**Medical Policy**

**Title:** Proteomic Testing for Systemic Therapy in Non-Small-Cell Lung Cancer

<table>
<thead>
<tr>
<th>Professional</th>
<th>Institutional</th>
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<tbody>
<tr>
<td>Original Effective Date: October 1, 2015</td>
<td>Original Effective Date: October 1, 2015</td>
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<td>Revision Date(s): October 1, 2015; January 1, 2016; January 20, 2016; March 29, 2017; December 20, 2017; May 23, 2018; January 4, 2019</td>
<td>Revision Date(s): October 1, 2015; January 1, 2016; January 20, 2016; March 29, 2017; December 20, 2017; May 23, 2018; January 4, 2019</td>
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<tr>
<td>Current Effective Date: October 1, 2015</td>
<td>Current Effective Date: October 1, 2015</td>
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<table>
<thead>
<tr>
<th>Populations</th>
<th>Interventions</th>
<th>Comparators</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Individuals: With newly diagnosed non-small-cell lung cancer and EGFR-negative variant status</td>
<td>Interventions of interest are: • Management with a serum proteomic test to predict survival and select treatment</td>
<td>Comparators of interest are: • Standard medical management</td>
<td>Relevant outcomes include: Overall survival</td>
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<td>• Treatment-related morbidity</td>
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<tr>
<td>Individuals: With newly diagnosed non-small-cell lung cancer and unknown EGFR-variant status</td>
<td>Interventions of interest are: • Management with a serum proteomic test to predict survival and select treatment</td>
<td>Comparators of interest are: • Standard medical management</td>
<td>Relevant outcomes include: Overall survival</td>
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</tbody>
</table>
DESCRIPTION
Proteomic testing has been proposed as a way to predict survival outcomes, as well as the response to and selection of targeted therapy for patients with non-small-cell lung cancer (NSCLC). One commercially available test, the VeriStrat assay, has been investigated as a predictive marker for response to epidermal growth factor receptor (EGFR) tyrosine kinase inhibitors (TKIs).

OBJECTIVE
The objective of this policy is to determine whether the use of proteomic testing to select therapy improves the net health outcome in patients with non-small-cell lung cancer.

BACKGROUND
Non-Small-Cell Lung Cancer
Lung cancer is the leading cause of cancer death in the United States, with an estimated 221,200 new cases and 158,040 deaths due to the disease in 2015. Non-small cell lung cancer (NSCLC) accounts for approximately 85% of lung cancer cases and includes nonsquamous carcinoma (adenocarcinoma, large cell carcinoma, other cell types) and squamous cell carcinoma.

Diagnosis
The stage at which lung cancer is diagnosed has the greatest impact on prognosis. Localized disease confined to the primary site has a 55.6% relative 5-year survival but accounts for only 16% of lung cancer cases at diagnosis. Mortality increases sharply with advancing stage. Metastatic lung cancer has a relative 5-year survival of 4.5%. Overall, advanced disease, defined as regional involvement and metastatic, accounts for approximately 80% of cases of lung cancer at diagnosis. These statistics are mirrored for the population of NSCLC, with 85% of cases presenting as advanced disease and up to 40% of patients with metastatic disease.

In addition to tumor stage; age, sex, and performance status are independent prognostic factors for survival particularly in early-stage disease. Wheatley-Price et al (2010) reported on a retrospective pooled analysis of 2349 advanced NSCLC patients from 5
randomized chemotherapy trials. Women had a higher response rate to platinum-based chemotherapy than men. Greater overall survival (OS) than men were among those with adenocarcinoma histology. A small survival advantage exists for squamous cell carcinoma over non-bronchiolar nonsquamous histology.

The oncology clinical care and research community use standard measures of performance status: Eastern Cooperative Oncology Group scale and Karnofsky Performance Scale.

Treatment
Treatment approaches are multimodal and generally include surgery, radiotherapy, and chemotherapy (either alone or in combination with another treatment, depending on disease stage and tumor characteristics). The clinical management pathway for stage I or II NSCLC is shown in Figure 1.

The clinical management pathway for newly diagnosed advanced NSCLC is shown in Figure 2. Treatment recommendations are based on the overall health or performance status of the patient as well as the presence or absence of a treatment-sensitizing genetic variant. The latter is used to select for targeted therapy or platinum-based chemotherapy.

The clinical management pathway for advanced NSCLC after progression on first-line treatment or recurrence is shown in Figure 3. Treatment options are based on objective response to prior therapy, duration of response, as well as the type of and duration of prior therapy (either targeted therapy or chemotherapy).

**Figure 1. Clinical Management Pathways for Newly Diagnosed Stage I or II NSCLC**

- Surgical Intervention
- Individuals with newly diagnosed stage I or II NSCLC
- P-Stage 1A
- P-Stage 1B with risk factors
- P-II/III
- Medically Inoperable
- Surveillance
- Adjuvant Chemotherapy
- Outcomes: PFS, OS, ORR
- SBRT or Conventional RT
- Adverse Events

NSCLC: non-small-cell lung cancer; ORR: overall response rate; OS: overall survival; PFS: progression-free survival; RT: radiotherapy; SBRT: stereotactic body radiotherapy.
**Figure 2. Clinical Management Pathways for Newly Diagnosed Advanced NSCLC**

- **Test for driver variants:** EGFR, ALK, ROS1 variants
  - **Driver variant detected**
    - Treat TT: EGFR+ erlotinib, gefitinib, afatinib OR ALK+ crizotinib, ceritinib, afatinib OR ROS1+ crizotinib
  - **Driver variant not detected**
    - Outcomes: PFS, OS, ORR

- **Test for PD-L1 expression**
  - **Driver variant not detected, PD-L1 ≥50%**
    - Treat with pembrolizumab
  - **Driver variant not detected, PD-L1 <50%**
    - Treat with platinum-based chemotherapy
    - Outcomes: PFS, OS, ORR

NSCLC: non-small-cell lung cancer; ORR: overall response rate; OS: overall survival; PD-L1: programmed death-ligand 1; PFS: progression-free survival; TT: targeted treatment.
Figure 3. Clinical Management Pathways for Advanced NSCLC That Has Progressed

NSCLC: non-small-cell lung cancer; ORR: overall response rate; OS: overall survival; PD-L1: programmed death-ligand 1; PFS: progression-free survival; TT: targeted treatment.

Genomic Alterations
Several common genetic alterations in NSCLC have been targets for drug therapy, the most well-established of which are tyrosine kinase inhibitors (TKIs) targeting the epidermal growth factor receptor (EGFR) and crizotinib targeting the anaplastic lymphoma kinase (ALK) gene rearrangement.

EGFR Variants
EGFR, a tyrosine kinase receptor (TK), is frequently overexpressed and activated in NSCLC. Drugs that inhibit EGFR-signaling either prevent ligand-binding to the extracellular domain (monoclonal antibodies) or inhibit intracellular TK activity (small molecule TKIs). These targeted therapies dampen signal transduction through pathways downstream to the EGFR, such as the RAS/RAF/MAPK cascade. RAS proteins are G proteins that cycle between active and inactive forms in response to stimulation from cell surface receptors such as EGFR, acting as binary switches between cell surface EGFR and downstream signaling pathways. These pathways are important in cancer cell proliferation, invasion, metastasis, and the stimulation of neovascularization.

Variants in 2 regions of the EGFR gene, including small deletions in exon 19 and a point mutation in exon 21 (L858R), appear to predict tumor response to TKIs such as erlotinib. The prevalence of EGFR variants in NSCLC varies by population, with the highest prevalence in nonsmoking Asian women with adenocarcinoma; for that subpopulation, EGFR variants have been reported to as high as 30% to 50%. The reported prevalence
of EGFR variants in lung adenocarcinoma patients in the United States is approximately 15%.5

**ALK Variants**

For 2% to 7% of NSCLC patients in the United States, tumors express a fusion gene comprising portions of the echinoderm microtubule–associated protein-like 4 (EML4) gene and the ALK gene (EML4-ALK), which is created by an inversion on chromosome 2p.6 The EML4 fusion leads to ligand-independent activation of ALK, which encodes a receptor TK whose precise cellular function is not completely understood. EML4-ALK variants are more common in never smokers or light smokers, tend to be associated with younger age of NSCLC onset, and typically do not occur in conjunction with EGFR variants.

Testing for the EML4-ALK fusion gene in patients with adenocarcinoma-type NSCLC is used to predict response to the small molecule TKI crizotinib.

**Other Genetic Variants**

Other genetic variants, identified in subsets of patients with NSCLC, are summarized in Table 1. The role of testing for these variants to help select targeted therapies for NSCLC is less well-established than for EGFR variants.

**Table 1. Non-EGFR Variants in NSCLC**

<table>
<thead>
<tr>
<th>Gene</th>
<th>Gene Function</th>
<th>Estimated Variants Prevalence in NSCLC</th>
<th>Patient and Tumor Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRAS</td>
<td>Encodes RAS proteins; variants associated with constitutively activated protein</td>
<td>20%-30%</td>
<td>Adenocarcinomas; Heavy smokers</td>
</tr>
<tr>
<td>ROS1</td>
<td>Encodes a receptor TK in the insulin receptor family</td>
<td>0.9%-3.7%</td>
<td>Adenocarcinoma; Never smokers</td>
</tr>
<tr>
<td>RET</td>
<td>Proto-oncogene that encodes a receptor TK growth factor</td>
<td>0.6%-2%</td>
<td></td>
</tr>
<tr>
<td>MET</td>
<td>Oncogene that encodes a receptor TK that is activated in response to binding of hepatocyte growth factor</td>
<td>2%-4% of previously untreated NSCLC; 5%-20% of patients with acquired resistance to EGFR TKIs</td>
<td>Patients with acquired resistance to EGFR TKIs</td>
</tr>
<tr>
<td>BRAF</td>
<td>Serine-threonine kinase downstream from RAS in RAS-RAF-ERK-MAPK pathway</td>
<td>1%-3% of adenocarcinomas</td>
<td>Heavy smokers</td>
</tr>
<tr>
<td>HER</td>
<td>HER (EGFR) family of TK receptors; dimerizes with EGFR family members when activated</td>
<td>1%-2% of NSCLC</td>
<td>Adenocarcinomas; Nonsmoking women</td>
</tr>
<tr>
<td>PIK3CA</td>
<td>Intracellular signaling pathway</td>
<td>~4% of NSCLC</td>
<td></td>
</tr>
</tbody>
</table>

EGFR: epidermal growth factor receptor; HER: human epidermal growth factor receptor; NSCLC: non-small-cell lung cancer; TK: tyrosine kinase; TKI: tyrosine kinase inhibitor.

**Targeted Treatment Options**

**EGFR-Selective Small Molecule TKIs**

Three orally administered EGFR-selective small molecule TKIs have been identified for treating NSCLC: gefitinib (Iressa), erlotinib (Tarceva), and afatinib (Gilotrif) (see Table 2). Although the Food and Drug Administration (FDA) approved gefitinib in 2004, a phase 3 trial suggested gefitinib was not associated with a survival benefit. In 2003, FDA revised gefitinib labeling, further limiting its use to patients who had previously benefited...
or were currently benefiting from the drug; no new patients were to be given gefitinib. However, in 2015, FDA approved gefitinib as first-line treatment for patients with metastatic NSCLC for patients with \textit{EGFR}-mutated tumors. Erlotinib and afatinib also have approval by FDA.

In 2015, osimertinib (Tagrisso), an irreversible selective EGFR inhibitor that targets T790M variant–positive NSCLC, received FDA approval for patients with T790M variant–positive NSCLC who have progressed on an EGFR TKI.

A meta-analysis by Lee et al (2013) assessing 23 trials on the use of erlotinib, gefitinib, and afatinib in patients with advanced NSCLC reported improved progression-free survival (PFS) in \textit{EGFR} variant–positive patients treated with EGFR TKIs in the first- and second-line settings and as maintenance therapy.\textsuperscript{7} Comparators were chemotherapy, chemotherapy and placebo, and placebo in the first-line, second-line, and maintenance therapy settings. Among \textit{EGFR} variant–negative patients, PFS was improved with EGFR TKIs compared with placebo for maintenance therapy but not in the first- and second-line settings. OS did not differ between treatment groups in either variant-positive or variant-negative patients. Statistical heterogeneity was not reported for any outcomes. Reviewers concluded that \textit{EGFR}-variant testing is indicated to guide treatment selection in NSCLC patients.

On the basis of the results of 5 phase 3 randomized controlled trials, the American Society of Clinical Oncology has recommended that patients with NSCLC being considered for first-line therapy with an EGFR-TKI (patients who have not previously received chemotherapy or an EGFR TKI) should have their tumor tested for \textit{EGFR} variants to determine whether an EGFR TKI or chemotherapy is the appropriate first-line therapy.\textsuperscript{5}

The primary target population for TKIs in NSCLC is for \textit{EGFR} variant–positive patients with advanced NSCLC. The use of TKIs in NSCLC in \textit{EGFR} variant–negative patients is controversial. The TITAN trial as reported by Ciuleanu et al (2012) demonstrated no significant differences in OS between erlotinib and chemotherapy as second-line treatment for patients unselected on the basis of \textit{EGFR}-variant status, with fewer serious adverse events in erlotinib-treated patients.\textsuperscript{8} Karampeazis et al (2013) reported similar efficacy between erlotinib and standard chemotherapy (pemetrexed) for second-line therapy in patients unselected on the basis of \textit{EGFR}-variant status.\textsuperscript{9} By contrast, in the TAILOR trial, as reported by Garassino et al (2013), standard chemotherapy was associated with longer OS than erlotinib for second-line therapy in patients with wild-type \textit{EGFR}.\textsuperscript{10} Auliac et al (2014) compared sequential erlotinib plus docetaxel with docetaxel alone as second-line therapy among patients with advanced NSCLC and \textit{EGFR} wild-type or unknown status.\textsuperscript{11} Based on Simon’s optimal 2-stage design, the erlotinib plus docetaxel strategy was rejected. Despite the rejection, it is worth noting that in the erlotinib plus docetaxel arm 18 of the 73 patients achieved PFS at 15 weeks; comparatively, in the docetaxel arm, 17 of 74 patients achieved PFS at 15 weeks.
Cicenas et al (2016) reported on results of the IUNO randomized controlled trial, which compared maintenance therapy using erlotinib followed by second-line chemotherapy if progression occurred to placebo followed by erlotinib if progression occurred in 643 patients who had advanced NSCLC and no known EGFR variant. Because there were no significant differences between groups regarding PFS, objective response rate, or disease control rate, maintenance therapy with erlotinib in patients without EGFR variants was not considered efficacious.

**Anti-EGFR Monoclonal Antibodies**
For the treatment of KRAS-mutated NSCLC, anti-EGFR monoclonal antibodies have been investigated as possible treatment options. Available anti-EGFR monoclonal antibodies include cetuximab and panitumumab. Neither drug has an established role in the treatment of NSCLC either as a component of initial therapy or as second-line therapy.

**Programmed Death-Ligand 1 Inhibitors**
Some tumors, including some NSCLCs, express a programmed death-ligand 1 (PD-L1) on the cell surfaces to interact with host T cells and evade the immune system. Several humanized monoclonal antibodies have been developed to act as immune checkpoint inhibitors by interfering with this interaction, to interact with the PD-L1, block cancer/T-cell interaction, and thus act as immune checkpoint inhibitors. Pembrolizumab, nivolumab, and atezolizumab, which inhibit the programmed death 1 receptor, and atezolizumab, which inhibits the PD-L1, are used in NSCLC that have a PD-L1 expression on its cells. Durvalumab also targets the PD-L1 protein but is used in unresectable, stage III NSCLC whose disease has not progressed following concurrent platinum-based chemotherapy and radiotherapy.

**Other Targeted Therapies**
Crizotinib is a novel MET, ROS1, and ALK TKI, and associated with improved PFS in patients with advanced NSCLC who are ALK gene rearrangement–positive. Crizotinib is considered first-line therapy for advanced ALK-positive lung adenocarcinoma. Other small molecule TKIs, designed to selectively bind to and inhibit ALK activation, have FDA approval: ceritinib, alectinib, and brigatinib.

Proposed targeted therapies for other genetic alterations in NSCLC are trastuzumab for HER2 variants, crizotinib for MET amplification and ROS1 rearrangement, vemurafenib and dabrafenib for BRAF variants, and cabozantinib for RET rearrangements.

**Proteomics Testing for Selecting Targeted Treatment for NSCLC**
The term proteome refers to the entire complement of proteins produced by an organism, or cellular system and proteomics refers to the large-scale comprehensive study of a specific proteome. The proteome may differ from cell to cell and may vary over time and in response to selected stressors.
A cancer cell’s proteome is related to its genome and genomic alterations. The proteome may be measured by mass spectrometry (MS) or protein microarray. For cancer, proteomic signatures in the tumor or bodily fluids (ie, pleural fluid or blood) other than the tumor have been investigated as a biomarker for cancer activity.

A commercially available serum-based test (VeriStrat) has been developed and proposed to be used as a prognostic tool to predict expected survival for standard therapies used in the treatment of NSCLC. The test is also proposed to have predictive value for response to EGFR TKIs.\(^\text{14}\) The test uses matrix-assisted laser desorption ionization MS analysis, and a classification algorithm was developed on a training set of pretreatment sera from 3 cohorts (Italian A, Japan A, Japan B) totaling 139 patients with advanced NSCLC who were treated with second-line gefitinib.\(^\text{15}\) The classification result is either “good” or “poor. Two validation studies using pretreatment sera from 2 cohorts of patients (Italian B, Eastern Cooperative Oncology Group 3503) totaling 163 patients have been reported (see Tables 3 and 4).

This assay uses an 8-peak proteomic signature; 4 of the 8 have been identified as fragments of serum amyloid A protein 1.\(^\text{16}\) This protein has been found to be elevated in individuals with a variety of conditions associated with acute and chronic inflammation.\(^\text{17-21}\) The specificity for malignant biologic processes and conditions has not been determined.\(^\text{22}\) With industry support, Fidler et al (2018) used convenience biorepository samples to investigate 102 analytes for potential correlations between the specific peptide and protein biomarkers and VeriStrat classification.\(^\text{23}\)

Although the VeriStrat matrix-assisted laser desorption ionization MS-based predictive algorithm has the largest body of literature associated with it, other investigators have used alternative MS methods, such as surface-enhanced laser desorption ionization/time-of-flight MS, and alternative predictive algorithms, to assess proteomic predictors of lung cancer risk.\(^\text{24}\)

Best practices for peptide measurement and guidelines for publication of peptide and protein identification have been published for the research community.\(^\text{25}\)

**Table 2.** Targeted Treatment Options Approved by FDA

<table>
<thead>
<tr>
<th>Drug</th>
<th>Indication</th>
<th>Manufacturer</th>
<th>Approved</th>
<th>NDA/BLA</th>
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<tbody>
<tr>
<td>Gefitinib</td>
<td>• Monotherapy for locally advanced or metastatic NSCLC after failure of platinum-based and docetaxel chemotherapies</td>
<td>AstraZeneca</td>
<td>05/03</td>
<td>NDA 21-399</td>
</tr>
<tr>
<td>(Iressa®)</td>
<td>• Revised label to limit use to patients currently benefiting or previously benefited from gefitinib</td>
<td></td>
<td>06/05</td>
<td></td>
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<tr>
<td></td>
<td>• First-line treatment of patients with metastatic NSCLC whose tumors have EGFR exon 19 deletions or exon 21 (L858R) substitution variants as detected by an FDA-approved test</td>
<td></td>
<td>06/15</td>
<td>NDA 206995</td>
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<tr>
<td>Drug</td>
<td>Indication</td>
<td>Manufacturer</td>
<td>Approved</td>
<td>NDA/BLA</td>
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<tr>
<td>Erlotinib</td>
<td>• Monotherapy for treatment of patients with locally advanced or metastatic NSCLC after failure of at least 1 prior chemotherapy regimen&lt;br&gt;• Maintenance therapy for patients with locally advanced or metastatic NSCLC whose disease has not progressed after 4 cycles of platinum-based first-line chemotherapy&lt;br&gt;• First-line treatment of patients with metastatic (NSCLC) whose tumors have EGFR exon 19 deletions or exon 21 (L858R) substitution variants as detected by an FDA-approved test&lt;br&gt;• Treatment of patients with metastatic NSCLC whose tumors have EGFR exon 19 deletions or exon 21 (L858R) substitution variants as detected by an FDA-approved test receiving first-line, maintenance, or second- or greater line treatment after progression following at least 1 prior chemotherapy regimen</td>
<td>OSI Pharmaceuticals and Genentech</td>
<td>11/04</td>
<td>NDA 021743</td>
</tr>
<tr>
<td>Afatinib</td>
<td>• First-line treatment of patients with metastatic (NSCLC) whose tumors have EGFR exon 19 deletions or exon 21 (L858R) substitution variants as detected by an FDA-approved test&lt;br&gt;• Treatment of patients with metastatic, squamous, NSCLC progressing after platinum-based chemotherapy&lt;br&gt;• Treatment of patients with NSCLC whose tumors have nonresistant EGFR variants as detected by an FDA-approved test, which includes additional variants other than EGFR exon 19 deletions or exon 21 (L858R) substitution variants</td>
<td>Boehringer Ingelheim</td>
<td>07/13</td>
<td>NDA 201292</td>
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<td>04/16</td>
<td>NDA 201292/S7</td>
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<td>01/18</td>
<td>NDA 201292/S14</td>
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<tr>
<td>Necitumumab</td>
<td>• EGFR antagonist indicated, in combination with gemcitabine and cisplatin, for first-line treatment of patients with metastatic squamous NSCLC</td>
<td>Eli Lilly</td>
<td>11/15</td>
<td>BLA 125547</td>
</tr>
<tr>
<td>Osimertinib</td>
<td>• Treatment of patients with metastatic EGFR T790M variant–positive NSCLC, as detected by an FDA-approved test, who have progressed on or after EGFR TKI therapy</td>
<td>AstraZeneca</td>
<td>11/15</td>
<td>NDA 208065</td>
</tr>
<tr>
<td>Crizotinib</td>
<td>• Treatment of patients with locally advanced or metastatic NSCLC that is ALK-positive as detected by an FDA-approved test&lt;br&gt;• Treatment of patients with metastatic NSCLC whose tumors are ROS1-positive</td>
<td>Novartis</td>
<td>08/11</td>
<td>NDA 202570</td>
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<td>Ceritinib</td>
<td>• A kinase inhibitor indicated for treatment of patients with ALK-positive metastatic NSCLC who have progressed on or are intolerant to crizotinib</td>
<td>Novartis</td>
<td>03/16</td>
<td>NDA 202570/S16</td>
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<tr>
<td>Alectinib</td>
<td>• A kinase inhibitor indicated for treatment of patients with ALK-positive metastatic NSCLC who have progressed on or are intolerant to crizotinib</td>
<td>Hoffman-La Roche</td>
<td>04/14</td>
<td>NDA 205755</td>
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<td>12/15</td>
<td>NDA 208434</td>
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<td>NDA/BLA</td>
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<tr>
<td>Brigatinib (Alunbrig®)</td>
<td>• A kinase inhibitor indicated for treatment of patients with ALK-positive metastatic NSCLC as detected by an FDA-approved test</td>
<td>ARIAD</td>
<td>04/17</td>
<td>NDA 208772</td>
</tr>
<tr>
<td></td>
<td>• Treatment of patients with ALK-positive metastatic NSCLC who have progressed on or are intolerant to crizotinib</td>
<td></td>
<td>11/17</td>
<td>NDA 208434/S3</td>
</tr>
<tr>
<td>Pembrolizumab (Keytruda®)</td>
<td>• Treatment of patients with metastatic, PD-L1-positive NSCLC, as determined by an FDA-approved test, with disease progression on or after platinum-containing chemotherapy</td>
<td>Merck</td>
<td>10/15</td>
<td>BLA 125514/S5</td>
</tr>
<tr>
<td></td>
<td>• Treatment of patients with metastatic NSCLC whose tumors express PD-L1 [Tumor Proportion Score (TPS) ≥ 1%] as determined by an FDA-approved test, with disease progression on or after platinum-containing chemotherapy</td>
<td></td>
<td>10/16</td>
<td>BLA 125514/S8</td>
</tr>
<tr>
<td></td>
<td>• Expansion of metastatic NSCLC indication to include first-line treatment of patients whose tumors have high PD-L1 expression (TPS ≥ 50%) as determined by an FDA-approved test, with no EGFR or ALK genomic tumor aberrations</td>
<td></td>
<td>05/17</td>
<td>BLA 125514/S12</td>
</tr>
<tr>
<td></td>
<td>• Use in combination with pemetrexed and carboplatin, for the first-line treatment of patients with metastatic nonsquamous NSCLC</td>
<td></td>
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<tr>
<td>Nivolumab (Opdivo®)</td>
<td>• Treatment of patients with metastatic NSCLC with progression on or after platinum-based chemotherapy. Patients with EGFR or ALK genomic tumor aberrations should have disease progression on FDA-approved therapy for these aberrations prior to receiving drug</td>
<td>Bristol-Myers Squibb</td>
<td>10/15</td>
<td>BLA 125554/S005</td>
</tr>
<tr>
<td>Atezolizumab (Tecentriq®)</td>
<td>• Metastatic NSCLC patients who have disease progression during or following platinum-containing chemotherapy. Patients with EGFR or ALK genomic tumor aberrations should have disease progression on FDA-approved therapy for these aberrations prior to receiving Tecentriq.</td>
<td>Genentech</td>
<td>4/17</td>
<td>BLA 761034</td>
</tr>
<tr>
<td>Durvalumab (Imfinzi®)</td>
<td>• Use in unresectable, stage III NSCLC whose disease has not progressed following concurrent platinum-based chemotherapy and radiotherapy</td>
<td>AstraZeneca</td>
<td>02/18</td>
<td>BLA 761069/S-002</td>
</tr>
</tbody>
</table>

**ALK:** anaplastic lymphoma kinase; **BLA:** biologics license application; **EGFR:** epidermal growth factor receptor; **FDA:** Food and Drug Administration; **NDA:** new drug application; **NSCLC:** non-small-cell lung cancer; **PD-L1:** programmed death-ligand 1; **TKI:** tyrosine kinase inhibitor.

**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. The commercially available proteomic test (VeriStrat®; Biodesix) is available under 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 this test.

**POLICY**
The use of proteomic testing, including, but not limited to, the VeriStrat assay, is considered experimental / investigational for all uses in the management of non-small-cell lung cancer.

**RATIONALE**
Updated literature reviews were conducted most recently through August 4, 2018.

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.

**Non-Small-Cell Lung Cancer**
**Clinical Context and Test Purpose**
The purpose of proteomic testing in individuals with non-small-cell lung cancer (NSCLC) who are epidermal growth factor receptor (EGFR)−negative or EGFR-status unknown NSCLC is to predict expected survival when receiving standard therapies for treatment of NSCLC. More specifically, the testing could impact the decision point for the selection of treatment based on a prediction of response to EGFR tyrosine kinase inhibitors (TKIs). That is, that the VeriStrat classification is predictive of a differential response to EGFR TKIs.

The question addressed in this evidence review is: Does proteomic testing in patients with NSCLC who have EGFR-negative or EGFR-status unknown NSCLC predict survival after receiving standard therapies and response to systemic therapy and improve health outcomes?

The following PICOTS were used to select literature to inform this review.

**Patients**
The relevant populations of interest are patients with EGFR-negative or EGFR-status unknown NSCLC who are newly diagnosed or who have progressed after first-line treatment.

**Intervention**
The test being considered is management with a serum proteomic test to predict survival and select systemic therapy.
**Comparator**
The following practice is currently being used to manage NSCLC: standard medical management.

**Outcomes**
The outcomes of interest are overall survival (OS) and progression-free survival (PFS).

**Timing**
The timing of testing is when patients are newly diagnosed with NSCLC or have failed to respond to first-line therapy.

**Setting**
The test is available commercially through a single laboratory.

**Technically Reliable**
Assessment of technical reliability focuses on specific tests and operators and requires review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review, and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

**Clinically Valid**
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

**Proteomic Testing in NSCLC for Disease Prognosis**
The largest body of evidence on the clinical validity of proteomic testing for NSCLC relates to its ability to predict disease outcomes.

No published studies were identified that assessed the use of VeriStrat proteomic testing in newly diagnosed stage I or II NSCLC.

For individuals with newly diagnosed advanced NSCLC without prior systemic therapy, multiple studies (Amann et al [2010], Kuiper et al [2012], Akerley et al [2013], Gautschi et al [2013], Stinchcombe et al [2013]) have assessed the use of VeriStrat score (good or poor) as a prognostic test to discriminate between OS (primary outcome) and PFS (secondary outcome) outcomes. All studies were retrospective and intended to validate the extent to which the VeriStrat proteomic classification correlated with OS or PFS. Grossi et al (2017) was an observational nonrandomized study with prospective sample collection for proteomic testing before NSCLC treatment and reported PFS as the primary outcome. This is the only study that included a first-line treatment consistent with current guidelines-based recommendations; platinum-doublet-based chemotherapy with cisplatin or carboplatin in combination with pemetrexed.

A summary of study characteristics and results of these 5 studies is presented in Tables 3 and 4.

The VeriStrat classification was not used to direct selection of treatment in any of the clinical trials from which the validation samples were derived. Testing for the presence of a sensitizing variant (EGFR) for targeted therapy with TKIs was variably performed in these studies. When testing was performed and results known as wild-type (negative) or positive, the analysis of OS
and PFS was variably adjusted for variant status. The relation between VeriStrat classification and OS and PFS in populations with unknown variant status, when reported, was not analyzed. Disposition of populations with variant status “not reported” was generally not clear and could not be construed as “unknown” when wild-type or positive variant status was reported.

For individuals with advanced NSCLC who had recurrent disease or who had failed prior systemic therapy, multiple studies assessed (Taguchi et al [2007], Carbone et al [2010], Keshtgarpour et al [2016], Spigel et al [2018]) the use of VeriStrat as a prognostic test to discriminate between good and poor survival outcomes. All studies were retrospective and intended to validate the extent to which VeriStrat proteomic classification correlated with OS or PFS. The VeriStrat classification was not used to direct selection of treatment in any of the clinical trials from which the validation samples were derived. None of the trials from which the samples for VeriStrat proteomic classification were derived used a therapy consistent with current guideline-based recommendations. The populations in all studies were unselected for EGFR-variant status.

A summary of study characteristics and results of these studies is presented in Tables 3 and 4.

Grossi et al (2018) conducted a retrospective study that combined samples from 3 separate cohorts of treatment-naive recurrent or advanced NSCLC patients who received platinum-based chemotherapy. One cohort, identified as Italian, is duplicative of the population reported in Grossi et al (2017). The NExUS and eLung cohorts reported data that is only referenced in abstracts in Grossi et al (2018) and, thus, is of limited value to the evidentiary appraisal of VeriStrat classification. The data imported into the publication for the PFS outcome showed that the median PFS of 5.7 months for VeriStrat “good” is included in the outer bound of the confidence interval (CI) for VeriStrat “poor” in the NExUS cohort. The median PFS of 5.1 months for VeriStrat “good” is included within the CI of VeriStrat “poor” in the eLung cohort. A summary of study characteristics and results of this study is presented in Tables 3 and 4. Appendix Table 1 summarizes the treatment regimens used in Grossi et al (2018). As noted, only the Italian cohort included from Grossi et al (2017) represents current approaches to treatment. Cetuximab does not have an established role in the treatment of NSCLC either as a component of initial therapy or as second-line therapy.

While most of the literature has focused on the use of matrix-assisted laser desorption ionization (MALDI) mass spectrometry (MS) techniques and predictive algorithms similar to those used in the VeriStrat assay, other MS techniques, and predictive algorithms have been investigated. Jacot et al (2008) used surface-enhanced laser desorption ionization/time-of-flight MS technology in combination with a predictive algorithm to discriminate between malignant and benign disease and between good and poor outcomes. Using data from a population of 87 patients with stage III or IV NSCLC receiving conventional first-line chemotherapy and with at least 1-year follow-up available, the authors developed a predictive survival classifier to differentiate between poor prognosis (n=33; OS <12 months) and good prognosis (n=54; OS >12 months). In the multivariate analysis, the proteomic-based predictor was significantly associated with OS (hazard ratio [HR], 3.45; 95% CI, 1.22 to 6.13; p<0.001).

The purpose of the gaps tables (see Tables 5 and 6) is to display notable gaps identified in each study. This information is synthesized as a summary of the body of evidence following each table and provides the conclusions on the sufficiency of the evidence supporting the position statement.
The characteristics and results of additional studies using non-VeriStrat proteomic assays are summarized in Table 7.

**Table 3. Clinical Validity Study Characteristics of Proteomic Testing in NSCLC for Disease Prognosis**

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>N</th>
<th>Population</th>
<th>Selection Criteria</th>
<th>Participant Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VeriStrat-specific studies</strong></td>
<td></td>
<td></td>
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<tr>
<td>Taguchi et al (2007)&lt;sup&gt;15&lt;/sup&gt;,&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>67</td>
<td>Sequential cohort of late-stage or recurrent NSCLC treated with single-agent gefitinib used as VS algorithm validation set.</td>
<td>ECOG PS: 29.8% grade 0; 46.3% grade 1; 23.9% grade 2  Histology: 56.7% adeno; 22.4% squamous; 20.9% NOS</td>
<td>2 (3%) had stage II disease</td>
</tr>
<tr>
<td>Italian B validation set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Taguchi et al (2007)&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>96</td>
<td>ECOG 3503 single-arm phase 2 trial of first-line erlotinib in patients with stage IIIB or IV or recurrent NSCLC used as VS algorithm validation set.</td>
<td>ECOG PS: 30.2% grade 0; 43.8% grade 1; 26.0% grade 2  Histology: 64.6% adeno; 11.5% squamous; 1% LCC; 22.9% NOS</td>
<td>20 (20.8%) had postoperative occurrence</td>
</tr>
<tr>
<td>Amann et al (2010)&lt;sup&gt;23&lt;/sup&gt;,&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>88</td>
<td>Sample of ECOG 3503 trial patients (enrolled 137) with stage IIIB or IV in phase 2 single-arm treatment with first-line erlotinib</td>
<td>ECOG PS: 28.4% grade 0; 46.1% grade 1; 25.5% grade 2  Histology: 64.7% adeno; 10.8% squamous; 1% LCC; 16.7% NOS; 6.9% other</td>
<td>102 analyzable pretreatment biologic samples  Missing values: 14 (16%) VS score  EGF exon 19 status: 61 (60%)  EGF exon 21 status: 61 (60%)  No EGF exon 19–positive samples</td>
</tr>
<tr>
<td>Carbone et al (2010)&lt;sup&gt;24&lt;/sup&gt;,&lt;sup&gt;26&lt;/sup&gt;, Herbst et al (2005)&lt;sup&gt;24&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>35</td>
<td>Sample of phase 1/2 stage IIIB or IV (N=40): phase 1 (n=12), phase 2 (n=28) recurrent, nonsquamous NSCLC treated with open-label erlotinib and bevacizumab</td>
<td>KPS: 7.5% KPS 70%; 47.5% KPS 80%; 45% KPS 90%  Histology: 75% adeno; 22.5% NOS; 2.5% other</td>
<td>35 available pretreatment samples with associated clinical data</td>
</tr>
<tr>
<td>Kuiper et al (2012)&lt;sup&gt;27&lt;/sup&gt;,&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>50</td>
<td>Sample of chemotherapy-naive patients (N=50) with pathologically documented, inoperable, locally advanced, recurrent, or metastatic NSCLC; single-arm phase 2 treated with erlotinib and sorafenib</td>
<td>ECOG PS: 40% grade 0; 60% grade 1  Histology: 68% adeno; 32% other</td>
<td>VS score not available or indeterminate (n=2)  EGF status: (31) 62% WT; (7) 14% variant positive; 12 (24%) unknown</td>
</tr>
<tr>
<td>Akerley et al (2013)&lt;sup&gt;28&lt;/sup&gt;,&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Retrospective</td>
<td>42</td>
<td>Sample of stage IIIB or IV or recurrent nonsquamous NSCLC, with no prior chemotherapy for metastatic disease (n=40), treated with erlotinib and bevacizumab;</td>
<td>ECOG PS: 26% grade 0; 74% grade 1  Histology: 48% adeno; 48% NOS; 4% other</td>
<td>Previously treated brain metastases allowed in expanded cohort  Participant accrual (n=20) prior to interim safety analysis; additional 20</td>
</tr>
<tr>
<td>Study</td>
<td>Study Type</td>
<td>N</td>
<td>Population</td>
<td>Selection Criteria</td>
<td>Participant Disposition</td>
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</table>
| Gautschi et al (2013)       | Retrospective | 117 | Pooled analysis of patients (158 enrolled) from SAKK19/05 (n=101) and NTR528 trials (n=47): untreated, advanced nonsquamous NSCLC, treated with first-line therapy using erlotinib and bevacizumab | ECOG PS: 52.9% grade 0; 42.5% grade 1; 4.6% grade 2 History: 89.7% adenoc; 10.2% other | participants accrued after safety threshold of PFS at 6 mo exceeded  
42 VS assays performed on pretreatment sera  
28 patients received cytotoxic chemotherapy after study therapy  
117 pretreatment frozen serum available for VS assay (SAKK19/05, n=88; NTR528, n=29)  
SAKK19/05: EGFR variant status: positive identification but data NR  
NTR528: EGFR variant status: NR |
| Stinchcombe et al (2013)    | Retrospective | 98  | Sample from noncomparative randomized phase 2 trial of first-line treatment for stage IIB or IV NSCLC:  
Arm A (gemcitabine)  
Arm B (erlotinib) or  
Arm C (gemcitabine and erlotinib) | Age: ≥70 y  
ECOG PS: 0-2  
Histology: unselected | Treatment arm assignment stratified for sex, smoking history (never or light vs current or former use), and PS  
146 eligible patients received protocol therapy  
124 samples available for VS assay  
14 samples unevaluable  
110 samples assayed |
Determine use of VS in African-Americans  
Determine relation between VS and comorbidities using CCI | Baseline histology and PS not reported | 49 cases qualified for inclusion  
VS pretreatment: 31  
VS during or after first-line chemotherapy |
| Grossi et al (2017)         | Prospective | 76  | Clinically based stage IIB NSCLC with supraclavicular lymph node metastases, or stage IV or recurrent NSCLC, chemotherapy-naive  
To be treated with platinum doublet chemotherapy: pemetrexed plus carboplatin or cisplatin | ECOG PS: 26% grade 0; 71% grade 1; 3% grade 2  
Histology: 100% nonsquamous | 105 participants enrolled  
89 with nonsquamous histology included  
15 with squamous histology and 1 with small cell lung cancer excluded  
6 additional patients ineligible (no treatment, consent, had surgery)  
83 eligible for VS  
7 did not receive VS classification  
Choice of chemotherapy regimen at physician discretion based on age, ECOG PS, creatinine clearance |
| Grossi et al (2018)         | Retrospective | 481 | 3 cohorts (NExUS, Italian, eLung) of treatment-naive recurrent or advanced NSCLC patients who received platinumbased chemotherapy  
NExUS cohort: prospective RCT of gemcitabine plus cisplatin and sorafenib vs gemcitabine plus cisplatin and placebo  
Italian: clinically based cohort treated with platinum-doublet chemotherapy  
eLung: multicenter randomized phase 2b study of cetuximab | NExUS: stage IIB or IV NSCLC, ECOG PS: 0/1  
Histology: NR  
Italian: stage IIB NSCLC with supraclavicular lymph node metastases, or stage IV or recurrent NSCLC  
Histology: 100% nonsquamous (Grossi et al [2017])  
eLung: ECOG PS: 0/1  
Histology: nonsquamous and squamous | NExUS: Baseline plasma samples 419 of 722 nonsquamous participants available for VS assay  
Italian: 105 participants enrolled  
89 with nonsquamous histology included  
15 with squamous histology and 1 with small cell lung cancer excluded  
6 additional patients ineligible (no treatment, consent, had surgery) |


*Contains Public Information*
### Study Details

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>N</th>
<th>Population</th>
<th>Selection Criteria</th>
<th>Participant Disposition</th>
</tr>
</thead>
</table>
| Grossi et al (2018)\(^{34, b}\) | Retrospective | 481   |            | plus platinum-based chemotherapy as first-line treatment.                                                                ächterlich und cetoxycheimab then maintenance cetoxycheimab  
|                            |              |       |            | o Arm A: carboplatin plus paclitaxel and cetoxycheimab then maintenance cetoxycheimab  
|                            |              |       |            | o Arm B: carboplatin or cisplatin (investigator choice) plus gencitabine and cetoxycheimab then maintenance cetoxycheimab  
|                            |              |       |            | o Arm C: carboplatin or cisplatin (investigator choice) plus pemetrexed and cetoxycheimab then maintenance cetoxycheimab  
|                            |              |       |            | o Arm C limited to squamous histology  
|                            |              |       |            | o Delivery of 4, 5, or 6 cycles of chemotherapy at investigator discretion  
|                            |              |       |            | • 83 eligible for VS  
|                            |              |       |            | • 7 did not receive VS classification  
|                            |              |       |            | • eLung: 206 of 601 participants had serum available for VS assay  
|                            |              |       |            | • 203 VS assay performed  
| Spigel et al (2018)\(^{33}\) | Retrospective | 192   |            | Sample from RCT of treatment for stage IV NSCLC following 1-2 chemotherapy regimens  
|                            |              |       |            | • Arm A (erlotinib plus pazopanib)  
|                            |              |       |            | or  
|                            |              |       |            | • Arm B (erlotinib plus placebo)  
|                            |              |       |            | • NEUS: stage IIIIB or IV NSCLC  
|                            |              |       |            | o ECOG PS: 0/1  
|                            |              |       |            | o Histology: NR  
|                            |              |       |            | • Italian: stage IIIIB NSCLC with supraclavicular lymph node metastases, or stage IV or recurrent NSCLC  
|                            |              |       |            | o Histology: 100% nonsquamous (Grossi et al [2017])  
|                            |              |       |            | • eLung  
|                            |              |       |            | o ECOG PS: 0/1  
|                            |              |       |            | o Histology: nonsquamous and squamous  
|                            |              |       |            | • NEUS: Baseline plasma samples 419 of 722 nonsquamous participants available for VS assay  
|                            |              |       |            | • Italian: 105 participants enrolled  
|                            |              |       |            | • 89 with nonsquamous histology included  
|                            |              |       |            | • 15 with squamous histology and 1 with small cell lung cancer excluded  
|                            |              |       |            | • 6 additional patients ineligible (no treatment, consent, had surgery)  
|                            |              |       |            | • 83 eligible for VS  
|                            |              |       |            | • 7 did not receive VS  
|                            |              |       |            | • eLung: 206 of 601 participants had serum available for VS  
|                            |              |       |            | • 203 VS performed  

### Previous Chemotherapy

<table>
<thead>
<tr>
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<th>n (%)</th>
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<tbody>
<tr>
<td>Previous Chemotherapy(^{a})</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>119 (62%)</td>
</tr>
<tr>
<td>2</td>
<td>73 (38%)</td>
</tr>
</tbody>
</table>

\(^{a}\) Assuming previous chemotherapy from the table above.

\(^{b}\) Study may have additional criteria not listed above.
Table 4. Clinical Validity Study Results of Proteomic Testing in NSCLC for Disease Prognosis

<table>
<thead>
<tr>
<th>Study Type</th>
<th>N</th>
<th>Study</th>
<th>Summary of Outcomes: OS for “Good” vs “Poor” Assay</th>
<th>Summary of Outcomes: PFS for “Good” vs “Poor” Assay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VeriStrat-specific studies</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Taguchi et al (2007)(^a) Italian B validation set</td>
<td>67</td>
<td>Sequential cohort of late-stage or recurrent NSCLC treated with single-agent gefitinib: VS “good”: 39 (58.3%) VS “poor”: 27 (40.3%) VS undefined: 1</td>
<td>Unadjusted: HR of death, 0.50 (95% CI, 0.24 to 0.78; p=0.005)</td>
<td>Unadjusted: TTP: HR=0.56 (95% CI, 0.28 to 0.89; p=0.02)</td>
</tr>
<tr>
<td>Taguchi et al (2007)(^b) ECOG 3503 validation set</td>
<td>96</td>
<td>ECOG 3503 single-arm, phase 2 trial of first-line erlotinib in patients with stage IIIB or IV or recurrent NSCLC: VS “good”: 69 (71.9%) VS “poor”: 27 (28.1%) VS undefined: 0</td>
<td>Unadjusted: HR of death, 0.4 (95% CI, 0.24 to 0.70; p&lt;0.001)</td>
<td>Unadjusted: TTP: HR=0.53 (95% CI, 0.33 to 0.85; p=0.007)</td>
</tr>
<tr>
<td>Amann et al (2010)(^c)</td>
<td>88</td>
<td>VS “good” (n=64), VS “poor” (n=24): EGFR exon 19 WT: 41 EGFR exon 19–positive: none identified EGFR exon 21 WT: 38 EGFR exon 21–positive: 3 EGFR exon 21–positive and VS “good”: 2 EGFR exon 21–positive and VS “poor”: 1</td>
<td>Unadjusted: HR of death, 0.36 (95% CI, 0.21 to 0.60; p=0.001)</td>
<td>Unadjusted: TTP: HR=0.51 (95% CI, 0.28 to 0.90; p=0.02)</td>
</tr>
<tr>
<td>Carbone et al (2010)(^d)</td>
<td>35</td>
<td>Treatment-experienced recurrent stage IIIB or IV, nonsquamous NSCLC treated with erlotinib and bevacizumab enrolled in a phase 1 dose-finding and phase 2 efficacy and tolerability study: VS “good”: 26 VS “poor”: 8</td>
<td>Unadjusted: HR of death, 0.14 (61 wk vs 24 wk; 95% CI, 0.03 to 0.58)</td>
<td>Unadjusted: PFS: HR=0.045 (36 wk vs 8 wk; 95% CI, 0.008 to 0.237)</td>
</tr>
<tr>
<td>Kuiper et al (2012)(^e)</td>
<td>50</td>
<td>Chemotherapy-naive patients with pathologically documented, inoperable, locally advanced, recurrent, or metastatic NSCLC, treated with erlotinib and sorafenib VS classification was performed at 3 time points (pretreatment, 1 and 3 weeks after initiation therapy) Pretreatment VS “good” (n=33), VS “poor” (n=15):  EGFR WT: 31 EGFR–positive: 7 EGFR unknown: 12</td>
<td>Unadjusted using pretreatment classification only: HR for OS=0.30 (95% CI, 0.12 to 0.74; p=0.009)</td>
<td>Unadjusted using pretreatment classification only: PFS: HR=0.40 (95% CI, 0.17 to 0.94; p=0.035)</td>
</tr>
<tr>
<td>Akerley et al (2013)(^f)</td>
<td>42</td>
<td>Stage IIIB or IV or recurrent nonsquamous NSCLC, with no prior chemotherapy for metastatic disease, treated with erlotinib and bevacizumab: VS “good”: 32 (76%) VS “poor”: 9 (21%) VS indeterminate: 1 (2%)</td>
<td>Unadjusted on study therapy HR for OS=0.27 (95% CI, 0.11 to 0.64) Median OS= 71.4 wk vs VS “good” and 19.9 wk for VS “poor” (p=0.002)</td>
<td>Unadjusted on study therapy Median PFS=16.9 wk VS “good” vs 6.3 wk VS “poor” (p=0.004)</td>
</tr>
</tbody>
</table>

\(^a\) Industry sponsorship or collaboration.

\(^b\) Number of prior chemotherapy regimens.

- adeno: adenocarcinoma; CCI: Charleston Comorbidity Index; CI: confidence interval; ECOG: European Cooperative Oncology Group; EGFR: epidermal growth factor receptor; KPS: Karnofsky Performance Status; LCC: large cell carcinoma; NOS: not otherwise specified; NR: not reported; NSCLC: non-small-cell lung cancer; PET: positron emission tomography; PFS: progression-free survival; PS: Performance Status; TKI: tyrosine kinase inhibitor; VS: VeriStrat; WT: wild-type.
### Summary of Outcomes: OS for “Good” vs “Poor” Assay

<table>
<thead>
<tr>
<th>Study Type</th>
<th>N</th>
<th>Study</th>
<th>Median OS for “good”</th>
<th>Median OS for “poor”</th>
</tr>
</thead>
</table>
| Gautschi et al (2013) | 117 | Pooled analysis from SAKK19/05 and NTR528 trials: untreated, advanced nonsquamous NSCLC, treated with first-line therapy with erlotinib and bevacizumab:  
  • VS “good”: 87 (SAKK19/05, n=70; NTR528, n=17)  
  • VS “poor”: 27 (SAKK19/05, n=16; NTR528, n=11)  
  • SAKK19/05: EGFR variant status: positive identification but data NR  
  • NTR528: EGFR variant status: NR | 13.4 mo | 6.2 mo |

### Summary of Outcomes: PFS for “Good” vs “Poor” Assay

<table>
<thead>
<tr>
<th>Study Type</th>
<th>N</th>
<th>Study</th>
<th>Median PFS for “good”</th>
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| Gautschi et al (2013) | 117 | Pooled analysis from SAKK19/05 and NTR528 trials: untreated, advanced nonsquamous NSCLC, treated with first-line therapy with erlotinib and bevacizumab:  
  • VS “good”: 87 (SAKK19/05, n=70; NTR528, n=17)  
  • VS “poor”: 27 (SAKK19/05, n=16; NTR528, n=11)  
  • SAKK19/05: EGFR variant status: positive identification but data NR  
  • NTR528: EGFR variant status: NR | 4.0 mo | 3.2 mo |

### Study Type: Retrospective 98

- 110 samples VS assayed:  
  - VS “good”: 64  
  - VS “poor”: 39  
  - VS Indeterminate: 7  
  - (5 samples could not be matched with clinical data VS “good”: 1 and VS “poor”: 4)  
- VS results matched with clinical data:  
  - VS “good”: 63  
  - VS “poor”: 35  
- Arm A (gemcitabine):  
  - VS “good”: 20  
  - VS “poor”: 8  
  - 12 of 28 also received erlotinib as second-line therapy on protocol in absence of disease progression or unacceptable toxicity  
- Arm B (erlotinib):  
  - VS “good”: 26  
  - VS “poor”: 12  
  - 14 of 38 received second-line therapy (type NR) off protocol  
- Arm C (gemcitabine and erlotinib):  
  - VS “good”: 17  
  - VS “poor”: 15  
  - 13 of 32 received second-line therapy (type NR) off protocol

### Study Type: Retrospective 49

- Advanced-stage squamous and nonsquamous NSCLC seen at a single clinic:  
  - VS “good”: 32  
  - VS “poor”: 16  
  - VS indeterminate: 1

### Study Type: Prospective 76

- Stage IIIB NSCLC with supraclavicular lymph node metastases, or stage IV or recurrent NSCLC,
Study Type | N | Study | Summary of Outcomes: OS for “Good” vs “Poor” Assay | Summary of Outcomes: PFS for “Good” vs “Poor” Assay
--- | --- | --- | --- | ---
chemotherapy-naive treated with platinum doublet chemotherapy
• Carboplatin plus pemetrexed (n=43; median age, 57 y)
• Cisplatin plus pemetrexed (n=33; median age, 70 y)
VS “good”: 50
• VS “good”: carboplatin/pemetrexed: 28
• VS “good”: cisplatin/pemetrexed: 22
• VS “poor”: carboplatin/pemetrexed: 26
• VS “poor”: cisplatin/pemetrexed: 15
VS “poor”: cisplatin/pemetrexed: 11
TKI-sensitizing variant status
• KRAS WT: 31 (41%)
• KRAS WT: 67 (88%)
• KRAS WT: 16 (21%)
ALK translocation
• ALK translocation: 28 (38%)
• ALK translocation: 1 (1%)
• ALK translocation: 21 (28%)
KRAS: 31 (41%)
KRAS-positive: 29 (38%)
KRAS unknown: 16 (21%)
NExUS: VS assay: 202 patients in gemcitabine/cisplatin/placebo arm:
• VS “good”: 136
• VS “poor”: 66
Italian: VS assay: 76 patients pemetrexed plus carboplatin or cisplatin:
• VS “good”: 50
• VS “good”: carboplatin plus pemetrexed: 28
• VS “good”: cisplatin plus pemetrexed: 22
• VS “poor”: carboplatin plus pemetrexed: 26
• VS “poor”: cisplatin plus pemetrexed: 15
• VS “poor”: cisplatin plus pemetrexed: 11
eLung: VS assay: 203
• VS “good”: 142
• VS “good”: carboplatin plus paclitaxel and cetuximab: 52
• VS “good”: carboplatin or cisplatin plus gemcitabine and cetuximab: 56
• VS “good”: carboplatin or cisplatin plus pemetrexed and cetuximab: 34

• Median OS 10.8 mo in VS “good” vs 3.4 mo in VS “poor”
• Unadjusted secondary outcome based on treatment-defined group
  • Carboplatin plus pemetrexed vs cisplatin plus pemetrexed:
    • HR=1.64 (95% CI, 0.96 to 2.82; p=0.070)
  • Median OS carboplatin plus pemetrexed, 6.9 mo vs cisplatin plus pemetrexed, 10.3 mo (95% CI, 6.6 to 17.9 mo)
  • Carboplatin plus pemetrexed VS “good” vs VS “poor”:
    • HR=0.25 (95% CI, 0.10 to 0.55; p=0.001)
  • Median OS VS “good”, 14.7 mo (95% CI, 4.2 to 10.0 mo) vs VS “poor”, 13.6 mo (95% CI, 6.6 to 17.9 mo)
  • Carboplatin plus pemetrexed, 6.0 mo vs cisplatin plus pemetrexed, 5.7 mo (95% CI, 3.8 to 8.8 mo)
• Cisplatin plus pemetrexed
  • cisplatin/pemetrexed: 116
  • cisplatin/pemetrexed: 22
  • cisplatin/pemetrexed: 15
  • cisplatin/pemetrexed: 11
  • cisplatin/pemetrexed: 11
  • cisplatin/pemetrexed: 11
  • cisplatin/pemetrexed: 11

• Median OS VS “good”, 9.4 mo (95% CI, 5.0 to 15.3 mo) vs VS “poor”, 3.4 mo (95% CI, 1.0 to 4.3 mo)
• Cisplatin plus pemetrexed VS “good” vs VS “poor”:
  • HR=0.25 (95% CI, 0.10 to 0.55; p=0.001)
  • Median OS VS “good”, 17.7 mo (95% CI, 9.9 to 24.19 mo) vs VS “poor”, 4.2 mo (95% CI, 2.6 to 8.9 mo)

• Median PFS 6.5 mo in VS “good” vs 1.6 mo in VS “poor”
• Unadjusted primary outcome based on treatment-defined group
  • Carboplatin plus pemetrexed vs cisplatin plus pemetrexed:
    • HR=0.39 (95% CI, 0.18 to 0.85; p=0.014)
  • Median PFS VS “good”, 3.8 mo (95% CI, 2.7 to 4.7 mo) vs VS “poor”, 1.6 mo (95% CI, 1.0 to 2.5 mo)
  • Carboplatin plus pemetrexed, 2.8 mo vs cisplatin plus pemetrexed, 2.0 mo (95% CI, 0.2 to 4.0 mo)
  • Carboplatin plus pemetrexed, 5.7 mo (95% CI, 3.8 to 8.8 mo)

• Median PFS=6.5 mo in VS “good” vs 1.6 mo in VS “poor”
• Unadjusted primary outcome based on treatment-defined group
  • Carboplatin plus pemetrexed vs cisplatin plus pemetrexed:
    • HR=0.39 (95% CI, 0.18 to 0.85; p=0.014)
  • Median PFS VS “good”, 3.8 mo (95% CI, 2.7 to 4.7 mo) vs VS “poor”, 1.6 mo (95% CI, 1.0 to 2.5 mo)
  • Carboplatin plus pemetrexed, 2.8 mo vs cisplatin plus pemetrexed, 2.0 mo (95% CI, 0.2 to 4.0 mo)
  • Carboplatin plus pemetrexed, 5.7 mo (95% CI, 3.8 to 8.8 mo)

• Median PFS=6.5 mo in VS “good” vs 1.6 mo in VS “poor”

Summary of Outcomes: OS for “Good” vs “Poor” Assay

Summary of Outcomes: PFS for “Good” vs “Poor” Assay
Study Type | N | Study | Summary of Outcomes: OS for “Good” vs “Poor” Assay | Summary of Outcomes: PFS for “Good” vs “Poor” Assay
--- | --- | --- | --- | ---
Spigel et al (2018)33 | Retrospective | 88 | Stage IV NSCLC, with prior chemotherapy | Unadjusted secondary outcome
• VA "poor": 61
• VS "poor": 27
• VS "poor": 8
• VS "poor": 40
• VS "poor": 26
• VS "good": 63
• VS "good": 27
• VS "good": 30
• VS "good": 8
| Unadjusted primary outcome
• HR=0.42 (0.26 to 0.69; p<0.001)
• Median OS=8.6 mo (6.6 to 11.6 mo) for VS "good" vs 2.8 mo (1.4 to 4.9 mo) for VS "poor"
| Unadjusted secondary outcome based on VS-defined groups
• VS "good" o HR=1.02 (0.58 to 1.81; p=0.934)
| o Median PFS: erlotinib plus pazopanib, 8.2 mo (5.4 to 12.4 mo) vs erlotinib plus placebo, 8.6 mo (5.1 to 13.9 mo)
| o VS "poor" o HR=2.10 (0.83 to 5.26; p=0.1089)
| o Median PFS: erlotinib plus pazopanib, 2.8 mo (1.2 to 4.7 mo) vs erlotinib plus placebo, 7.5 mo (0.9 to 16.8 mo)
| Unadjusted primary outcome based on VS-defined groups
• VS "good" o HR=0.47 (0.26 to 0.86; p=0.010)
| o Median PFS: erlotinib plus pazopanib, 3.6 mo (1.8 to 4.1 mo) vs erlotinib plus placebo, 1.8 mo (1.7 to 2.5 mo)
| o VS "poor" o HR=0.87 (0.37 to 2.05; p=0.745)
| o Median PFS: erlotinib plus pazopanib, 1.8 mo (1.0 to 2.5 mo) vs erlotinib plus placebo, 1.7 mo (0.8 to 2.8 mo)

CI: confidence interval; ECOG: European Cooperative Oncology Group; EGFR: epidermal growth factor receptor; HR: hazard ratio; MALDI: matrix-assisted laser desorption ionization; MS: mass spectrometry; NSCLC: non-small-cell lung cancer; OS: overall survival; PFS: progression-free survival; PS: Performance Status; TKI: tyrosine kinase inhibitor; TTP: time to progression; VS: VeriStrat; WT: wild-type.

a Adjusted based on age, performance status, sex, histology, smoking history, and MALDI-MS classification.

b Adjusted based on age, number of involved sites, prior weight loss, histology, and MALDI-MS classification.

c Adjusted based on clinical characteristics: VS classification, sex, smoking status (ever vs never), EGFR PS (≥1 vs 0), KRAS status (mutant vs WT or unknown), KRAS (known vs unknown), maintenance (yes vs no).

d Adjusted based on clinical characteristics and treatment: VS classification, sex, cisplatin/pemetrexed vs carboplatin/pemetrexed smoking status (ever vs never), ECOG PS (≥1 vs 0), KRAS status (mutant vs WT or unknown), KRAS (known vs unknown), maintenance (yes vs no).

e Adjusted for VS status, histology (other histologies vs adenocarcinoma), race (nonwhite vs white), sex (female vs male), treatment arm (erlotinib vs gemcitabine), treatment arm (gemcitabine/erlotinib vs gemcitabine), smoking history (never vs ever), performance status (2 vs 0 or 1), stage IV vs IIIB.

Table 5. Clinical Validity Relevance Gaps for Proteomic Testing in NSCLC for Disease Prognosis
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcomes</th>
<th>Follow-Up</th>
</tr>
</thead>
</table>
| ECOG 3503 validation set | EGFR variant status  
2. 20 (20.8%) of participants had postoperative recurrence which may be an indicator of earlier stage at diagnosis | features still being investigated at time of publication | Other related:  
• Decision model based on outdated clinical pathway | therapy  
Other related:  
• Decision model based on outdated clinical pathway |  |
| Amann et al (2010)26 | 1. EGFR variant status unknown excluded  
4. Use of erlotinib (or other TKIs) in EGFR variant-negative population no longer accepted treatment approach  
5. 90 (88.2%) with multisite metastatic disease; 55 (54%) had prior radiotherapy or surgery | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
Other related:  
• Decision model based on outdated clinical pathway |  |
| Carbone et al (2010)32 | 1. No determination of EGFR variant status  
4. Study population participating in phase 1/2 study  
4. Use of erlotinib (or other TKIs) in EGFR variant-negative or unknown population no longer accepted treatment approach  
4. Use of combination EGFR (erlotinib) and VEGF inhibition (bevacizumab) not currently accepted treatment approach | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
Other related:  
• Decision model based on outdated clinical pathway |  |
| Kuiper et al (2012)27 | 4. Use of erlotinib (or other TKIs) in EGFR variant-negative or unknown population no longer accepted treatment approach  
4. Use of combination EGFR (erlotinib) and VEGF inhibition (sorafenib) not currently accepted | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Atypical clinical assessment tool used | 1. VeriStrat classification not used to direct therapy  
Other related:  
• Decision model based on outdated clinical pathway  
• No outcome reported for EGFR variant status unknown |  |
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcomes</th>
<th>Follow-Up</th>
</tr>
</thead>
</table>
| Akerley et al (2013)          | 1. Participants may have received prior adjuvant chemotherapy  
3. Use of combination EGFR (erlotinib) and VEGF inhibition (bevacizumab) not currently accepted treatment approach | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
3. Survival of participants without VeriStrat assay reported as not different but not data provided | |
| Gautschi et al (2013)         | 4. Use of combination EGFR (erlotinib) and VEGF inhibition (bevacizumab) not currently accepted treatment approach | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
Other related:  
• Decision model based on outdated clinical pathway | |
2. Participants in 2 arms received treatment off protocol  
4. Use of erlotinib (or other TKIs) in EGFR variant negative or unknown population no longer accepted treatment approach | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
Other related:  
• Decision model based on outdated clinical pathway | |
| Keshtgarpour et al (2016)     | 1. No determination of EGFR variant status  
1. Participants may have received prior first-line chemotherapy  
4. Use of erlotinib (or other TKIs) in EGFR variant negative or unknown population no longer accepted treatment approach | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | Other related:  
• Decision model based on outdated clinical pathway | |
| Grossi et al (2017)           | 3. Median age (57 y) of patients in cisplatin plus pemetrexed arm significantly younger than median age (70 y) in carboplatin plus pemetrexed arm | Other related:  
• Identity of proteins that make up the MALDI-MS features still being investigated at time of publication | 3. Clinical assessment of prognosis not used | 1. VeriStrat classification not used to direct therapy  
2. Inclusion of KRAS variant/exclusion of EGFR and ALK testing results in adjusted analyses appears to be potential new |
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcomes</th>
<th>Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grossi et al (2018) (^3)</td>
<td>1. NExUS cohort reference is abstract only 1. eLung cohort reference is abstract only 2. NExUS cohort reference is abstract only 2. eLung cohort results based on treatment (cetuximab) not currently used for first- or second-line NSCLC</td>
<td>• Other related: Identity of the proteins that make up the MALDI-MS features still being investigated at the time of publication</td>
<td>1. VeriStrat classification not used to direct therapy • Other related-decision model based on outdated clinical pathway in NExUS and eLung cohorts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spigel et al (2018) (^3)</td>
<td>1. No determination of EGFR variant status 4. Use of erlotinib (or other TKIs) in EGFR variant−negative or −unknown population no longer accepted treatment approach</td>
<td>Other related: Identity of the proteins that make up the MALDI-MS features still being investigated at the time of publication</td>
<td>1. VeriStrat classification not used to direct therapy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

EGFR: epidermal growth factor receptor; FU: follow-up; MALDI-MS: matrix-assisted laser desorption ionization mass spectrometry; NSCLC: non-small-cell lung cancer; OS: overall survival; PFS: progression-free survival; TKI: tyrosine kinase inhibitor; TNVEGF: vascular endothelial growth factor.

\(^a\) Population key: 1. Intended use population unclear; 2. Clinical context is unclear; 3. Study population is unclear; 4. Study population not representative of intended use.

\(^b\) Intervention key: 1. Classification thresholds not defined; 2. Version used unclear; 3. Not intervention of interest.

\(^c\) Comparator key: 1. Classification thresholds not defined; 2. Not compared to credible reference standard; 3. Not compared to other tests in use for same purpose.

\(^d\) Outcomes key: 1. Study does not directly assess a key health outcome; 2. Evidence chain or decision model not explicated; 3. Key clinical validity outcomes not reported (sensitivity, specificity and predictive values); 4. Reclassification of diagnostic or risk categories not reported; 5. Adverse events of the test not described (excluding minor discomforts and inconvenience of venipuncture or noninvasive tests).

\(^e\) Follow-Up key: 1. Follow-up duration not sufficient with respect to natural history of disease (true positives, true negatives, false positives, false negatives cannot be determined).
## Table 6. Clinical Validity Study Design and Conduct Gaps for Proteomic Testing in NSCLC for Disease Prognosis

<table>
<thead>
<tr>
<th>Study</th>
<th>Selection</th>
<th>Blinding</th>
<th>Delivery of Test</th>
<th>Selective Reporting</th>
<th>Completeness of Follow-Up</th>
<th>Statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taguchi et al (2007) Italian B validation set</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Sample sizes small • Impacts test of difference in multivariate analysis</td>
<td></td>
</tr>
<tr>
<td>Taguchi et al (2007) ECOG 3503 validation set</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Proteomic testing not applied to EGFR variant status unknown population</td>
<td>Other related: • Confidence that the proteomic classifier is independent of EGFR variant status is limited by very small number of positive variants • Small sample sizes • Unadjusted for demographic and histologic characteristics associated with prognosis</td>
<td></td>
</tr>
<tr>
<td>Amann et al (2010)</td>
<td>2. Selection not random nor consecutive (ie, convenience)</td>
<td>None noted</td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Sample sizes small • Impacts test of difference in multivariate analysis</td>
<td></td>
</tr>
<tr>
<td>Carbone et al (2010) Herbst et al (2005)</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: 1. p-value not reported • Sample sizes small • Unadjusted for demographic and histologic characteristics associated with prognosis</td>
<td></td>
</tr>
<tr>
<td>Kuiper et al (2012)</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Sample sizes small • Unadjusted for demographic and histologic characteristics associated with prognosis</td>
<td></td>
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<tr>
<td>Akerley et al (2013)</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Small sample sizes</td>
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<tr>
<td>Gautschi et al (2013)</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Sample sizes small • OS (primary outcome) and PFS (secondary outcome) data not shown for reported multivariate analysis or stratification by trial • Adjusted analysis (sex, age, histology, disease stage, PS, smoking status) reported as no significant association between VeriStrat and tumor variant status; data not shown</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Selection</td>
<td>Blinding</td>
<td>Delivery of Test</td>
<td>Selective Reporting</td>
<td>Completeness of Follow-Up</td>
<td>Statistical</td>
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<td>--------------------------------------------</td>
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<tr>
<td>Stinchcombe et al (2013)³⁰</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Other related:</td>
<td></td>
</tr>
<tr>
<td>Keshtgarpour et al (2016)¹⁸</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Small sample sizes</td>
<td></td>
</tr>
<tr>
<td>Grossi et al (2017)¹¹</td>
<td>2. Participant recruitment not random from single lung cancer treatment unit</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Variable response assessment times and intervals</td>
<td></td>
</tr>
<tr>
<td>Grossi et al (2018)³⁴</td>
<td>2. Participant selection differs between and among cohorts</td>
<td></td>
<td>2. VeriStrat classification results for 2 of 3 cohorts imported from abstract sources</td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Small sample sizes</td>
<td></td>
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<tr>
<td>Spigel et al (2018)³³</td>
<td>2. Selection not random or consecutive (ie, convenience)</td>
<td></td>
<td></td>
<td>Other related: • Variable response assessment times and intervals</td>
<td>Other related: • Statistical key: Other related:</td>
<td></td>
</tr>
</tbody>
</table>

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

OS: overall survival; PFS: progression-free survival; PS: performance status.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>N</th>
<th>Population</th>
<th>Summary of Outcomes: OS for “Good” vs “Poor” Assay</th>
<th>Summary of Outcomes: PFS for “Good” vs “Poor” Assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon et al (2009)³⁶ Erlotinib/ bevacizumab generation set ³¹</td>
<td>Retrospective</td>
<td>35</td>
<td>Stage III or IV, recurrent, nonsquamous NSCLC treated with erlotinib and bevacizumab</td>
<td>Adjusted HR of death, 1.024 (95% CI, 1.009 to 1.040; p=0.003)</td>
<td></td>
</tr>
<tr>
<td>Salmon et al (2009) ECOG 3503 validation set ³¹</td>
<td>Retrospective</td>
<td>82</td>
<td>ECOG 3503 trial patients with stage III or IV or recurrent</td>
<td>Adjusted HR of death, 1.024 (95% CI, 1.009 to 1.040; p=0.003)</td>
<td></td>
</tr>
</tbody>
</table>
Proteomic Testing for Systemic Therapy in Non-Small-Cell Lung Cancer

### Study

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>N</th>
<th>Population</th>
<th>Assay</th>
<th>Summary of Outcomes: OS for “Good” vs “Poor”</th>
<th>Summary of Outcomes: PFS for “Good” vs “Poor”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu et al (2013)(^{37}) &lt;br&gt; Validation set(^\text{b})</td>
<td>Retrospective</td>
<td>44</td>
<td>Stage IIB or IV NSCLC failed or intolerant to chemotherapy, treated with gefitinib or erlotinib  &lt;br&gt; <strong>Histology:</strong> 79.2% adenocarcinoma; 20.6% squamous</td>
<td>OS (predicted “good” vs predicted “poor”);  &lt;br&gt; HR=0.357 (95% CI, 0.186 to 0.688; p=0.002)</td>
<td>PFS (predicted “good” vs predicted “poor”);  &lt;br&gt; HR=0.06 (95% CI, 0.022 to 0.016; p&lt;0.001)</td>
<td></td>
</tr>
<tr>
<td>Yang et al (2015)(^{38}) &lt;br&gt; Validation set(^\text{e})</td>
<td>Retrospective</td>
<td>12</td>
<td>Stage IIB or IV NSCLC with a known <strong>EGFR</strong> variant status  &lt;br&gt; <strong>Variant status:</strong> 42.9% with EGFR-TKI-sensitive variant; 57.7% with EGFR WT  &lt;br&gt; <strong>Previous EGFR treatment:</strong> 67.5% (30.9% as first-line, 26.8% as second-line, 9.8% as third-line or greater)  &lt;br&gt; Following EGFR-TKI treatment (81 patients in validation set): OS=29.0 mo for assay “mutant” and 28.0 mo for assay “wild” (p=NS)</td>
<td>Following EGFR-TKI treatment (81 patients in validation set): PFS=10.0 mo for assay “mutant” and 2.3 mo for assay “wild” (p&lt;0.001)</td>
<td></td>
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</tr>
</tbody>
</table>

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### Proteomic Testing in NSCLC to Predict Response to Therapy

No studies were identified that used VeriStrat proteomic testing to inform therapeutic options for patients with stage I or II NSCLC if surgery or surgery plus radiotherapy had been completed or who were upstaged as a result of surgical findings.

No studies were identified that used VeriStrat proteomic testing to inform therapeutic options for patients with stage I or II NSCLC who were considered medically inoperable.

Based on the association between VeriStrat status and outcomes in patients treated with EGFR TKIs, it was postulated that VeriStrat testing might predict response to EGFR TKIs.

No studies were identified that used VeriStrat proteomic testing to predict response to first-line targeted therapies or first-line chemotherapy in patients with newly diagnosed advanced NSCLC.

**Randomized Controlled Trials:** In the PROSE trial, Gregorc et al (2014) prospectively evaluated the VeriStrat test in a randomized controlled trial (RCT) comparing erlotinib with chemotherapy as second-line treatment for patients with stage IIB or IV NSCLC, stratified by performance status, smoking history, treatment center, and (masked) pretreatment VeriStrat classification.\(^{39}\)

In a multivariate model to predict OS, which included clinical characteristics and **EGFR**-variant status, VeriStrat classification was significantly associated with OS (HR for VeriStrat “good” vs “poor,” 1.88; 95% CI, 1.25 to 2.84; p=0.003).

In the entire analysis cohort, the median OS was 9.0 months in the chemotherapy group and 7.7 months in the erlotinib group; OS did not differ significantly by treatment group in adjusted or unadjusted analyses. Moreover, PFS did not differ significantly by treatment group in unadjusted analysis but was improved for the chemotherapy group in adjusted analysis (HR = 1.35; 95% CI, 1.10 to 1.65; p=0.002).
1.05 to 1.73; p=0.020). Stratification of patients by VeriStrat classification changed the estimate of the effect of chemotherapy. In the VeriStrat “good” group, there was no significant difference in OS between the 2 treatment groups, whereas, in the VeriStrat “poor” group, OS was shorter for patients treated with erlotinib (see Tables 8-10).

The authors of the PROSE trial concluded that the VeriStrat proteomic test predicted differential benefit for erlotinib compared with chemotherapy as second-line treatment of NSCLC, suggesting that patients classified as VeriStrat “poor” would have better outcomes with chemotherapy than erlotinib.

Peters et al (2017) published a randomized phase 2, open-label (EMPHASIS) trial exploring the differential effect of second-line erlotinib vs docetaxel in VeriStrat “good” vs VeriStrat “poor” patients. Patients had stage IIIB or IV squamous cell NSCLC and had failed first-line platinum-based doublet chemotherapy. Recruitment for the trial ended early due to low enrollment and the release of results from other trials (eg, PROSE). The EMPHASIS investigators analyzed trial findings and conducted an exploratory analysis combining EMPHASIS results with those from the squamous cell NSCLC cohort in the PROSE trial. Eighty patients were randomized, of whom 58 (72.5%) were categorized as VeriStrat “good.” The primary end point was PFS and was analyzed on an intention-to-treat basis. After a median follow-up of 20.5 months, 73 patients had experienced disease progression (median PFS, 2.7 months). Median PFS was 1.6 months in the erlotinib group and 3.0 months in the docetaxel group; the difference between groups was not statistically significant (p=0.37). PFS did not differ significantly by VeriStrat status, and there was no significant interaction between treatment and VeriStrat status (p=0.80). These trial characteristics and results, as well as results for the secondary outcome OS, are presented in Tables 8 to 10. This trial was restricted to squamous NSCLC histology, and the treatment decision model is not representative of current guideline recommendations.

Retrospective Studies: Several retrospective analyses of data from RCTs evaluating the efficacy of TKIs have examined VeriStrat as a prognostic and/or predictive test. Carbone et al (2012) investigated the prognostic and predictive effects of VeriStrat classification on response to treatment and survival in a subset of patients enrolled in a phase 3 trial of erlotinib vs placebo.41 BR.21, a randomized, placebo-controlled study of erlotinib, enrolled 731 previously treated patients with advanced NSCLC. In the primary study, PFS and OS were prolonged by erlotinib. EGFR variants were prognostic for OS, but not predictive of erlotinib benefit, while increased EGFR copy number variants were both prognostic and predictive of erlotinib benefit. For the present trial, plasma from 441 patients was tested with the VeriStrat test, of which 436 (98.9%) could be classified as “good” or “poor.”

Among the 144 placebo patients, VeriStrat test results were prognostic, with “good” patients (median OS=6.6 months; 95% CI, 4.4 to 8.2 months) surviving significantly longer than “poor” patients (median OS=3.1 months; 95% CI, 2.2 to 3.7 months; HR=0.44, 95% CI, 0.31 to 0.63; p<0.001). Similar results were seen for PFS, with VeriStrat “good” patients having longer PFS than “poor” patients (HR=0.59; 95% CI, 0.42 to 0.86; p=0.002). Median survival was 10.5 months for VeriStrat “good” patients treated with erlotinib and 6.6 months for those on placebo (HR=0.63; 95% CI, 0.47 to 0.85; p=0.002), while for VeriStrat “poor” patients, the median survival for erlotinib was 3.98 months and 3.09 months for placebo (HR=0.77; 95% CI, 0.55 to 1.06; p=0.11). For 252 erlotinib-treated patients with data available to evaluate for objective response, VeriStrat “good” patients (n=157 [62%]) had a significantly higher response rate.
(11.5%) than VeriStrat “poor” patients (1.1%; p=0.002). In a Cox multivariate regression model to predict OS, the interaction between VeriStrat status and treatment type was not statistically significant, indicating that both “good” and “poor” cohorts derived a similar survival benefit from erlotinib. The authors concluded that VeriStrat status predicted response to erlotinib but did not predict differential benefit from erlotinib for OS or PFS.

Gadgeel et al (2017) retrospectively analyzed data from the LUX-Lung 8 trial, which compared second-line treatment with 1 of 2 TKIs (erlotinib, afatinib) in patients with advanced-stage IIIB or IV squamous NSCLC. EGFR-variant status was not considered in study eligibility. Blood samples for VeriStrat analysis were available for 691 (87%) of 795 randomized patients; of these, 12 were indeterminate results, and 4 could not be analyzed. The primary objective of the analysis was to evaluate whether VeriStrat status pretreatment is associated with OS and in the afatinib vs erlotinib groups. In the cohort with VeriStrat results (n=675), OS was significantly longer in the afatinib group (median, 7.8 months) than in the erlotinib group (median, 6.9 months; p=0.03). When stratified by VeriStrat status, OS was significantly longer with afatinib than with erlotinib in the VeriStrat “good” group (median, 11.5 months vs 8.9 months; HR=0.79; 95% CI, 0.63 to 0.98) but not the VeriStrat “poor” group (median, 4.7 months vs 4.8 months; HR=0.90; 95% CI, 0.70 to 1.16). In the VeriStrat stratified analysis, findings were similar for PFS. The study lacked a group receiving chemotherapy with which to compare the efficacy of TKIs.

Buttigliero et al (2018) retrospectively examined VeriStrat as a prognostic and/or predictive test in a randomized controlled phase 3 RCT (MARQUEE trial) of previously treated patients with advanced nonsquamous NSCLC who were given erlotinib plus tivantinib or placebo. EGFR-variant status was not considered in trial eligibility, and patients previously treated with EGFR inhibitors were excluded from the trial. Of the 1048 patients assigned to treatment protocols, 976 (93%) patients discontinued treatment by protocol (duration of therapy, 0.1-92 weeks), which was discontinued for futility at an interim analysis. In this cohort, no significant difference was seen between the treatment arms for OS. Intention-to-treat analysis of VeriStrat pretreatment status was performed on data for 996 patients.

When stratified by VeriStrat status, PFS and OS were significantly longer for patients in the VeriStrat “good” group than the VeriStrat “poor” group for both treatment arms (p<0.01); no direct comparison of treatment arms within the VeriStrat “good” or “poor” groups was performed. A prespecified Cox multivariate regression analysis of OS for the cohort demonstrated that there was a statistically significant difference between VeriStrat “good” and “poor” groups (p<0.001). There was a significant correlation between treatment and VeriStrat status (p=0.037) in multivariate analysis considering EGFR variant status; this interaction was no longer significant (p=0.068) when KRAS variant status was entered into the analysis. For patients who were EGFR wild-type (n=895 [90%]), OS was higher for both treatment arms in the VeriStrat “good” group (tivantinib arm median, 10.3 months; 95% CI, 8.9 to 11.5 months; placebo arm median, 9.2 months; 95% CI, 7.8 to 10.2 months) than in the VeriStrat “poor” group (tivantinib arm median, 3.9 months; 95% CI, 3.1 to 4.3 months; placebo arm median, 3.8 months; 95% CI, 2.9 to 5.4 months). The trial was restricted to nonsquamous NSCLC and lacked a group receiving chemotherapy with which to compare the efficacy of TKIs.

Section Summary: Clinically Valid
No published studies were identified that assessed the prognostic use of VeriStrat proteomic testing in newly diagnosed stage I or II NSCLC.
For individuals with newly diagnosed advanced NSCLC without prior systemic therapy, 5 retrospective studies assessed the use of VeriStrat ("good" or "poor") as a prognostic test to discriminate between OS (primary outcome) and PFS (secondary outcome) outcomes using available samples from previously conducted clinical trials as validation of the classification. Classification based on proteomic testing (ie, VeriStrat "good" vs "poor") was associated with survival outcomes in analyses that were primarily unadjusted for clinical and patient factors known to be associated with disease survival. The evidence is limited by heterogeneity in the patient population characteristics such as histology and the treatment regimens used. The treatment regimens using EGFR TKIs represent an outdated clinical decision model. The populations studied were unselected for EGFR-sensitizing variants or unknown variant status was excluded. Use of erlotinib (or other TKIs) in EGFR variant-negative or -unknown population is no longer an accepted treatment approach. Combination EGFR plus VEGF inhibition therapy is not an accepted treatment approach. The disposition of indeterminate proteomic test results varied, and sample sizes in the classification groups were small. There is a single observational, nonrandomized study with prospective sample collection for proteomic testing before NSCLC treatment; it reported PFS as the primary outcome. This is the only study that included a first-line treatment consistent with current guidelines-based recommendations (platinum-doublet-based chemotherapy with cisplatin or carboplatin in combination with pemetrexed). Participant recruitment was nonrandom from a single lung cancer treatment unit. Adjusted analyses for PFS and OS did not include age or other sensitizing variants (EGFR, ALK), although data were reported. Overall, sample sizes in classification groups were small and limited generalizability.

For individuals with advanced NSCLC that was recurrent or had advanced on prior systemic therapy, retrospective studies have assessed the use of VeriStrat ("good" or "poor") as a prognostic test to discriminate between OS (primary outcome) and PFS (secondary outcome) outcomes using available samples from previously conducted clinical trials as validation of the classification. None of the trials from which the samples for VeriStrat proteomic classification were derived used a therapy consistent with current guidelines-based recommendations. The populations in all studies were unselected for EGFR-variant status. One study used pre- and posttreatment proteomic test scores and added an indeterminate result to the "good" result data pool.

One additional retrospective study (Grossi et al [2018]) has limited evidentiary value. It combined the previously reported single prospective study cohort with results from 2 cohorts that are only referenced in abstract form.

No published studies were identified that assessed the use of VeriStrat proteomic testing to inform treatment options in newly diagnosed stage I or II NSCLC.

No published studies were identified that assessed the use of VeriStrat proteomic testing to inform treatment options for newly diagnosed advanced NSCLC patients who had not received prior systemic therapy.

The literature on the predictive value of proteomic testing consists of 2 RCTs in patients with advanced NSCLC who failed first-line chemotherapy. The 2 RCTs demonstrated that classification based on proteomic testing (ie, VeriStrat "good" vs "poor") is associated with survival outcomes. The evidence is limited by heterogeneity in the treatment regimens used and patient population characteristics. In the PROSE RCT, for patients classified as VeriStrat "good," there were no
significant differences in OS between the erlotinib and chemotherapy groups; however, for patients classified as VeriStrat “poor,” there was a significantly longer median OS in patients in the erlotinib group. In the EMPHASIS trial, there were no significant differences in PFS or OS among patients with VeriStrat “good” status receiving erlotinib or chemotherapy or among patients with VeriStrat “poor” status receiving erlotinib or chemotherapy. Moreover, in both the PROSE and EMPHASIS RCTs, there were no significant benefits to PFS or OS with erlotinib treatment compared with chemotherapy overall, making the application of VeriStrat in this population uncertain.

Tables 11 and 12 summarize gaps analyses for proteomic testing in NSCLC to predict response to therapy.

Table 8. Clinical Validity Study Characteristics of Proteomic Testing in NSCLC to Predict Response to Therapy

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>N</th>
<th>Population</th>
<th>Selection Criteria</th>
<th>Participant Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregorc et al (2014)⁵⁰</td>
<td>Prospective multicenter</td>
<td>263</td>
<td>Stage IIIB or IV NSCLC progressed on or were judged to be refractory to 1 prior platinum-based chemotherapy regimen randomized 1:1 to erlotinib or chemotherapy (single-agent pemetrexed or docetaxel investigator choice)</td>
<td>ECOG PS: 0-2 (93.9% grade 0-1) Histology: 63.5% adenoc: 17.8% squamous: 18.6% other</td>
<td>296 patients screened; 285 randomized (2/11 exclusions due to “not classified as good or poor”); 142 assigned to chemotherapy; 129 primary analysis population in chemotherapy group (13 exclusions); 143 assigned to erlotinib; 134 primary analysis population in erlotinib arm (9 exclusions); Total: 19 (7.2%) exclusions due to not starting treatment; Patients with controlled brain metastases could be included</td>
</tr>
<tr>
<td>Peters et al (2017)⁵⁰ (EMPHASIS-lung Trial)⁵⁰</td>
<td>Prospective multicenter</td>
<td>80</td>
<td>Randomized phase 3 second-line erlotinib vs docetaxel in VS “good” vs VS “poor”</td>
<td>ECOG PS: 0-2 Histology: squamous cell</td>
<td>Stage IIIB patients not amenable to radical radiotherapy were eligible: 94 assessed for eligibility; 81 randomized (1 randomized by mistake); Intention-to-treat cohort: Erlotinib arm: 38; Docetaxel arm: 42</td>
</tr>
</tbody>
</table>

adeno: adenocarcinoma; ECOG: Eastern Cooperative Oncology Group; EGFR: epidermal growth factor receptor; NSCLC: non-small-cell lung cancer; PS: performance status; WT: wild-type.

Table 9. Clinical Validity Results of Proteomic Testing in NSCLC to Predict Response to Therapy

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Median (95% CI), mo</th>
<th>Median (95% CI), mo</th>
<th>HR (95% CI)</th>
<th>HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregorc et al (2014)⁵⁰</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td>11.0 (9.3 to 12.6)</td>
<td>3.7 (2.9 to 5.2)</td>
<td>2.5 (1.88 to 3.31; p&lt;0.001)</td>
<td>Unadjusted HR=1.14 (0.88 to 1.49; p=0.313)</td>
</tr>
<tr>
<td>PFS</td>
<td>3.4 (2.4 to 4.6)</td>
<td>2.0 (1.6 to 2.4)</td>
<td>1.75 (1.34 to 2.29; p&lt;0.001)</td>
<td>Unadjusted HR=1.27 (0.99 to 1.62; p=0.60)</td>
</tr>
</tbody>
</table>
Table 10. Clinical Validity Results of Proteomic Testing in NSCLC Predict Response to Therapy

<table>
<thead>
<tr>
<th>Classification</th>
<th>Gregorc et al (2014)39</th>
<th>VeriStrat “good” (n=58)</th>
<th>VeriStrat “Poor” (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>Chemotherapy</td>
<td>Erlotinib</td>
</tr>
<tr>
<td>VeriStrat “good”</td>
<td>88 (48)</td>
<td>96 (52)</td>
<td></td>
</tr>
<tr>
<td>VeriStrat “poor”</td>
<td>41 (52)</td>
<td>38 (48)</td>
<td></td>
</tr>
<tr>
<td>Peters et al (2017)40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VeriStrat “good”</td>
<td>58</td>
<td>7.8</td>
<td>8.4</td>
</tr>
<tr>
<td>VeriStrat “poor”</td>
<td>22</td>
<td>4.4</td>
<td>5.2</td>
</tr>
</tbody>
</table>

OS by treatment group stratified by VeriStrat classification in randomized controlled trial. CI: confidence interval; NR: not reported; NSCLC: non-small-cell lung cancer.

Table 11. Clinical Validity Relevance Gaps for Proteomic Testing in NSCLC to Predict Response to Therapy

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcomes</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregorc et al (2014)39 (PROSE)</td>
<td>2. Table 5 reports other drug interventions used as third-line treatment without protocol information</td>
<td>Other related: • Identity of proteins that make up the MALDI-MS features still being investigated at the time of publication</td>
<td>1. VeriStrat assay not used to direct clinical management</td>
<td>1. Other related: • Decision model based on outdated clinical pathway • Variable response assessment times and intervals</td>
<td></td>
</tr>
<tr>
<td>Peters et al (2017)40 (EMPHASIS-lung Trial)</td>
<td>1. Accrual terminated 3. PROSE (Gregorc et al, 2014) squamous cell cohort not described</td>
<td>Other related: • Identity of proteins that make up the MALDI-MS features still being investigated at the time of publication</td>
<td>1. VeriStrat assay not used to direct clinical management</td>
<td>1. Other related: • Decision model based on outdated clinical pathway for treatment of squamous cell histology • Variable response assessment times and intervals • Incomplete data on PROSE squamous cell cohort</td>
<td></td>
</tr>
</tbody>
</table>

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment. EGFR: epidermal growth factor receptor; MALDI-MS: matrix-assisted laser desorption ionization mass spectrometry; NSCLC: non-small-cell lung cancer.

Population key: 1. Intended use population unclear; 2. Clinical context is unclear; 3. Study population is unclear; 4. Study population not representative of intended use.

Intervention key: 1. Classification thresholds not defined; 2. Version used unclear; 3. Not intervention of interest.
c Comparator key: 1. Classification thresholds not defined; 2. Not compared to credible reference standard; 3. Not compared to other
tests in use for same purpose.
d Outcomes key: 1. Study does not directly assess a key health outcome; 2. Evidence chain or decision model not explicated; 3. Key
clinical validity outcomes not reported (sensitivity, specificity and predictive values); 4. Reclassification of diagnostic or risk categories
not reported; 5. Adverse events of the test not described (excluding minor discomforts and inconvenience of venipuncture or
noninvasive tests).
e Follow-Up key: 1. Follow-up duration not sufficient with respect to natural history of disease (true positives, true negatives, false
positives, false negatives cannot be determined).

Table 12. Clinical Validity Study Design and Conduct Gaps for Proteomic Testing in NSCLC to
Predict Response to Therapy

<table>
<thead>
<tr>
<th>Study</th>
<th>Selection</th>
<th>Blinding</th>
<th>Delivery of Test</th>
<th>Selective Reporting</th>
<th>Completeness of Follow-Up</th>
<th>Statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregorc et al (2014)</td>
<td></td>
<td></td>
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<tr>
<td>Peters et al (2017)</td>
<td></td>
<td></td>
<td></td>
<td>Other related:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(EMPHASIS-lung Trial)</td>
<td></td>
<td></td>
<td></td>
<td>• Incomplete data</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>on PROSE squamous</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>cell cohort</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The evidence gaps stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.
PFS: progression-free survival.

a Selection key: 1. Selection not described; 2. Selection not random or consecutive (ie, convenience).
b Blinding key: 1. Not blinded to results of reference or other comparator tests.
c Test Delivery key: 1. Timing of delivery of index or reference test not described; 2. Timing of index and comparator tests not same; 3. Procedure for interpreting tests not described; 4. Expertise of evaluators not described.
e Data Completeness key: 1. Inadequate description of indeterminate and missing samples; 2. High number of samples excluded; 3. High loss to follow-up or missing data.
f Statistical key: 1. Confidence intervals and/or \( p \) values not reported; 2. Comparison to other tests not reported.

Clinically Useful
A test is clinically useful if the use of the results informs management decisions that improve the
net health outcome of care. The net health outcome can be improved if patients receive correct
therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence
Direct evidence of clinical utility is provided by studies that have compared health outcomes for
patients managed with and without the test. Because these are intervention studies, the
preferred evidence would be from RCTs.

The proposed clinical utility of VeriStrat is for use by physicians to predict expected survival for
standard therapies in the treatment of patients with NSCLC. Clinical utility is also proposed for
physicians to use VeriStrat to select patients for systemic therapy based on the presence or
absence of \( EGFR \)-sensitizing variants. Direct evidence from studies that demonstrate improved
outcomes for patients managed with a strategy that includes proteomic testing compared with a
strategy that does not, is not available for use of proteomic testing to select targeted therapy or
other systemic therapy for NSCLC. Confidence that the proteomic classifier is independent of
\( EGFR \)-variant status, as well as other tumor and patient characteristics, has not been
demonstrated and, thus, VeriStrat lacks clinical validity. The identity of the proteins that make up
the MALDI-MS features was still being investigated at the time of publication of the studies for
both prognostic and predictive uses, further challenging the specificity for malignant biologic
processes and conditions.
**Chain of Evidence**

Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Absent direct evidence, a chain of evidence could be used to support the use of VeriStrat to select patients for EGFR TKI therapy. If EGFR TKI therapy were used as a standard of care in patients with unknown or negative EGFR status in the first-, second-, or third-line settings, proteomic testing could be used to select patients who are least likely to benefit. However, the IUNO trial did not find that erlotinib was efficacious in patients with NSCLC with no known EGFR variant, and the PROSE and EMPHASIS trials found that OS did not differ significantly for patients with advanced NSCLC treated with second-line erlotinib or chemotherapy. There were mixed findings on PFS in the PROSE and EMPHASIS trials. Due to study findings and the lack of support from guidelines for EGFR TKIs in this setting, EGFR TKI therapy is no longer standard therapy for any EGFR-negative or -unknown patients. Platinum-based chemotherapy and immunotherapy (based on programmed death-ligand 1 testing) are the guidelines-based options for previously untreated advanced EGFR-negative or -unknown patient with NSCLC or those with recurrent NSCLC or who have progressed on prior systemic therapy.

The available evidence does not demonstrate that the addition of a VeriStrat proteomic classification of “good” or “poor” to the standard clinical assessment of prognosis would influence treatment or define a treatment pathway. Similarly, there is no evidence to demonstrate the impact of substitution of a VeriStrat proteomic classification in the standard of care treatment pathways. The negative predictive value of a VeriStrat “poor” score has not been demonstrated; there has been no validation in patients who received no or surgical therapy only.

Although studies of physician decision making using VeriStrat proteomic testing have been reported; they did not evaluate patient outcomes and did not evaluate the impact of EGFR testing on treatment recommendations (the number of patients who had previously received EGFR tests was not reported). Thus, these studies are insufficient to demonstrate clinical utility.

Two studies have evaluated the impact of VeriStrat testing on physician treatment recommendations. Akerley et al (2013) reported on 226 physicians who provided pre- and posttest treatment plan information for 403 VeriStrat tests. In the 262 cases where pretreatment recommendations were for erlotinib only, for those patients who were classified as VeriStrat “poor,” physicians recommended erlotinib in 13.3%. In a larger study, Akerley et al (2017) reported on 2411 physicians who received 14,327 VeriStrat test results. The investigators only included tests that were ordered for NSCLC, were ordered as the sole test, were not indeterminate, and were not ordered in patients with known EGFR-variant status. VeriStrat findings were a classification of “good” for 1950 (78.2%) patients and “poor” for 544 (21.8%) patients. After receiving the test results, physicians changed their treatment recommendations in 28.2% of the cases; within this group, 13.2% were classified as VeriStrat “good” and 81.6% as VeriStrat “poor.” Physicians initially considered treatment with an EGFR TKI in 484 (89.0%) of 544 classified as VeriStrat “poor”; after receiving test results only, 49 (10%) were actually recommended EGFR TKI treatment.

**Section Summary: Clinically Useful**

No direct evidence for a serum proteomic test for the selection of an NSCLC treatment strategy was identified. Absent direct evidence, a chain of evidence could be developed to support the use
of VeriStrat to select patients for EGFR TKI therapy. If EGFR TKI therapy were used as a standard of care in patients with EGFR-unknown or -negative status in the first-, second-, or third-line settings, proteomic testing could be used to identify patients who are least likely to benefit. However, given the evidence from the available trials and the lack of support from guidelines for EGFR TKIs in this setting, EGFR TKI therapy is no longer standard therapy for any EGFR-negative or -unknown patient. There are no studies that have directly evaluated the use of the proteomic classification to inform treatment selection based on current treatment pathways that consider other targeted therapy, chemotherapy, or immunotherapy options. Two studies by the same research group evaluated changes in treatment recommendations before and after receiving VeriStrat test results; patient outcomes were not reported.

SUMMARY OF EVIDENCE

For individuals with newly diagnosed NSCLC and EGFR-negative variant status who receive management with a serum proteomic test to predict survival and select treatment, the evidence includes retrospective studies and a prospective nonrandomized study. Relevant outcomes are overall survival, disease-specific survival, and treatment-related mortality and morbidity. No published studies were identified that assessed the prognostic use of VeriStrat proteomic testing in newly diagnosed stage I or II NSCLC. For individuals with newly diagnosed advanced NSCLC and EGFR-negative variant status without prior systemic therapy, 5 studies have assessed the use of VeriStrat ("good" or "poor") as a prognostic test to discriminate between overall survival (primary) and progression-free survival (secondary) outcomes. All studies were retrospective and intended to validate the extent to which the VeriStrat proteomic classification correlated with overall survival or progression-free survival. Only 1 of the 5 studies reported the percentage of participants who were EGFR-negative, but it did not report outcomes based on variant status. One observational, nonrandomized study with prospective sample collection for proteomic testing before NSCLC treatment reported the percentage of participants who were EGFR-negative, but it did not report outcomes based on variant status. This was also the only study that included a first-line treatment consistent with current guideline-based recommendations—platinum-doublet-based chemotherapy plus cisplatin or carboplatin plus pemetrexed. The VeriStrat classification was not used to direct selection of treatment in any of the clinical trials from which the validation samples were derived. Disposition of populations with variant status “not reported” was generally not clear and could not be construed as “unknown” when wild-type or positive were reported. No studies were identified that used VeriStrat proteomic testing to inform therapeutic options for patients with stage I or II NSCLC if surgery or surgery plus radiotherapy have been completed or who were upstaged as a result of surgical findings. No studies were identified that used VeriStrat proteomic testing to inform therapeutic options for patients with stage I or II NSCLC who were considered medically inoperable. No studies were identified that used VeriStrat proteomic testing to predict response to first-line targeted therapies or first-line chemotherapy in patients with newly diagnosed advanced NSCLC. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals with newly diagnosed NSCLC and unknown EGFR-variant status who receive management with a serum proteomic test to predict survival and select treatment, the evidence includes 4 retrospective studies and a prospective study. Relevant outcomes are overall survival, disease-specific survival, and treatment-related mortality and morbidity. All study populations were either unselected for EGFR-variant status or status was expressly reported as unknown in conjunction with negative or positive status reports. None of the studies that reported unknown EGFR-variant status reported outcomes for the proteomic score based on unknown EGFR-variant
status. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals with NSCLC and EGFR-negative variant status and disease progression after first-line systemic therapy who receive management with a serum proteomic test to predict survival and select treatment, the evidence includes an RCT and a retrospective analysis. Relevant outcomes are overall survival, disease-specific survival, and treatment-related mortality and morbidity. No studies were identified that reported or analyzed outcomes using the proteomic test as a prognostic tool in EGFR-negative variant status populations. The evidence includes an RCT (PROSE) using proteomic testing to predict response to erlotinib compared with chemotherapy as second-line treatment for patients with stage IIIB or IV NSCLC, stratified by performance status, smoking history, treatment center, and (masked) pretreatment VeriStrat classification. In a multivariate model to predict overall survival, which included clinical characteristics and EGFR-variant status, VeriStrat classification was significantly associated with overall survival (hazard ratio for VeriStrat “good” vs “poor,” 1.88; 95% confidence interval, 1.25 to 2.84; p=0.003). However, 62% of the combined study population was EGFR-negative. A retrospective analysis was also performed on the MARQUEE trial, a phase 3 RCT in patients with stage IIIB or IV nonsquamous NSCLC, comparing the patient response to erlotinib in conjunction with either tivantinib or a placebo; patients were stratified by EGFR and KRAS variant status, sex, smoking history, and treatment history. Protocol treatments were subsequently discontinued by 93% of patients, and the trial discontinued after prespecified interim futility analysis. In a multivariate model to predict overall survival, which included clinical characteristics and EGFR-variant status, VeriStrat classification was significantly associated with overall survival (hazard ratio for VeriStrat “good” vs “poor,” 0.52; 95% confidence interval, 0.40 to 0.67; p<0.001). Ninety percent of the combined study population was EGFR-negative. An interaction between treatment and VeriStrat status was significant for multivariate analysis including EGFR status (p=0.036) but not significant for multivariate analysis including both EGFR and KRAS variant status (p=0.068). Currently, the use of erlotinib in patients unselected for the presence or absence of an EGFR-sensitizing variant is not standard clinical practice. It is recommended that variant status be determined, if not previously ascertained, before selecting treatment after progression or recurrence. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals with NSCLC and unknown EGFR-variant status with disease progression after first-line systemic therapy who receive management with a serum proteomic test to predict survival and select treatment, the evidence includes 2 RCTs and 3 retrospective studies. Relevant outcomes are overall survival, disease-specific survival, and treatment-related mortality and morbidity. The use of VeriStrat as a prognostic test to discriminate between good and poor survival outcomes was assessed in 3 retrospective studies intended to validate the extent to which VeriStrat proteomic classification correlates with overall survival or progression-free survival. The VeriStrat classification was not used to direct treatment selection in any of the trials from which the validation samples were derived. None of the clinical trials from which the samples for VeriStrat proteomic classification were derived used a therapy consistent with current guidelines-based recommendations. The populations in all 3 studies were unselected for EGFR-variant status. In the PROSE RCT, using a multivariate model to predict overall survival, which included clinical characteristics and EGFR-variant status, VeriStrat classification was significantly associated with overall survival (hazard ratio for VeriStrat “good” vs “poor,” 1.88; 95% CI, 1.25 to 2.84; p=0.003). However, 32.6% of the combined study population had unknown EGFR
status. In the EMPHASIS RCT, there were no significant differences in progression-free survival or overall survival among patients with VeriStrat “good” status receiving erlotinib or chemotherapy or among patients with VeriStrat “poor” status receiving erlotinib or chemotherapy. The results of the EMPHASIS RCT were restricted to squamous NSCLC histology. Currently, the use of erlotinib in patients unselected for the presence or absence of an EGFR-sensitizing variant is not standard clinical practice. It is recommended that variant status be determined, if not previously ascertained, before selecting treatment after progression or recurrence. The evidence is insufficient to determine the effects of the technology on health outcomes.

**CLINICAL INPUT FROM PHYSICIAN SPECIALTY SOCIETIES AND ACADEMIC MEDICAL CENTERS**

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests, input was received from 1 academic medical center and 2 community health systems, one of which provided 4 responses, while this policy was under review in 2017. Input was uniform that erlotinib is not considered routine for individuals with non-small-cell lung cancer (NSCLC) who are EGFR-negative or EGFR-status unknown in the second-line setting. Reviewers had limited confidence that there is adequate evidence that the use of VeriStrat to guide treatment selection will improve outcomes for individuals with NSCLC who are EGFR-negative or EGFR-status unknown in the second-line setting.

**PRACTICE GUIDELINES AND POSITION STATEMENTS**

**National Comprehensive Cancer Network Guidelines**
The National Comprehensive Cancer Network (v.1.2019) guidelines on the management of non-small-cell lung cancer (NSCLC) recommend routine testing for epidermal growth factor receptor (EGFR) variants in patients with metastatic nonsquamous NSCLC (category 1 recommendation) and consideration for EGFR-variant testing in patients with metastatic squamous NSCLC who were never smokers or with small biopsy specimens or mixed histology (category 2A recommendation). Recommendations for first-line treatment for EGFR-positive patients with advanced or metastatic NSCLC, and EGFR-negative or -unknown patients as well as for patients in either category who have progressed on therapy are provided.

**American Society of Clinical Oncology**
The American Society of Clinical Oncology (2017) updated its clinical practice guidelines on systemic therapy for stage IV NSCLC. New or revised recommendations included the following recommendations: first-line treatment for patients with nonsquamous cell carcinoma or squamous cell carcinoma (without positive markers, eg, EGFR, ALK, ROS1), based on programmed death-ligand 1 expression; second-line treatment in patients who received first-line chemotherapy, without prior immune checkpoint therapy based on programmed death-ligand 1 expression; as well as recommendations for those patients who cannot receive immune checkpoint inhibitor. Recommendations are included for patients with a sensitizing EGFR variant, for patients with disease progression after first-line EGFR tyrosine kinase inhibitor therapy based on the results of T790M variant testing, and for patients with ROS1 gene rearrangements without prior crizotinib may be offered crizotinib, or if they previously received crizotinib, they may be offered chemotherapy.
The Society (2018) endorsed practice guidelines from other medical associations (College of American Pathologists, International Association for the Study of Lung Cancer, Association for Molecular Pathology) addressing molecular testing for the selection of patients with lung cancer for treatment with targeted tyrosine kinase inhibitors.48

American College of Chest Physicians
The American College of Chest Physicians (2013) updated its evidence-based clinical practice guidelines on the treatment of stage IV NSCLC.49 Based on a review of the literature, the College reported improved response rates, progression-free survival, and toxicity profiles with first-line erlotinib or gefitinib compared with first-line platinum-based therapy in patients with EGFR variants, especially exon 19 deletion and L858R variant. Moreover, the College recommended “testing patients with NSCLC for EGFR mutations at the time of diagnosis whenever feasible, and treating with first-line EGFR-TKIs if mutation-positive.”

U.S. PREVENTIVE SERVICES TASK FORCE RECOMMENDATIONS
Not applicable.

ONGOING AND UNPUBLISHED CLINICAL TRIALS
Some currently unpublished trials that might influence this review are listed in Table 13.

Table 14. Summary of Key Trials
<table>
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<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
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<td>Ongoing</td>
<td>Clinical Effectiveness Assessment of VeriStrat® Testing and Validation of Immunotherapy Tests in NSCLC Subjects (INSIGHT)</td>
<td>1000</td>
<td>Dec 2020</td>
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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. 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.

CPT/HCPCS
81235 EGFR (epidermal growth factor receptor) (eg, non-small cell lung cancer) gene analysis, common variants (eg, exon 19 LREA deletion, L858R, T790M, G719A, G719S, L861Q)
81479 Unlisted molecular pathology procedure
81538 Oncology (lung), mass spectrometric 8-protein signature, including amyloid A, utilizing serum, prognostic and predictive algorithm reported as good versus poor overall survival
81599 Unlisted multianalyte assay with algorithmic analysis

- There is a specific code for epidermal growth factor receptor (EGFR): 81235.
- There is a specific CPT code for the Veristrat test: 81538.
For proteomic testing other than VeriStrat, there are no specific CPT codes. If the test includes multiple assays, uses an algorithmic analysis, and is reported as a numeric score or a probability, the unlisted multianalyte assay with algorithmic analysis code 81599 would be reported. Otherwise, the unlisted molecular pathology code 81479 would be used.

**Diagnoses**

Experimental / Investigational for all diagnoses related to this medical policy.

**REVISIONS**

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**REFERENCES**


**Other References**

1. Blue Cross and Blue Shield of Kansas Pathology Liaison Committee, July 2016; January 2017.
## APPENDIX

### Appendix Table 1. Summary Characteristics of 3 Cohorts

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Platinum</th>
<th>Doublet Component</th>
<th>Other Drug Component</th>
<th>N</th>
<th>VeriStrat</th>
<th>EGFR Receptor Variant Status</th>
<th>Included in Analysis</th>
<th>Excluded From Analysis</th>
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<td>Gemcitabine</td>
<td>Sorafenib</td>
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<td>NExUS</td>
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<td>Gemcitabine</td>
<td>Cetuximab</td>
<td>82a</td>
<td>56</td>
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<td>X</td>
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<td>Cetuximab</td>
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<td>34</td>
<td>8</td>
<td>NR</td>
<td>Subpopulation of nonsquamous histology</td>
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</table>

Adapted from Grossi et al (2018).33

EGFR: epidermal growth factor receptor; NA: not available; NR: not reported.

a Not reported separately.