

Corporate Medical Policy

Liquid Biopsy AHS-G2054

File Name: liquid_biopsy
Origination: 1/2019
Last Review: 12/2023

Description of Procedure or Service

The National Cancer Institute (NCI) defines liquid biopsy as a test done on a sample of blood, urine, or other bodily fluid to look for cancer cells from a tumor or small pieces of DNA, RNA, or other molecules released by tumor cells into a person's body fluids. Liquid biopsies are non-invasive blood tests since circulating tumor cells (CTCs) and cell free tumor DNA (cfDNA) fragments are shed into the bloodstream from existing tumors and can be detected in blood (Curigliano, 2014; Haber & Velculescu, 2014). The presence of CTCs can be indicative of metastatic disease (Alix-Panabieres & Pantel, 2013).

For guidance concerning Tumor Mutational Burden Testing (TMB) and/or Microsatellite instability (MSI) analysis, please refer to AHS-M2178-Microsatellite Instability and Tumor Mutational Burden Testing policy.

*****Note: This Medical Policy is complex and technical. For questions concerning the technical language and/or specific clinical indications for its use, please consult your physician.**

Policy

BCBSNC will provide coverage for liquid biopsy in cancer management when it is determined the medical criteria or reimbursement guidelines below are met.

Benefits Application

This medical policy relates only to the services or supplies described herein. Please refer to the Member's Benefit Booklet for availability of benefits. Member's benefits may vary according to benefit design; therefore member benefit language should be reviewed before applying the terms of this medical policy.

When Liquid Biopsy is covered

1. For individuals diagnosed with non-small cell lung cancer (NSCLC), cell-free DNA/circulating tumor DNA (cfDNA/ctDNA) testing is considered medically necessary in **any** of the following situations:
 - a. When tissue-based testing is infeasible (i.e., quantity not sufficient for tissue-based test or invasive biopsy is medically contraindicated).
 - b. In the initial diagnostic setting when there is insufficient tissue to allow testing for broad molecular analysis following pathological confirmation of NSCLC (if an oncogenic driver is not identified, follow-up tissue based analysis should be considered).
 - c. In the initial diagnostic setting when tissue-based molecular analysis does not completely assess all recommended biomarkers due to tissue quantity or testing methodologies available. Recommended biomarkers include:
 - i) *ALK* rearrangements.
 - ii) *BRAF* mutations.
 - iii) *EGFR* mutations.

Liquid Biopsy AHS-G2054

- iv) *ERBB2 (HER2)* mutations.
 - v) *KRAS* mutations.
 - vi) *MET**ex14* skipping mutations.
 - vii) *NTRK1/2/3* fusions.
 - viii) *RET* arrangements.
 - ix) *ROS1* rearrangements.
 - x) *PD-L1* expression levels.
- d. To aid biomarker evaluation for treatment selection in the initial diagnostic setting (when the feasibility of timely tissue-based testing is uncertain).
2. For individuals diagnosed with HR-positive/HER2-negative breast cancer and who are being considered for targeted therapy, cfDNA/ctDNA testing for *PIK3CA* is considered medically necessary.
 3. For individuals diagnosed with castration-resistant prostate cancer, cfDNA/ctDNA testing of the following biomarkers is considered medically necessary:
 - a. Androgen receptor variant 7 (AR-V2) to guide therapy selection in the post-abiraterone/enzalutamide metastatic CRPC setting.
 - b. Somatic analysis of *BRCA1* and *BRCA2* to select patients for rucaparib treatment.
 4. For individuals meeting the above criteria, cfDNA/ctDNA testing (annually) is considered medically necessary.

When Liquid Biopsy is not covered

1. For all other situations not described above, liquid biopsy testing for screening, detecting **and/or** monitoring any other malignancy or tumor is considered investigational.
2. For all situations not addressed above, analysis of PD-L1 by liquid biopsy is considered investigational.
3. For the screening, detection, and/or diagnosis of cancer, urinary liquid biopsy (i.e., use of cell-free DNA [“UcfDNA”] or circulating tumor DNA obtained in a urine sample) (e.g., SelectMDX) is considered investigational.
4. Liquid biopsy testing on CSF samples is considered investigational.
5. Cell capture-enumeration assays of CTCs (e.g., CELLSEARCH® CTC) is considered investigational.

Policy Guidelines

The science of noninvasive disease monitoring has advanced greatly since circulating cell free DNA (cfDNA) was first reported in body fluids by Mandel and Metais. Since then, the evolution of sensitive cfDNA detection technologies has enabled the development of liquid biopsies with many clinical applications. For example, in oncology, the use of liquid biopsy allows for patient stratification (companion diagnostics), screening, monitoring treatment response and detection of minimal residual disease after surgery/recurrence. Liquid biopsies have grown in importance because, the genetic profile of tumors can affect how well they respond to a certain treatment. However, this characterization is currently achieved through a biopsy despite the inherent problems in procurement of tissue samples and the limitations of tumor analyses. For example, the invasive nature of a biopsy poses a risk to patients and can have a significant cost (Brock et al., 2015).

Liquid Biopsy AHS-G2054

Tumor sampling from some cancer types also remains difficult resulting in inadequate amount of tissue for genetic testing (Brock et al., 2015). In the case of advanced or metastatic non-small cell lung cancers (NSCLC) as many as 69% of cases do not have accessible tissue (Douillard et al., 2009). Even when tissue can be collected, preservation methods such as formalin fixation can cause false positive for results for genetic tests (Quach et al., 2004). Finally, due to tumor heterogeneity, biopsies often suffer from sample bias (Bedard et al., 2013). Liquid biopsies are becoming more popular as they provide an opportunity to genotype in a less invasive and expensive manner. However, the low sensitivity (between 60-80%) and higher number of false negative cases compared to traditional tissue biopsy are limitations associated with liquid biopsies (Sequist & Neal, 2022).

Approaches to Liquid Biopsy Analysis

Circulating tumor cells (CTCs)

According to Brock et al. (2015), CTCs are cells shed into the vasculature from a primary tumor and may constitute seeds for subsequent growth of additional tumors (metastasis) in distant organs (Brock et al., 2015). CTCs generally confer the advantage of containing RNA, DNA, and protein from tumor cells including both nuclear and cytoplasmic biomarkers, which is not attainable from ctDNA or exosomes (Yu et al., 2021). They have been detected in various metastatic carcinomas for example breast, prostate, lung, and colorectal cancer (Mavroudis, 2010) but are extremely rare in healthy subjects and patients with nonmalignant diseases (Brock et al., 2015). Clinical evidence indicates that patients with metastatic lesions are more likely to have CTCs amenable to isolation but their frequency is low, often ~1-10 CTCs per mL of whole blood (Miller, Doyle, & Terstappen, 2010). As 1 mL of blood contains $\sim 7 \times 10^6$ white blood cells and $\sim 5 \times 10^9$ red blood cells, technologies capable of reproducibly isolating a single CTC from the background of all other blood components are fundamental. While such levels of sensitivity are challenging, there are several novel developments in this area. These include positive selection, negative selection, physical properties or even enrichment-free assays to efficiently isolate these rare CTCs (Alix-Panabieres & Pantel, 2013). However, Bettgowda et al. (2014) stated that an advantage of ctDNA is that it can be analyzed from bio-banked biofluids, such as frozen plasma (Bettgowda et al., 2014).

Typically, CTCs are defined as cells with an intact viable nucleus, cytokeratin positive, epithelial cell adhesion molecule (EpCAM) positive and with the absence of CD45 (Brock et al., 2015). Unfortunately EpCAM and other markers are not always expressed on CTCs and are down-regulated by processes such as epithelial to mesenchymal transition (Grover et al., 2014). In addition, non-tumor epithelial cells are known to circulate in the blood of patients with prostatitis or patients undergoing surgery (Brock et al., 2015; Murray et al., 2013). The heterogeneity of CTCs is a major challenge from a technical standpoint. This has led to alternative strategies of CTC enrichment, such as the CTC-iChip which does not rely on tumor antigen expression (Brock et al., 2015; Karabacak et al., 2014).

Sequencing the genetic material from CTCs has demonstrated that the majority are not cancer cells, even when the isolated cell(s) fit the phenotypic criteria of being a CTC. One study by Marchetti et al. (2014) developed a protocol to recover the CTC enriched samples from the cartridge of the Veridex platform and found that from 37 NSCLC patients, the *EGFR* mutation allele abundance ranged between 0.02% and 24.79% with a mean of 6.34%. Brock et al. (2014) concluded that the number of CTCs found in the blood is therefore highly dependent on how the platform defines a cell as a CTC (Brock et al., 2015; Marchetti et al., 2014). The CellSearch CTC test, a Food and Drug Administration (FDA) approved actionable CTC test, requires that samples are processed within 96 hours of collection after being drawn into the Cellsave preservative tube. This test does not analyze the molecular genetics of the tumor; rather Cellsave is a platform for CTC numeration. A positive test (more than five detected CTCs for metastatic breast and prostate cancer and more than three CTCs for metastatic colorectal cancer per 7.5 mL of blood) is associated with decreased progression-free survival and decreased overall survival in these patients (Aggarwal et al., 2013).

Overall, although CTCs have produced some promising results in evaluating prognosis of patients with varying cancers, further studies are needed to assess the clinical utility of these biomarkers (Adamczyk et al., 2015; Bidard, et al., 2016; Foukakis & Bergh, 2022; Ignatiadis & Dawson, 2014).

Liquid Biopsy AHS-G2054

Cell free DNA (cfDNA)

There is currently an intensive research effort to understand the utility of cfDNA in various clinical fields such as cancer research, non-invasive prenatal testing and transplant rejection diagnostics (Brock et al., 2015). In a systematic review and meta-analysis of 20 studies and 2012 cases covering assessment of EGFR mutational status in NSCLC, Luo et al.(2014) found a sensitivity of 0.674, a specificity of 0.935, and area under the curve of 0.93. The authors concluded that detection of EGFR mutation by cfDNA is of adequate diagnostic accuracy and cfDNA analysis could be a promising screening test for NSCLC (Luo et al., 2014).

In a study Jiang et al (2015) observed that most cfDNA in plasma is reportedly fragmented, around 150-180 bp in length with a higher prevalence of tumor associated mutations in the shorter fragments. Per authors, when analyzing the mutation abundance with massively parallel sequencing a significant correlation was found between mutations and fragments less than 150 bp. Notably, the size of the majority of cfDNA fragments overlaps well with the size of histone DNA (Jiang et al., 2015).

A direct comparison of mutation detection on cfDNA vs. CTCs showed a higher abundance of the mutation on the cfDNA from the same patient; moreover, recent large studies comparing the effectiveness of cfDNA analysis to tissue biopsy in NSCLC showed the clinical value of the liquid biopsy approach (Douillard et al., 2014). This positive result led to an approval to use cfDNA analysis for *EGFR* mutation analysis for IRESSA in Europe (in patients where a tumor sample was not evaluable), making it the first *EGFR* tyrosine kinase inhibitor for which cfDNA testing is included in the label. Although promising, challenges remain when using cfDNA to characterize the mutation status of a tumor. In addition to the low copy number of mutant alleles, the median half-life of cfDNA in circulation ranges from 15 minutes to a few hours (Brock et al., 2015).

Brock et al, (2015) in their review observed that the total concentration of cfDNA in the blood of cancer patients varies considerably with tumor specific mutations ranging from undetectable (less than 1 copy per 5 mL of plasma) to patients with over a hundred thousand copies of the mutation per mL of plasma. The authors note that “the challenge of how to maximize the yield of the cfDNA and pair this with a platform sensitive enough to detect rare variants in the background of wild-type DNA remains. Optimally, the ability to detect mutations in plasma should not be limited to a subpopulation of patients with very high mutant copy numbers in circulation” (Brock et al., 2015). This has been proven to be challenging in early stage cancers (Yu et al., 2021).

While many analytical platforms report the mutation load with an allelic frequency compared to the wild-type DNA platforms relying solely on the allelic frequency without recording the number of mutations have limitations. This is because the allelic frequency of a gene is affected by the amount of wild-type DNA not related to the tumor. Therefore, it is important to consider the processes that affect the amount of wild-type DNA in circulation (Brock et al., 2015). For example, exercise increases cfDNA levels almost 10-fold (Breitbach et al., 2014). Other pre-analytical variables such as blood collection, the cellular process leading to its release, and extraction protocols affect the amount and size range of cfDNA fragments in a sample (Devonshire et al., 2014).

Exosomes

In the last few years, the exosome field has grown exponentially impacting various areas of research. Studies demonstrating that exosomes are actively released vesicles (carrying RNA, DNA and protein) and can function as inter-cellular messengers, have contributed to their elevated recognition in the scientific community. Yáñez-Mo et al, (2015) in a review outlining the biological properties of exosomes and other extracellular vesicles (EV's) highlights these developments. However, Gould andRaposo (2013) observed that the exosome field still lags behind as the standardization of extracellular vesicle (EV) types are not yet firmly established. The majority of exosomes range in size from 30-200 nanometer in diameter and are isolated from all bio-fluids, including serum, plasma, saliva, urine and cerebrospinal fluid (Brock et al., 2015).

Due to the size of an exosome, on average just over 100 nanometers, the entire transcriptome cannot be packaged inside every vesicle. By way of comparison, retrovirus particles with a similar size can package only

Liquid Biopsy AHS-G2054

around 10 kb, so it is likely that a single vesicle of that size carries only a limited number of transcripts. However, exosomes are extremely abundant (10e11 per mL of plasma) and when isolating the vesicle fraction, most of the transcriptome can be detected (Brock et al., 2015). Per Huang et al. (2013), and Kahlert et al. (2014), exosomal RNA can be used for mutation detection as well as global profiling of most types of RNA, and the profile alone (without mutation characterization) can be utilized for diagnostics (Brock et al., 2015). In the study 'Immune modulation of T-cell and NK (natural killer) cell activities by TEXs (tumour-derived exosomes)' Whiteside (2013) observed that exosome investigations have focused on the important physiologic and pathophysiologic functions of these vesicles in micro-metastasis, angiogenesis and immune modulation and as a means for detection of tumor specific mutations in bio-fluids (Whiteside, 2013). Consequently, in 2012, interest in this new field increased when the National Institute of Health (NIH) dedicated the large strategic Common Fund to study these new entities of extracellular RNA. The goal of this effort is to better understand how exosomes can be utilized for biomarkers and therapeutics as well as understanding this new mechanism of intercellular communication (NIH, 2017).

Mutation detection and RNA profiling

Analysis of nucleic acids present in bodily fluids can provide a better understanding of the disease, as summarized in the Table below.

Comparison of the analysis capability of CTC's, cfDNA and exosomes from: (Brock et al., 2015)

Analysis capability	Examples	CTCs	cfDNA	Exosome
Mutations	Point mutations, amplifications, translocations, InDels, deletions,	Yes	Yes	Yes
Epigenetic modifications	Methylation patterns	Yes	Yes	Yes
RNA transcription profiles	Levels/activity of mRNA, microRNA, long non codingRNA, RNA splice variants	Yes	No	Yes
Phenotypic studies of cells from the tumor	Cell morphology, protein localization, <i>in vivo</i> studies	Yes	No	No
Inflammatory response, stromal and other systemic changes	Inflammatory RNA and protein markers	No	No	Yes
Analysis of RNA as well as DNA and protein profiles from tumor cells	Separate or in combination	Yes	No	Yes
Can utilize bio-banked samples	Frozen plasma, urine and other bio-fluids	No	Yes	Yes

CTCs, circulating tumor cells; cfDNA, cell free DNA; InDels, insertions/deletions. (Brock et al., 2015)

RNA profiling from biofluids also poses numerous challenges. However, the discovery that exosomes contained RNA made it possible to separate the fragile RNA from the large amounts of RNases and PCR inhibitors that are present in most biofluids. As cell-free RNA in blood is immediately degraded, RNAs in serum and plasma are either protected inside vesicles like an exosome, in protein complexes with the Ago2 protein or associated with HDL particles (Brock et al., 2015). The levels of these microRNAs are tightly regulated in normal cells, and dysregulation has been implicated in a number of human diseases, e.g., cardiovascular (Thum & Condorelli, 2015) and neurological, and is strongly linked to cancer development and progression. However, microRNAs represent only a minor fraction of the transcriptome. By contrast, the nucleic acids in exosomes can be isolated and the entire transcriptome examined (Brock et al., 2015).

Liquid Biopsy AHS-G2054

The most significant hurdle for all forms of liquid biopsy remains the relative rarity of nucleic acid derived from a tumor against the background of normal material found in most patient samples. In fact, the majority of cell, cell-free nucleic acids, microRNAs and exosomes in a liquid biopsy will have originated from normal cells with numbers fluctuating as a consequence of biological variations (Brock et al., 2015).

Furthermore, although liquid biopsy was first introduced with serum, other liquid media, such as urine and cerebrospinal fluid (CSF), have been used to evaluate other conditions. Cell-free DNA is not necessarily confined to blood, and other media have been proposed.

Urine

Urine's primary advantage over blood is that it is non-invasive, allowing for more convenient testing. Urinary cell-free DNA (UcfDNA) has been proposed as a biomarker for the detection and diagnosis of certain cancers, particularly bladder and prostate cancer (Lu & Li, 2017). An example of this is SelectMDX. SelectMDX evaluates two mRNA cancer-related biomarkers (HOXC6 and DLX1 with *KLK3* as a reference gene) to assist a clinician in deciding to continue routine screening or to order a prostate biopsy. This test is considered a "non-invasive urine test" (a liquid biopsy) and reports a binary result of "increased risk" or "very low risk" (MDx, 2018). Van Neste et al. evaluated this test at a 0.90 area under curve in a validation cohort. The authors concluded that the mRNA signature was one of the most significant components of the validation results (Van Neste et al., 2016). Shore et al assessed the effect of SelectMDX results on clinical decision making and found that out of 253 patients SelectMDX evaluated as "negative", only 12% underwent a biopsy (Shore et al., 2019).

Xu et al. (2021) assessed the diagnostic value of urinary exosomes for urological tumors. The authors performed a systematic review and meta-analysis of 16 studies with a total of 3224 patients. Diagnostic value was calculated based on the number of true positives, false positives, true negatives, and false negatives. The sensitivity of using urinary exosomes for the diagnosis of urological tumors was 83% and the specificity was 88%. Sensitivity and specificity results were similar regardless of urinary exosome content type and tumor type. The authors conclude that "urinary exosomes may serve as novel non-invasive biomarkers for urological cancer detection" (Xu et al., 2021).

Cerebrospinal Fluid (CSF)

CSF is a colorless, clear liquid produced by the choroid plexus. CSF acts to control flow of molecules to the central nervous system (CNS). Due to the tight control of the CSF, it may play a significant role in assessing several conditions. CSF is traditionally used to evaluate conditions such as meningitis, but it has also been used to assess central nervous system cancers, such as leptomeningeal metastases (Demopoulos, 2022; Johnson, 2021). In addition to widely-known measures of pathology in CSF (opening pressure, total protein, glucose, cell count with differential), circulating tumor cells in CSF have also been proposed as markers for epithelial tumors (Demopoulos, 2022).

Lin et al. (2017) evaluated the diagnostic accuracy of circulating tumor cells in CSF (CSF-CTC) in patients with leptomeningeal metastasis (LM). 30 of 95 total patients were diagnosed with LM based on a combination of CSF cytology and MRI. CSF-CTCs were detected in 43 patients (median 19.3 CSF-CTC/mL). Based on receiver operating curve analysis, the optimal cutoff was found to be 1 CSF-CTC/mL, identifying patients at a rate of 93% sensitivity, 95% specificity, positive predictive value 90%, and negative predictive value 97% (Lin et al., 2017). Diaz et al. (2022) studied the clinical utility of CSF-CTC by evaluating how CSF-CTC quantification was able to predict the outcome of LM. The authors performed a single institution retrospective study of 101 LM patients with solid tumors. The CSF-CTC count significantly predicted survival continuously ($p=0.0027$). The authors conclude that "CSF-CTCs quantification predicts survival in newly diagnosed LM, and outperforms neuroimaging" and suggest CSF-CTC can be used for LM prognosis and to assess disease burden (Diaz et al., 2022).

Mathios and Phallen (2022) published a review paper noting "significant strides" towards understanding the molecular mechanisms of brain cancer. Research advances in the field include a focus on the "tumor microenvironment" and identifying molecular biomarkers with liquid-based analyses (such as CSF in liquid

Liquid Biopsy AHS-G2054

biopsy). While it is a rapidly advancing area of research, clinical utility is currently limited, that is, there are currently “no approved noninvasive tests that are clinically useful” for gliomas. The authors point to Cristiano et al. (2019) as an example of a study that analyzed genome-wide cfDNA fragment features (in a variety of cancers); the authors were able to distinguish patients with cancer from non-cancer patients (as well as isolate the tissue of origin). In another glioma-specific study, Mouliere et al. (2018) detected 5 of 13 patients’ brain tumors (38%) using a cfDNA fragmentation-based approach to analyze cfDNA fragments and copy number alterations in CSF. In conclusion, the authors note that, despite recent excitement over promising studies, liquid biopsy approaches to brain cancer are still “in their infancy” (Mathios & Phallen, 2022).

Proprietary Testing

FDA approval of use of the Roche Cobas *EGFR* Mutation Test in plasma was based on evaluation of plasma samples from the ENSURE study (Wu et al., 2015), a multicenter, open-label, randomised, Phase III study of stage IIIB/IV NSCLC patients. 98.6% of the patients enrolled (214/217) had a plasma sample available for testing. The agreement between the cobas *EGFR* Mutation Test in plasma and tissue was evaluated for detection of *EGFR* mutations. In 76.7% of tissue-positive specimens, plasma was also positive for an *EGFR* mutation. Plasma was negative for *EGFR* mutation in 98.2% (95.4%, 99.3%) of tissue-negative cases. The patients whose plasma results were positive for exon 19 deletion and/or an L858R mutations treated with erlotinib had improved progression-free survival (PFS) compared to those treated with chemotherapy (FDA, 2016).

Another commercially available, FDA-approved test is Guardant360 by Guardant Health Inc. Guardant360 is a gene panel that sequences 74 genes (including 18 amplifications and 6 fusions) associated with NSCLC and reports the percentage of cfDNA (Guardant, 2022). The manufacturer purports that this genetic test will allow providers to make better treatment decisions based on the mutations present in the patient (Health, 2023). The gene panel was analytically validated, with 99.8% accuracy on 1000 consecutive samples (Lanman et al., 2015).

FoundationOne has also created proprietary FDA-approved test that examines cell-free DNA. Foundation One’s liquid CDx test evaluates 324 genes using circulating cell-free DNA and is FDA-approved to report short variants in 311 genes (FoundationOne, 2022, 2023). A prior version of this test (covering 62 genes) was evaluated based on 2666 reference samples. The assay reached >99% sensitivity of short variants of allele frequencies of >0.5%, >95% sensitivity of allele frequencies 0.25%-0.5%, and >70% sensitivity of allele frequencies 0.125%-0.25%. Out of 62 healthy volunteers, no false positives were detected (Clark et al., 2018).

Biodesix is another laboratory that offers a liquid biopsy panel. Biodesix offers two tests; one called GeneStrat, tests *EGFR*, *ALK*, *ROS1*, *RET*, *BRAF*, and *KRAS* (Biodesix, 2023). Sensitivities of 78%-100% for *EGFR*, *ALK*, and *KRAS* with the GenStrat test were shown in multiple validation studies (Mellert et al., 2017). GeneStrat also detected over 88% of *RET* or *ROS1*-positive patients (Mellert et al., 2018). Biodesix also offers GeneStrat NGS, a broad 52 gene panel also evaluated through blood-based liquid biopsy technology.

Other firms that offer liquid biopsy testing include ResolutionBio (now part of Agilent) which offers Agilent Resolution ctDx FIRST (“companion diagnostic to KRAZATI™ adagrasib) for the detection of *KRAS* G12C in non-small cell lung cancer [NSCLC]”) and Agilent Resolution ctDx LUNG, which focuses on actionable genes for lung cancer such as *EGFR* and *ALK*; Circulogene (tests *BRAF*, *EGFR*, *KRAS*, *ALK*, *ROS1*, PD-L1, and MSI), Neogenomics (InvisionFirst, 37-gene panel including 10 actionable genes), and Biocept (CNSide™). As liquid biopsy is a rapidly emerging field, it is possible that many more tests will find their way into the clinical setting (Biocept, 2023; Circulogene, 2023; Neogenomics, 2022; ResolutionBio, 2021).

Clinical Validity and Utility

Seeberg et al. (2015) conducted a prospective study to assess the prognostic and predictive value of CTCs in 194 patients with colorectal liver metastasis referred to surgery. 153 patients underwent a resection (41 patients had an unresectable tumor), and CTCs were detected in 19.6% of patients. Patients with unresectable tumors

Liquid Biopsy AHS-G2054

had a 46% CTC positivity rate compared to 11.7% for resectable tumors. Patients with two or more CTCs experienced reduced time to relapse/progression. Two or more CTCs was a strong predictor of progression and mortality in all subgroups of patients. The authors concluded that “CTCs predict nonresectability and impaired survival. CTC analysis should be considered as a tool for decision-making before liver resection in these patients” (Seeberg et al., 2015).

Groot et al. (2013) performed systematic review and meta-analysis to investigate the prognostic value of CTCs in patients with resectable colorectal liver metastases or widespread metastatic colorectal cancer (CRC). The results of 12 studies representing 1,329 patients were suitable for pooled analysis. The overall survival and progression-free survival were worse in patients with CTCs, with hazard ratios of 2.47 for overall survival rate and 2.07 for progression-free survival. The authors concluded that “the detection of CTCs in peripheral blood of patients with resectable colorectal liver metastases or widespread metastatic CRC is associated with disease progression and poor survival (Groot Koerkamp, Rahbari, Buchler, Koch, & Weitz, 2013).”

Zhang et al. (2012) conducted a meta-analysis of published literature on the prognostic value of CTC in breast cancer. Forty-nine eligible studies enrolling 6,825 patients were identified. The presence of CTC was significantly associated with shorter survival in the total population and the prognostic value of CTC was significant in both early and metastatic breast cancer. The authors concluded that “the detection of CTC is a stable prognosticator in patients with early-stage and metastatic breast cancer. Further studies are required to explore the clinical utility of CTC in breast cancer (Zhang et al., 2012).”

Pinzani et al. (2021) assessed that the clinical validity of CTCs has been demonstrated in cancer screening, prognosis, and monitoring treatment responses. In the original article by Cabel et al. (2017), using the Cellsearch® technique in early non-metastatic cancer has reported low CTC detection rates (5-30% depending on cancer type), with limited specificity since “some circulating epithelial cells can be found in individuals with inflammatory disease or even in some healthy individuals.” However, in the preliminary report of another study, it was found that a CTC count >25 could “distinguish lung cancer from benign lesions in patients with abnormal lung imaging. CTC count was also shown to be an “independent prognostic factor in non-small cell lung cancer and small cell lung cancer;” despite this, CTCs are rare in the non-metastatic setting, and thus cannot be completely utilized as an independent prognostic factor in the localized setting. With respect to the independent cancers, Cabel et al. (2017) summarizes the clinical validity of CTC detection in **Figure 1**. (Gregory et al., 2013)(Gregory et al., 2013)(Gregory et al., 2013).

On the clinical utility of CTC, Cabel et al. (2017) initially stated “the clinical utility of CTC detection (i.e. does it improve patient outcome) has yet to be demonstrated before it can be implemented in routine clinical practice.” In recent time, it was seen that specific CTC features may have clinical utility in “[predicting] the sensitivity to specific immunotherapies,” and in the case of ER+ MBCs, ER-CTCs can develop and reflect “acquisition of therapy resistance by the primary tumor” (Pinzani et al., 2021).

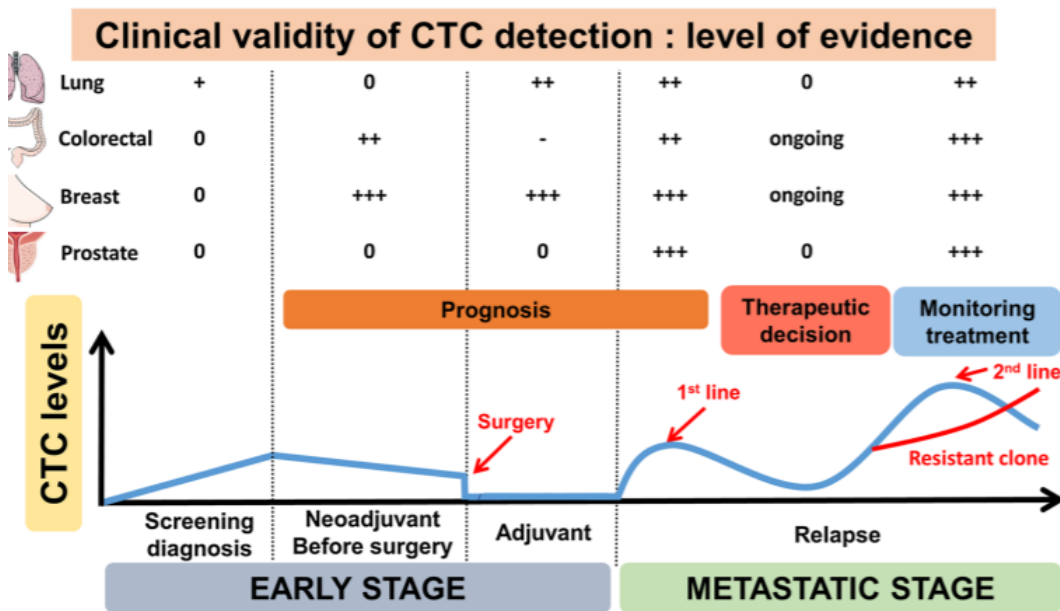


Figure 1. Clinical validity of circulating tumor cells (CTC): level of evidence according to clinical settings (Cabel et al., 2017).

Oxnard et al. found that: “Sensitivity of plasma genotyping for detection of T790M was 70%. Of 58 patients with T790M-negative tumors, T790M was detected in plasma of 18 (31%). ORR and median PFS were similar in patients with T790M-positive plasma (Objective response rate [ORR], 63%; progression-free survival [PFS], 9.7 months) or T790M-positive tumor (ORR, 62%; PFS, 9.7 months) results. Although patients with T790M-negative plasma had overall favorable outcomes (ORR, 46%; median PFS, 8.2 months), tumor genotyping distinguished a subset of patients positive for T790M who had better outcomes (ORR, 69%; PFS, 16.5 months) as well as a subset of patients negative for T790M with poor outcomes (ORR, 25%; PFS, 2.8 months) (Oxnard et al., 2016).” The authors concluded that “upon availability of validated plasma T790M assays, some patients could avoid a tumor biopsy for T790M genotyping (Oxnard et al., 2016).”

A review by Sacher et al. genotyped 180 patients with NSCLC using plasma droplet PCR (plasma ddPCR). This was done to validate the plasma droplet PCR technique, and the study identified 115 *EGFR* mutations and 25 *KRAS* mutations. The plasma ddPCR was measured to have 82% sensitivity for the *EGFR* 19 del, 74% for L858R, 77% for T790M, and 64% for *KRAS*. The positive predictive value was 100% for every mutation apart from T790M at 79%. The authors concluded that the technique “detected *EGFR* and *KRAS* mutations rapidly with the high specificity needed to select therapy and avoid repeat biopsies”. The authors also noted that this assay “may also detect *EGFR* T790M missed by tissue genotyping due to tumor heterogeneity in resistant disease (Sacher et al., 2016).”

Kim et al. evaluated the clinical utility of Guardant360. This study used the Guardant360 panel to detect mutations in patients with metastatic NSCLC and other cancers. Somatic mutations were detected in 59 patients, 25 of which had actionable mutations. Out of the 73-patient NSCLC cohort, 62 were found to have somatic mutations and 34 had actionable mutations. After these genetic findings were identified, molecularly matched therapy was provided to 10 patients with gastric cancer (GC) and 17 with NSCLC. Response rate was 67% in GC and 87% in patients with NSCLC, while disease control rate was 100% for both types (Kim et al., 2017).

Odegaard et al. validated the Guardant360 cell-free DNA sequencing test and aimed to “demonstrate its clinical feasibility”. The authors found that the test could detect variants down to “0.02% to 0.04% allelic

Liquid Biopsy AHS-G2054

fraction/2.12 copies with $\leq 0.3\%/2.24\text{-}2.76$ copies". Clinical validation in a cohort of over 750 patients demonstrated high accuracy and specificity, with positive percent agreement (with PCR) of 92%-100% and negative percent agreement of over 99%. In terms of feasibility, the authors performed the test in 10593 patients and found the technical success rate to be over 99.6% and the clinical sensitivity to be 85.9%. The authors also noted that 16.7% of these mutations were targetable with FDA-approved treatments (with 72% with "treatment or trial recommendations") with as many as 34.5% of non-small cell cancer samples having a targetable mutation (Odegaard et al., 2018).

Aggarwal et al. (2019) evaluated the utility of plasma-based sequencing in improving mutation detection in patients with non-small cell lung cancer. The authors first performed next-generation sequencing (NGS) on tissue, then plasma-based sequencing. 229 patients had concurrent sequencing, and NGS alone detected 47 targetable mutations. Addition of plasma sequencing brought that number to 82 targetable mutations. Furthermore, 36 of 42 patients that received "plasma next-generation sequencing–indicated therapy" achieved a "complete or a partial response or stable disease". The authors concluded that "adding plasma next-generation sequencing testing to the routine management of metastatic non–small cell lung cancer appears to increase targetable mutation detection and improve delivery of targeted therapy" (Charu Aggarwal et al., 2019).

Leighl et al. (2019) evaluated the utility of "comprehensive cell-free DNA analysis" to identify genomic biomarkers in patients with newly diagnosed metastatic non-small cell lung cancer (NSCLC). 282 patients were included. Tissue genotyping (current standard of care) identified a guideline-recommended biomarker in 60 patients, whereas cell-free DNA identified a relevant biomarker in 77 patients. Concordance between the two methods was 80% (48 biomarkers detected in both methods). For FDA-approved targets (*EGFR*, *ALK*, *ROS1*, *BRAF*), concordance was $>98.2\%$ with 100% positive predictive value for cell-free DNA. Cell-free DNA was also found to have a faster median turnaround time (9 days compared to 15 for tissue genotyping), and "guideline-complete" (assessment of all eight guideline-recommended biomarkers [*EGFR*, *ALK*, *ROS1*, *BRAF*, *RET*, *MET* amplification and exon 14 skipping, and *HER2*]), was significantly more likely (268 patients vs 51) (Leighl et al., 2019).

Dudley et al. (2019) have developed a novel high-throughput sequencing method that uses urine-derived tumor DNA (utDNA) known as utDNA CAPP-Seq (uCAPP-Seq) to detect bladder cancer. This technique was used to analyze samples from 118 patients with early stage bladder cancer and 67 healthy adults. "We detected utDNA pretreatment in 93% of cases using a tumor mutation-informed approach and in 84% when blinded to tumor mutation status, with 96% to 100% specificity (Dudley et al., 2019)." These results show that utDNA can be used to diagnose early-stage bladder cancer with high sensitivity and specificity.

Wang et al. (2018) performed a meta-analysis to determine the diagnostic performance of cell-free DNA (both blood and urine) assays in bladder cancer. 11 studies encompassing 802 patients were included. The authors evaluated cell-free DNA assays at the following statistics: "sensitivity 0.71, specificity 0.78 positive likelihood ratio 3.3, negative likelihood ratio 0.37, diagnostic odds ratio 9, and area under curve 0.80. No publication bias was identified. The authors concluded that "cell-free DNA has a high diagnostic value in bladder cancer" (Wang et al., 2018).

cfDNA can hopefully be used to indicate prognoses of personalized peptide vaccine therapy in patients with NSCLC. Waki et al. (2021) identified that cfDNA integrity "decreased after the first cycle of vaccination" and that those with "high prevaccination cfDNA integrity survived longer than those with low prevaccination integrity (median survival time (MST): 17.9 versus 9.0 months, respectively; hazard ratio (HR): 0.58, $p = .0049$)," showing that monitoring cfDNA levels could contribute to quantifying treatment success and predicting patient lifespans.

For exosome-based liquid biopsy, Yu et al. (2021) have proposed a synergistic alternative of combining cfDNA and exosomal RNA to "increase the sensitivity of mutation detection... the exosome component enables a combination of exosomal RNA, cfDNA, and disease specific proteins... the unique composition of the exosome compartment makes these vesicles particularly amenable for multi-analyte testing, since they carry cancer-informative DNA, RNA, proteins, lipids, oligosaccharides, and metabolites. In one study, a high sensitivity (92%) for *EGFR* mutations was found for utilizing exosomal RNA and ctDNA together and

Liquid Biopsy AHS-G2054

remained high in a subpopulation that's been difficult for ctDNA assays to detect (88% sensitivity). ExoRNA and ctDNA combined analyses on *BRAF*, *KRAS*, and *EGFR* mutations in exosomes and respective ctDNA have also better correlated the biomarkers with treatment outcomes when compared to ctDNA alone (Yu et al., 2021).

Lee et al. (2021) analyzed the clinical utility of ctDNA to reliably detect *EGFR* in ctDNA. The authors compared *EGFR* analysis results between tissueDNA (tDNA) and ctDNA from 554 NSCLC cases. ctDNA analysis detected *EGFR* mutation in 57.3% of cases. ctDNA detection correlated with metastatic stage and disease progression ($p < 0.001$). The authors followed up after an average of 41.09 month and found that, "survival analysis revealed ctDNA status and M stage ($p < 0.001$) to be independent predictors of overall survival in the multivariate analysis." The authors conclude that ctDNA is clinically useful for *EGFR* analysis, but note the possibility of false negatives and recommend using tDNA to confirm ctDNA results in some situations (Lee et al., 2021). Syeda et al. (2021) evaluated the use of ctDNA as a biomarker for melanoma. The authors measured changes in ctDNA and survival following "BRAF, MEK, or BRAF plus MEK inhibitor therapy" in patients participating in two clinical trials. The BRAF^{V600}-mutant was measured in ctDNA before and during treatment. "Elevated baseline BRAF^{V600} mutation-positive ctDNA concentration was associated with worse overall survival outcome." The authors conclude that BRAF^{V600}-mutation ctDNA analysis can be used as a biomarker to predict clinical outcomes (Syeda et al., 2021).

State and Federal Regulations, as applicable

Food and Drug Administration (FDA)

There are four FDA-approved liquid biopsy tests as of January 10, 2023. The Cobas *EGFR* Mutation Test v2 from Roche Diagnostics is an assay purported to detect epidermal growth factor receptor (*EGFR*) gene mutations in NSCLC patients. The test is intended as a companion diagnostic test for the cancer drug Tarceva (FDA, 2016), and a similar test for the T790M mutation has been produced by the same company. A second test is the Cell Search® Circulating Tumor (CTC) Test, which is used to predict and analyze outcomes for individuals with metastatic breast, prostate, or colon cancer (CellSearch, 2023). A third test is Guardant360® CDx, which detects ctDNA and other common genetic errors in order to help in the choice of a therapeutic or treatment (Health, 2023). Lastly, FoundationOne® Liquid CDx is an FDA-approved liquid biopsy test that detects ctDNA and may be able to assist a provider in determining the type of treatment that will be most effective (FoundationOne, 2022).

Many labs have developed specific tests that they must validate and perform in house. These laboratory-developed tests (LDTs) are regulated by the Centers for Medicare and Medicaid (CMS) as high-complexity tests under the Clinical Laboratory Improvement Amendments of 1988 (CLIA '88). As an LDT, the U. S. Food and Drug Administration has not approved or cleared this test; however, FDA clearance or approval is not currently required for clinical use.

Guidelines and Recommendations

National Comprehensive Cancer Network (NCCN)

NCCN guidelines for non-small cell lung cancer (NSCLC) strongly advise "broader molecular profiling with the goal of identifying rare driver mutations for which effective drugs may already be available, or to appropriately counsel patients regarding the availability of clinical trials. Broad molecular profiling is a key component of the improvement of care of patients with NSCLC". Furthermore, the NCCN states that "data suggest that plasma genotyping (also known as plasma testing or liquid biopsy) may be considered at progression instead of tissue biopsy to detect whether patients have T790M; however, if the plasma biopsy is negative, then tissue biopsy is recommended" (NCCN, 2023b).

However, the NCCN goes on to state that cell-free or circulating tumor DNA testing should not be used in lieu of histologic tissue diagnosis. The NCCN notes that specificity is generally very high for cell-free tumor testing but is lacking in sensitivity (up to 30% false-negative rate) and that standards for testing have not been

Liquid Biopsy AHS-G2054

well established. The use of cell-free or circulating tumor DNA may be considered in specific clinical situations, such as if a patient is medically unfit for an invasive tissue sampling or if there is insufficient material for a molecular analysis following pathologic confirmation of an NSCLC diagnosis (but only if “follow-up tissue-based analysis is planned for all patients in which an oncogenic driver is not identified”). The NCCN notes that “recent data suggest that plasma cell-free/circulating tumor DNA testing can be used to identify *EGFR*, *ALK*, and other oncogenic biomarkers that would otherwise not be identified in patients with metastatic NSCLC” (NCCN, 2023b).

For NSCLC, the NCCN provides the following specific recommendations for liquid biopsy:

“The use of cell-free/circulating tumor DNA testing can be considered in specific clinical circumstances, most notably:

- If a patient is medically unfit for invasive tissue sampling
- In the initial diagnostic setting, if following pathologic confirmation of a NSCLC diagnosis there is insufficient material for molecular analysis, cell-free/circulating tumor DNA can be used; however, follow-up tissue-based analysis for all patients in which an oncogenic driver is not identified should be planned (see NSCL-18 for oncogenic drivers with available targeted therapy options).
- In the initial diagnostic setting, if tissue-based testing does not completely assess all recommended biomarkers owing to tissue quantity or testing methodologies available, consider repeat biopsy and/or cell-free/circulating tumor DNA testing.
- In the initial diagnostic setting, if the feasibility of timely tissue-based testing is uncertain, concurrent cfDNA testing may aid in biomarker evaluation for treatment selection, provided negative results are considered per above limitations.”

The NCCN lists “comprehensive germline and somatic profiling to identify candidates for additional targeted therapies” as part of the workup for recurrent stage IV (M1) breast cancer.” They go on to specifically note that “tissue or plasma-based circulating tumor DNA (ctDNA) assays may be used. Tissue-based assays have greater sensitivity, but ctDNA may reflect tumor heterogeneity more accurately.” The NCCN also states that assessment of the *PIK3CA* mutation may be performed through liquid biopsy if the tumor is HR-positive, HER2 negative, and if therapy with alpelisib plus fulvestrant is being considered. Finally, for the management of breast cancer with liquid biopsy techniques, the NCCN states that “the clinical use of Circulating Tumor Cells (CTC) or circulating DNA (ctDNA) in metastatic breast cancer is not yet included in the NCCN Guidelines for Breast Cancer for disease assessment and monitoring”, though the sentence that follows would indicate that this statement refers to a count of CTCs, not their use for genotyping: “Patients with persistently increased CTC after 3 weeks of first-line chemotherapy have a poor PFS and OS” (NCCN, 2022c).

The NCCN states that AR-V7 testing in CTCs “can be considered to help guide selection of therapy in the post-abiraterone/enzalutamide metastatic CRPC [castration-resistant prostate cancer] setting”. The NCCN does not comment on any particular liquid medium over another (e.g. urine, CSF, serum). However, the NCCN does specify the use of circulating DNA for rucaparib treatment, stating that “the preferred method of selecting patients for rucaparib treatment is somatic analysis of *BRCA1* and *BRCA2* using a circulating tumor DNA sample” (NCCN,2023a). SelectMDx is also acknowledged by the NCCN; “the panel believes that SelectMDx score is potentially informative in patients who have never undergone biopsy, and it can therefore be considered in such men” (NCCN, 2022).

With regards to circulating tumor DNA (ctDNA) in colon cancer, the NCCN “panel believes that there are insufficient data to recommend the use of multigene assays, Immunoscore, or post-surgical ctDNA to estimate risk of recurrence or determine adjuvant therapy” (NCCN, 2021d). NCCN guidelines for small cell lung cancer do not address use of CTCs or ctDNA for patient management (NCCN, 2022e).

NCCN guidelines for small cell lung cancer do not address use of CTCs or ctDNA for patient management (NCCN, 2023c).

Liquid Biopsy AHS-G2054

For neuroendocrine tumors, NCCN notes that CTCs have been studied as prognostic markers, but state that more research is required. There is no single biomarker available that is satisfactory as a diagnostic, prognostic, or predictive marker (NCCN, 2022h).

For a primary CNS lymphoma, the NCCN remarks that cerebrospinal fluid analysis may “possibly” include gene rearrangement evaluation. For leptomeningeal metastases, the NCCN notes that assessment of CTCs in CSF “increases sensitivity of tumor cell detection and assessment of response to treatment” (NCCN, 2022d).

For pancreatic adenocarcinomas, the NCCN acknowledges that circulating cell-free DNA is being investigated as a biomarker for screening. The NCCN also notes that if tumor tissue is not available, cell-free DNA testing may be considered (NCCN, 2022i).

For esophageal, esophagogastric junction cancers, and gastric cancers, the NCCN states “testing using a validated NGS-based [next generation sequencing] genomic profiling assay performed in a CLIA-approved laboratory may be considered for some patients. A negative result should be interpreted with caution, as this does not exclude the presence of tumor mutations or amplifications. The liquid biopsy platform is in its early phase of development and more research would be necessary before it can be considered standard of care” (NCCN, 2022f). The NCCN does not comment on the usage of liquid biopsies, ctDNA, or CTCs for testing for hepatobiliary cancers (NCCN, 2022g).

For acute myeloid leukemia, the NCCN notes that “morphologically detectable,” circulating leukemic blasts from peripheral blood may be used to detect molecular abnormalities (NCCN, 2022a).

For bladder cancer, the NCCN mentions RT-PCR testing for *FGFR2/3* gene alterations, but does not specify whether this can be done through a liquid biopsy or cell-free DNA. The only comment made is that the laboratory should be CLIA-approved (NCCN, 2022b).

American Society of Clinical Oncology (ASCO)

In 2016, ASCO published updated recommendations for the use of tumor markers in treatment of metastatic breast cancer. ASCO found that although CTCs may be prognostic, they are not predictive for clinical benefit when used to guide or influence decisions on systemic therapy for metastatic breast cancer. ASCO recommends clinicians to not use these markers as adjunctive assessments (Van Poznak et al., 2015). Similarly, ASCO recommended against use of CTCs to guide decisions about adjuvant systemic therapy for women with early stage invasive breast cancer (Andre et al., 2019).

In 2019, ASCO stated that clinicians “should not use circulating biomarkers as a surveillance strategy for detection of recurrence in patients who have undergone curative-intent treatment of stage I-III NSCLC or SCLC”. ASCO states that further data is required to validate this approach (Schneider et al., 2019).

In 2018, ASCO and the College of American Pathologists (CAP) released a joint review on “circulating tumor DNA analysis in patients with cancer”. In it, they note that apart from the assays that have received “regulatory appeal”, most assays have “insufficient evidence” for both clinical validity and clinical utility. They note discordant results between circulating DNA assays and tissue genotyping. Furthermore, they remark on the lack of evidence for use in monitoring therapy effectiveness, diagnosing early-stage cancer, or cancer screening.

However, they point to evidence that well-validated assays may support initiation of targeted therapy (Merker et al., 2018).

National Academy of Clinical Biochemistry (NACB) now known as the American Association for Clinical Chemistry (AACC)

In 2010, the NACB issued practice guidelines for the use of tumor markers in liver, bladder, cervical, and gastric cancers. It found that CTCs had “questionable” clinical utility in the assessment of liver cancer and did not recommend their use (Sturgeon et al., 2010).

Liquid Biopsy AHS-G2054

The NACB published an updated guideline in 2020. For liver cancer, they note circulating cell-free serum DNA as “undergoing evaluation” for “predictive marker for distant metastasis of hepatitis C virus–related HCC.” The plasma proteasome is also undergoing evaluation for “assessment of early HCC in patients with chronic viral chronic hepatitis; assessment of metastatic potential of HCC.” Finally, circulating methylated DNA is undergoing evaluation for HCC screening, detection, and prognosis. No other circulating tumor markers for bladder, cervical, and gastric cancers were mentioned (Sturgeon et al., 2020).

College of American Pathologists (CAP), the International Association for the Study of Lung Cancer (IASLC), and the Association for Molecular Pathology (AMP)

An expert panel was convened to review and update the CAP-IASLC-AMP Molecular Testing Guideline for Selection of Lung Cancer Patients for *EGFR* and *ALK* Tyrosine Kinase Inhibitors. This panel consists of practicing pathologists, oncologists, and a methodologist.

The panel states there is “insufficient evidence to support the use of circulating cell-free plasma DNA (cfDNA) molecular methods for the diagnosis of primary lung adenocarcinoma”. According to the panel, there is also “insufficient evidence to support the use of circulating tumor cell (CTC) molecular analysis for the diagnosis of primary lung adenocarcinoma, the identification of *EGFR* or other mutations, or the identification of *EGFR* T790M mutations at the time of *EGFR* TKI-resistance” (College of American Pathologists, 2018; Lindeman et al., 2018).

However, the panel acknowledges that “In some clinical settings in which tissue is limited and/or insufficient for molecular testing, physicians may use a cell-free plasma DNA (cfDNA) assay to identify *EGFR* mutations” (Lindeman et al., 2018).

In 2021, the IASLC published an updated consensus statement on liquid biopsy testing. They note that liquid biopsy “includes a variety of methodologies for circulating analytes. From a clinical point of view, plasma circulating tumor DNA is the most extensively studied and widely adopted alternative to tissue tumor genotyping in solid tumors, including NSCLC” (Rolfo et al., 2021).

The following recommendations were presented in a consensus statement:

1. In clinical practice, ctDNA collection, sample handling, and automated processing should be performed using standardized and clinically validated procedures to reduce operator variability and false-negative results.
2. Because of the growing number of guideline-recommended oncogene targets to be assessed in advanced NSCLC, testing of plasma ctDNA should be performed by a clinically validated NGS platform rather than single-gene, PCR-based approaches, both in treatment-naïve patients and those associated with multiple mechanisms of acquired resistance (MOR) to targeted agents. Where plasma NGS is not available owing to technical and economic constraints, single-gene or low multiplex-based approaches may represent appropriate alternatives. Use of limited PCR analysis for *EGFR* mutations as the initial step in molecular assessment, for example, remains highly relevant in areas of the world where the *EGFR* mutation rate is high. Nevertheless, single-gene testing should not be considered complete, and if negative, serial testing for additional actionable biomarkers must be pursued.
3. The benefit of tissue and plasma NGS is now established in several clinical practice settings. It is anticipated, owing to broad-based coverage of requisite oncogenes, decreased turnaround times, and emerging data on cost effectiveness, that in the near future, NGS will become increasingly available worldwide. Implementation of a multidisciplinary MTB to assist clinicians in treatment decision-making is advisable, as described previously.
4. In patients with oncogene-addicted NSCLC, liquid biopsy is emerging as not only complementary to tissue-based analysis but also acceptable as the initial approach (“plasma first”) for biomarker evaluation at the time of diagnosis and for monitoring the efficacy of targeted therapies. Finally, a plasma-first approach is appropriate for identification of MOR to targeted therapies in many clinical settings.
5. Indications for liquid biopsy in patients with nononcogene-addicted NSCLC are less well defined at this time, although there are several promising areas of investigation. As noted previously, bTMB is an

Liquid Biopsy AHS-G2054

emerging biomarker, pending completion of ongoing prospective randomized trials and refinement of methodology.

American Society for Clinical Pathology, College of American Pathologists, Association for Molecular Pathology, and American Society of Clinical Oncology

These joint guidelines from these societies were published regarding molecular biomarkers for colorectal cancer. Despite the potential of liquid biopsy for assessment of tumor recurrence and treatment resistance, the technique “awaits robust validation and further studies to determine their clinical utility” (Sepulveda et al., 2017).

European Society for Medical Oncology (ESMO) and Chinese Society of Clinical Oncology (CSCO)

These guidelines state that liquid biopsy can be used as “the initial test for the detection of a T790M mutation [for *EGFR* in NSCLC], and if tests are negative, a re-biopsy should be attempted if feasible” (Wu et al., 2018).

The European Association of Urology (EAU), European Society for Radiotherapy and Oncology (ESTRO), European Society of Urogenital Radiology (ESUR), and the International Society of Geriatric Oncology (SIOG)

The joint guidelines on prostate cancer state that “In asymptomatic men with a prostate-specific antigen (PSA) level between 2-10 ng/mL and a normal digital rectal examination, use one of the following tools:

- risk-calculator;
- imaging;
- an additional serum, urine, or tissue-based test”.

These joint guidelines acknowledged SelectMDX as a test to select for repeat biopsies, but the guidelines noted SelectMDX as having an “uncertain role” and “probably not cost-effective” (EAU, 2021).

American Society of Colon and Rectal Surgeons (ASCRS)

The ASCRS released clinical practice guidelines for the management of colon cancer. The guidelines state that “the use of multigene assays, CDX2 expression analysis, and ctDNA may be used to complement multidisciplinary decision-making for patients with stage II or III colon cancer” (Vogel et al., 2022).

Billing/Coding/Physician Documentation Information

This policy may apply to the following codes. Inclusion of a code in this section does not guarantee that it will be reimbursed. For further information on reimbursement guidelines, please see Administrative Policies on the Blue Cross Blue Shield of North Carolina web site at www.bcbsnc.com. They are listed in the Category Search on the Medical Policy search page.

Applicable service codes: 81162, 81163, 81164, 81194, 81210, 81235, 81275, 81276, 81309, 81405, 81406, 81462 81479, 86152, 86153, 0011M, 0091U, 0155U, 0177U, 0179U, 0229U, 0317U, 0332U, 0333U, 0337U, 0338U, 0343U, 0356U, 0368U, 0410U

BCBSNC may request medical records for determination of medical necessity. When medical records are requested, letters of support and/or explanation are often useful, but are not sufficient documentation unless all specific information needed to make a medical necessity determination is included.

Scientific Background and Reference Sources

For Policy Titled: Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management

Liquid Biopsy AHS-G2054

Adamczyk, L. A., Williams, H., Frankow, A., Ellis, H. P., Haynes, H. R., Perks, C., . . . Kurian, K. M. (2015). Current Understanding of Circulating Tumor Cells - Potential Value in Malignancies of the Central Nervous System. *Front Neurol*, 6, 174. <https://doi.org/10.3389/fneur.2015.00174>

Aggarwal, C., Meropol, N. J., Punt, C. J., Iannotti, N., Saidman, B. H., Sabbath, K. D., . . . Cohen, S. J. (2013). Relationship among circulating tumor cells, CEA and overall survival in patients with metastatic colorectal cancer. *Ann Oncol*, 24(2), 420-428. <https://doi.org/10.1093/annonc/mds336>

Aggarwal, C., Thompson, J. C., Black, T. A., Katz, S. I., Fan, R., Yee, S. S., . . . Carpenter, E. L. (2019). Clinical Implications of Plasma-Based Genotyping With the Delivery of Personalized Therapy in Metastatic Non-Small Cell Lung Cancer. *JAMA Oncol*, 5(2), 173-180. <https://doi.org/10.1001/jamaoncol.2018.4305>

Alix-Panabieres, C., & Pantel, K. (2013). Circulating tumor cells: liquid biopsy of cancer. *Clin Chem*, 59(1), 110-118. <https://doi.org/10.1373/clinchem.2012.194258>

Andre, F., Ismaila, N., Henry, N. L., Somerfield, M. R., Bast, R. C., Barlow, W., . . . Stearns, V. (2019). Use of Biomarkers to Guide Decisions on Adjuvant Systemic Therapy for Women With Early-Stage Invasive Breast Cancer: ASCO Clinical Practice Guideline Update—Integration of Results From TAILORx. *Journal of Clinical Oncology*, 37(22), 1956-1964. <https://doi.org/10.1200/JCO.19.00945>

Bedard, P. L., Hansen, A. R., Ratain, M. J., & Siu, L. L. (2013). Tumour heterogeneity in the clinic. *Nature*, 501(7467), 355-364. <https://doi.org/10.1038/nature12627>

Bettegowda, C., Sausen, M., Leary, R. J., Kinde, I., Wang, Y., Agrawal, N., . . . Diaz, L. A., Jr. (2014). Detection of circulating tumor DNA in early- and late-stage human malignancies. *Sci Transl Med*, 6(224), 224ra224. <https://doi.org/10.1126/scitranslmed.3007094>

Bidard, F. C., Proudhon, C., & Pierga, J. Y. (2016). Circulating tumor cells in breast cancer. *Mol Oncol*, 10(3), 418-430. <https://doi.org/10.1016/j.molonc.2016.01.001>

Biocept. (2023). CNSide™ Biomarkers. <https://biocept.com/biomarkers-test/>

Biodesix. (2023). GENESTRAT® GENOMIC TEST. <https://www.biodesix.com/products/lung-cancer/lung-reflex/genestrat>

Breitbach, S., Sterzing, B., Magallanes, C., Tug, S., & Simon, P. (2014). Direct measurement of cell-free DNA from serially collected capillary plasma during incremental exercise. *J Appl Physiol* (1985), 117(2), 119-130. <https://doi.org/10.1152/jappphysiol.00002.2014>

Brock, G., Castellanos-Rizaldos, E., Hu, L., Coticchia, C., & Skog, J. (2015). Liquid biopsy for cancer screening, patient stratification and monitoring. [\[Review Article\]. Transl Cancer Res](https://pdfs.semanticscholar.org/a1e9/69c8b0a267142506f0ef4925b4f93886bb1c.pdf), 4. <https://pdfs.semanticscholar.org/a1e9/69c8b0a267142506f0ef4925b4f93886bb1c.pdf>

Cabel, L., Proudhon, C., Gortais, H., Loirat, D., Coussy, F., Pierga, J.-Y., & Bidard, F.-C. (2017). Circulating tumor cells: clinical validity and utility. *International Journal of Clinical Oncology*, 22(3), 421-430. <https://doi.org/10.1007/s10147-017-1105-2>

[CellSearch. \(2023\). What is a CellSearch CTC Test? https://www.cellsearchctc.com/about-cellsearch/what-is-cellsearch-ctc-test](https://www.cellsearchctc.com/about-cellsearch/what-is-cellsearch-ctc-test)

[Circulogene. \(2023\). How It Works. https://circulogene.com/patients/how-it-works](https://circulogene.com/patients/how-it-works)

Clark, T. A., Chung, J. H., Kennedy, M., Hughes, J. D., Chennagiri, N., Lieber, D. S., . . . Lipson, D. (2018). Analytical Validation of a Hybrid Capture-Based Next-Generation Sequencing Clinical Assay for Genomic Profiling of Cell-Free Circulating Tumor DNA. *J Mol Diagn*, 20(5), 686-702. <https://doi.org/10.1016/j.jmoldx.2018.05.004>

Liquid Biopsy AHS-G2054

College of American Pathologists, I. A. f. t. S. o. L. C., and the Association for Molecular Pathology. (2018). Updated Molecular Testing Guideline for the Selection of Lung Cancer Patients for Treatment with Targeted Tyrosine Kinase Inhibitors. Retrieved from <https://www.amp.org/AMP/assets/File/clinical-practice/Lung%20Update%20Methods%20SDC%20January%202018%20Updated%2002052018-AMP.pdf>

Cristiano, S., Leal, A., Phallen, J., Fiksel, J., Adleff, V., Bruhm, D. C., Jensen, S., Medina, J. E., Hruban, C., White, J. R., Palsgrove, D. N., Niknafs, N., Anagnostou, V., Forde, P., Naidoo, J., Marrone, K., Brahmer, J., Woodward, B. D., Husain, H., . . . Velculescu, V. E. (2019). Genome-wide cell-free DNA fragmentation in patients with cancer. *Nature*, *570*(7761), 385-389. <https://doi.org/10.1038/s41586-019-1272-6>

Curigliano, G. (2014). Liquid biopsies: Tumour diagnosis and treatment monitoring in a blood test | ESMO. ESMO 2014.

Demopoulos, A. (2022, 5/24/2022). Clinical features and diagnosis of leptomeningeal metastases from solid tumors. <https://www.uptodate.com/contents/clinical-features-and-diagnosis-of-leptomeningeal-metastases-from-solid-tumors>

Devonshire, A. S., Whale, A. S., Gutteridge, A., Jones, G., Cowen, S., Foy, C. A., & Huggett, J. F. (2014). Towards standardisation of cell-free DNA measurement in plasma: controls for extraction efficiency, fragment size bias and quantification. *Anal Bioanal Chem*, *406*(26), 6499-6512. <https://doi.org/10.1007/s00216-014-7835-3>

Diaz, M., Singh, P., Kotchetkov, I., Skakodub, A., Meng, A., Tamer, C., . . . Ramanathan, L. (2022). Quantitative Assessment of Circulating Tumor Cells in Cerebrospinal Fluid as a Clinical Tool to Predict Survival in Leptomeningeal Metastases.

Douillard, J.-Y., Shepherd, F. A., Hirsh, V., Mok, T., Socinski, M. A., Gervais, R., . . . Kim, E. S. (2009). Molecular Predictors of Outcome With Gefitinib and Docetaxel in Previously Treated Non-Small-Cell Lung Cancer: Data From the Randomized Phase III INTEREST Trial. *Journal of Clinical Oncology*, *28*(5), 744-752. <https://doi.org/10.1200/JCO.2009.24.3030>

Douillard, J. Y., Ostoros, G., Cobo, M., Ciuleanu, T., Cole, R., McWalter, G., . . . McCormack, R. (2014). Gefitinib treatment in EGFR mutated caucasian NSCLC: circulating-free tumor DNA as a surrogate for determination of EGFR status. *J Thorac Oncol*, *9*(9), 1345-1353. <https://doi.org/10.1097/jto.0000000000000263>

Dudley, J. C., Schroers-Martin, J., Lazzareschi, D. V., Shi, W. Y., Chen, S. B., Esfahani, M. S., . . . Diehn, M. (2019). Detection and Surveillance of Bladder Cancer Using Urine Tumor DNA. *Cancer Discov*, *9*(4), 500-509. <https://doi.org/10.1158/2159-8290.Cd-18-0825>

EAU. (2021). Prostate Cancer. Retrieved 2/10/21 from <https://uroweb.org/guideline/prostate-cancer/#5>

FDA. (2016). Approved Drugs - cobas EGFR Mutation Test v2 (WebContent). <https://www.fda.gov/Drugs/InformationOnDrugs/ApprovedDrugs/ucm504540.htm>

Foukakis, T., & Bergh, J. (2022, 11/9/22). Prognostic and predictive factors in early, nonmetastatic breast cancer - UpToDate <https://www.uptodate.com/contents/prognostic-and-predictive-factors-in-early-nonmetastatic-breast-cancer>

FoundationOne. (2022). Technical Specifications. https://assets.ctfassets.net/w98cd481qyp0/wVEm7VtICYR0sT5C1VbU7/fd055e0476183a6acd4eae6b583e3a00/F1LCDx_Technical_Specs_072021.pdf

FoundationOne. (2023). Liquid CDx. <https://www.foundationmedicine.com/test/foundationone-liquid-cdx>

Liquid Biopsy AHS-G2054

Gould, S. J., & Raposo, G. (2013). As we wait: coping with an imperfect nomenclature for extracellular vesicles. *J Extracell Vesicles*, 2. <https://doi.org/10.3402/jev.v2i0.20389>

Groot Koerkamp, B., Rahbari, N. N., Buchler, M. W., Koch, M., & Weitz, J. (2013). Circulating tumor cells and prognosis of patients with resectable colorectal liver metastases or widespread metastatic colorectal cancer: a meta-analysis. *Ann Surg Oncol*, 20(7), 2156-2165. <https://doi.org/10.1245/s10434-013-2907-8>

Grover, P. K., Cummins, A. G., Price, T. J., Roberts-Thomson, I. C., & Hardingham, J. E. (2014). Circulating tumour cells: the evolving concept and the inadequacy of their enrichment by EpCAM-based methodology for basic and clinical cancer research. *Ann Oncol*, 25(8), 1506-1516. <https://doi.org/10.1093/annonc/mdu018>

Haber, D. A., & Velculescu, V. E. (2014). Blood-based analyses of cancer: circulating tumor cells and circulating tumor DNA. *Cancer Discov*, 4(6), 650-661. <https://doi.org/10.1158/2159-8290.Cd-13-1014>

Health, G. (2023). Guardant360. <http://www.guardant360.com/>

Huang, X., Yuan, T., Tschannen, M., Sun, Z., Jacob, H., Du, M., . . . Wang, L. (2013). Characterization of human plasma-derived exosomal RNAs by deep sequencing. *BMC Genomics*, 14, 319. <https://doi.org/10.1186/1471-2164-14-319>

Ignatiadis, M., & Dawson, S. J. (2014). Circulating tumor cells and circulating tumor DNA for precision medicine: dream or reality? *Ann Oncol*, 25(12), 2304-2313. <https://doi.org/10.1093/annonc/mdu480>

Jiang, P., Chan, C. W., Chan, K. C., Cheng, S. H., Wong, J., Wong, V. W., . . . Lo, Y. M. (2015). Lengthening and shortening of plasma DNA in hepatocellular carcinoma patients. *Proc Natl Acad Sci U S A*, 112(11), E1317-1325. <https://doi.org/10.1073/pnas.1500076112>

Johnson, K., Sexton, Daniel. (2021, 7/7/21). Cerebrospinal fluid: Physiology and utility of an examination in disease states. <https://www.uptodate.com/contents/cerebrospinal-fluid-physiology-and-utility-of-an-examination-in-disease-states?>

Kahlert, C., Melo, S. A., Protopopov, A., Tang, J., Seth, S., Koch, M., . . . Kalluri, R. (2014). Identification of double-stranded genomic DNA spanning all chromosomes with mutated KRAS and p53 DNA in the serum exosomes of patients with pancreatic cancer. *J Biol Chem*, 289(7), 3869-3875. <https://doi.org/10.1074/jbc.C113.532267>

Karabacak, N. M., Spuhler, P. S., Fachin, F., Lim, E. J., Pai, V., Ozkumur, E., . . . Toner, M. (2014). Microfluidic, marker-free isolation of circulating tumor cells from blood samples. *Nat Protoc*, 9(3), 694-710. <https://doi.org/10.1038/nprot.2014.044>

Kim, S. T., Banks, K. C., Lee, S.-H., Kim, K., Park, J. O., Park, S. H., . . . Lee, J. (2017). Prospective Feasibility Study for Using Cell-Free Circulating Tumor DNA-Guided Therapy in Refractory Metastatic Solid Cancers: An Interim Analysis. *JCO Precision Oncology*, 1(1), 1-15. <https://doi.org/10.1200/PO.16.00059>

Lanman, R. B., Mortimer, S. A., Zill, O. A., Sebisano, D., Lopez, R., Blau, S., . . . Talasaz, A. (2015). Analytical and Clinical Validation of a Digital Sequencing Panel for Quantitative, Highly Accurate Evaluation of Cell-Free Circulating Tumor DNA. *PLoS One*, 10(10), e0140712. <https://doi.org/10.1371/journal.pone.0140712>

Lee, H., Han, J., & Choi, Y.-L. (2021). Real-World Analysis of the EGFR Mutation Test in Tissue and Plasma Samples from Non-Small Cell Lung Cancer. *Diagnostics*, 11(9), 1695.

Leighl, N. B., Page, R. D., Raymond, V. M., Daniel, D. B., Divers, S. G., Reckamp, K. L., . . . Papadimitrakopoulou, V. A. (2019). Clinical Utility of Comprehensive Cell-Free DNA Analysis to Identify

Liquid Biopsy AHS-G2054

Genomic Biomarkers in Patients with Newly Diagnosed Metastatic Non-Small Cell Lung Cancer. *Clinical Cancer Research*, clincanres.0624.2019. <https://doi.org/10.1158/1078-0432.CCR-19-0624>

Lin, X., Fleisher, M., Rosenblum, M., Lin, O., Boire, A., Briggs, S., . . . Pentsova, E. I. (2017). Cerebrospinal fluid circulating tumor cells: a novel tool to diagnose leptomeningeal metastases from epithelial tumors. *Neuro Oncol*, 19(9), 1248-1254. <https://doi.org/10.1093/neuonc/nox066>

Lindeman, N. I., Cagle, P. T., Aisner, D. L., Arcila, M. E., Beasley, M. B., Bernicker, E. H., . . . Yatabe, Y. (2018). Updated Molecular Testing Guideline for the Selection of Lung Cancer Patients for Treatment With Targeted Tyrosine Kinase Inhibitors: Guideline From the College of American Pathologists, the International Association for the Study of Lung Cancer, and the Association for Molecular Pathology. *J Mol Diagn*, 20(2), 129-159. <https://doi.org/10.1016/j.jmoldx.2017.11.004>

Lu, T., & Li, J. (2017). Clinical applications of urinary cell-free DNA in cancer: current insights and promising future. *Am J Cancer Res*, 7(11), 2318-2332.

Luo, J., Shen, L., & Zheng, D. (2014). Diagnostic value of circulating free DNA for the detection of EGFR mutation status in NSCLC: a systematic review and meta-analysis. *Sci Rep*, 4, 6269. <https://doi.org/10.1038/srep06269>

Marchetti, A., Del Gramastro, M., Felicioni, L., Malatesta, S., Filice, G., Centi, I., . . . Buttitta, F. (2014). Assessment of EGFR mutations in circulating tumor cell preparations from NSCLC patients by next generation sequencing: toward a real-time liquid biopsy for treatment. *PLoS One*, 9(8), e103883. <https://doi.org/10.1371/journal.pone.0103883>

Mathios, D., & Phallen, J. (2022). Advances in molecular biomarkers and liquid biopsy in gliomas. *Neuro-Oncology Advances*, 4(Supplement 2), ii15-ii21. <https://doi.org/10.1093/oaajnl/vdac151>

Mavroudis, D. (2010). Circulating cancer cells. *Ann Oncol*, 21 Suppl 7, vii95-100. doi:10.1093/annonc/mdq378

MDx. (2018). SelectMDx for Prostate Cancer. <https://mdxhealth.com/selectmdx-prostate-cancer>

Mellert, H., Foreman, T., Jackson, L., Maar, D., Thurston, S., Koch, K., . . . Pestano, G. A. (2017). Development and Clinical Utility of a Blood-Based Test Service for the Rapid Identification of Actionable Mutations in Non-Small Cell Lung Carcinoma. *J Mol Diagn*, 19(3), 404-416. <https://doi.org/10.1016/j.jmoldx.2016.11.004>

Mellert, H. S., Alexander, K. E., Jackson, L. P., & Pestano, G. A. (2018). A Blood-based Test for the Detection of ROS1 and RET Fusion Transcripts from Circulating Ribonucleic Acid Using Digital Polymerase Chain Reaction. *J Vis Exp*(134). <https://doi.org/10.3791/57079>

Merker, J. D., Oxnard, G. R., Compton, C., Diehn, M., Hurley, P., Lazar, A. J., . . . Turner, N. C. (2018). Circulating Tumor DNA Analysis in Patients With Cancer: American Society of Clinical Oncology and College of American Pathologists Joint Review. *Journal of Clinical Oncology*, 36(16), 1631-1641. <https://doi.org/10.1200/JCO.2017.76.8671>

Miller, M. C., Doyle, G. V., & Terstappen, L. W. (2010). Significance of Circulating Tumor Cells Detected by the CellSearch System in Patients with Metastatic Breast Colorectal and Prostate Cancer. 1, *J Oncol* 2010, 617421. <https://doi.org/10.1155/2010/617421>

Murray, N. P., Reyes, E., Badinez, L., Orellana, N., Fuentealba, C., Olivares, R., . . . Duenas, R. (2013). Circulating Prostate Cells Found in Men with Benign Prostate Disease Are P504S Negative: Clinical Implications. *J Oncol*, 2013, 165014. <https://doi.org/10.1155/2013/165014>

Liquid Biopsy AHS-G2054

- NCCN. (2022a, June 14, 2022). NCCN Clinical Practice Guidelines in Oncology for Acute Myeloid Leukemia version 3.2022. https://www.nccn.org/professionals/physician_gls/pdf/aml.pdf
- NCCN. (2022b, December 21, 2022). NCCN Clinical Practice Guidelines in Oncology for Bladder Cancer version 3.2022. https://www.nccn.org/professionals/physician_gls/pdf/bladder.pdf
- NCCN. (2022c, June 21, 2022). NCCN Clinical Practice Guidelines in Oncology for Breast Cancer version 4.2022. Retrieved from tps://www.nccn.org/professionals/physician_gls/pdf/breast.pdf
- NCCN. (2022d, September 29, 2022). NCCN Clinical Practice Guidelines in Oncology for Central Nervous System Cancers version 2.2022. https://www.nccn.org/professionals/physician_gls/pdf/cns.pdf
- NCCN. (2022e, October 27, 2022). NCCN Clinical Practice Guidelines in Oncology for Colon Cancer version 3.2022. https://www.nccn.org/professionals/physician_gls/pdf/colon.pdf
- NCCN. (2022f, December 5, 2022). NCCN Clinical Practice Guidelines in Oncology for Esophageal and Esophagogastric Junction Cancers version 5.2022. https://www.nccn.org/professionals/physician_gls/pdf/esophageal.pdf
- NCCN. (2022g, December 9, 2022). NCCN Clinical Practice Guidelines in Oncology for Hepatobiliary Cancers version 4.2022. https://www.nccn.org/professionals/physician_gls/pdf/hepatobiliary.pdf
- NCCN. (2022h, September 21, 2022). NCCN Clinical Practice Guidelines in Oncology for Neuroendocrine and Adrenal Tumors version 2.2022. https://www.nccn.org/professionals/physician_gls/pdf/neuroendocrine.pdf
- NCCN. (2022i, December 6, 2022). NCCN Clinical Practice Guidelines in Oncology for Pancreatic Adenocarcinoma version 2.2022. https://www.nccn.org/professionals/physician_gls/pdf/pancreatic.pdf
- NCCN. (2022j, February 16, 2022). NCCN Clinical Practice Guidelines in Oncology for Prostate Cancer Early Detection version 2.2022. https://www.nccn.org/professionals/physician_gls/pdf/prostate_detection.pdf
- NCCN. (2023a, September 16, 2022). NCCN Clinical Practice Guidelines for Prostate Cancer version 1.2023. https://www.nccn.org/professionals/physician_gls/pdf/prostate.pdf
- NCCN. (2023b, December 22, 2022). NCCN Clinical Practice Guidelines in Oncology for Non-Small Cell Lung Cancer version 1.2023. https://www.nccn.org/professionals/physician_gls/pdf/nscl.pdf
- NCCN. (2023c, December 21, 2022). NCCN Clinical Practice Guidelines in Oncology for Small Cell Lung Cancer version 3.2023. https://www.nccn.org/professionals/physician_gls/pdf/sclc.pdf
- Neogenomics. (2022). InvisionFirst-Lung (Liquid Biopsy). <https://neogenomics.com/patients/invisionfirst-lung-liquid-biopsy>
- NIH. (2017). Extracellular RNA Communication - Home | NIH Common Fund. Retrieved from <https://www.ncbi.nlm.nih.gov/pubmed/>
- Odegaard, J. I., Vincent, J. J., Mortimer, S., Vowles, J. V., Ulrich, B. C., Banks, K. C., . . . Talasz, A. (2018). Validation of a Plasma-Based Comprehensive Cancer Genotyping Assay Utilizing Orthogonal Tissue- and Plasma-Based Methodologies. *Clin Cancer Res*, 24(15), 3539-3549. <https://doi.org/10.1158/1078-0432.Ccr-17-3831>
- Oxnard, G. R., Thress, K. S., Alden, R. S., Lawrance, R., Paweletz, C. P., Cantarini, M., . . . Janne, P. A. (2016). Association Between Plasma Genotyping and Outcomes of Treatment With Osimertinib (AZD9291)

Liquid Biopsy AHS-G2054

in *Advanced Non-Small-Cell Lung Cancer*. *J Clin Oncol*, 34(28), 3375-3382. <https://doi.org/10.1200/jco.2016.66.7162>

Pinzani, P., D'Argenio, V., Del Re, M., Pellegrini, C., Cucchiara, F., Salvianti, F., & Galbiati, S. (2021). Updates on liquid biopsy: current trends and future perspectives for clinical application in solid tumors. *Clin Chem Lab Med*. <https://doi.org/10.1515/cclm-2020-1685>

Quach, N., Goodman, M. F., & Shibata, D. (2004). In vitro mutation artifacts after formalin fixation and error prone translesion synthesis during PCR. *BMC Clin Pathol*, 4(1), 1. <https://doi.org/10.1186/1472-6890-4-1>

ResolutionBio. (2021). Resolution ctDx Lung™. <http://www.resolutionbio.com/assays/ctDx-Lung.html>

Rolfo, C., Mack, P., Scagliotti, G. V., Aggarwal, C., Arcila, M. E., Barlesi, F., Bivona, T., Diehn, M., Dive, C., Dziadziuszko, R., Leighl, N., Malapelle, U., Mok, T., Peled, N., Raez, L. E., Sequist, L., Sholl, L., Swanton, C., Abbosh, C., . . . Gandara, D. (2021). Liquid Biopsy for Advanced NSCLC: A Consensus Statement From the International Association for the Study of Lung Cancer. *Journal of Thoracic Oncology*, 16(10), 1647-1662. <https://doi.org/https://doi.org/10.1016/j.jtho.2021.06.017>

Sacher, A. G., Paweletz, C., Dahlberg, S. E., Alden, R. S., O'Connell, A., Feeney, N., Mach, S. L., Janne, P. A., & Oxnard, G. R. (2016). Prospective Validation of Rapid Plasma Genotyping for the Detection of EGFR and KRAS Mutations in Advanced Lung Cancer. *JAMA Oncol*, 2(8), 1014-1022. <https://doi.org/10.1001/jamaoncol.2016.0173>

Schneider, B. J., Ismaila, N., Aerts, J., Chiles, C., Daly, M. E., Detterbeck, F. C., . . . Altorki, N. (2019). Lung Cancer Surveillance After Definitive Curative-Intent Therapy: ASCO Guideline. *Journal of Clinical Oncology*, JCO.19.02748. <https://doi.org/10.1200/JCO.19.02748>

Seeberg, L. T., Waage, A., Brunborg, C., Hugenschmidt, H., Renolen, A., Stav, I., . . . Wiedswang, G. (2015). Circulating tumor cells in patients with colorectal liver metastasis predict impaired survival. *Ann Surg*, 261(1), 164-171. <https://doi.org/10.1097/sla.0000000000000580>

Sepulveda, A. R., Hamilton, S. R., Allegra, C. J., Grody, W., Cushman-Vokoun, A. M., Funkhouser, W. K., . . . Nowak, J. A. (2017). Molecular Biomarkers for the Evaluation of Colorectal Cancer: Guideline From the American Society for Clinical Pathology, College of American Pathologists, Association for Molecular Pathology, and American Society of Clinical Oncology. *J Mol Diagn*, 19(2), 187-225. <https://doi.org/10.1016/j.jmoldx.2016.11.001>

Sequist, L., & Neal, J. (2022, 12/14/2022). Personalized, genotype-directed therapy for advanced non-small cell lung cancer - UpToDate. <https://www.uptodate.com/contents/personalized-genotype-directed-therapy-for-advanced-non-small-cell-lung-cancer>

Shore, N., Hafron, J., Langford, T., Stein, M., DeHart, J., Brawer, M., Hessels, D., Schalken, J., Criekinge, W. V., Groskopf, J., & Wojno, K. (2019). Urinary Molecular Biomarker Test Impacts Prostate Biopsy Decision Making in Clinical Practice. *Urology Practice*, 6(4), 256-261. <https://doi.org/doi:10.1016/j.urpr.2018.09.002>

Sturgeon, C. M., Duffy, M. J., Hofmann, B. R., Lamerz, R., Fritsche, H. A., Gaarenstroom, K., . . . Diamandis, E. P. (2010). National Academy of Clinical Biochemistry Laboratory Medicine Practice Guidelines for use of tumor markers in liver, bladder, cervical, and gastric cancers. *Clin Chem*, 56(6), e1-48. <https://doi.org/10.1373/clinchem.2009.133124>

Sturgeon, C. M., Hoffman, B. R., Chan, D. W., Ch'ng, S. L., Hammond, E., Hayes, D. F., . . . Diamandis, E. P. (2008). National Academy of Clinical Biochemistry Laboratory Medicine Practice Guidelines for use of tumor markers in clinical practice: quality requirements. *Clin Chem*, 54(8), e1-e10. <https://doi.org/10.1373/clinchem.2007.094144>

Liquid Biopsy AHS-G2054

- Syeda, M. M., Wiggins, J. M., Corless, B. C., Long, G. V., Flaherty, K. T., Schadendorf, D., . . . Polsky, D. (2021). Circulating tumour DNA in patients with advanced melanoma treated with dabrafenib or dabrafenib plus trametinib: a clinical validation study. *Lancet Oncol*, 22(3), 370-380. [https://doi.org/10.1016/s1470-2045\(20\)30726-9](https://doi.org/10.1016/s1470-2045(20)30726-9)
- Thum, T., & Condorelli, G. (2015). Long noncoding RNAs and microRNAs in cardiovascular pathophysiology. *Circ Res*, 116(4), 751-762. <https://doi.org/10.1161/circresaha.116.303549>
- Van Neste, L., Hendriks, R. J., Dijkstra, S., Trooskens, G., Cornel, E. B., Jannink, S. A., . . . Schalken, J. A. (2016). Detection of High-grade Prostate Cancer Using a Urinary Molecular Biomarker-Based Risk Score. *Eur Urol*, 70(5), 740-748. <https://doi.org/10.1016/j.eururo.2016.04.012>
- Van Poznak, C., Somerfield, M. R., Bast, R. C., Cristofanilli, M., Goetz, M. P., Gonzalez-Angulo, A. M., Hicks, D. G., Hill, E. G., Liu, M. C., Lucas, W., Mayer, I. A., Mennel, R. G., Symmans, W. F., Hayes, D. F., & Harris, L. N. (2015). Use of Biomarkers to Guide Decisions on Systemic Therapy for Women With Metastatic Breast Cancer: American Society of Clinical Oncology Clinical Practice Guideline. *J Clin Oncol*, 33(24), 2695-2704. <https://doi.org/10.1200/JCO.2015.61.1459>
- Vogel, J. D., Felder, S. I., Bhamra, A. R., Hawkins, A. T., Langenfeld, S. J., Shaffer, V. O., . . . Paquette, I. M. (2022). The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for the Management of Colon Cancer. *Dis Colon Rectum*, 65(2), 148-177. <https://doi.org/10.1097/dcr.0000000000002323>
- Waki, K., Yokomizo, K., Yoshiyama, K., Takamori, S., Komatsu, N., & Yamada, A. (2021). Integrity of circulating cell-free DNA as a prognostic biomarker for vaccine therapy in patients with nonsmall cell lung cancer. *Immunopharmacol Immunotoxicol*, 1-14. <https://doi.org/10.1080/08923973.2021.1872619>
- Wang, X. S., Zhao, M. Q., Zhang, L., Kong, D. J., Ding, X. Z., Hu, X. C., . . . Gao, S. G. (2018). Cell-free DNA in blood and urine as a diagnostic tool for bladder cancer: a meta-analysis. *Am J Transl Res*, 10(7), 1935-1948.
- Whiteside, T. L. (2013). Immune modulation of T-cell and NK (natural killer) cell activities by TEXs (tumour-derived exosomes). *Biochem Soc Trans*, 41(1), 245-251. <https://doi.org/10.1042/bst20120265>
- Wu, Y. L., Planchard, D., Lu, S., Sun, H., Yamamoto, N., Kim, D. W., . . . Douillard, J. Y. (2018). Pan-Asian adapted Clinical Practice Guidelines for the management of patients with metastatic non-small-cell lung cancer: a CSCO–ESMO initiative endorsed by JSMO, KSMO, MOS, SSO and TOS. *Annals of Oncology*, 30(2), 171-210. <https://doi.org/10.1093/annonc/mdy554>
- Wu, Y. L., Zhou, C., Liang, C. K., Wu, G., Liu, X., Zhong, Z., . . . Zuo, Y. (2015). First-line erlotinib versus gemcitabine/cisplatin in patients with advanced EGFR mutation-positive non-small-cell lung cancer: analyses from the phase III, randomized, open-label, ENSURE study. *Ann Oncol*, 26(9), 1883-1889. <https://doi.org/10.1093/annonc/mdv270>
- Xu, Y., Lou, J., Yu, M., Jiang, Y., Xu, H., Huang, Y., . . . Zhao, A. (2021). Urinary Exosomes Diagnosis of Urological Tumors: A Systematic Review and Meta-Analysis. *Front Oncol*, 11, 734587. <https://doi.org/10.3389/fonc.2021.734587>
- Yanez-Mo, M., Siljander, P. R., Andreu, Z., Zavec, A. B., Borrás, F. E., Buzas, E. I., . . . De Wever, O. (2015). Biological properties of extracellular vesicles and their physiological functions. *J Extracell Vesicles*, 4, 27066. <https://doi.org/10.3402/jev.v4.27066>
- Yu, W., Hurley, J., Roberts, D., Chakraborty, S., Enderle, D., Noerholm, M., . . . Skog, J. (2021). Exosome-based Liquid Biopsies in Cancer: Opportunities and Challenges. *Ann Oncol*. <https://doi.org/10.1016/j.annonc.2021.01.074>

Liquid Biopsy AHS-G2054

Zhang, L., Riethdorf, S., Wu, G., Wang, T., Yang, K., Peng, G., . . . Pantel, K. (2012). Meta-analysis of the prognostic value of circulating tumor cells in breast cancer. *Clin Cancer Res*, 18(20), 5701-5710. <https://doi.org/10.1158/1078-0432.ccr-12-1587>

Medical Director review 5/2019

Medical Director review 7/2019

For Policy Titled: Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management (Liquid Biopsy)

Medical Director review 11/2019

Specialty Matched Consultant Advisory Panel 3/2020

Medical Director review 3/2020

Medical Director review 4/2020

Medical Director review 2/2021

Specialty Matched Consultant Advisory Panel 3/2021

Medical Director review 3/2021

Medical Director review 4/2021

Medical Director review 6/2021

For Policy Titled: Liquid Biopsy

Medical Director review 4/2022

Medical Director review 4/2023

Policy Implementation/Update Information

For Policy Titled: Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management

- 1/1/2019 New policy developed. BCBSNC will provide coverage for detection of circulating tumor cells and cell free DNA in cancer management when it is determined to be medically necessary and criteria are met. Medical Director review 1/1/2019. Policy noticed 1/1/2019 for effective date 4/1/2019. (lpr)
- 6/11/19 Reviewed by Avalon 1st Quarter 2019 CAB. Added CPT 81479 to Billing/Coding section. Deleted CPT codes 86152 and 86153 from Billing/Coding section. No change to policy statement. Medical Director review 5/2019. (lpr)
- 7/30/19 Under “When Covered” section: removed item B. “Testing is performed using the Cobas EGFR Mutation Test, Guardant360 test, or OncoBEAM test.” Medical Director review 7/2019. (lpr)
- 11/12/19 Deleted coding table from Billing/Coding section. Wording in the Policy, When Covered, and/or Not Covered section(s) changed from Medical Necessity to Reimbursement language, where needed. Minor reformatting of policy statements; no change to policy statement intent. (hb)

Liquid Biopsy AHS-G2054

For Policy Titled: Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management (Liquid Biopsy)

- 12/31/19 Reviewed by Avalon 3rd Quarter 2019 CAB. Under “When Not Covered” section added the statement “Testing to predict treatment response using circulating tumor DNA in all other cancer types is investigational. Added “Liquid Biopsy” to the title of the policy. **Policy Title changed from “Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management” to Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management (Liquid Biopsy).**” Added CPT codes 81277, 81404, 86152, 86153 to Billing/Coding section. Medical Director review 11/2019. (lpr)
- 4/14/20 Specialty Matched Consultant Advisory Panel review 3/18/2020. No change to policy statement. (lpr)
- 5/12/20 Reviewed by Avalon 1st Quarter 2020 CAB. Medical Director review 4/2020. Added CPT codes 81301, 0091U to Billing/Coding section. Updated When Covered section statement. Added CellSearch is investigational to When Not Covered section. References added. (lpr)
- 2/23/21 Off cycle review. Under “When Covered” section: Added coverage criteria for additional mutations for NSCLC as well as use for breast cancer. Medical Director review 2/2021. (lpr)
- 4/6/21 Specialty Matched Consultant Advisory Panel review 3/17/2021. No change to policy statement. (lpr)
- 7/1/21 Reviewed by Avalon 1st Quarter 2021 CAB. Medical Director review 4/2021, 6/2021. Added CPT codes 81162, 81163, 81164, 0011M, 0155U, 0177U, 0179U, 0229U, 0239U, 0242U to Billing/Coding section; removed CPT 81277. Updated Description and Policy Guidelines. Added Related Policies section under Description. Under “When Covered” section, added “Note: If the above criteria for medical necessity have been met (i.e., when tissue biopsy is contraindicated or quantity of tissue available is insufficient), panel testing using NGS for up to 50 genes may be performed.” Added references. No change to policy intent. (lpr)

For Policy Titled: Liquid Biopsy

- 5/31/22 Reviewed by Avalon 1st Quarter 2022 CAB. “When Covered” section reformatted and removed 50 gene limit sentences. Moved Note 1 & 2 and reformatted “When Not Covered” section. Updated policy guidelines, references. Added policy AHS- M2178 to related policies section and removed AHS-M2109 due to archival. Added CPT 0137U to Billing/Coding section. Medical Director review 4/2022. **Policy title changed from “Detection of Circulating Tumor Cells and Cell Free DNA in Cancer Management (Liquid Biopsy)” to “Liquid Biopsy.”** (lpr)
- 9/30/22 Added the following CPT codes to Billing/Coding section: 0332U, 0333U, 0337U, 0338U, 0343U, 0346U. (lpr)
- 12/30/22 Added PLA code 0356U to Billing/Coding section for effective date 1/1/2023. (lpr)
- 3/31/23 Added PLA code 0368U to Billing/Coding section. (lpr)
- 5/16/23 Reviewed by Avalon 1st Quarter 2023 CAB. Medical Director review 4/2023. Expanded medical necessity criteria under “When Covered” section. Updated policy guidelines, description, and references. Removed Notes 1, 2. Deleted related policies section. Under Billing/Coding section, added CPT codes: 81194, 81210, 81275, 81276, 81405, 81406, 0332U, 0333U, 0337U, 0338U, 0343U, 0356U, 0368U; deleted CPT codes: 81301, 81404, 0239U, 0242U, 0346U. (lpr)
- 9/29/23 Added PLA code 0410U to Billing/Coding section for 10/1/23 code update. (lpr)

Liquid Biopsy AHS-G2054

12/29/23 Added CPT code 81462 to Billing/Coding section for 1/1/2024 code update. (lpr)

Medical policy is not an authorization, certification, explanation of benefits or a contract. Benefits and eligibility are determined before medical guidelines and payment guidelines are applied. Benefits are determined by the group contract and subscriber certificate that is in effect at the time services are rendered. This document is solely provided for informational purposes only and is based on research of current medical literature and review of common medical practices in the treatment and diagnosis of disease. Medical practices and knowledge are constantly changing and BCBSNC reserves the right to review and revise its medical policies periodically.