style="list-style-type: none"> • Overall survival • Disease-specific survival • Test validity • Quality of life • Treatment-related morbidity
<p>Individuals:</p> <ul style="list-style-type: none"> • With previously treated, unresectable or metastatic breast cancer who are being considered for immunotherapy 	<p>Interventions of interest are:</p> <ul style="list-style-type: none"> • MSI-H/dMMR testing 	<p>Comparators of interest are:</p> <ul style="list-style-type: none"> • Standard treatment without MSI-H/dMMR testing 	<p>Relevant outcomes include:</p> <ul style="list-style-type: none"> • Overall survival • Disease-specific survival • Test validity • Quality of life • Treatment-related morbidity
<p>Individuals:</p> <ul style="list-style-type: none"> • With unresectable or metastatic breast cancer who are being considered for immunotherapy 	<p>Interventions of interest are:</p> <ul style="list-style-type: none"> • Tumor Mutational Burden Testing 	<p>Comparators of interest are:</p> <ul style="list-style-type: none"> • Standard treatment without TMB testing 	<p>Relevant outcomes include:</p> <ul style="list-style-type: none"> • Overall survival • Disease-specific survival • Test validity • Quality of life

Populations	Interventions	Comparators	Outcomes
			<ul style="list-style-type: none"> Treatment-related morbidity
Individuals: <ul style="list-style-type: none"> With hormone receptor-positive, HER2 negative advanced or metastatic breast cancer 	Interventions of interest are: <ul style="list-style-type: none"> Testing of circulating tumor DNA to select targeted treatment 	Comparators of interest are: <ul style="list-style-type: none"> Using tissue biopsy to select targeted treatment 	Relevant outcomes include: <ul style="list-style-type: none"> Overall survival Disease-specific survival Test validity Quality of life Treatment-related morbidity
Individuals: <ul style="list-style-type: none"> With hormone receptor-positive, HER2 negative metastatic breast cancer 	Interventions of interest are: <ul style="list-style-type: none"> Testing of circulating tumor cells (CTCs) to select targeted treatment 	Comparators of interest are: <ul style="list-style-type: none"> Standard treatment without using CTCs to select treatment 	Relevant outcomes include: <ul style="list-style-type: none"> Overall survival Disease-specific survival Test validity Quality of life Treatment-related morbidity

DESCRIPTION

Multiple biomarkers are being evaluated to predict response to targeted treatments and immunotherapy for patients with advanced breast cancer. These include tissue-based testing as well as circulating tumor DNA and circulating tumor cell testing (known as liquid biopsy).

OBJECTIVE

The objective of this evidence review is to determine whether biomarker testing using tissue biopsy, circulating tumor DNA testing, or circulating tumor cells improves the net health outcome in patients with metastatic, inoperable, or recurrent breast cancer.

BACKGROUND

PIK3CA Testing

Alterations in the protein coding gene *PIK3CA* (Phosphatidylinositol-4,5-Bisphosphate 3-Kinase Catalytic Subunit Alpha) occur in approximately 40% of patients with HR-positive, HER2-negative breast cancer.

***NTRK* Gene Fusions**

Neurotrophic-tropomyosin receptor kinase (*NTRK*) gene fusions encode tropomyosin receptor kinase fusion proteins that act as oncogenic drivers for solid tumors including lung, salivary gland, thyroid, and sarcoma. *NTRK* gene fusion findings might be more highly associated with rare breast cancer subtypes (eg secretory carcinoma).¹

Programmed Cell Death Ligand Protein-1

Programmed death ligand-1 (PD-L1) is a transmembrane protein expressed on the surface of multiple tissue types, including many tumor cells. Blocking the PD-L1 protein may prevent cancer cells from inactivating T cells.

Mismatch Repair Deficiency/Microsatellite Instability

Mismatch repair deficiency (dMMR) and high levels of microsatellite instability (MSI-H) describe cells that have alterations in certain genes involved in correcting errors made when DNA is replicated. dMMR tumors are characterized by a high tumor mutational load and potential responsiveness to anti-PD-L1-immunotherapy. MMR deficiency is most common in colorectal cancer, other types of gastrointestinal cancer, and endometrial cancer, but it may also be found in other cancers including breast cancer. Microsatellite instability testing is generally performed using polymerase chain reaction (PCR) for 5 biomarkers, although other biomarker panels and next generation sequencing are sometimes performed. High microsatellite instability is defined as 2 or more of the 5 biomarkers showing instability or more than 30% of the tested biomarkers showing instability depending on what panel is used. Microsatellite instability testing is generally paired with immunohistochemistry (IHC) assessing lack of protein expression from 4 DNA mismatch repair genes thereby reflecting dMMR.²

Tumor Mutational Burden

Tumor mutational burden (TMB), a measure of gene mutations within cancer cells, is an emerging biomarker of outcomes with immunotherapy in multiple tumor types. Initially, assessments of TMB involved whole exome sequencing (WES). More recently, targeted next generation sequencing (NGS) panels are being adapted to estimate TMB. Currently Foundation One CDx is the only U.S. Food and Drug Administration (FDA) approved panel for estimating TMB, but others are in development.³

Circulating Tumor DNA

Normal and tumor cells release small fragments of DNA into the blood, which is referred to as cell-free DNA. Cell-free DNA from nonmalignant cells is released by apoptosis. Most cell-free tumor DNA is derived from apoptotic and/or necrotic tumor cells, either from the primary tumor, metastases, or CTCs.¹ Unlike apoptosis, necrosis is considered a pathologic process and generates larger DNA fragments due to incomplete and random digestion of genomic DNA. The length or integrity of the circulating DNA can potentially distinguish between apoptotic and necrotic origin. Circulating tumor DNA can be used for genomic characterization of the tumor.

Circulating Tumor Cells

Intact CTCs are released from a primary tumor and/or a metastatic site into the bloodstream. The half-life of a CTC in the bloodstream is short (1-2 hours), and CTCs are cleared through extravasation into secondary organs. Most assays detect CTCs through the use of surface

epithelial markers such as EpCAM and cytokeratins. The primary reason for in detecting CTCs is prognostic, through quantification of circulating levels.

Regulatory Status

Clinical laboratories may develop and validate tests in-house and market them as a laboratory service; laboratory-developed tests must meet the general regulatory standards of the Clinical Laboratory Improvement Amendments. Laboratories that offer laboratory-developed tests must be licensed by the Clinical Laboratory Improvement Amendments for high-complexity testing. To date, the U.S. Food and Drug Administration has chosen not to require any regulatory review of these tests.

Table 1 summarizes available targeted treatments with FDA approval for recurrent or metastatic breast cancer (including immunotherapy) and the FDA approved companion diagnostic tests associated with each.

Table 1. Targeted Treatments for Metastatic Breast Cancer and FDA Approved Companion Diagnostic Tests

Treatment	Class	Indications in Breast Cancer	Companion Diagnostic
ado-trastuzumab emtansine (Kadcyla)	HER2-targeted antibody and microtubule inhibitor conjugate	<p>As a single agent, for:</p> <ul style="list-style-type: none"> • Treatment of patients with HER2-positive, metastatic breast cancer who previously received trastuzumab and a taxane, separately or in combination. Patients should have either: <ul style="list-style-type: none"> ○ received prior therapy for metastatic disease, or ○ developed disease recurrence during or within 6 months of completing adjuvant therapy. • Adjuvant treatment of patients with HER2-positive early breast cancer who have residual invasive disease after neoadjuvant taxane and trastuzumab-based treatment. 	<p>FoundationOne CDx HER2 FISH pharmDx Kit HercepTest INFORM HER2 Dual ISH DNA Probe Cocktail PATHWAY anti-Her2/neu (4B5) Rabbit Monoclonal Primary Antibody</p>
Alpelisib (Piqray)	Kinase inhibitor	In combination with fulvestrant for the treatment of postmenopausal women, and men, with hormone receptor (HR) positive, human epidermal growth factor receptor 2 (HER2)-negative, PIK3CA-mutated, advanced or metastatic breast cancer as detected by an FDA approved test following progression on or after an endocrine-based regimen	<p>FoundationOne CDx FoundationOne Liquid CDx therascreen PIK3CA RGQ PCR Kit</p>
Atezolizumab (Tecentriq)	PD-L1 blocking antibody	In combination with paclitaxel protein-bound for the treatment of adult patients with unresectable locally advanced or metastatic TNBC whose tumors express PD-L1, as determined by an FDA approved test.	<p>VENTANA PD-L1(SP142) Assay</p>
Entrectinib (Rozlytrek)	Kinase inhibitor	Adult and pediatric patients 12 years of age and older with solid tumors that:	<p>No FDA approved companion diagnostic test</p>

Treatment	Class	Indications in Breast Cancer	Companion Diagnostic
		<ul style="list-style-type: none"> have a neurotrophic tyrosine receptor kinase (NTRK) gene fusion without a known acquired resistance mutation, are metastatic or where surgical resection is likely to result in severe morbidity, and have progressed following treatment or have no satisfactory alternative therapy 	
Larotrectinib (Vitrakvi)	Kinase inhibitor	<p>Adult and pediatric patients 12 years of age and older with solid tumors that:</p> <ul style="list-style-type: none"> have a neurotrophic tyrosine receptor kinase (NTRK) gene fusion without a known acquired resistance mutation, are metastatic or where surgical resection is likely to result in severe morbidity, and have progressed following treatment or have no satisfactory alternative therapy 	FoundationOne CDx
Olaparib (Lynparza)	PARP inhibitor	<p>Adult patients with deleterious or suspected deleterious germline BRCA mutated, HER2-negative metastatic breast cancer who have been treated with chemotherapy in the neoadjuvant, adjuvant or metastatic setting. Patients with hormone receptor (HR)-positive breast cancer should have been treated with a prior endocrine therapy or be considered inappropriate for endocrine therapy. Select patients for therapy based on an FDA approved companion diagnostic for Lynparza.</p>	BRACAnalysis CDx
Pembrolizumab (Keytruda)	PD-L1-blocking antibody	<ul style="list-style-type: none"> in combination with chemotherapy, for the treatment of patients with locally recurrent unresectable or metastatic TNBC whose tumors express PD-L1 as determined by an FDA approved test 	PD-L1 IHC 22C3 pharmDx
		<ul style="list-style-type: none"> Adult and pediatric patients with unresectable or metastatic, microsatellite instability-high (MSI-H) or mismatch repair deficient (dMMR) solid tumors that have progressed following prior treatment and who have no satisfactory alternative treatment options 	No FDA approved companion diagnostic test
		<ul style="list-style-type: none"> Unresectable or metastatic tumor mutational burden-high (≥ 10 mutations/megabase) solid tumors, as determined by an FDA approved test, that have progressed following prior treatment and who have no satisfactory alternative treatment options. 	FoundationOne CDx (Solid tumors TMB ≥ 10 mutations per megabase)

Treatment	Class	Indications in Breast Cancer	Companion Diagnostic
Pertuzumab (Perjeta)	HER2/neu receptor antagonist	<ul style="list-style-type: none"> • Use in combination with trastuzumab and docetaxel for treatment of patients with HER2-positive metastatic breast cancer who have not received prior anti-HER2 therapy or chemotherapy for metastatic disease. • Use in combination with trastuzumab and chemotherapy as <ul style="list-style-type: none"> ○ neoadjuvant treatment of patients with HER2-positive, locally advanced, inflammatory, or early stage breast cancer (either greater than 2 cm in diameter or node positive) as part of a complete treatment regimen for early breast cancer. ○ adjuvant treatment of patients with HER2-positive early breast cancer at high risk of recurrence 	HER2 FISH pharmDx Kit HercepTest FoundationOne CDx
Talzenna (Talzoparib)	PARP inhibitor	Adult patients with deleterious or suspected deleterious germline BRCA-mutated HER2-negative locally advanced or metastatic breast cancer.	BRACAnalysis CDx
Trastuzumab (Herceptin)	HER2/neu receptor antagonist	The treatment of HER2-overexpressing breast cancer	Bond Oracle HER2 IHC System FoundationOne CDx HER2 CISH pharmDx Kit HER2 FISH pharmDx Kit HercepTest INFORM HER-2/neu INFORM HER2 Dual ISH DNA Probe Cocktail InSite Her-2/neu KIT PathVysion HER-2 DNA Probe Kit PATHWAY anti-Her2/neu (4B5) Rabbit Monoclonal Primary Antibody SPOT-LIGHT HER2 CISH Kit

Treatment	Class	Indications in Breast Cancer	Companion Diagnostic
			VENTANA HER2 Dual ISH DNA Probe Cocktail

dMMR: mismatch repair deficient; FDA: U.S. Food & Drug Administration; HER2: human epidermal growth factor receptor 2; MSI-H: microsatellite instability-high; NTRK: neurotrophic-tropomyosin receptor kinase; PD-L1: programmed death-ligand 1 ; PIK3CA: phosphatidylinositol 3-kinase catalytic alpha polypeptide; TNBC: triple-negative breast cancer

Sources: [4,5](#).

POLICY

A. *PIK3CA* Testing

1. *PIK3CA* testing may be **medically necessary** to predict treatment response to alpelisib (Piqray) in patients with hormone receptor-positive, HER2 negative advanced or metastatic breast cancer who have progressed on or after an endocrine-based regimen(see Policy Guidelines).

- When tumor tissue is available, use of tissue for testing is preferred but is not required (see Circulating Tumor DNA Testing below).

2. *PIK3CA* testing of tissue in patients with breast cancer is considered **experimental/ investigational** in all other situations.

B. *NTRK* Gene Fusion Testing

1. Analysis of *NTRK* gene fusions may be considered **medically necessary** to predict treatment response to entrectinib (Rozlytrek) or larotrectinib (Vitrakvi) in patients with locally advanced or metastatic breast cancer that has progressed following standard treatment and who have no alternative treatment option.

2. Analysis of *NTRK* gene fusions in patients with breast cancer is considered **experimental/ investigational** in all other situations.

C. PD-L1 Testing

1. PD-L1 testing may be considered **medically necessary** to predict treatment response to atezolizumab (Tecentriq) in patients with hormone receptor-negative/HER2-negative (triple negative) metastatic or unresectable breast cancer.

2. PD-L1 testing may be considered **medically necessary** to predict treatment response to pembrolizumab (Keytruda) in patients with hormone receptor-negative/HER2-negative (triple negative) recurrent or metastatic breast cancer..

3. PD-L1 testing in patients with breast cancer is considered **experimental/ investigational** in all other situations.

D. MSI-H/dMMR Testing

1. MSI-H/dMMR testing may be considered **medically necessary** to predict treatment response to pembrolizumab (Keytruda) in patients with unresectable or metastatic breast cancer that has progressed following standard treatment and who have no alternative treatment option (see Policy Guidelines).

2. MSI-H/dMMR testing in patients with breast cancer is considered **experimental/ investigational** in all other situations.

E. Tumor Mutational Burden Testing

Tumor mutational burden testing to predict response to immunotherapy in patients with breast cancer is considered **experimental/ investigational**.

F. Circulating Tumor DNA Testing (Liquid Biopsy)

1. *PIK3CA* testing using FoundationOne Liquid CDx may be considered **medically necessary** to predict treatment response to alpelisib (Piqray) in patients with hormone receptor-positive, HER2 negative advanced or metastatic breast cancer who have progressed on or after an endocrine-based regimen.

When tumor tissue is available, use of tissue for testing is preferred but is not required.

2. Circulating tumor DNA testing in patients with breast cancer is considered **experimental/ investigational** in all other situations.

G. Circulating Tumor Cell Testing

Analysis of circulating tumor cells to select treatment in patients with breast cancer is considered **experimental/ investigational**.

Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

RATIONALE

This evidence review was created in December 2020, with a search of the PubMed database through November 20, 2020.

Evidence reviews assess whether a medical test is clinically useful. A useful test provides information to make a clinical management decision that improves the net health outcome. That is, the balance of benefits and harms is better when the test is used to manage the condition than when another test or no test is used to manage the condition.

The first step in assessing a medical test is to formulate the clinical context and purpose of the test. The test must be technically reliable, clinically valid, and clinically useful for that purpose. Evidence reviews assess the evidence on whether a test is clinically valid and clinically useful. Technical reliability is outside the scope of these reviews, and credible information on technical reliability is available from other sources.

Biomarker Testing Using Tissue Biopsy to Select Targeted Treatment

Clinical Context and Test Purpose

Breast cancer treatment selection is informed by tumor type, grade, stage, patient performance status and preference, prior treatments, and the molecular characteristics of the tumor such as the presence of driver mutations. One purpose of biomarker testing of patients who have advanced cancer is to inform a decision regarding treatment selection (eg, whether to select a targeted treatment or standard treatment).

The question addressed in this evidence review is: Does biomarker testing of tumor tissue for *PIK3CA*, *NTRK* gene fusions, PD-L1, MSI-H/dMMR, or TMB improve the net health outcome in individuals with breast cancer?

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest is patients with advanced or metastatic breast cancer for whom the selection of treatment depends on the molecular characterization of the tumor. The setting of interest is oncology care.

Interventions

The technologies being considered are testing for *PIK3CA*, *NTRK* gene fusions, PD-L1, MSI-H/dMMR, or TMB using tissue biopsy.

Comparators

Decisions about treatment in advanced breast cancer are based on clinical characteristics.

Outcomes

The general outcomes of interest in oncology are overall survival, disease-specific survival, quality of life, treatment-related mortality and morbidity.

Beneficial outcomes resulting from a true-positive test result are prolonged survival, reduced toxicity, and improved QOL associated with receiving a more effective targeted therapy. Beneficial outcomes from a true negative result are prolonged survival associated with receiving chemotherapy in those without driver mutations.

Harmful outcomes resulting from a false-negative test result include shorter survival from receiving less effective and more cytotoxic chemotherapy in those with driver mutations; possible harmful outcomes resulting from a false-positive test result are a shorter survival from receiving potentially ineffective targeted treatment and delay in initiation of chemotherapy in those without driver mutations.

The overall response rate (ORR) may be used as a surrogate endpoint reasonably likely to predict clinical benefit in patients with refractory solid tumors. ORR can be measured by the proportion of patients with best overall confirmed response of complete response) or partial response by the Response Evaluation Criteria in Solid Tumors, version 1.1 (RECIST 1.1),⁶ or Response Assessment in Neuro-Oncology criteria,⁷ as appropriate by a blinded and independent adjudication committee.

There are clearly defined quantitative thresholds for the follow-up of patients in oncology trials. A general rule is a continuation of treatment until disease progression or unacceptable toxicity. Long-term follow-up outside of a study setting is conducted to determine survival status. The duration of follow-up for the outcomes of interest is 6 months and 1 year.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.

- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

The evidence is presented below by biomarker (*PIK3CA*, *NTRK*, PD-L1, MIS-H/dMMR, TMB) and by recommended therapy.

PIK3CA

Companion Diagnostic Tests

U.S. Food and Drug Administration (FDA) approved companion diagnostic tests for alpelisib in patients with *PIK3CA*-mutated breast cancer include both tissue-based and liquid biopsy assays (see Table 1). These tests are approved to measure 11 variants in the *PIK3CA* gene.

Randomized Controlled Trial

Andre et al (2019) reported results of SOLAR-1 (Clinical Studies of Alpelisib in Breast Cancer 1), a phase 3 trial to evaluate alpelisib plus fulvestrant in patients with HR-positive, HER2-negative advanced breast cancer who had received endocrine therapy previously.⁸ Patients were enrolled into 2 cohorts based on tumor-mutation status (*PIK3CA*-mutated vs not *PIK3CA*-mutated) and randomly assigned within cohorts to receive oral alpelisib plus fulvestrant or placebo plus fulvestrant. *PIK3CA* status was determined with the use of a tumor-tissue sample, and patients had to have adequate tumor tissue for central analysis of *PIK3CA* mutational status. The primary end point was progression-free survival in the cohort of patients with *PIK3CA*-mutated cancer. Among patients with *PIK3CA*-positive tumors who received targeted therapy, PFS was 11.0 months (95% CI, 7.5 to 14.5), compared to 5.7 months (95% CI, 3.7 to 7.4) in *PIK3CA*-positive patients who received standard care (HR 0.65; 95% CI, 0.50 to 0.85). In contrast, the hazard ratio for PFS in the cohort without *PIK3CA*-mutated cancer was not significantly different for the active vs placebo groups.

Table 2. RCT of Alpelisib in Patients with *PIK3CA*-Mutated Breast Cancer-Characteristics

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints	Median Duration of follow-up
					Active	Comparator		
Andre et al (2019) ⁸ , SOLAR-1 NCT02437318	Multiple, US, Asia, Europe (N=34)	198	2015-2018	Men and postmenopausal women with HR-positive, HER2-negative advanced breast cancer, eligible to receive further endocrine therapy after	Alpelisib plus fulvestrant n=169	Placebo plus fulvestrant n=172	Primary: PFS in the cohort of patients with <i>PIK3CA</i> -mutated cancer. Secondary: OS (not reported in the primary	20.0 months (10.7 to 33.3)

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints	Median Duration of follow-up
					Active	Comparator		
				relapse or progression, and receiving or had received aromatase inhibitor treatment in the context of neoadjuvant or adjuvant therapy or for advanced disease.			publication), overall response, clinical benefit (complete or partial response or stable disease for >6 months), safety	

N: sample size; PIK3CA: phosphatidylinositol 3-kinase catalytic alpha polypeptide; RCT: randomized controlled trial; SOLAR-1: Study Assessing the Efficacy and Safety of Alpelisib Plus Fulvestrant in Men and Postmenopausal Women With Advanced Breast Cancer Which Progressed on or After Aromatase Inhibitor Treatment

Table 3. RCT of Alpelisib in Patients with *PIK3CA*-Mutated Breast Cancer- Results

Study	PFS (95% CI)	PFS at 12 months (95% CI)	Overall Response	Clinical Benefit	Adverse events-Grade 3 or 4
Andre et al (2019) ⁸ . SOLAR-1NCT02437318					
N analyzed	341	341	341	341	571
Targeted therapy	11.0 months (95% CI, 7.5 to 14.5)	46.3%	45/169 26.6% (20.1 to 34.0)	45/169 26.6 (20.1 to 34.0)	Serious AEs: 34.9% Hyperglycemia:36.6% Rash: 9.9% Maculopapular rash: 8.8% Diarrhea: 6.7% Discontinuation due to AEs: 25.0% Death: 2.5%
Standard care	5.7 months (95% CI,	32.9%	22/172 12.8 (8.2 to 18.7)	22/172 12.8 (8.2 to 18.7)	Serious AEs: 16.7% Hyperglycemia: 0.7% Rash: 0.3% Maculopapular rash:

Study	PFS (95% CI)	PFS at 12 months (95% CI)	Overall Response	Clinical Benefit	Adverse events- Grade 3 or 4
	3.7 to 7.4)				0.3% Diarrhea: 0.3% Discontinuation due to AEs:4.2% Death: 4.2%
HR (95% CI)	0.65; 95% CI, 0.50 to 0.85				
p	<.001				

CI: confidence interval; HR: hazard ratio; N: sample size; PFS: progression-free survival; PIK3CA: phosphatidylinositol 3-kinase catalytic alpha polypeptide; RCT: randomized controlled trial; SOLAR-1: Study Assessing the Efficacy and Safety of Alpelisib Plus Fulvestrant in Men and Postmenopausal Women With Advanced Breast Cancer Which Progressed on or After Aromatase Inhibitor Treatment

Section Summary: *PIK3CA* Testing

In a randomized, placebo-controlled trial of alpelisib compared to placebo in men and postmenopausal women with advanced breast cancer who had previously received endocrine therapy, PFS was longer among patients with *PIK3CA*-positive tumors who received targeted therapy, PFS was 11.0 months (95% CI, 7.5 to 14.5), compared to 5.7 months (95% CI, 3.7 to 7.4) in *PIK3CA*-positive patients who received standard care. In contrast, the hazard ratio for PFS in the cohort without *PIK3CA*-mutated cancer was not significantly different for the active vs placebo groups. The overall response rate was higher in patients with *PIK3CA*-positive tumors compared to the rate in the standard care group (26.6% [95% CI [20.1 to 34.0] vs 12.8% [8.2-18.7%]), with an acceptable side effect profile.

NTRK Gene Fusions

Companion Diagnostic Tests

There is currently no FDA approved companion diagnostic test for entrectinib. FoundationOne CDX is an approved companion diagnostic test for larotrectinib.

Nonrandomized Trials of Targeted Treatment

Entrectinib

Doebele et al (2020) reported an analysis of data from 3 Phase 1-2 trials of entrectinib in patients with *NTRK*-fusion solid tumors (Table 4).⁹ Of 54 patients included in the analysis, 6 had breast cancer (11%). Patients were assessed for eligibility for the 3 trials using either local molecular profiling or central RNA-based next-generation sequencing to test for the presence of *NTRK* fusions. The primary endpoints were objective response and duration of response. PFS and OS were secondary endpoints.

Of the total cohort of 54 patients, 31 had an objective response (57%; 95% CI 43.2–70.8) (Table 5). Four patients (7%) had a complete response and 27 a partial response (50%). Responses were recorded in all tumor types, including 5 (83%; 36–100) of 6 patients with breast cancer. Median PFS for the full cohort was 11 months (95% CI 8.0–1) and median overall survival was 21

months (95% CI 14.9 to not estimable). There were 7 serious treatment-related adverse events (10%), and 3 (4%) patients discontinued due to a treatment-related adverse event.

Table 4. Entrectinib in *NTRK*-Fusion-Positive Solid Tumors - Study Characteristics

Studies	Design	Countries	Sites	Dates	Participants	Intervention	Endpoints
Doebele et al (2020) ⁹ ; STARTRK-1 (NCT02097810); STARTRK-2 (NCT02568267); ALKA-372-001 (EudraCT, 2012-000148-88)	Phase 1 (STARTRK-1 and ALKA) and Phase 2 (STARTRK-2)	STARTRK-1: US, Spain, Korea STARTRK-2: multiple (N=15) ALKA: Italy	STARTRK1: 10 sites STARTRK-2: 150 sites ALKA: 2 sites	STARTRK-1: August 2014-May 2018 STARTRK-2: November 2015-ongoing ALKA: October 2012-March 2018	54 adults with metastatic or locally advanced NTRK fusion-positive solid tumors; included patients with 10 different tumor types and 19 different histologies (11%) had breast tumors	Entrectinib	Primary: objective response, duration of response Secondary: PFS, OS, clinical benefit rate, time to CNS progression, and safety.

CNS: central nervous system; NTRK: neurotrophic-tropomyosin receptor kinase; OS: overall survival; PFS: progression-free survival; STARTRK-1: Study of Oral RXDX-101 in Adult Patients with Locally Advanced or Metastatic Cancer Targeting NTRK1, NTRK2, NTRK3, ROS1, or ALK Molecular Alterations; STARTRK-2: Basket Study of Entrectinib (RXDX-101) for the Treatment of Patients With Solid Tumors Harboring NTRK 1/2/3 (Trk A/B/C), ROS1, or ALK Gene Rearrangements (Fusions)

Table 5. Entrectinib in *NTRK*-Fusion-Positive Solid Tumors - Study Results

Studies	Objective Response	Duration of Response	Median PFS	Median OS	Adverse Events
Doebele et al (2020) ⁹ ; STARTRK-1 (NCT02097810); STARTRK-2 (NCT02568267); ALKA-372-001 (EudraCT, 2012-000148-88)					
N analyzed	54	54	54	54	68
	31/54 (57%; 95% CI 43.2-70.8)	10 months (95% CI 7.1	11 months (95% CI 8.0-1)	21 months (95% CI	7 serious treatment-related adverse events (10%) 3

Studies	Objective Response	Duration of Response	Median PFS	Median OS	Adverse Events
	<ul style="list-style-type: none"> 4 (7%) complete response 27 (50%) partial response. Responses were recorded in all tumor types, including 5 (83%; 36–100) of 6 patients with breast cancer,	to not estimable)		14.9 to not estimable)	(4%) patients discontinued due to a treatment-related adverse events deaths (9%)

CI: confidence interval; N: sample size; NTRK: neurotrophic-tropomyosin receptor kinase; OS: overall survival; PFS: progression-free survival; STARTRK-1: Study of Oral RDX-101 in Adult Patients with Locally Advanced or Metastatic Cancer Targeting NTRK1, NTRK2, NTRK3, ROS1, or ALK Molecular Alterations; STARTRK-2: Basket Study of Entrectinib (RDX-101) for the Treatment of Patients With Solid Tumors Harboring NTRK 1/2/3 (Trk A/B/C), ROS1, or ALK Gene Rearrangements (Fusions)

Larotrectinib

Hong et al (2020) reported an analysis of 3 phase 1-2 trials of larotrectinib in patients with *NTRK*-fusion positive solid tumors in adults and children.¹⁰

NTRK fusions were identified by next-generation sequencing, according to the procedures and analytic pipelines established by each laboratory, or by fluorescence in situ hybridization. The trials included adults and children with 17 different solid tumors. Five patients had breast cancer (3%).

These results were consistent with a preliminary analysis of data from these trials reported by Drilon et al in 2018.¹¹

Table 6. Larotrectinib in *NTRK*-Fusion-Positive Solid Tumors - Study Characteristics

Study	Dates	Participants	Intervention	Endpoints
Hong et al (2020) ¹⁰ , NCT02122913, NCT02637687, NCT02576431	May 2014-Feb 2019	159 adults and children with locally advanced or metastatic <i>NTRK</i> -fusion positive solid tumors.5 (3%) with breast cancer	Larotrectinib	Primary: Objective response, as assessed by an independent radiology review committee Secondary: Overall response according to the investigator’s assessment, duration of response, PFS, and safety.

NTRK: neurotrophic-tropomyosin receptor kinase; PFS: progression-free survival

Table 7. Larotrectinib in *NTRK*-Fusion-Positive Solid Tumors - Study Results

Study	Overall response	Duration of response	PFS	OS	Adverse events
Hong et al (2020) ¹⁰ , NCT02122913, NCT02637687, NCT02576431					
N analyzed	153	108	159	159	260 (expanded safety population)
Targeted therapy	<p>Overall: 79% (95% CI 72 to 85) Complete: 16% of the patients (24 patients) had a complete response, Partial: 63% (97) had a partial response, Stable disease: 12% (19) had stable disease, Progressive disease: 6% (9) had progressive disease Not evaluated due to early withdrawal for clinical deterioration: 3% (4) Patients with breast cancer (n=4): 3 (75%; 19%-99%)</p>	<p>Median 35.2 months (95% CI 22.8-NE). At 12 months 80% (95% CI 71-89) NE for patients with breast cancer</p>	<p>Median: 28.3 months (95% CI 22.1-NE) At 12 months: 67% (95% CI 58-76)</p>	<p>Median: 44.4 months (95% CI 36.5-NE) Proportion surviving at 12 months: 88% (95% CI 83-94)</p>	<p>23 deaths (14%) at median follow-up of 13.9 months The most common grade 3 or worse treatment-emergent adverse events (regardless of attribution) were anemia (25 [10%] of 260 patients) and decreased neutrophil count (14 [5%]; table 4). The most common treatment-emergent serious adverse events were pneumonia (6 [2%] of 260 patients), pyrexia (6 [2%]), abdominal</p>

Study	Overall response	Duration of response	PFS	OS	Adverse events
					pain (5 [2%]), and diarrhea (5 [2%]);

CI: confidence interval; N: sample size; NE: not estimable; NTRK: neurotrophic-tropomyosin receptor kinase; OS: overall survival; PFS: progression-free survival; PFS: progression-free survival

Section Summary: NTRK Gene Fusion Testing

In an analysis of 159 patients with *NTRK*-fusion positive solid tumors who received larotrectinib, including 5 patients with breast tumors, the overall response rate was 79% (95% CI 72-85). The median PFS was 28.3 months (95% CI 22.1 to not estimable), and 67% of patients were progression-free at 12 months (95% CI 58–76). In an integrated analysis of 3 phase 1-2 trials in 54 patients with *NTRK*-positive solid tumors who received entrectinib, 6 of whom had breast cancer, the overall response rate was 57% (95% CI 43.2–70.8). At data cutoff, 16 (30%) of 54 patients had died, and the estimated median overall survival was 21 months (95% CI 14.9 to not estimable). Responses were observed regardless of tumor type or age of the patient.

PD-L1 Testing

FDA Companion Diagnostic Tests

VENTANA PD-L1(SP142) Assay is an approved companion diagnostic test to select patients with triple negative breast cancer for treatment with atezolizumab.

PD-L1 IHC 22C3 pharmDx is an approved companion diagnostic test to select patients with triple negative breast cancer for treatment with

pembrolizumab. https://www.accessdata.fda.gov/cdrh_docs/pdf15/P150013S020B.pdf

Randomized and Nonrandomized Trials of Immunotherapy

Atezolizumab

Schmid et al (2018) reported results of a randomized, placebo-controlled trial of atezolizumab in combination with nab-paclitaxel for patients with metastatic or unresectable triple-negative breast cancer and PD-L1-positive tumors (defined as expression on ≥1% of tumor-infiltrating immune cells).¹² PFS was longer in the group of PD-L1-positive patients who received targeted treatment, compared to those who received placebo (Table 9).

Table 8. RCT of Atezolizumab plus Nab-Paclitaxel in Patients with PD-L1-Positive Triple Negative Breast Cancer - Characteristics

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints
					Active	Comparator	
Schmid et al 2018 ¹² . IMpassion130NCT02425891	41 (Europe, US, Canada, Asia,	246	Jun 2015 -May 2017	Patients with metastatic or unresectab	n=185Atezolizumab + Nab-Paclitaxel	n=184Placebo + Nab-Paclitaxel	Primary: Investigator-assessed PFS and

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints
					Active	Comparator	
	Latin America, Australia)			le locally advanced triple-negative breast cancer with PD-L1-positive tumors (expression on tumor-infiltrating immune cells ≥1%)			OS. Secondary: Rate and duration of objective response, safety

Impassion130: A Study of Atezolizumab in Combination with Nab-Paclitaxel Compared with Placebo with Nab-Paclitaxel for Participants with Previously Untreated Metastatic Triple-Negative Breast Cancer; n: sample size; OS: overall survival; PD-L1: programmed death-ligand 1 ; PFS: progression-free survival; RCT: randomized controlled trial

Table 9. RCT of Atezolizumab plus Nab-Paclitaxel in Patients with PD-L1-Positive Triple Negative Breast Cancer - Results

Study	Median PFS (95% CI)	PFS at 12 months	Median OS	2-Year Rate of OS	Objective response	Median Duration of Response	Adverse events
Schmid et al 2018 ¹² , IMpassion130 NCT02425891							
Number analyzed	369	369	369	369	368		
Targeted therapy	7.5 months (6.7-9.2)	29.1%	25.0 months (22.6-NE)	53.5 (42.3-64.6)	58.9 (51.5-66.1)	8.5 months (7.3-9.7)	Deaths: 64/185 (34.6%)
Standard care	5.0 months (3.8-5.6)	16.4%	15.5 month (13.1-19.4)	36.6 (26.4-46.7)	42.6 (35.4-50.1)	5.5 months (3.7-7.1)	Deaths: 88/184 (47.8%)
HR (95% CI)	0.62; (95% CI, 0.49 to 0.78)		0.62 (95% CI, 0.45-0.86)		1.96 (1.29-2.98)	0.60 (0.43-0.86)	

CI: confidence interval; HR: hazard ratio; Impassion130: A Study of Atezolizumab in Combination with Nab-Paclitaxel Compared with Placebo with Nab-Paclitaxel for Participants with Previously Untreated Metastatic Triple-Negative Breast Cancer ; NE: not estimable; OS: overall survival; PD-L1: programmed death-ligand 1; PFS: progression-free survival; RCT: randomized controlled trial

Pembrolizumab

Two nonrandomized, single-arm trials reported outcomes in a total of 111 patients with PD-L1 positive TNBC treated with pembrolizumab (Tables 10 and 11).^{13,14.}

Table 10. Pembrolizumab in Patients with PD-L1-Positive Triple Negative Breast Cancer - Study Characteristics

Study	Design	Participants	Intervention	Endpoints
Adams et al (2019) ^{13.} KEYNOTE-086 NCT02447003	Nonrandomized, multicohort, phase 2	84 patients with metastatic triple-negative breast cancer 86.9% received prior (neo)adjuvant therapy; none had prior systemic therapy for metastatic disease	Pembrolizumab monotherapy	Primary: Safety Secondary: Objective response, disease control rate, duration of response, PFS, OS
Nanda et al 2016 ^{14.} KEYNOTE-012 NCT01848834	Nonrandomized, multicohort, phase Ib	27 Patients with recurrent or metastatic PD-L1 positive triple-negative breast cancer. Most were heavily pretreated, having received therapy in both the early and advanced disease settings.	Pembrolizumab monotherapy	Primary: OR : defined as percentage of patients with a best overall response of complete response or partial response Secondary: PFS, duration of response, OS

OS: overall survival; PD-L1: programmed death-ligand 1; PFS: progression-free survival

Table 11. Pembrolizumab in Patients with PD-L1-Positive Triple Negative Breast Cancer - Study Results

Study	Response	Median PFS	Duration of Response	OS	Adverse Events
Adams et al (2019) ^{13.} NCT02447003					
N analyzed	84	84			84
Targeted therapy	Objective response rate: 21.4% (95% CI 13.9–31.4)	Median: 2.1 months (95% CI 2.0–2.2) Rate at 6 months: 27.0%	Median: 10.4 months (range 4.2 to 19.2+)	Median 18.0 months (95% CI 12.9–23.0) 6-month rate 81.0% 12-month rate: 61.7%	53 (63.1%) patients experienced 1 or more treatment-related AE, 8 (9.5%) with 1 or more grade 3 event. No grade 4

Study	Response	Median PFS	Duration of Response	OS	Adverse Events
					events, no AEs that led to death ¹ (1.2%) discontinued due to AEs. Most common treatment-related AEs were fatigue (26.2%), nausea (13.1%), and diarrhea (11.9%) ⁴³ deaths (51.2%)
Nanda et al 2016 ¹⁴ .KEYNOTE-012NCT01848834					
N Analyzed	27	22			
C	Overall response rate:18.5% (95% CI, 6.3 to 38.1) Complete response: 1 (3.7%) Partial response: 4 (14.8%) PD 13 (48.1%)	Median 1.9 months (95% CI, 1.7 to 5.5), 6 months PFS: 24.4%	Median not yet reached (range 15.0 to ≥47.3 weeks)	Median : 11.2 months (95% CI, 5.3 to [not reached]) 6 month rate: :66.7% 12-month OS: 43.1%	56.3% of patients experienced at least one treatment-related toxicity, including 15.6% who experienced at least one grade 3 to 5 event. One patient died as a result of disseminated intravascular coagulation(DIC) accompanied by grade 4 decreased blood fibrinogen, both of which were considered by the investigator to be treatment related.

AE: adverse events; CI: confidence interval; OS: overall survival; PD-L1: programmed death-ligand 1; PFS: progression-free survival

Section Summary: PD-L1 Testing

In a placebo controlled trial of atezolizumab in combination with nab-paclitaxel for patients with PD-L1 positive TNBC, median PFS (HR 0.62; 95% CI, 0.49 to 0.78) and OS 0.62 (95% CI, 0.45–0.86) were longer among patients who received the targeted immunotherapy. In 2 nonrandomized trials of pembrolizumab for patients with PD-L1 positive TNBC, the objective response rate was 21.4% (95% CI, 13.9 to 31.4) and 18.5% (95% CI, 6.3 to 38.1).

**MSI-H/dMMR Testing
FDA Companion Diagnostic Tests**

There is no FDA approved test for the detection of MSI-H or dMMR. In clinical trials, the identification of MSI-H or dMMR tumor status for the majority of patients (135/149) was prospectively determined using local laboratory-developed, polymerase chain reaction (PCR) tests for MSI-H status or immunohistochemistry (IHC) tests for dMMR.

**Nonrandomized Trials of Immunotherapy
Pembrolizumab**

Marabelle et al.(2020) reported results of a phase 2 trial of pembrolizumab in 233 previously treated patients with MSI-H solid tumors (Tables 12 and 13), 5 of whom had breast cancer.¹⁵ The overall response rate, the primary outcome, was 34.3% (95% CI, 28.3% to 40.8%). Median PFS was 4.1 months (95% CI, 2.4 to 4.9 months) and median OS was 23.5 months (95% CI, 13.5 months to not reached). Treatment-related adverse events occurred in 151 patients (64.8%). Earlier, Le et al (2015) reported on a small (N = 41) phase 2 trial that compared response to pembrolizumab in patients with solid tumors that did or did not have mismatch repair.¹⁶ Most of the patients had colorectal cancer, but a cohort of 9 patients with dMMR tumors that were not colorectal was included. In the full cohort, mismatch-repair status predicted clinical benefit of pembrolizumab, and patients with dMMR noncolorectal cancer had responses similar to those of patients with dMMR colorectal cancer.

Table 12. Pembrolizumab in Patients with MSI-H/dMMR-Positive Solid Tumors - Study Characteristics

Study	Countries	Sites	Dates	Design	Participants	Interventions	Endpoints
Marabelle et al (2020) ¹⁵ .KEYNOTE-158NCT02628067	Multiple (N=21)	81	Feb 2016-May 2018	Nonrandomized, open-label, multisite phase 2	233 patients 18 years or older with unresectable and/or metastatic incurable noncolorectal solid tumor with disease progression on or intolerance to prior standard therapy. 27 tumor types 5 patients had breast cancer (2.1%)	Pembrolizumab	Primary: Overall response rate Secondary : duration of response, PFS, OS, safety

dMMR: mismatch repair deficient; MSI-H: microsatellite instability-high; N: sample size; OS: overall survival; PFS: progression-free survival

Table 13. Pembrolizumab in Patients with MSI-H/dMMR-Positive Solid Tumors - Study Results

Study	Response	Duration of Response	PFS	OS	Adverse events
<i>Marabelle et al (2020)</i> ¹⁵ KEYNOTE-158 NCT02628067					
N analyzed	233				233
Targeted therapy	Overall response rate: 34.3% (95% CI, 28.3% to 40.8%) Complete: 23 (9.9%) Partial: 57 (24.5%)	Median: not reached, range, 2.9 to 31.3+ months Response 12 months or longer: 86.9% 24 months or longer: 77.6%	Median: 4.1 months (95% CI, 2.4 to 4.9 months) 12 months: 33.9% 24-months: 29.3%	Median: 23.5 months (95% CI, 13.5 months to not reached) 12 months: 60.7% 24-months: 48.9%	Overall, 151 patients (64.8%) had treatment-related adverse events and 34 (14.6%) had grade 3 to 5 treatment-related adverse events, one of which was grade 5 (pneumonia). Eighteen patients (7.7%) had serious treatment-related adverse events, and 22 (9.4%) discontinued treatment because of a treatment-related adverse event Deaths: 113 (48.5%)

CI: confidence interval; dMMR: mismatch repair deficient; MSI-H: microsatellite instability-high; N: sample size; OS: overall survival; PFS: progression-free survival

Section Summary: MSI-H/dMMR Testing

In a phase 2 trial of pembrolizumab in 233 previously treated patients with MSI-H solid tumors, the overall response rate was 34.3% (95% CI, 28.3% to 40.8%). Median PFS was 4.1 months (95% CI, 2.4 to 4.9 months) and median OS was 23.5 months (95% CI, 13.5 months to not reached). Treatment-related adverse events occurred in 151 patients (64.8%).

Tumor Mutational Burden FDA Companion Diagnostic Test

FoundationOne is an FDA approved companion diagnostic test to measure TMB in patients with solid tumors being considered for pembrolizumab treatment.

Nonrandomized Trials

Ott et al (2018) reported an exploratory analysis of the association between TMB and response to pembrolizumab. All patients in the study were PD-L1 positive.¹⁷

Marabelle et al (2020) reported the association of high TMB to response to pembrolizumab in patients with solid tumors enrolled in a prespecified exploratory analysis of the KEYNOTE-158 study.¹⁸ High TMB was defined as >10 mutations per megabase according to the FoundationOne CDx panel. The proportion of patients with an objective response in the tTMB-high group was 29%. At a median follow-up of approximately 3 years, the median duration of response was not reached in the tTMB-high group and was 33·1 months in the non-tTMB-high group. Notably, TMB-high status was associated with improved response irrespective of PD-L1. Median PFS and OS did not differ between the high and non-high TMB groups. Objective responses were observed in 24 (35%; 95% CI 24–48) of 68 participants who had both tTMB-high status and PD-L1-positive tumours (ie, PD-L1 combined positive score of ≥1) and in 6 (21%; 8–40) of 29 participants who had tTMB-high status and PD-L1-negative tumors.

Table 14. Association of TMB to Response to Pembrolizumab in Patients with Solid Tumors Enrolled in the KEYNOTE-158 Study

Study	Response	Median Duration of Response	Median PFS	Median OS (95% CI)	Adverse events
Marabelle et al (2020) ¹⁸ , NCT02628067					
TMB ≥10 per megabase; N=102	Objective Response: 29% (21-39%) Complete: 4%	Median not yet reached range 2·2+ to 34·8+ months	2·1 months (95% CI 2·1–4·1)	Median: 11·7 months (95% CI 9·1–19·1)	Deaths: 69/102 (68%)
TMB <10 per megabase; N=688	Objective Response: 6% (5-8%) Complete: 2%	Median 33·1 months (4·0 to 35·7+)	2·1 months (2·1–2·2)	12·8 months (11·1–14·1)	534/688 (78%)

CI: confidence interval N: sample size; OS: overall survival; PFS: progression-free survival; TMB: tumor mutational burden

Section Summary: Tumor Mutational Burden

In a prespecified subgroup analysis of a nonrandomized trial of pembrolizumab in patients with various solid tumors, objective responses were observed in 24 (35%; 95% CI 24–48) of 68 participants who had both tTMB-high status and PD-L1-positive tumors and in 6 (21%; 8–40) of 29 participants who had tTMB-high status and PD-L1-negative tumors. In exploratory analyses, retrospective observational studies have reported an association between higher TMB and longer

PFS and OS in patients receiving immunotherapy. These results need to be confirmed in additional, well-designed prospective studies.

Circulating Tumor DNA Testing to Select Targeted Treatment Clinical Context and Test Purpose

The purpose of circulating tumor DNA testing in patients who have advanced or metastatic breast cancer is to inform a decision about selecting targeted treatment.

The question addressed in this evidence review is: Does biomarker testing using circulating tumor DNA improve the net health outcome in individuals with breast cancer?

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest is individuals with advanced or metastatic breast cancer..

Interventions

The test being considered is circulating tumor DNA testing.

Comparators

Tissue biopsy is used to make decisions about targeted treatment or immunotherapy for metastatic breast cancer.

Outcomes

Liquid biopsies are easier to obtain and less invasive than tissue biopsies. True-positive liquid biopsy test results lead to the initiation of appropriate treatment (eg, targeted therapy) without a tissue biopsy. False-positive liquid biopsy test results lead to the initiation of inappropriate therapy, which could shorten progression-free survival.

In patients able to undergo a tissue biopsy, negative liquid biopsies reflex to tissue testing. In patients unable to undergo a tissue biopsy, a negative liquid biopsy result would not change empirical treatment. Therefore, health outcomes related to negative test results do not differ between liquid biopsy and tissue biopsy.

Study Selection Criteria

For the evaluation of clinical validity of the circulating tumor DNA test, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores)
- Included a suitable reference standard (describe the reference standard)
- Patient/sample clinical characteristics were described
- Patient/sample selection criteria were described.

Companion Diagnostic Test for Targeted Treatment

FoundationOne Liquid is FDA approved as a companion diagnostic test for alpelisib (Piqray) for measuring 11 variants in the *PIK3CA* gene.

Clinical Validity

Woodhouse 2020 reported the clinical validity of FoundationOne liquid for detection of *PIK3CA* alterations through retrospective testing of plasma samples of patients enrolled in the SOLAR-1 trial.¹⁹

All available plasma samples from patients collected at baseline prior to randomization into the SOLAR-1 clinical trial were tested with FoundationOne Liquid CDx, with results compared to tissue genotyping performing using the SOLAR-1 CTA. The positive predictive agreement and negative predictive agreement between FoundationOne Liquid CDx and the tissue-based CTA assay were 71.7% (95% CI 65.4%, 77.5%) and 100% (97.2%, 100%), respectively.

Table 15. Clinical Validity of FoundationOne Liquid CDx to detect *PIK3CA* Alterations-Results

Study	Study Population	Reference Standard	Initial N	Final N	Excluded Samples	Prevalence of Condition	Clinical Validity(95% Confidence Interval)	
							PPA	NPA
Woodhouse et al (2020) ¹⁹	Plasma samples from advanced or metastatic HR-positive, HER2-negative breast cancer patients enrolled in the SOLAR-1 trial	Tumor tissue PCR-based clinical trial assay	432	375	16	230 positive 129 negative	71.7% (95% CI 65.4%, 77.5%)	100% (97.2%, 100%)

CI: confidence interval; N: sample size; NPA: negative predictive agreement; PCR: polymerase chain reaction; *PIK3CA*: phosphatidylinositol 3-kinase catalytic alpha polypeptide; PPA: positive predictive agreement

Clinical Utility

In the SOLAR-1 trial (discussed above in the section on *PIK3CA* testing), the clinical efficacy of alpelisib in combination with fulvestrant for the FoundationOne Liquid CDx-positive population was demonstrated with an estimated 54% risk reduction in disease progression or death in the alpelisib plus fulvestrant arm compared to the placebo plus fulvestrant arm (HR = 0.46, 95% CI: 0.30, 0.70).⁸

Section Summary: Circulating Tumor DNA Testing

Clinical validity of the FoundationOne Liquid CDx test was demonstrated through retrospective testing of plasma samples of patients enrolled in the SOLAR-1 trial. The positive predictive agreement and negative predictive agreement between FoundationOne Liquid CDx and the tissue-based assay were 71.7% (95% CI 65.4%, 77.5%) and 100% (97.2%, 100%), respectively. Among the circulating tumor DNA-positive population, there was an estimated 54%

risk reduction in disease progression or death in the alpelisib plus fulvestrant arm compared to the placebo plus fulvestrant arm (HR = 0.46, 95% CI: 0.30, 0.70).

Circulating Tumor Cell Testing to Select Targeted Treatment

Clinical Context and Test Purpose

The purpose of testing circulating tumor cells in patients who have breast cancer is to inform a decision about selecting targeted treatment.

The question addressed in this evidence review is: Does CTC testing improve the net health outcome in individuals with breast cancer?

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest is individuals with recurrent or metastatic breast cancer

Interventions

The test being considered is CTC testing.

The primary reason for CTCs would be to aid in decision-making about alternative treatment. CTC testing has been proposed as a method to guide the choice between chemotherapy and endocrine therapy as first-line treatment, or to change early to an alternative chemotherapy regimen in patients for whom chemotherapy has failed to reduce CTCs.

Comparators

Decisions about first-line treatment and alternative treatments in metastatic breast cancer are based on clinical evaluation and biopsy.

Outcomes

The general outcomes of interest in oncology are overall survival, disease-specific survival, quality of life, treatment-related mortality and morbidity.

Follow-up at 6-12 months is of interest to monitor outcomes.

Study Selection Criteria

For the evaluation of clinical validity of CTC test, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores)
- Included a suitable reference standard (describe the reference standard)
- Patient/sample clinical characteristics were described
- Patient/sample selection criteria were described.

Clinical Validity

Systematic reviews and meta-analyses have described an association between CTCs and poor prognosis in metastatic breast cancer. [20](#).

Clinical Utility

Randomized Controlled Trials

Two RCTs have evaluated the clinical utility of using CTC to guide treatment decisions in patients with metastatic breast cancer.

Smerage et al (2014) reported on the results of an RCT of patients with metastatic breast cancer and persistently increased CTC levels to test whether changing chemotherapy after 1 cycle of first-line therapy could improve overall survival.²¹ Level of CTCs were enumerated using the CellSearch system. Five or more CTCs per 7.5 mL WB was considered an increased level, and it served as the cut point for separation of favorable versus unfavorable prognosis. Patients who did not have increased CTC levels at baseline remained on initial therapy until progression (arm A), patients with initially increased CTC levels that decreased after 21 days of therapy remained on initial therapy (arm B), and patients with persistently increased CTC levels after 21 days of therapy were randomized to continue initial therapy (arm C1) or change to an alternative chemotherapy (arm C2). There were 595 eligible and evaluable patients, 276 (46%) of whom did not have increased CTC levels (arm A). Of patients with initially increased CTC levels, 31 (10%) were not retested, 165 were assigned to arm B, and 123 were randomized to arms C1 or C2. There was no difference in median OS between arms C1 (10.7 months) and C2 12.5 months; p=0.98). CTC levels were strongly prognostic, with a median OS for arms A, B, and C (C1 and C2 combined) of 35 months, 23 months, and 13 months, respectively (p<0.001). While the trial showed the prognostic significance of CTCs in patients with metastatic breast cancer, changing to an alternative chemotherapeutic regimen did not improve outcomes in patients whose CTCs were not reduced after 1 cycle of first-line chemotherapy.

More recently, Bidard et al (2020) reported on a noninferiority trial comparing CTC-driven vs clinician driven first-line therapy choice in patients with metastatic breast cancer.²² Median PFS was 15.5 months (95% CI, 12.7-17.3) in the CTC arm and 13.9 months (95% CI, 12.2-16.3) in the standard arm. The primary end point was met, with a hazard ratio of 0.94 (90% CI, 0.81-1.09).

Table 17. RCTs of CTC-Guided Treatment in Breast Cancer- Characteristics

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints
					Active	Comparator	
Smerage et al (2014) ²¹ NCT00382018			Oct 2006-Mar 2012	Women with histologically confirmed breast cancer and clinical and/or radiographic evidence of metastatic disease Persistent increased CTCs following 1 cycle of chemotherapy	Changing chemotherapy after 1 cycle of first-line chemotherapy N=59	Continued initial therapy N=64	OS, PFS

Study	Countries	Sites	Dates	Participants	Interventions		Endpoints
					Active	Comparator	
Bidard et al 2020) ²² .	France	17	Feb 2012-Jul 2016	778 women with hormone-receptor positive, HER2-negative metastatic breast	CTC-driven treatment choice N=391	Clinician-driven treatment choice N=387	PFS, OS, rate of treatment changes, AEs

AEs: adverse events; CTC: circulating tumor cell; HER2: human epidermal growth factor receptor 2; N: sample size; OS: overall survival; PFS: progression-free survival; RCTs: randomized controlled trials

Table 18. RCTs of CTC-Guided Treatment in Breast Cancer- Results

Study	OS	PFS
Smerage et al (2014) ²¹ .		
N analyzed		
CTC-Directed Treatment	12.5 months	4.6 months
Standard care	10.7 months	3.5 months
HR (95% CI)	1.00 (95% CI, 0.69 to 1.47)	0.92 (95% CI, 0.64 to 1.32)
p	.98	.64
Bidard et al 2020) ²² .		
N analyzed		
CTC-directed treatment		15.5 months (12.7-17.3)
Standard care		13.9 months (12.2-16.3)
HR (95% CI)		0.94 (0.81 to 1.09)

CI: confidence interval; CTC: circulating tumor cell; HR: hazard ratio; N: sample size; OS: overall survival; PFS: progression-free survival; RCTs: randomized controlled trials

Section Summary: Circulating Tumor Cell Testing

Systematic reviews and meta-analyses have described an association between CTCs and poor prognosis in metastatic breast cancer, but evidence that CTC-driven treatment improves health outcomes is lacking. One RCT found no improvement in OS or PFS with CTC-driven treatment (early switching to a different chemotherapy regimen) compared to continuing initial therapy. A second RCT found that CTC-driven first-line therapy was noninferior to clinician-driven therapy in previously untreated patients with metastatic breast cancer (hazard ratio for PFS 0.94; 95% CI 0.81 to 1.09).

Summary of Evidence

For individuals with hormone receptor-positive, HER2 negative advanced or metastatic breast cancer who receive *PIK3CA* gene testing to select targeted treatment, the evidence includes a randomized, placebo-controlled trial of alpelisib compared to placebo in men and postmenopausal women with advanced breast cancer who had previously received endocrine therapy. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. Among patients with *PIK3CA*-positive tumors who received targeted therapy, PFS was 11.0 months (95% CI, 7.5 to 14.5), compared to 5.7 months (95% CI, 3.7 to 7.4) in *PIK3CA*-positive patients who received standard care. In contrast, the hazard ratio for PFS in the cohort without *PIK3CA*-mutated cancer was not significantly different for the active vs placebo groups. The overall response rate was higher in patients with *PIK3CA*-positive tumors compared to the rate in the standard care group (26.6% [95% CI [20.1- 34.0] vs 12.8% [8.2- 18.7%]). The evidence is sufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with locally advanced or metastatic breast cancer being considered for immunotherapy who receive *NTRK* gene fusion testing, the evidence includes integrated analyses of nonrandomized trials of larotrectinib and entrectinib in patients with *NTRK*-fusion positive solid tumors. Relevant outcomes are OS, disease-specific survival, test validity, QOL, and treatment-related morbidity. In an analysis of 159 patients with *NTRK*-fusion positive solid tumors who received larotrectinib, including 5 patients with breast tumors, the overall response rate was 79% (95% CI 72 to 85). The median PFS was 28.3 months (95% CI 22.1 to not estimable), and 67% of patients were progression-free at 12 months (95% CI 58–76). In an integrated analysis of 3 phase 1-2 trials in 54 patients with *NTRK*-positive solid tumors who received entrectinib, 6 of whom had breast cancer, the overall response rate was 57% (95% CI 43.2–70.8). At data cutoff, 16 (30%) of 54 patients had died, and the estimated median overall survival was 21 months (95% CI 14.9 to not estimable). Responses were observed regardless of tumor type or age of the patient. The evidence is sufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with recurrent, metastatic, or unresectable hormone receptor-negative, HER2 negative (triple negative) breast cancer being considered for immunotherapy who receive PD-L1 testing, the evidence includes a RCT of atezolizumab and nonrandomized trials of pembrolizumab. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. In a placebo controlled trial of atezolizumab in combination with nab-paclitaxel for patients with PD-L1 positive TNBC, median PFS (HR 0.62; 95% CI, 0.49 to 0.78) and OS 0.62 (95% CI, 0.45–0.86) were longer among patients who received the targeted immunotherapy. In 2 nonrandomized trials of pembrolizumab for patients with PD-L1 positive TNBC, the objective response rate was 21.4% (95% CI, 13.9 to 31.4) and 18.5% (95% CI, 6.3 to 38.1). The evidence is sufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with unresectable or metastatic breast cancer who are being considered for immunotherapy who receive MSI-H/dMMR testing, the evidence includes nonrandomized trials of pembrolizumab in patients with solid tumors. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. In a phase 2 trial of pembrolizumab in 233 previously treated patients with MSI-H solid tumors, the overall response

rate was 34.3% (95% CI, 28.3% to 40.8%). Median PFS was 4.1 months (95% CI, 2.4 to 4.9 months) and median OS was 23.5 months (95% CI, 13.5 months to not reached). Treatment-related adverse events occurred in 151 patients (64.8%). The evidence is sufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with unresectable or metastatic breast cancer who are being considered for immunotherapy who receive tumor mutational burden (TMB) testing, the evidence includes prospective and retrospective subgroup analyses of nonrandomized trials. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. In a prespecified subgroup analysis of a nonrandomized trial of pembrolizumab in patients with various solid tumors, objective responses were observed in 24 (35%; 95% CI 24–48) of 68 participants who had both tTMB-high status and PD-L1-positive tumors and in 6 (21%; 8–40) of 29 participants who had tTMB-high status and PD-L1-negative tumors. In exploratory analyses, retrospective observational studies have reported an association between higher TMB and longer PFS and OS in patients receiving immunotherapy. These results need to be confirmed in additional, well-designed prospective studies. The evidence is insufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with hormone receptor-positive, HER2 negative advanced or metastatic breast cancer who receive circulating tumor DNA testing to select targeted treatment, the evidence includes a randomized, placebo-controlled trial of alpelisib compared to placebo in men and postmenopausal women with advanced breast cancer who had previously received endocrine therapy. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. Clinical validity of the FoundationOne Liquid CDx test was demonstrated through retrospective testing of plasma samples of patients enrolled in the SOLAR-1 trial. The positive predictive agreement and negative predictive agreement between FoundationOne Liquid CDx and the tissue-based assay were 71.7% (95% CI 65.4%, 77.5%) and 100% (97.2%, 100%), respectively. Among the circulating tumor DNA-positive population, there was an estimated 54% risk reduction in disease progression or death in the alpelisib plus fulvestrant arm compared to the placebo plus fulvestrant arm (HR = 0.46, 95% CI: 0.30, 0.70). The evidence is sufficient to determine that the technology results in an improvement in the net health outcomes.

For individuals with metastatic breast cancer who receive CTC testing to guide treatment decisions, the evidence includes randomized controlled trials, observational studies, and systematic reviews. Relevant outcomes include overall survival, disease-specific survival, test validity, quality of life, and treatment-related morbidity. Systematic reviews and meta-analyses have described an association between CTCs and poor prognosis in metastatic breast cancer, but evidence that CTC-driven treatment improves health outcomes is lacking. One RCT found no improvement in OS or PFS with CTC-driven treatment (early switching to a different chemotherapy regimen) compared to continuing initial therapy. A second RCT found that CTC-driven first-line therapy was noninferior to clinician-driven therapy in previously untreated patients with metastatic breast cancer (hazard ratio for PFS 0.94; 95% CI 0.81 to 1.09). The evidence is insufficient to determine that the technology results in an improvement in the net health outcomes.

SUPPLEMENTAL INFORMATION
Professional Society Guidelines
National Comprehensive Cancer Network

Table 19 summarizes National Comprehensive Cancer Network guidelines (v.6.2020) on biomarker testing for the biomarkers included in this policy.¹ The guidelines state that the use of circulating tumor cells or circulating tumor DNA in metastatic breast cancer is not yet included in algorithms for disease assessment and monitoring. For patients being considered for treatment with alpelisib, testing for PIK3CA with either tissue or liquid biopsy is recommended (category of evidence 2A). The guidelines do not address TMB testing.

Table 19. National Comprehensive Cancer Network Guidelines on Biomarker Testing for Targeted Treatment of Breast Cancer

Biomarker	Breast Cancer Subtype	FDA Approved Agents	Testing Recommendation	Targeted Therapy Category of Evidence	Targeted Therapy Category of Preference
PIK3CA	HR-positive/HER2-negative	Alpelisib + fulvestrant	For HR-positive/HER2-negative breast cancer, assess for PIK3CA mutations with tumor or liquid biopsy to identify candidates for alpelisib plus fulvestrant. PIK3CA mutation testing can be done on tumor tissue or ctDNA in peripheral blood (liquid biopsy). If liquid biopsy is negative, tumor tissue testing is recommended.	1	Preferred second-line therapy
PD-L1 expression (≥1% on tumor-infiltrating immune cells)	HR-negative/HER2-negative	Atezolizumab + albumin-bound paclitaxel	For triple-negative breast cancer, assess PD-L1 expression biomarker status on tumor-infiltrating immune cells to identify patients most likely to benefit from candidates for atezolizumab plus albumin-bound paclitaxel	2A	Preferred
NTRK fusion	Any	Larotrectinib Entrectinib	No specific testing recommendation. If a patient with recurrent/stage IV breast cancer presents with a tumor with an NTRK fusion, treatment with an NTRK inhibitor is an option if no satisfactory alternative treatments exist or that have progressed following	2A	Useful in certain circumstances

Biomarker	Breast Cancer Subtype	FDA Approved Agents	Testing Recommendation	Targeted Therapy Category of Evidence	Targeted Therapy Category of Preference
			treatment, treatment with an NTRK inhibitor is an option		
MSI-H/dMMR	Any	Pembrolizumab	No specific testing recommendation. If a patient with recurrent/stage IV breast cancer has a tumor with a MSI-H/dMMR mutation, whose disease has progressed following prior treatments and no satisfactory alternative treatments exist, treatment with pembrolizumab is an option	2A	Useful in certain circumstances

Source: Adapted from National Comprehensive Cancer Network guidelines on Breast Cancer (v.6.2020)¹

Ongoing and Unpublished Clinical Trials

Some currently unpublished trials that might influence this review are listed in Table 20.

Table 20. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
<i>Ongoing</i>			
NCT02889978 ^a	The Circulating Cell-free Genome Atlas Study	15000	Mar 2024
NCT02568267 ^a	An Open-Label, Multicenter, Global Phase 2 Basket Study of Entrectinib for the Treatment of Patients With Locally Advanced or Metastatic Solid Tumors That Harbor NTRK1/2/3, ROS1, or ALK Gene Rearrangements	500	Dec 2024
NCT04098640	Molecular Profiling Using FoundationOne CDx in Young (<50 Years of Age) Patients With Metastatic Breast Cancer (ML41263)	200	Jul 2021
NCT04591431	The Rome Trial From Histology to Target: the Road to Personalize Target Therapy and Immunotherapy	384	Aug 2024

NCT: national clinical trial.

^a Denotes industry-sponsored or cosponsored trial.

CODING

The following codes for treatment and procedures applicable to this policy are included below for informational purposes. This may not be a comprehensive list of procedure codes applicable to this policy.

Inclusion or exclusion of a procedure, diagnosis or device code(s) does not constitute or imply member coverage or provider reimbursement. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

The code(s) listed below are medically necessary ONLY if the procedure is performed according to the "Policy" section of this document.

CPT/HCPCS

- 0037U Targeted genomic sequence analysis, solid organ neoplasm, DNA analysis of 324 genes, interrogation for sequence variants, gene copy number amplifications, gene rearrangements, microsatellite instability and tumor mutational burden (PLA for the FoundationOne CDx™ (F1CDx®) test)
- 0048U Oncology (solid organ neoplasia), DNA, targeted sequencing of protein-coding exons of 468 cancer-associated genes, including interrogation for somatic mutations and microsatellite instability, matched with normal specimens, utilizing formalin-fixed paraffin-embedded tumor tissue, report of clinically significant mutation(s) (PLA code for the MSK-IMPACT™ (Integrated Mutation Profiling of Actionable Cancer Targets), Memorial Sloan Kettering Cancer Center)
- 0155U Oncology (breast cancer), DNA, PIK3CA (phosphatidylinositol-4,5-bisphosphate 3-kinase, catalytic subunit alpha) (eg, breast cancer) gene analysis (ie, p.C420R, p.E542K, p.E545A, p.E545D [g.1635G>T only], p.E545G, p.E545K, p.Q546E, p.Q546R, p.H1047L, p.H1047R, p.H1047Y), utilizing formalin-fixed paraffin-embedded breast tumor tissue, reported as PIK3CA gene mutation status (PLA code for the theascreen® PIK3CA RGQ PCR Kit from QIAGEN)
- 0177U Oncology (breast cancer), DNA, PIK3CA (phosphatidylinositol-4,5-bisphosphate 3-kinase catalytic subunit alpha) gene analysis of 11 gene variants utilizing plasma, reported as PIK3CA gene mutation status (PLA code for the theascreen® PIK3CA RGQ PCR Kit test from QIAGEN) (eff 7/1/2020)
- 0211U Oncology (pan-tumor), DNA and RNA by next-generation sequencing, utilizing formalin-fixed paraffin-embedded tissue, interpretative report for single nucleotide variants, copy number alterations, tumor mutational burden, and microsatellite instability, with therapy association (PLA code for the MI Cancer Seek™ – NGS Analysis from Caris MPI d/b/a Caris Life Sciences.) (eff 10/1/2020)
- 0239U Targeted genomic sequence analysis panel, solid organ neoplasm, cell-free DNA, analysis of 311 or more genes, interrogation for sequence variants, including substitutions, insertions, deletions, select rearrangements, and copy number variations (eff 1/1/2021)
- 81191 NTRK1 (neurotrophic receptor tyrosine kinase 1) (eg, solid tumors) translocation analysis (new eff 1/1/2022)
- 81192 NTRK2 (neurotrophic receptor tyrosine kinase 2) (eg, solid tumors) translocation analysis (new eff 1/1/2022)

CPT/HCPCS

- 81193 NTRK3 (neurotrophic receptor tyrosine kinase 3) (eg, solid tumors) translocation analysis (new eff 1/1/2022)
- 81994 NTRK (neurotrophic-tropomyosin receptor tyrosine kinase 1, 2, and 3) (eg, solid tumors) translocation analysis (new eff 1/1/2022)
- 81301 Microsatellite instability analysis (eg, hereditary non-polyposis colorectal cancer, Lynch syndrome) of markers for mismatch repair deficiency (eg, BAT25, BAT26), includes comparison of neoplastic and normal tissue, if performed
- 81309 PIK3CA (phosphatidylinositol-4, 5-biphosphate 3-kinase, catalytic subunit alpha) (eg, colorectal and breast cancer) gene analysis, targeted sequence analysis (eg, exons 7, 9, 20)
- 81445 Targeted genomic sequence analysis panel, solid organ neoplasm, DNA analysis, and RNA analysis when performed, 5-50 genes (eg, ALK, BRAF, CDKN2A, EGFR, ERBB2, KIT, KRAS, NRAS, MET, PDGFRA, PDGFRB, PGR, PIK3CA, PTEN, RET), interrogation for sequence variants and copy number variants or rearrangements, if performed
- 81455 Targeted genomic sequence analysis panel, solid organ or hematolymphoid neoplasm, DNA analysis, and RNA analysis when performed, 51 or greater genes (eg, ALK, BRAF, CDKN2A, CEBPA, DNMT3A, EGFR, ERBB2, EZH2, FLT3, IDH1, IDH2, JAK2, KIT, KRAS, MLL, NPM1, NRAS, MET, NOTCH1, PDGFRA, PDGFRB, PGR, PIK3CA, PTEN, RET), interrogation for sequence variants and copy number variants or rearrangements, if performed
- 88360 Morphometric analysis, tumor immunohistochemistry (eg, Her-2/neu, estrogen receptor/progesterone receptor), quantitative or semiquantitative, per specimen, each single antibody stain procedure; manual
- 88361 Morphometric analysis, tumor immunohistochemistry (eg, Her-2/neu, estrogen receptor/progesterone receptor), quantitative or semiquantitative, per specimen, each single antibody stain procedure; using computer-assisted technology
- 81479 Unlisted molecular pathology procedure

ICD-10 DIAGNOSES	
C50.011	Malignant neoplasm of nipple and areola, right female breast
C50.012	Malignant neoplasm of nipple and areola, left female breast
C50.019	Malignant neoplasm of nipple and areola, unspecified female breast
C50.02	Malignant neoplasm of nipple and areola, male
C50.021	Malignant neoplasm of nipple and areola, right male breast
C50.022	Malignant neoplasm of nipple and areola, left male breast
C50.029	Malignant neoplasm of nipple and areola, unspecified male breast
C50.111	Malignant neoplasm of central portion of right female breast
C50.112	Malignant neoplasm of central portion of left female breast
C50.119	Malignant neoplasm of central portion of unspecified female breast
C50.121	Malignant neoplasm of central portion of right male breast
C50.129	Malignant neoplasm of central portion of unspecified male breast
C50.211	Malignant neoplasm of upper-inner quadrant of right female breast

ICD-10 DIAGNOSES	
C50.212	Malignant neoplasm of upper-inner quadrant of left female breast
C50.219	Malignant neoplasm of upper-inner quadrant of unspecified female breast
C50.221	Malignant neoplasm of upper-inner quadrant of right male breast
C50.222	Malignant neoplasm of upper-inner quadrant of left male breast
C50.229	Malignant neoplasm of upper-inner quadrant of unspecified male breast
C50.311	Malignant neoplasm of lower-inner quadrant of right female breast
C50.312	Malignant neoplasm of lower-inner quadrant of left female breast
C50.319	Malignant neoplasm of lower-inner quadrant of unspecified female breast
C50.321	Malignant neoplasm of lower-inner quadrant of right male breast
C50.322	Malignant neoplasm of lower-inner quadrant of left male breast
C50.329	Malignant neoplasm of lower-inner quadrant of unspecified male breast
C50.411	Malignant neoplasm of upper-outer quadrant of right female breast
C50.422	Malignant neoplasm of upper-outer quadrant of left male breast
C50.429	Malignant neoplasm of upper-outer quadrant of unspecified male breast
C50.511	Malignant neoplasm of lower-outer quadrant of right female breast
C50.512	Malignant neoplasm of lower-outer quadrant of left female breast
C50.519	Malignant neoplasm of lower-outer quadrant of unspecified female breast
C50.521	Malignant neoplasm of lower-outer quadrant of right male breast
C50.522	Malignant neoplasm of lower-outer quadrant of left male breast
C50.529	Malignant neoplasm of lower-outer quadrant of unspecified male breast
C50.611	Malignant neoplasm of axillary tail of right female breast
C50.612	Malignant neoplasm of axillary tail of left female breast
C50.619	Malignant neoplasm of axillary tail of unspecified female breast
C50.621	Malignant neoplasm of axillary tail of right male breast
C50.622	Malignant neoplasm of axillary tail of left male breast
C50.629	Malignant neoplasm of axillary tail of unspecified male breast
C50.811	Malignant neoplasm of overlapping sites of right female breast
C50.812	Malignant neoplasm of overlapping sites of left female breast
C50.819	Malignant neoplasm of overlapping sites of unspecified female breast
C50.821	Malignant neoplasm of overlapping sites of right male breast
C50.822	Malignant neoplasm of overlapping sites of left male breast
C50.829	Malignant neoplasm of overlapping sites of unspecified male breast
C50.911	Malignant neoplasm of unspecified site of right female breast
C50.912	Malignant neoplasm of unspecified site of left female breast
C50.919	Malignant neoplasm of unspecified site of unspecified female breast
C50.921	Malignant neoplasm of unspecified site of right male breast
C50.922	Malignant neoplasm of unspecified site of left male breast
C50.929	Malignant neoplasm of unspecified site of left male breast

REVISIONS

01-29-2022	Policy added to the bcbsks.com web site.
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