# Immune Cell Function Assay

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**Last Review:** 12/2018  
**Origination:** 12/2015  
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## Policy
Blue Cross and Blue Shield of Kansas City (Blue KC) will not provide coverage for Immune Cell Function Assay. This is considered investigational.

## When Policy Topic is covered
n/a

## When Policy Topic is not covered
Use of the immune cell function assay to monitor and predict immune function after solid organ transplantation is considered **investigational**.

Use of the immune cell function assay to monitor and predict immune function after hematopoietic cell transplantation is considered **investigational**.

Use of the immune cell function assay for all other indications is considered **investigational**.

## Description of Procedure or Service

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| Individuals:  
  • With a solid organ transplant                 | Interventions of interest are:  
  • Immune cell function assay with ImmuKnow       | Comparators of interest are:  
  • Standard monitoring of immunosuppression        | Relevant outcomes include:  
  • Overall survival  
  • Test accuracy  
  • Other test performance measures  
  • Morbid events                                   |
| Individuals:  
  • With a hematopoietic cell transplant           | Interventions of interest are:  
  • Immune cell function assay with ImmuKnow       | Comparators of interest are:  
  • Standard of care                                | Relevant outcomes include:  
  • Overall survival  
  • Test accuracy  
  • Other test performance measures  
  • Morbid events                                   |
| Individuals:  
  • With a solid organ transplant                  | Interventions of interest are:  
  • Immune cell function assay with Pleximmune     | Comparators of interest are:  
  • Standard monitoring of immunosuppression        | Relevant outcomes include:  
  • Overall survival  
  • Test accuracy  
  • Other test performance measures                |
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Careful monitoring of lifelong immunosuppression is required to ensure long-term viability of solid organ allografts without incurring an increased risk of infection. The monitoring of immunosuppression parameters attempts to balance the dual risks of rejection and infection. It is proposed that individual immune profiles, such as an immune cell function assay, will help assess the immune function of the transplant recipient and individualize immunosuppressive therapy.

For individuals who have a solid organ transplant or hematopoietic cell transplant (HCT) who receive testing using an immune cell function assay with ImmuKnow, the evidence includes numerous studies on the association of assay test values and subsequent rejection or infection, and 1 randomized controlled trial in liver transplant patients. Relevant outcomes are overall survival, test accuracy, other test performance measures, and morbid events. The ImmuKnow test has shown variable associations with infection and rejection, depending on the type of transplant and context of the study. Across all the studies among various types of patients, ImmuKnow levels are associated with the risk of rejection when levels are high and risk of infection when levels are low. However, the absolute risk and increments of risk are uncertain because of heterogeneity of the studies. The predictive characteristics of the test are still uncertain, and do not allow a strong chain of logic for clinical utility. The trial of ImmuKnow test in liver transplant patients showed improvement in overall survival; however, the trial has several limitations. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have a solid organ transplant or HCT who receive testing using an immune cell function assay with Pleximmune, the evidence includes Food and Drug Administration (FDA) documentation and 1 report on the test’s development and validation. Relevant outcomes are overall survival, test accuracy, other measures of test performance, and morbid events. Small studies have shown that Pleximmune values correlate with long-term survival. Pleximmune test results correlated with rejection, but conclusions are uncertain because of extremely limited evidence deriving from a small number of patients described briefly in FDA approval documents and a second study, in which the confidence interval bounds for sensitivity and specificity estimates were wide. No direct studies of clinical utility were identified. An argument for clinical utility by a chain of evidence would rely on both a demonstration of clinical validity and a rationale that specific clinical interventions based the results of the test decrease the risk of a poor health outcome. At present, the clinical interventions that would occur as a result of the
test result are uncertain, and so the clinical validity is uncertain. The evidence is insufficient to determine the effects of the technology on health outcomes.

**Background**

**Immunosuppression for Transplant**

In current clinical practice, levels of immunosuppression in patients being managed after a solid organ transplant or hematopoietic cell transplantation are determined by testing for clinical toxicity (eg, leukopenia, renal failure) and by therapeutic drug monitoring when available. However, drug levels are not a surrogate for overall drug distribution or efficacy because pharmacokinetics often differ among individuals due to clinical factors such as underlying diagnosis, age, sex, and race; circulating drug levels may not reflect the drug concentration in relevant tissues; and serum level of an individual immunosuppressant drug may not reflect the cumulative effect of other concomitant immunosuppressants. The main value of therapeutic drug monitoring is the avoidance of toxic. Individual immune profiles, such as an immune cell function assay, could support clinical decision making and help to manage the risk of infection from excessive immunosuppression and the risk of rejection from inadequate immunosuppression.

**Treatment**

Several commercially available tests of immune cell function have been developed to support clinical decision making.

ImmuKnow measures the concentration of adenosine triphosphate (ATP) in whole blood after a 15- to 18-hour incubation with phytohemagglutinin (a mitogenic stimulant). Cells that respond to stimulation show increased ATP synthesis during incubation. Concurrently, whole blood is incubated in the absence of stimulant for the purpose of assessing basal ATP activity. CD4-positive T lymphocytes are immunoselected from both samples using anti-CD4 monoclonal antibody–coated magnetic particles. After washing the selected CD4-positive cells on a magnet tray, a lysis reagent is added to release intracellular ATP. A luminescence reagent added to the released ATP produces light measured by a luminometer, which is proportional to the concentration of ATP. The characterization of the cellular immune response of a specimen is made by comparing the ATP concentration for that specimen with fixed ATP production ranges.

Pleximmune measures CD154 expression on T-cytotoxic memory cells in patient’s peripheral blood lymphocytes. CD154 is a marker of inflammatory response. To characterize the risk of rejection, the patient’s inflammatory response to (transplant) donor cells is expressed as a fraction of the patient’s inflammatory response to third-party cells. This fraction or ratio is called the Immunoreactivity Index (IR). If the donor-induced response exceeds the response to third-party cells, the individual is at increased risk for rejection. Cells are cultured and then analyzed with fluorochrome-stained antibodies to identify the cells expressing CD154. For posttransplant blood samples, an IR greater than 1.1 indicates an increased risk of rejection, and an IR less than 1.1 indicates a decreased risk of rejection. For pretransplant samples, the threshold for IR is 1.23.
Regulatory Status
In April 2002, ImmuKnow® (Cylex, acquired by ViraCor-IBT Laboratories, Lee’s Summit, MO), an immune cell function assay, was cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k) process. The FDA-indicated use of ImmuKnow® is for the detection of cell-mediated immune response in populations undergoing immunosuppressive therapy for organ transplant.

In April 2002, Immune Cell Function Assay (Cylex) was cleared for marketing by the FDA through the 510(k) process. The FDA-indicated use of the Immune Cell Function Assay is for the detection of cell-mediated immune response in an immunosuppressed population. In 2010, a device modification for this assay was cleared for marketing by the FDA through the 510(k). There were no changes to the indications or intended use.¹

In August 2014, Pleximmune™ (Plexision, Pittsburgh, PA) was approved by the FDA through the humanitarian device exemption process.² The test is intended for use in the pretransplantation and early and late posttransplantation period in pediatric liver and small bowel transplant patients for the purpose of predicting the risk of transplant rejection within 60 days after transplantation or 60 days after sampling.

Rationale
This evidence review was created in August 2009 and has been updated regularly with searches of the MEDLINE database. The most recent literature update was performed through October 27, 2017.

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.

The immune cell function assays are generally not meant to diagnose a condition (infection or rejection) that is concurrently present or absent; instead, the assays are designed to predict future risk of infection or rejection. Thus although many studies have evaluated immune function assays using these measures, they are not the ideal method to assess the value of the test, because these measures will be sensitive to the specific context of the study and will vary according to study characteristics (eg, time horizon, baseline risk of outcome). Risk-stratification can

1. ImmuKnow®
2. Pleximmune™
result in improved health outcomes if specific clinical interventions is on based the tests results and also decrease the risk of a poor health outcome.

In the case of immune cell function tests, it is proposed that immunosuppression regimen can be modified based on test results to minimize the risk of infection or rejection. Ideally, clinical trials comparing management of transplant patients with or without immune function testing would provide robust evidence of clinical utility. Lacking such trials, clinical utility might be inferred by a strong chain of evidence that would link evidence on the predictive characteristics of the immune function assay and evidence that the interventions based on test results would produce the desired outcomes.

**Immune Cell Function Assays**

**Clinical Context and Test Purpose**
The purpose of immune cell function assay in patients who have received solid organ or hematopoietic cell transplant is to inform treatment and management decisions with immunosuppressive therapy.

The question addressed in this evidence review is: Does use of immune cell function assays improve health outcomes in individuals who have received solid organ or hematopoietic cell transplants?

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

**Patients**
The relevant populations of interest are individuals who have a solid organ transplant or a hematopoietic cell transplant.

**Interventions**
The relevant interventions(s) of interest are immune cell function testing with ImmuKnow or Pleximmune.

**Comparators**
The relevant comparators of interest are standard monitoring of immunosuppression for those who have solid organ transplants and standard of care for those with hematopoietic cell transplantations.

**Outcomes**
The primary outcomes of interest are acute and chronic rejection episodes, graft dysfunction, graft survival, morbidity associated with graft dysfunction and overall survival posttransplant.

**Timing**
Acute rejection following any transplant typically occurs within weeks, with the highest risk during the first three months, and rarely may occur years after transplant. Chronic rejection typically develops years after transplant.
Setting
Patients are followed in posttransplant clinic following solid organ or hematopoietic cell transplant.

ImmuKnow Test

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

Solid Organ Transplants
Numerous studies have evaluated ImmuKnow testing in relation to risk of future infection or rejection. In general, these studies have assessed the test using measures for assessing diagnostic tests. The studies tend to show that test results correlate with either infection or rejection at specified thresholds, but that diagnostic characteristics tend to show poor sensitivity and poor specificity. This is to be expected of a test that is not meant as a diagnostic tool but as a risk-stratification tool. Systematic reviews of ImmuKnow are first summarized, followed by individual studies of solid organ transplantation, organized by transplant type, and then individual studies of hematopoietic cell transplantation.

Systematic Reviews
Ling et al (2012) performed a meta-analysis of studies (published to July 2011) to assess the efficacy of ImmuKnow for identifying risks of infection and rejection in adult transplant recipients. Nine studies published between 2008 and 2011 met inclusion criteria. Meta-analysis of these 9 studies incorporated 2458 samples from transplant recipients, including 172 samples from patients with infection and 135 samples from patients with rejection. Three studies were of liver transplant recipients, three of kidney recipients, and one each of heart, lung, and mixed organ transplant recipients. Pooled estimates of ImmuKnow performance characteristics for identifying infection risk were: sensitivity of 58% (95% confidence interval [CI], 52% to 64%), specificity of 69% (95% CI, 66% to 70%), positive likelihood ratio of 2.37 (95% CI, 1.90 to 2.94), negative likelihood ratio of 0.39 (95% CI, 0.16 to 0.70), and diagnostic odds ratio of 7.41 (95% CI, 3.36 to 16.34). Pooled estimates for ImmuKnow for identifying risk of rejection were: sensitivity of 43% (95% CI, 34% to 52%), specificity of 75% (95% CI, 72% to 78%), positive likelihood ratio of 1.30 (95% CI, 0.74 to 2.28), negative likelihood ratio of 0.96 (95% CI, 0.85 to 1.07), and diagnostic odds ratio of 1.19 (95% CI 0.65 to 2.20). Due to significant heterogeneity across studies, reviewers conducted subgroup analyses in liver and renal transplant recipients. The liver transplantation group had a pooled sensitivity of 85%, and the renal transplantation group had a specificity of 80%, indicating that different types of organ transplanted may be a source of observed heterogeneity; however, the
positive likelihood ratio of the liver group was low, and the negative likelihood ratio of the renal group was high, suggesting that it may be inappropriate to use the assay result to identify infection risk in either group. Based on the overall findings, reviewers suggested that ImmuKnow does not have sufficient diagnostic accuracy to identify individuals at risk of infection or rejection. In particular, sensitivity is low and likelihood ratios close to 1.0 indicate that this test does not alter the probability of specified outcomes to a large degree.

Rodrigo et al (2012) conducted a systematic review and meta-analysis to identify studies (published to March 2012) documenting the use of ImmuKnow to monitor immune function in adult liver transplant recipients. Five studies analyzed ImmuKnow performance in infection (651 patients) and five in acute rejection (543 patients). Two (of 5) studies also were included in the previously discussed Ling systematic review. Pooled sensitivity, specificity, positive likelihood ratio, diagnostic odds ratio, and mean (standard deviation [SD]) area under the summary receiver operating characteristic curve for infection were 84% (95% CI, 78% to 88%), 75% (95% CI, 71% to 79%), 3.3 (95% CI, 2.8 to 4.0), 14.6 (95% CI, 9.6 to 22.3), and 0.824 (0.034), respectively. Pooled estimates for acute rejection were 66% (95% CI, 55% to 75%), 80% (95% CI, 76% to 84%), 3.4 (95% CI, 2.4 to 4.7), 8.8 (95% CI, 3.1 to 24.8), and 0.835 (0.060), respectively. Heterogeneity was low for infection and high for acute rejection studies. These findings suggested that ImmuKnow could be considered a valid tool to assess infection risk in adult liver transplant recipients. However, due to significant heterogeneity across studies, conclusions about the prediction of rejection risk with ImmuKnow are limited.

Pediatric Transplants
Several studies have found no association between adenosine triphosphate (ATP) production (as determined by ImmuKnow) and outcomes in pediatric solid organ transplant recipients. Rossano et al (2009) studied 83 pediatric patients (median age, 4.9 years) undergoing heart transplant. ImmuKnow testing was performed at routine follow-up visits from 3 months to more than 5 years after transplant. There were 26 episodes of acute rejection, 20 (77%) of which were cell-mediated, and the remainder were humoral rejection. There were 38 infections. No difference in ATP production (as measured by ImmuKnow) was detected between patients with or without acute rejection or with or without infection. Further, the manufacturer’s reported risk ranges for rejection (ATP production ≥525 ng/mL) or infection (ATP production ≤225 ng/mL) were not predictive of rejection or infection, respectively. The studies have noted, however, it may be that pediatric patients’ risks for posttransplant infection and rejection correspond to different ATP production levels. Subsequent retrospective studies by Wong et al (2014), Ryan et al (2014), and Wozniak et al (2014) found no association between ATP production and outcomes in pediatric recipients of heart, kidney, or intestinal transplantations, respectively. Ryan et al observed a positive correlation between total peripheral white blood cell (WBC) count and ATP production ($r=0.28$, $p=0.04$) and suggested that the proportion of activated T cells within submitted samples may provide more useful information.
Kidney Transplants
Torío et al (2011) grouped 227 samples from 116 kidney transplant recipients (mean age, 51.2 years; range, 19-77 years) by clinical course: stable (no infectious syndrome or acute rejection episode 1 month before and after immune cell assay; n=168), infection (fever plus at least 1 positive culture or positive polymerase chain reaction; n=24), or rejection (biopsy-proven acute rejection; n=35). Healthy blood donors served as controls (n=108). Immunosuppressive regimens included pretransplant basiliximab (an interleukin-2 receptor inhibitor) or antithymocyte globulin and posttransplant tacrolimus, mycophenolate mofetil, and corticosteroid, or calcineurin inhibitors. Mean (SD) ATP production in the stable group (375.3 [140.1] ng/mL) and in the control group (436.5 [112.0] ng/mL) were higher than in the infection group (180.5 [55.2] ng/mL; p<0.001 for both comparisons). No difference was observed between the rejection group (332.5 [131.7] ng/mL) and the stable group or the control group (p>0.05 for both comparisons).

Two retrospective studies of kidney transplant recipients found statistically significant correlations between ATP production and WBC. In a study of 39 patients at a single center in Japan, Nishikawa et al (2014) reported correlation coefficients ($R^2$) of 0.573 (p=0.03) and 0.510 (p=0.02) for associations between WBC and neutrophil counts, respectively. In this study, ATP levels in 5 patients who developed viral infections in the early posttransplantation period (<50 days) were within normal limits. Methodologic limitations prevented any conclusion about the association between ATP levels and infections in 8 patients in the late posttransplantation period (>120 days). In a study of 306 patients at a single U.S. center, Sageshima et al (2014) reported a correlation coefficient ($R^2$) of 0.264 (p<0.001) for the association between ATP production and WBC. In this study, mean (standard error [SE]) ATP levels in patients with biopsy-proven rejection (389 [56] ng/mL) and borderline/clinical rejection (254 [41] mg/mL) were not statistically higher than ATP levels in patients without rejection (not reported). Mean (SE) ATP levels in patients with opportunistic (349 [48] ng/mL) and other (345 [27] ng/mL) infections were not statistically lower than ATP levels in patients without infection (not reported).

Reinsmoen et al (2008) studied 126 kidney transplant recipients to determine whether pretransplant immune parameters (ATP production, human leukocyte antigen mismatch, human leukocyte antigen–specific antibodies, and interferon-gamma precursor frequencies to donor or third-party cells) are associated with posttransplant early acute rejection, unstable creatinine course, and poor graft outcome. Mean (SD) pretransplant ATP production in recipients who had no clinical reason for a biopsy was significantly lower (285.3 [143.2] ng/mL) than those in recipients who had biopsy-proven acute rejection at any posttransplant time point up to 36 months (414.3 [138.5] ng/mL). Recipients who underwent biopsy but had no diagnosis of acute cellular rejection (ACR) or antibody-mediated rejection had an intermediate value of 333.7 (156.3) ng/mL. Mean (SD) pretransplant ATP production were also significantly higher for recipients with early (<90 days) unstable creatinine levels (362.8 [141.2] ng/mL), a significant predictor of early acute rejection, than for recipients with stable creatinine values.
Post hoc analysis using a cutoff ATP production of 375 ng/mL revealed that recipients with pretransplant ATP greater than 375 ng/mL were significantly more likely to experience acute rejection (odds ratio [OR], 3.67; 95% CI, 1.195 to 11.201). Immune parameters were not used to guide modifications of the immunosuppression protocol. Graft survival and incidence of infection were not reported in this study.

Serban et al (2009) assessed ImmuKnow results for 76 kidney transplant recipients (mean age, 50 years) receiving antithymocyte globulin induction and maintenance immunosuppression. ATP levels were assigned to episodes of infection or rejection only if ImmuKnow measurement was performed within 30 days preceding the adverse event. Over a median of 10 months of follow-up, there was a statistically significant difference between ATP activity measured in 15 of 18 patients with infection requiring hospitalization (median, ≈110 ng/mL) and 44 stable patients (median, ≈220 ng/mL; p=0.002). Median ATP production for 9 of 11 patients with rejection (230 ng/mL) did not differ significantly from that observed in stable patients (p value not reported). Results of 3 patients whose blood was sampled for ImmuKnow are unknown. ATP activity did not correlate with the number of CD4-positive T-cells during the first 5 months posttransplant (r=0.129, p=0.153) but did correlate with the number of neutrophils and total WBCs within the first 3 months posttransplant (r>0.4, p<0.001). Because of substantial myeloid cell contamination of cells captured by ImmuKnow in patients with low CD4-positive T-cell counts, authors concluded that cells of the myeloid lineage substantially contributed to the ATP signal measured by ImmuKnow in these patients. Among 31 patients treated with darbepoetin, median ATP production within the first 2 months posttransplant was approximately 260 ng/mL compared with 160 ng/mL in 38 patients who did not receive darbepoetin (p=0.017). There was no association between ATP production and development of rejection or infection at any time during the entire 10-month follow-up. As suggested by the authors, in darbepoetin-treated patients, increased ATP activity might be due to myeloid cell mobilization induced by darbepoetin rather than T-cell activation and does not justify increased immunosuppression. The relation between ImmuKnow results and infections was further analyzed using receiver operating characteristic (ROC) curve analysis. Area under the curve (AUC) was 0.736, indicating a fair accuracy of ImmuKnow results for predicting infection risk. The ATP cutoff calculated based on the ROC curve was 165 ng/mL, and corresponding positive and negative predictive values were 0.513 and 0.874, respectively. This cutoff for increased risk of infection differs from the manufacturer’s cutoff of 225 ng/mL. However, because of the specific effects of antithymocyte globulin induction, results of this study cannot be extrapolated to transplant recipients receiving no induction therapy or receiving induction agents that do not cause vigorous lymphocyte depletion (eg, alemtuzumab, an anti-CD25 monoclonal antibody).

Zhou et al (2011) grouped 259 Chinese kidney transplant recipients (mean age, 38.8 years) by clinical course: stable (no adverse events 7 days before and after immune cell assay; n=174), infection (clinical and imaging evidence of infection within 7 days before or after assay; n=32), rejection (biopsy-proven acute
rejection diagnosed within 7 days before or after assay without antirejection therapy; n=16), or methylprednisolone (intravenous methylprednisolone given to treat biopsy-proven acute rejection within 3 days before or after assay; n=33). Posttransplant immunosuppressive regimens included corticosteroids, calcineurin inhibitors, and mycophenolate mofetil. Median ATP production in the infection group (116.4 ng/mL; range, 66.3-169.2 ng/mL) and the methylprednisolone group (182.3 ng/mL; range, 113.6-388.8 ng/mL) was lower than in the stable group (347.7 ng/mL; range, 297.9-411.7 ng/mL; p<0.001 for both comparisons). Median ATP production in the rejection group was higher than in the stable group (615.9 ng/mL; range, 548.8-743.5 ng/mL; p<0.001). ROC curve analysis was evaluated to determine optimal ATP cutoffs for infection and rejection in this sample. With a cutoff for infection of 238 ng/mL, the sensitivity and specificity were 93% and 100%, respectively (AUC=0.991). For rejection, a cutoff of 497 ng/mL maximized the sensitivity and specificity at 92% and 94%, respectively (AUC=0.988).

Huskey et al (2011) conducted a single-center, retrospective analysis to assess the predictive ability of ImmuKnow to identify kidney transplant recipients at risk for opportunistic infection or acute rejection when used in routine clinical management. ImmuKnow results were categorized by the manufacturer’s ATP cutoff values and correlated with infection or rejection occurring within 90 days after the assay. Patients were selected who had neither infection nor rejection as controls; patients were then matched according to age, sex, and time of testing posttransplant. Immunosuppressive regimens included prednisone, calcineurin inhibitors, and mycophenolate mofetil. Of the total patient population, 80% of the patients received pretransplant antithymocyte globulin. Standard cytomegalovirus and Pneumocystis carinii prophylaxis was administered. Ninety-four ImmuKnow assays were performed in 85 patients with subsequent opportunistic infection and in matched controls. Mean ATP production did not differ between cases (386 ng/mL) and controls (417 ng/mL; p=0.24). A low ATP production (≤225 ng/mL) was not associated with an increased risk of infection (OR=1.34; 95% CI, 0.64 to 2.82; p=0.43). Forty-seven ImmuKnow assays were performed in 47 patients with subsequent acute rejection and in matched controls. Mean ATP production did not differ between cases (390 ng/mL) and controls (432 ng/mL; p=0.25). A high ATP production (≥525 ng/mL) was not associated with an increased risk of rejection (OR=1.87; 95% CI, 0.47 to 8.38; p=0.48).

Subsequent studies in kidney transplant recipients have failed to demonstrate an association between ATP production and risk of acute rejection. Studies of that nature have also failed to demonstrate an association between ATP production and viral infections using manufacturer-recommended cutoffs for ImmuKnow. Moreover, not a single kidney study has suggested an alternative approach to determining optimal cutoff values. In a prospective cohort study of 55 patients followed for 3 years, Libri et al (2013) observed that ATP production was often lower in patients with acute rejection than in patients without acute rejection, and was often greater in patients with infection than in patients without infection. Using labelled cutoffs for ImmuKnow, the AUC was 0.44 (95% CI, 0.18 to 0.71) for acute rejection and 0.37 (95% CI, 0.22 to 0.53) for viral or major respiratory
tract infections. In a 2014 prospective study of 67 patients undergoing kidney transplant, patients with low preoperative ATP production had statistically fewer rejection episodes than those with high preoperative ATP production (p<0.001).\textsuperscript{17} The cutoff used for this analysis was 300 ng/mL. To optimize ImmuKnow performance, Quaglia et al (2014)\textsuperscript{18} and Wang et al (2014)\textsuperscript{19} both proposed assessing change in ATP production over time, rather than single values. In a retrospective study of 118 patients, Quaglia et al reported an AUC of 0.632 (95% CI, 0.483 to 0.781) for infection risk using a cutoff of -30 ng/mL for the decrease in ATP production from month 1 to month 3.\textsuperscript{18} In a prospective study of 140 patients, Wang et al reported an AUC of 0.929 for risk of acute rejection using a cutoff of 172.55 ng/mL for the increase in ATP production from “right before” the rejection episode to the occurrence of rejection.\textsuperscript{19}

### Heart Transplants

Three studies have examined ATP production in adult heart transplant recipients. Gupta et al (2008) studied 125 adult heart transplant recipients, most of whom underwent ImmuKnow testing more than 1 year posttransplant.\textsuperscript{20} There was no apparent association between ATP production and rejection (n=3). For 7 patients who developed infection, median ATP production was 267 ng/mL and did not differ statistically from median ATP production in 104 patients who did not develop infection (282 ng/mL). There was a significant correlation between ATP production and WBC count but not between ATP production and absolute lymphocyte count; this would suggest that nonlymphocytes may be able to influence ATP response. This idea was supported by a 1994 study of CD4-positive T-cell responsiveness to 3 stimulants (including phytohemagglutinin in HIV-positive patients).\textsuperscript{21} The authors suggested that assays performed in clinical laboratories should profile immunoregulatory cytokines (eg, interleukin 2), which modulate the complex interplay between cellular and humoral immune mechanisms.

Israeli et al (2010) correlated ImmuKnow results with clinical status in 50 immunosuppressed heart transplant recipients (median age, 58.5 years).\textsuperscript{22} Median ATP production for 280 blood samples collected from patients during clinical quiescence (ie, good clinical status with normal heart function) was 351 ng/mL. ATP levels were within the manufacturer’s “moderate” range of immune function (225-525 ng/mL) in 176 (63%) of these samples. Median ATP production for 22 blood samples collected during episodes of biopsy-proven acute rejection was 619 ng/mL, a statistically significant difference (p<0.05). Median ATP production for 19 blood samples collected during episodes of fungal or bacterial infection (ie, requiring hospitalization for intravenous antimicrobial therapy) was 129 ng/mL, a statistically significant difference from the production during clinical quiescence (p<0.05). Although these ATP levels fell within the manufacturer’s defined ranges for increased risk of infection (≤225 ng/mL) and increased risk of rejection (≥525 ng/mL), blood samples were drawn during the adverse event rather than before, making it uncertain whether the ImmuKnow results were predictive of the adverse event.

A retrospective study by Kobashigawa et al (2010) correlated ImmuKnow results from 296 adult heart transplant recipients (mean age, 54.6 years) with infection or
rejection episodes occurring within 1 month of assay. Assays were performed between 2 weeks and 10 years posttransplant (N=864). Infection was diagnosed by the treating physician and resulted in antibiotic therapy. Rejection was defined as any treated episode of cellular or antibody-mediated rejection, with or without hemodynamic compromise. Transplant recipients without infection or rejection served as controls (n=818 assays). All patients received immunosuppression with tacrolimus, mycophenolate mofetil, and corticosteroids, without induction therapy. Oral prednisone bolus and taper was used for asymptomatic rejection, and antithymocyte globulin was used for rejection with hemodynamic compromise. Mean (SD) ATP production was lower in patients with infection (187 [126] ng/mL) than in controls (280 [126] ng/mL, p<0.001). Ten percent of ATP production less than 200 ng/mL were associated with infection, and 2% of ATP production greater than 200 ng/mL were associated with infection (p<0.001). Mean (SD) ATP production levels did not differ between patients who developed rejection (327 ng/mL) and controls (280 ng/mL; p=0.35). The 200 ng/mL cutoff was chosen based on ROC curve analysis to maximize sensitivity (71%) and specificity (73%; AUC=0.728). Although limited by its retrospective design, this study suggested that ImmuKnow might be associated with prediction of infection, not with transplant rejection, in heart transplant patients.

Liver Transplants
Cabrera et al (2009) assessed the ability of ImmuKnow to differentiate between ACR and recurrent hepatitis C virus (HCV) infection in 42 adults with liver transplant due to HCV-related end-stage liver disease. All patients had liver enzyme abnormalities posttransplant and underwent liver biopsy to diagnose both ACR and recurrent HCV. The most sensitive indicator of HCV infection (HCV RNA detection by polymerase chain reaction) was not used to diagnose HCV. ImmuKnow was performed with blood collected before biopsy, and biopsy samples were interpreted by histopathologists blinded to ImmuKnow results. Median ATP production in 12 patients diagnosed with ACR was 283.3 ng/mL (range, 241.1-423.0 ng/mL), and median ATP production in 15 patients diagnosed with recurrent HCV was 148.0 ng/mL (range, 33.7-186.0 ng/mL), a statistically significant difference (p<0.001). Median ATP production levels in 15 patients with mixed biopsy features of both ACR and recurrent HCV, but predominance of neither, was 234.0 ng/mL (range, 155.3-325.0 ng/mL), a statistically significant difference for both the ACR group (p=0.02) and the recurrent HCV group (p<0.001). Of note, although 100% of patients with recurrent HCV had ATP production within the manufacturer’s range for increased risk of infection (<225 ng/mL), all patients with ACR had ATP production outside of the manufacturer’s cutoff for increased risk of rejection (>525 ng/mL).

To assess ImmuKnow’s ability to differentiate ACR from recurrent HCV infection in patients with liver transplanted due to HCV-related liver disease, Hashimoto et al (2010) retrospectively reviewed 54 allograft liver transplant recipients who had concomitant ImmuKnow results available (mean age, 52 years; range, 40-63 years). Liver biopsies were performed every 6 months after liver transplantation and when clinically indicated due to elevated liver function tests. Biopsies were read by a pathologist blinded to ImmuKnow results. Polymerase chain reaction
detection of HCV RNA was not used. Immunosuppressive regimens included basiliximab, calcineurin inhibitors, and mycophenolate mofetil. ImmuKnow assays were collected before biopsy. Results were divided into 4 groups based on biopsy findings: ACR (n=11), recurrent HCV (n=26), normal biopsy (n=12), and overlapping features of both ACR and recurrent HCV. Mean (SD) ATP production levels in ACR (365 [130] ng/mL; range, 210-666) was higher than in normal biopsy (240 [71] ng/mL; range, 142-387; p=0.006). Mean (SD) ATP production levels in recurrent HCV (152 [100] ng/mL; range, 20-487) were lower than in both ACR (p<0.001) and normal biopsy (p=0.019). Mean (SD) ATP production of patients with overlapping features of both ACR and recurrent HCV (157 [130] ng/mL; range, 25-355) did not differ statistically from the other groups. Further, 73% of patients with ACR had ATP production within the manufacturer-defined moderate range; 88% of patients with recurrent HCV had ATP production in the low range (p<0.001). ROC curve analysis yielded a cutoff level of 220 ng/mL with sensitivity of 89% and specificity of 91% (AUC=0.93; 95% CI, 0.85 to 1.00).

Cheng et al (2011) evaluated the capability of ImmuKnow to predict recurrence of hepatocellular carcinoma (HCC) in Chinese patients undergoing liver transplantation for HCC. A threshold ATP production of 175 ng/mL was initially determined from 176 assays of 60 patients with HCC (mean age, 49.8 years), 60 (34%) from patients with recurrent HCC posttransplant and 116 (66%) from stable patients without HCC recurrence, infection, or biopsy-proven rejection. Mean (SD) ATP production levels in patients with recurrent HCC (137.8 [6.4] ng/mL) were lower than those without recurrence (289.2 [133.9] ng/mL; p<0.01). The sensitivity and specificity for the 175-ng/mL threshold value were 83% and 84%, respectively (AUC=0.869). ImmuKnow was then administered to a second cohort of 92 patients with HCC undergoing liver transplantation (mean age, 50.1 years). Patients were stratified by high immune response (mean ATP production, >175 ng/mL) and low-immune response (mean ATP production, ≤175 ng/mL). Seventeen (23%) of 73 patients in the high-response group and 16 (84%) of 19 patients in the low-response group developed HCC recurrence (p<0.001). Mean (SD) ATP production levels were 295.3 (85.4) ng/mL and 126.6 (37.9) ng/mL in the high- and low-immune response groups, respectively (p<0.001). High immune response was associated with recurrence-free survival (OR=7.28; 95% CI, 3.23 to 16.13) but not overall survival (OR=2.20; 95% CI, 0.56 to 8.65). This study also correlated ImmuKnow results with clinical status (infection or rejection) among a cohort of the original 60 patients with HCC plus 45 additional patients with nonmalignant liver diseases. ImmuKnow assays were collected during infection (diagnosed by clinical features, positive microbiologic tests, and imaging), biopsy-proven acute or chronic rejection, and stability (defined as good liver function and good general health at least 2 weeks after transplantation, without evidence of infection, rejection, or tumor recurrence). Immunosuppressive regimens were not defined. Rejection episodes were treated with bolus steroids or antithymocyte globulin. Mean (SD) ATP production level during infection (145.2 [87.0] ng/mL) and rejection (418.9 [169.5] ng/mL) differed from mean (SD) production level during stability (286.6 [143.9] ng/mL, p<0.01 for both comparisons). ROC analysis showed that optimum cutoff for infection was 200 ng/mL, with a sensitivity of 79% and specificity of 75% (AUC=0.842). Optimum cutoff for
rejection was 304 ng/mL, with a sensitivity of 80% and specificity of 76% (AUC=0.806). Another retrospective study (2011) of 87 liver transplant recipients used a cutoff for rejection of 407 ng/mL based on ROC curve analysis, with a sensitivity and specificity of 86% and 81%, respectively (AUC=0.869).

An additional study (2015) reported on the correlation between ImmuKnow values with immunosuppression in liver transplant recipients.

**Lung Transplants**

Piloni et al (2016) reported on a retrospective cohort study evaluating the immunosuppressive association between oversuppression (ImmuKnow score, corresponding to intracellular ATP, \( \leq 226 \) ng/mL) and adequate or undersuppression (ImmuKnow score, \( >226 \) ng/mL) in a sample of 61 patients in follow-up for lung transplantation. ImmuKnow testing had been performed at 6-month follow-up for patients who entered the study at the time of transplant (n=28); for other patients, testing was obtained on an as-needed basis because of acute graft dysfunction or suspected immune oversuppression. Being in the immune oversuppression group was associated with higher odds of infection (51 cases of infection/71 ImmuKnow tests vs 25/56; OR=2.754; 95% CI, 1.40 to 5.39; p=0.003). However, given that many patients tested in the as-needed group might have been tested because of suspected immune oversuppression, the risk of bias is very high.

Bhorade et al (2008) assessed the relation between low posttransplant ATP production (\( \leq 225 \) ng/mL) and recent infection in 57 immunosuppressed adult lung transplant recipients. ImmuKnow assays were performed in 143 patients at routine clinic visits when each patient was on a stable dose of tacrolimus. Fifteen patients developed infections (bacterial or fungal pneumonia, cytomegalovirus infection); 14 (93%) of the 15 had ATP production levels less than 225 ng/mL at the time of their infections (sensitivity, 93%). Among the 42 noninfected patients, 16 (38%) had ATP production less than 225 ng/mL (specificity, 62%). Without comparing postinfection with preinfection ATP production, it is impossible to determine whether low ATP production levels contributed to or resulted from the development of infection. In a 2012 U.S. single-center study on 175 adult lung transplant recipients, Shino et al reported that the ImmuKnow test had some predictive ability but was unlikely to be sufficiently accurate for use in clinical care. The AUC was relatively low (0.61). At a cutoff of 525 ng/mL, there was a significant increase in the risk for ACR (OR=2.1; 95% CI, 1.1 to 3.8). However, at this cutoff, sensitivity was 35% and specificity was 82%. When a cutoff of 425 ng/mL was used, sensitivity was 53% and specificity was 65%.

Husain et al (2009) assessed the correlation between ImmuKnow results and different types of infections (bacterial, fungal, viral) in 175 adult lung transplant recipients receiving immunosuppression induction with alemtuzumab. Blood samples were collected prospectively as part of routine surveillance in all patients during 2 to 48 months of follow-up. Periods of stability were defined as no infection occurring 1 month before or after the blood draw. For infectious episodes, only ATP levels drawn within 1 month before the episode were analyzed. Median
ATP production during stability was 175 ng/mL (25th-75th percentile, 97-306 ng/mL). Significantly lower median ATP production levels were seen in 13 cytomegalovirus infections (49 ng/mL, p<0.001) and 14 bacterial pneumonias (92 ng/mL, p=0.002). Median ATP production for fungal disease (85 ng/mL) did not differ significantly from that in stability (p not reported). Four patients who developed invasive pulmonary aspergillosis all had ATP levels less than 50 ng/mL. Generalized estimating logistic regression analysis demonstrated an odds of 2.81 (95% CI, 1.48 to 4.98) for increased risk of infection with ATP levels less than 100 ng/mL; moreover, the analysis demonstrated an OR of 9 (95% CI not reported) with values less than 50 ng/mL. In comparison, a diagnosis of cystic fibrosis yielded an odds of 2.66 (95% CI, 1.26 to 5.63); cytomegalovirus mismatch (donor positive, recipient negative) yielded an OR of 2.97 (95% CI, 1.52 to 5.80). Note that all ImmuKnow levels, both during periods of stability and within the month before infectious episodes, fell below the manufacturer’s cutoff for increased risk of infection (225 ng/mL).

**Section Summary: Clinical Validity for Solid Organ Transplants**

Across all the studies among various types of solid organ transplants, ImmuKnow levels have been associated with the risk of rejection when levels are high and risk of infection when levels are low. However, the absolute risk and increments of risk are uncertain because of heterogeneity across studies. The timing of the test in relation to the observed outcomes and whether the test was routine or performed for suspected infection or rejection affect test performance characteristics. In many cases, the threshold values were declared after the study. Validation of the threshold values with external validation samples is needed. It cannot be determined from these studies whether the discrimination of risk is clinically important, and whether there is compelling chain of logic that treatment modifications based on predicted risk would improve patient outcomes.

**Hematopoietic Cell Transplants**

Two studies examined the association between ImmuKnow and prognosis in hematopoietic cell transplantation, one in autologous transplants and one in allogeneic transplants. Manga et al (2010) assessed ATP production in 16 adults (mean age, 52 years) with hematologic malignancies (multiple myeloma, B- or T-cell lymphoma, acute myeloid leukemia) undergoing mobilization with granulocyte-colony stimulating factor (G-CSF) with or without granulocyte-macrophage-colony stimulating factor for autologous hematopoietic cell transplantation. Mean (SD) ATP production on day 5 of G-CSF therapy in 10 patients who survived more than 2 years after mobilization (673 [274] ng/mL) was higher compared with 5 patients who died within 2 years (282 [194] ng/mL; p=0.014). ROC curve analysis identified a cutoff of 522 ng/mL for predicting patient survival, with a sensitivity and specificity of 80% and 100%, respectively (AUC=0.880). Gesundheit et al (2010) examined 170 ATP production collected from 40 patients (median age, 34 years; range, 3-64 years) after engraftment of allogeneic hematopoietic cell transplantation for various malignant (acute and chronic myeloid leukemia, acute and chronic lymphocytic leukemia, non-Hodgkin lymphoma, multiple myeloma, myelodysplastic syndrome, ovarian, breast, and testicular cancer) and nonmalignant (severe aplastic anemia, thalassemia major, adrenoleukodystrophy)
diseases.\textsuperscript{34} ImmuKnow results were categorized “low” or “normal” according to the manufacturer’s ATP cutoff values and correlated with postengraftment clinical course. Overall survival for the immunocompetent (“normal”) group was 83% (10/12 patients) at 13 months of follow-up. Overall survival for the immunocompromised (“low”) group was 12% (3/25 patients) at 12 months of follow-up. Although test results were associated with outcome, it is unclear how such information could be used to improve patient outcomes.

Section Summary: Clinical Validity for Hematopoietic Cell Transplants
Two studies evaluated the association between ImmuKnow and prognosis in hematopoietic cell transplantation. In autologous and allogeneic transplant populations, higher ImmuKnow levels were associated with patients with longer overall survival at 2 years and 12 months, respectively. However, it cannot be determined from these studies whether the discrimination of risk is clinically important, and whether there is compelling chain of evidence that treatment modifications based on predicted risk would improve patient outcomes.

Clinically Useful

Solid Organ Transplant
Liver Transplants
The only study identified comparing patients managed with and without immune response assays is a 2015 study by Ravaioli et al.\textsuperscript{35} This randomized trial included 202 liver transplant patients. One group was randomized to have ImmuKnow testing at periodic intervals after transplant, and at clinically indicated times after a suspected or confirmed rejection or infection event. In this group, tacrolimus doses were reduced by 25% when ImmuKnow values were less than 130 ng/mL, and increased by 25% when ImmuKnow values were greater than 450 ng/mL. In the control group, ImmuKnow testing was performed but not revealed to treating physicians, and tacrolimus was managed according to standard practice. Declared study outcomes were survival, infection rate, rejection rate, and graft loss. One-year survival was 95% in the ImmuKnow group and 82% in the control group (p<0.01). Of the 33 deaths, 11 were caused by infection (distribution of the 11 deaths by treatment group not reported). Patients in the control group were reported to have had higher bacterial and fungal infection rates but the numbers reported included errors and are inconsistent. There were no differences in rejection events between the ImmuKnow group and the control group. Although the study showed a 10% absolute benefit in mortality, we have concerns about the study’s validity. The standard of care monitoring practice is not described. The study was performed at a single center. The control mortality rate might not be representative of modern liver transplant outcomes. The difference in mortality rates seems implausibly large given the known characteristics of ImmuKnow in discriminating risk of infection. Although the study suggested a benefit of monitoring immunosuppression with ImmuKnow in liver transplant patients, many trial limitations indicated that it needs to be replicated.

Hematopoietic Cell Transplants
No studies assessing the clinical utility of the ImmuKnow test were identified.
Section Summary: ImmuKnow Test for Solid Organ Transplants
For solid organ transplants, the ImmuKnow test has shown variable associations with infection and rejection, depending on the type of transplant and context of the study. Across all the studies among various types of patients, ImmuKnow levels are associated with the risk of rejection when levels are high and risk of infection when levels are low. However, the absolute risk and increments of risk are uncertain because of heterogeneity of the studies. The predictive characteristics of the test are still uncertain, and do not allow a strong chain of evidence for clinical utility. The trial of the ImmuKnow test in liver transplant patients showed improvement in overall survival; however, the trial had several limitations.

Section Summary: ImmuKnow Test for Hematopoietic Cell Transplants
For hematopoietic cell transplants, the ImmuKnow test has shown associations with longer overall survival for both autologous and allogeneic transplant populations. However, no clinical utility studies were identified. Therefore, it cannot be determined whether the discrimination of risk is clinically important and could potentially alter treatment that would improve patient outcomes.

Pleximmune Test

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

Solid Organ Transplants
The Food and Drug Administration documents have described a clinical validation study of Pleximmune. Among a sample of 33 pretransplant patients, Pleximmune™ had 57% sensitivity and 89% specificity for identifying rejection. Among a sample of 64 posttransplant patients, Pleximmune™ had 84% sensitivity and 80% specificity for identifying rejection. Almost no details were provided on study validation. A study by Ashokkumar et al (2009) evaluated the association between CD154 expression and rejection among pediatric liver transplant patients. It is difficult to determine if the measure of CD154 expression used in this study is the same as the Pleximmune™ test. Using a different threshold value of Immunoreactivity Index (IR) than the current test, IR was associated with the risk of rejection.

A 2017 study by Ashokkumar et al reported on the preclinical development and validation of an allogeneic-specific CD154-positive T-cytotoxic memory cell test to predict ACR after liver or intestine transplantation in patients with pediatric liver or lung transplantation. Plexision (manufacturer of Pleximmune) was involved in
the study design and assay standardization. A total of 127 patients (120 analyzable samples) were included in the training set (enrolled from 2006 to 2010), and 87 patients (72 analyzable samples) were included in the validation set (enrolled from 2009 to 2012). The training and test sets differed significantly in terms of organ type composition, with a higher proportion of those in the training set represented by liver or liver/small bowel transplant (eg, 83% liver in training set vs 71% in validation set; p=0.007, for difference between groups). The IR was defined as the ratio of the reaction of donor-induced CD154-positive T-cytotoxic memory cell to the reaction exceed those induced by reference peripheral blood leukocytes; a ratio above 1 was considered to indicate an increased risk of rejection. An IR of 1.1 or greater as a cutoff in posttransplant samples was associated with an area under the summary receiver operating characteristic curve of 0.878 in the test set (0.791 in the validation set), while a pretransplant IR of 1.23 or greater was an associated with an ROC curve of 0.82 in the training set (0.842 in the validation set). The association test performance characteristics are shown in Table 1.

Table 1. Test Performance Characteristics

<table>
<thead>
<tr>
<th>Cutpoint</th>
<th>Performance Measures</th>
<th>Measure, %</th>
<th>95% Confidence Interval, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttransplant IR ≥1.1</td>
<td>Sensitivity</td>
<td>84</td>
<td>60 to 96</td>
</tr>
<tr>
<td></td>
<td>Specificity</td>
<td>80</td>
<td>65 to 90</td>
</tr>
<tr>
<td></td>
<td>Positive predictive value</td>
<td>64</td>
<td>43 to 81</td>
</tr>
<tr>
<td></td>
<td>Negative predictive value</td>
<td>92</td>
<td>78 to 98</td>
</tr>
<tr>
<td>Pretransplant IR ≥1.23</td>
<td>Sensitivity</td>
<td>57</td>
<td>30 to 81</td>
</tr>
<tr>
<td></td>
<td>Specificity</td>
<td>89</td>
<td>65 to 98</td>
</tr>
<tr>
<td></td>
<td>Positive predictive value</td>
<td>80</td>
<td>44 to 96</td>
</tr>
<tr>
<td></td>
<td>Negative predictive value</td>
<td>74</td>
<td>51 to 89</td>
</tr>
</tbody>
</table>

Adapted from Ashokkumar et al (2017).37
IR: Immunoreactivity Index.

Clinically Useful
We did not identify any studies directly demonstrating improved patient outcomes. An argument for clinical utility using a chain of evidence would rely on both a demonstration of clinical validity and a rationale that specific clinical interventions based the results of the test decrease the risk of a poor health outcome. At present, the clinical interventions that would occur as a result of the test result are uncertain, and the clinical validity is uncertain. Therefore, the clinical utility of Pleximmune is unknown for solid organ transplants and hematopoietic cell transplantations.

Section Summary: Pleximmune Test for Solid Organ Transplants
For the use of the Pleximmune test in the solid organ transplant population, extremely limited evidence is available and includes a study with a small number of patients described briefly in the Food and Drug Administration approval documents and a second study in which the confidence interval bounds for sensitivity and specificity estimates were wide. No direct studies of clinical utility were identified.
Section Summary: Pleximmune Test for Hematopoietic Cell Transplants
No evidence for the clinical validity or clinical utility of the Pleximmune test for hematopoietic cell transplant populations were identified.

Summary of Evidence
For individuals who have a solid organ transplant or hematopoietic cell transplant who receive testing using an immune cell function assay with ImmuKnow, the evidence includes numerous studies on the association between assay test values and subsequent rejection or infection, and a randomized controlled trial in liver transplant patients. Relevant outcomes are overall survival, test accuracy, other test performance measures, and morbid events. The ImmuKnow test has shown variable associations with infection and rejection, depending on the type of transplant and context of the study. Across all the studies among various types of patients, ImmuKnow levels are associated with the risk of rejection when levels are high and risk of infection when levels are low. However, the absolute risk and increments of risk are uncertain because of heterogeneity of the studies. The predictive characteristics of the test are still uncertain and do not allow a strong chain of evidence for clinical utility. The trial of the ImmuKnow test in liver transplant patients showed improvement in overall survival; however, the trial had several limitations. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have a solid organ transplant or hematopoietic cell transplant who receive testing using an immune cell function assay with Pleximmune, the evidence includes the U.S. Food and Drug Administration documentation and a report on the test’s development and validation. Relevant outcomes are overall survival, test accuracy, other measures of test performance, and morbid events. Small studies have shown that Pleximmune values correlate with long-term survival. Pleximmune test results correlated with rejection, but conclusions are uncertain because of extremely limited evidence deriving from a small number of patients described briefly in the Food and Drug Administration approval documents and a second study, in which the confidence interval bounds for sensitivity and specificity estimates were wide. No direct studies of clinical utility were identified. An argument for clinical utility using a chain of evidence would rely on both a demonstration of clinical validity and a rationale that specific clinical interventions based the results of the test decrease the risk of a poor health outcome. At present, the clinical interventions that would occur as a result of the test result are uncertain, and so the clinical validity is uncertain. The evidence is insufficient to determine the effects of the technology on health outcomes.

Supplemental Information

Practice Guidelines and Position Statements

Transplantation Society
The International Cytomegalovirus Consensus Group of the Transplantation Society published a consensus statement on the management of cytomegalovirus in solid organ transplant in 2010. The statement indicated that “there are no
clinical studies demonstrating that management decisions based on immunologic monitoring affect patient outcomes.” Routine immunologic monitoring was not recommended.

**International Society of Heart and Lung Transplantation**
Guidelines for the care of heart transplant recipients, published in 2010 by the International Society of Heart and Lung Transplantation, did not include ImmuKnow.  

**American Society of Transplantation**
In 2006, the American Society of Transplantation published recommendations on the screening, monitoring, and reporting of infectious complications in immunosuppression trials of organ transplant recipients. These recommendations defined relevant infectious complications to be included in the reporting of immunosuppression trials and recommended specific laboratory monitoring and surveillance methods. The immune cell function assay was not included.

**Guidelines on Use of Assays for Monitoring Autophagy in Higher Eukaryotes**
Guideline updates published in 2016 by Klionsky et al discussed a number of assays in the context of monitoring autophagy, concluding that the best approach would be to use a combination of several assays, as opposed to a single test. The guidelines did not address the topic specific to this evidence review (monitoring of immunosuppression in the context of transplant); they also made no mention of ImmuKnow or Pleximmune in their recommendations.

**U.S. Preventive Services Task Force Recommendations**
Not applicable.

**Medicare National Coverage**
There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

**Ongoing and Unpublished Clinical Trials**
Some currently unpublished trials that might influence this review are listed in Table 2.

### Table 2. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpublished</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT01859832a</td>
<td>Validation of a Novel Diagnostic Tool for the Evaluation of Post Renal Transplant Immunosuppression: The ImmuKnow Assay</td>
<td>19</td>
<td>May 2013 (completed)</td>
</tr>
</tbody>
</table>

NCT: national clinical trial.

a Denotes industry-sponsored or cosponsored trial.
References


Billing Coding/Physician Documentation Information

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>86352</td>
<td>Cellular function assay involving stimulation (eg, mitogen or antigen) and detection of biomarker (eg, ATP)</td>
</tr>
</tbody>
</table>

ICD-10 Codes

- **T86.10-** Complications of transplanted organs and tissue code range limited to solid organ transplants
- **T86.819; T86.890-**
- **T86.899**
- **Z94.0-** Transplanted organ and tissue status; kidney, heart, lung, heart & lungs,
- **Z94.83; Z94.89; Z94.9** liver, pancreas, other and unspecified codes

Additional Policy Key Words

- N/A

Policy Implementation/Update Information

- **12/1/15** New Policy; considered investigational.
- **12/1/16** No policy statement changes.
- **12/1/17** No policy statement changes.
- **12/1/18** No policy statement changes.

State and Federal mandates and health plan contract language, including specific provisions/exclusions, take precedence over Medical Policy and must be considered first in determining eligibility for coverage. The medical policies contained herein are for informational purposes. The medical policies do not constitute medical advice or medical care. Treating health care providers are independent contractors and are neither employees nor agents Blue KC and are solely responsible for diagnosis, treatment and medical advice. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, photocopying, or otherwise, without permission from Blue KC.