



# Selected highlights of the 2019 Pulmonary Pathology Society Biennial Meeting: PD-L1 test harmonization studies

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**Abstract:** Immune checkpoint inhibitors (ICI) including programmed death 1 (PD-1) inhibitors, such as nivolumab and pembrolizumab, or programmed death ligand 1 (PD-L1) inhibitors, such as atezolizumab and durvalumab, have recently emerged in advanced stage lung cancer as new standards of care. They are now indicated in first- line and second- or later-line treatment of metastatic or locally-advanced stage III non-small cell lung cancer (NSCLC), as well as for metastatic small cell lung cancer (SCLC), as single agent immunotherapy or in combination with chemotherapy. Four PD-L1 immunohistochemistry (IHC) assays have been established and validated in randomized trials, each for a specific ICI. They use different primary monoclonal antibodies, platforms and detection systems, as well as different scoring systems to assess PD-L1 expression either by tumor cells (TCs) and/or by infiltrating immune cells (ICs). Most studies have shown a close analytical performance of three of these clinically-validated standardized assays, but their use restricted to dedicated platforms, which are not all available in most laboratories, questions their applicability. In addition, the relative high costs of the assays have led to the development of in-house protocols in many pathology laboratories. Their use in clinical practice to assess the predictive value of PD-L1 expression for prescription of ICI raises the issue of their reliability and their validation as compared to standardized assays. This article discusses the main comparative studies available between LDT and assays, with clear evidence that LDT can reach a performance equivalent to the trial-validated assays. The requirements are an adequate validation as compared to an appropriate standard, and the participation to external quality assurance programs and training programs for PD-L1 IHC assessment for pathologists.

**Keywords:** Non-small cell lung cancer (NSCLC); immunotherapy; programmed death ligand 1 (PD-L1); immunohistochemistry (IHC); harmonization

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## Introduction

Immune checkpoint inhibitors (ICI) which target the programmed death 1 (PD-1)/programmed death ligand 1 (PD-L1) axis to restore antitumor immunity are now available in routine clinical practice for the treatment of both non-small cell lung cancer (NSCLC) and small cell

lung cancer (SCLC) patients with advanced or metastatic disease. For nearly 20% of NSCLC patients treated with ICIs a clear benefit has been reported, with increased progression-free survival (PFS) and/or overall survival (OS) (1-4). ICI are available as single immunotherapy agents, as well as in combination with chemotherapy. Pembrolizumab alone has been approved by the US Food and Drug

Administration (FDA), European Medicines Agency (EMA), and Japanese Ministry of Health, Labour and Welfare (MHLW) in first-line treatment: (I) of metastatic NSCLC patients selected on the expression of PD-L1 by 50% or more of tumor cells (TCs) (which corresponds to a Tumor Proportion Score or TPS  $\geq 50\%$ ) by immunohistochemistry (IHC), and in the absence of *EGFR/ALK* alterations (1,4); (II) in stage III wild-type *EGFR/ALK* patients who are not candidates for surgical resection or definitive chemoradiation and with a NSCLC with a TPS  $\geq 1\%$  (5). Regarding association of ICI and chemotherapy in first line setting, pembrolizumab was approved in combination with platinum/pemetrexed chemotherapy in non-squamous NSCLC, and with platinum/paclitaxel or nab-paclitaxel chemotherapy in squamous cell NSCLC (2,3). Atezolizumab has been authorized by the FDA in combination with platinum-paclitaxel-bevacizumab chemotherapy for non-squamous NSCLC with no *EGFR/ALK* alterations, and in Europe for patients with *EGFR* mutations or *ALK* rearrangements after tyrosine kinase inhibitors (6,7). In NSCLC patients previously treated with platinum-based chemotherapy, nivolumab and atezolizumab have been approved respectively by the FDA, EMA, and MHLW independently of PD-L1 expression by the TCs, and pembrolizumab when tumor exhibits a TPS  $\geq 1\%$  (8-10). Durvalumab has also been endorsed as consolidation treatment for unresectable, locally-advanced stage III NSCLC with no disease progression after chemoradiotherapy with a restriction to PD-L1 positive tumors (TPS  $\geq 1\%$ ) in Europe and Japan (11,12). Noteworthy, some immunotherapies are now available to SCLC patients in first, third- or later-line with single agent immunotherapy or in first line in combination with chemotherapy (13,14).

Several biomarkers have been reported to predict tumor response, but to date only PD-L1 expression assessed by IHC has been validated as a companion or complementary diagnostic to select patients who are more likely to take a real advantage from those therapies. It remains a semi-quantitative test that can be interpreted according to different scores, the most commonly used being TPS, or cut-off for PD-L1 expression, which opens eligibility for several indications of anti-PD-1 or anti-PD-L1 treatments.

To date, four PD-L1 IHC assays have been validated in clinical trials for the administration of the corresponding agents. Nevertheless, many pathology laboratories have set up laboratory-developed tests, which are less expensive than the clinical trial-validated assays and do not require

a dedicated platform. In addition, the small size of most lung cancer samples precludes testing each sample with different assays. Although PD-L1 IHC testing is now implemented in most pathology laboratories, harmonization and validation of the protocols is still required to facilitate the appropriate implementation of this test, which is to date the only one offering a predictive value for anti-PD-(L)1 agents in the clinical setting. The objective herein is to provide an overview of the different assays available either as companion or complementary diagnostics for ICI, and to discuss the main comparative studies between LDT and assays (15-17).

### Validated assays

To date, four assays have been clinically confirmed in randomized trials for specific anti-PD-1 or anti-PD-L1 agents in NSCLC. They have been approved either as companion or complementary tests, a companion diagnostic test being required for the prescription of a given therapy, whereas a complementary test is not required but can be helpful to select patients who could benefit from the treatment. Those assays are all based on a semi-quantitative assessment of PD-L1 expression on tumor tissue fixed in formalin and embedded in paraffin (FFPE) by IHC, but they use different primary monoclonal antibodies, platforms, detection systems, and scoring systems with various positivity thresholds validated in clinical trials. The PD-L1 IHC 22C3 PharmDx includes a mouse anti-PD-L1 clone 22C3. It was approved by the FDA and the MHLW and received CE-IVD (Conformité Européenne marking for *In Vitro* Diagnostic) designation in Europe to be used as a companion diagnostic test for the prescription of pembrolizumab (18). The PD-L1 IHC 28-8 PharmDx uses a rabbit anti-PD-L1 28-8 clone and has been endorsed by the FDA as a complementary diagnostic for the prescription of nivolumab. Both must be performed on the Agilent/Dako Autostainer Link 48 (Agilent Technologies, Santa Clara, CA, USA) with the EnVision FLEX visualization system, and at least 100 viable TCs are required for their interpretation (19). The Ventana PD-L1 (SP263) assay has obtained CE-IVD designation in Europe for durvalumab, pembrolizumab and nivolumab in NSCLC. This assay includes a rabbit anti-PD-L1 clone and has to be performed on Ventana BenchMark Ultra platform (Ventana Medical Systems, Tucson, AZ, USA). For PD-L1 IHC 22C3 PharmDx, PD-L1 IHC 28-8 PharmDx and the Ventana PD-L1 (SP263) assay, the score to be used is the Tumor

Proportion Score (TPS), corresponding to the percentage of viable TCs exhibiting a partial or complete membranous staining at any intensity. The test is considered as positive if  $TPS \geq 1\%$ , with a high PD-L1 expression when  $TPS \geq 50\%$  (20). The EMA and the FDA have approved the PD-L1 SP142 (Ventana) assay as a complementary test for prescription of atezolizumab. This assay includes a rabbit anti-PD-L1 SP142 clone and must be performed on Ventana BenchMark Ultra platform. The scoring system used for this assay differs from the previous ones and takes into account the proportion of viable TC showing PD-L1 membrane staining of any intensity, but if  $TPS < 50\%$ , it considers also the proportion of tumor area occupied by immune cells (IC) with PD-L1 expression of any intensity. The scores retained for atezolizumab treatment are either TC3 ( $TC \geq 50\%$ ) or IC3 ( $IC \geq 10\%$ ) (21,22).

Those assays have been approved for a given drug on a given platform, but not all laboratories are equipped with multiple platforms, questioning the interchangeability of these assays in clinical practice. Regarding the clones themselves, Gaule *et al.* found that SP142, E1L3N, 9A11, SP263, 22C3, and 28-8 were high concordant when the same protocol was used to stain PD-L1 and concluded that the discordance reported between the assays was probably related to tumor heterogeneity or assay- or platform-specific variables (23). When the assays were compared, the 22C3 PharmDX, the 28-8 PharmDX and the Ventana PD-L1 SP263 assays have been reported to offer similar analytical performance for the tumor cells staining (16,24-29) with moderate to good kappa weighted ranging from 0.63 to 0.89. In contrast, other series showed a higher PD-L1 staining of the TC by the SP263 assay (30-33). A similar prevalence of PD-L1 expression was observed with 22C3 and 28-8 assays at 1% and 50% cut-off (34), with a strong correlation (OPA 97–98%) or a high weighted kappa across all samples (30-33,35,36). Other studies have focused their comparison between the 22C3 PharmDX and the Ventana PD-L1 SP263 assays, which have been both validated for the pembrolizumab prescription as well as for durvalumab treatment, even if their interchangeability in the clinical setting has not been validated on a large scale (37). Whereas Fujimoto *et al.* found no differences between those two assays with agreement rates of the 22C3 and SP263 assays of 88% to 97% at various cut-offs (37), Kim *et al.* observed similar TPS at low cut-offs but higher TPS with SP263 at high cut-offs ( $\geq 10\%$ ), and Munari *et al.* higher TPS with SP263 at both 1% and 50% cut-offs (38,39). The reliability and interchangeability of the assays on small samples were

addressed by two studies, the Blueprint phase 2B project (32) and the study conducted by Kim *et al.* (40). Both evaluated the PD-L1 expression heterogeneity on matched specimen of lung cancer including surgical resection, core needle biopsy and fine needle aspiration cytology. A good agreement among pathologists was observed in assessing PD-L1 status on cell blocks in both studies, with an ICC from 0.78 to 0.85 for the first study, and a kappa coefficient for agreement around 0.65 at 1% cut off for 22C3 and 0.58 at 50% cut off for SP263 for the second. Of note, most studies agreed on the low TPS found on TC with the SP142 assay (24,30-33,41) and the poor agreement for the IC assessment between observers with all the assays used (27,30,42). Recently a meta-analysis of 22 publications including 376 assay comparisons at different cut-off points, has addressed PD-L1 assay interchangeability based on diagnostic accuracy, sensitivity and specificity of the tests for established clinical purposes (43). Considering that a test was adequate for clinical applications when both sensitivity and specificity were  $\geq 90\%$ , the authors found that PD-L1 IHC 28.8 pharmDx and Ventana PD-L1 (SP263) showed a precision sufficient for diagnostic at 50% cut-off, with a lower specificity at 1%. In contrast, PD-L1 IHC 22C3 pharmDx did not attain  $\geq 90\%$  for both sensitivity and specificity at 1% cut off. When SP263 was considered as the reference test, most other assays reached an acceptable specificity, even if the sensitivity was too low for both 1% and 50% cut-off points (Table 1; Figure 1A,B).

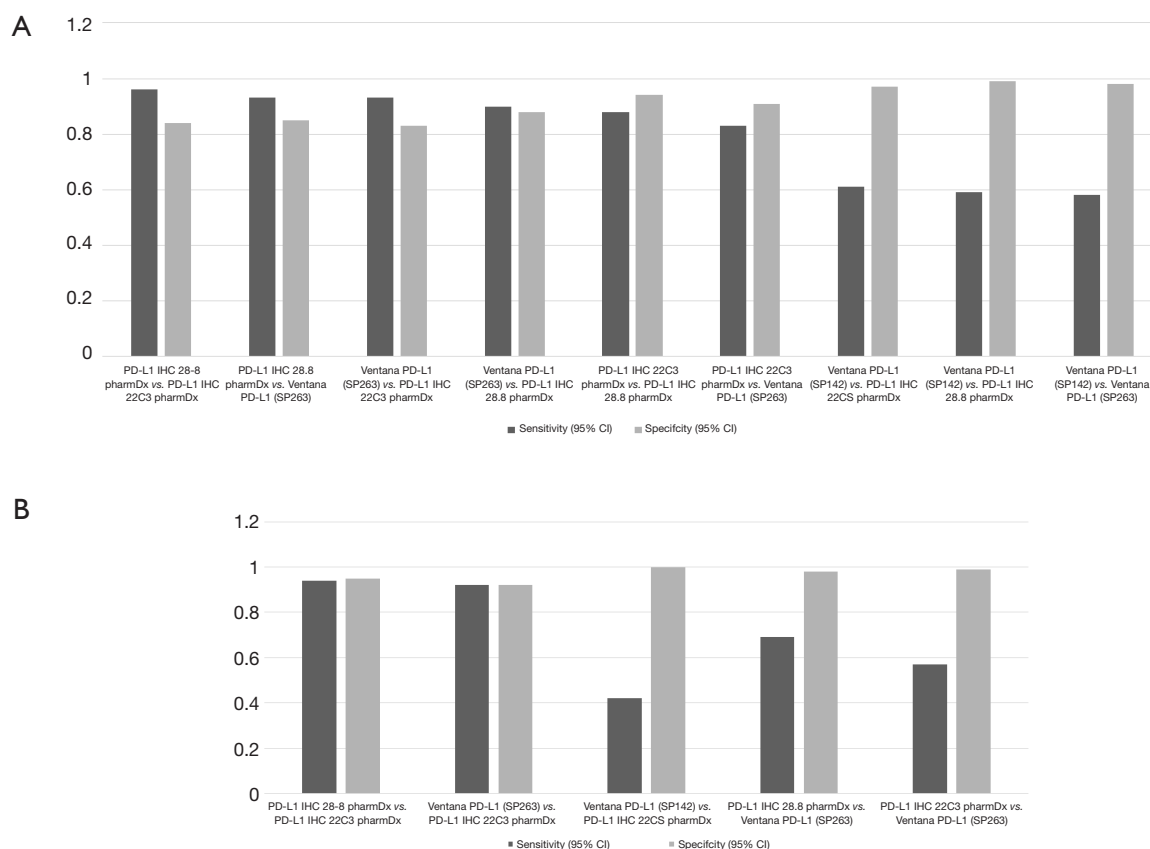
### Laboratory developed tests (LDT)

Laboratories may, by choice or necessity, implement an IHC PD-L1 test that has not been validated in a clinical trial. The main factors explaining the use of LDT for PD-L1 testing are the unavailability of IHC platforms to perform dedicated assays (in particular Agilent/Dako AS Link 48 to perform the 22C3 companion diagnostic assay for pembrolizumab) and the lack of funding (either public or industry-sponsored) given the high cost of reagents to perform standardized assays. An LDT differs from a clinically-validated and standardized assay by its reagents (primary clone, detection kits), the platform used or the protocol integrating different methods of antigen retrieving, detection or amplification. These tests have been frequently developed with the concentrated antibodies used in the assays (clones 22C3 and 28-8) or with other monoclonal antibodies not used in the assays, in particular the clone E1L3N (validated for research use only - RUO) or the clone

**Table 1** Comparison among the four assays

Assay	Compare to	1% cutoff	50% cutoff	Correlations	Samples number	References	
22C3 pharmDx	28-8 pharmDx	ICC =0.281			368 TMA spots	(33)	
		OPA =97%	OPA =93%		87	(26)	
		OPA =94%	OPA =97%		493	(25)	
		OPA =95%			39	(24)	
		OPA =97%	OPA =98%		412	(35)	
		OPA =89%	OPA =92%		420	(36)	
					$r^2=0.42$	20	(41)
				$k=0.89$	58	(31)	
		SP263	ICC =0.403			368 TMA spots	(33)
					CCC =0.89–0.97	100 TMA spots	(29)
			OPA =88%	OPA =97%		100	(28)
			OPA =91%	OPA =93%	$r^2=0.92$	493	(25)
			OPA =89%			39	(24)
					$r^2=0.29$	20	(41)
				$k=0.75$	58	(31)	
	SP142	ICC =0.112			368 TMA spots	(33)	
		OPA =63%			39	(24)	
				$r^2=0.46$	20	(41)	
				$k=0.63$	58	(31)	
SP263	28-8 pharmDx	ICC =0.384			368 TMA spots	(33)	
		OPA =92%	OPA =96%	$r^2=0.95$	493	(25)	
		OPA =89%			39	(24)	
				$r^2=0.41$	20	(41)	
				$k=0.59$	58	(31)	
		SP142	ICC =0.077			368 TMA spots	(33)
				$r^2=0.71$	20	(41)	
			$k=0.45$	58	(31)		
28-8 pharmDx	SP142	ICC =0.027			368 TMA spots	(33)	
		OPA =63%			39	(24)	
				$r^2=0.25$	20	(41)	
				$k=0.56$	58	(31)	

Weighed kappa (linear weight) value was reported for scoring 0–5;  $r^2$ : Spearman correlation coefficient. OPA, overall percentage agreement; ICC, intraclass correlation coefficient.



**Figure 1** Graphical representation of sensitivity and specificity comparison results between validated assays. (A) Comparison of assays at 1% cut-off [adapted from Torlakovic *et al.* (43)]\*; (B) comparison of assays at 50% cut-off [adapted from Torlakovic *et al.* (43)]\*; (\*, non covering data excluded when the number of studies was less than four or when the data were sparse due to the presence of a zero result in contingency tables).

QR1 (CE-IVD labeled) (44). More rarely, LDT have been set up with pre-diluted antibodies recovered from PD-L1 assays, to be used on non-dedicated platforms such as Leica Bond IHC platforms.

Given the abundant literature on the topic for the last years, some LDT can reasonably provide technical performance comparable to that of tests validated. Many studies have proposed LDTs combining different clones, platforms and protocols with performance comparable to the standards validated in clinical trials (45-47), but most of these studies were based on a single center experience. The NCCN multicenter study (42) has shown that an LDT using the E1L3N clone could give satisfactory results, but after having thoroughly validated the different protocols. Two other multicenter studies conducted by the French thoracic pathology group PATTERN (27) and in Germany (30) have evaluated the used of several clones on several IHC

platforms. These studies have shown very similar results with approximately one half of LDT evaluated (14/27 and 6/11, respectively) considered as concordant enough for clinical use, emphasizing the difficulty in validating PD-L1 LDT. Some combinations of antibodies and platforms were also identified as most effective in achieving a good concordance with dedicated PD-L1 assays (27). Recently, a Swiss cross-validation study has shown that clone 22C3 provided satisfying results on Ventana Benchmark Ultra platform, but a high variability on Leica Bond platforms (48). A summary of all the studies ‘results’ assessing inter-assay, inter-laboratory and inter-observer concordance among standardized assays and LDT has been recently published (49). A recent meta-analysis (43) has demonstrated that the highest diagnostic accuracy was observed between the 22C3 LDT and the PD-L1 IHC pharmDx 22C3, with sensitivity and specificity of 100% in 8 out of 9 assays for the 50% cut-off

**Table 2** Comparison between the different LDT and the assays

LDT	Platform	Assay	Level of concordance LDT/assay	Level of concordance among pathologists	References
E1L3N	Ventana, Dako, Leica	22C3 pharmDx 28-8 pharmDx SP263 SP142	High   Low	Globally high, but influenced by the threshold (higher at 50% that 1%)	(27,41,42,45,49,51,52)
22C3*	Ventana, Dako, Leica	22C3 pharmDx	High		(27,33,39,46-50,53)
28-8 Abcam	Ventana	22C3 pharmDx 28-8 pharmDx SP263 SP142	High   Low		(31,49)
QR1	Ventana	22C3 pharmDx SP263	High	NA	(44)

\*, both concentrated and diluted (from pharmDx kit). High = ICC  $\geq 0.85$ , or OPA  $\geq 80\%$ , or r (correlation coefficient)  $\geq 0.8$ , or kappa  $\geq 0.8$ . Low = ICC  $< 0.85$ , or OPA  $< 80\%$ , or r (correlation coefficient)  $\geq 0.8$ , or kappa  $< 0.8$ . ICC, intraclass correlation coefficient; OPA, overall percent agreement.

and almost at the 1% cut-off, in contrast with E1L3N which showed excellent results, but in 3 out of 12 comparisons. The authors noted that a properly validated LDT may have a higher diagnostic accuracy than PD-L1 FDA-endorsed companion diagnostic assay, and suggest that when a laboratory is unable to use a test that has been validated and approved in clinical practice for a given treatment, it is preferable to develop a LDT and to rigorously validate it in comparison with the recommended assay, rather than using another assay validated for another indication. It should be noted that these concordance studies may be limited by many factors such as sample types, positivity levels and pathologists' intra-observer and inter-observer variability (29,46,47,50-52). Thus, the use of LDT has to be validated properly in each center. The main data are summarized in *Table 2*.

### Practical considerations

PD-L1 stays an imperfect biomarker, as it is both a dynamic and an inducible marker with biological variations of expression according to histological sub-types, previous treatments and many biological factors (production of interferon gamma, STING inhibition, oncogene-driven expression, *LKB1/STK11*, *KEAP1* or P53 mutations,

amplification of *PD-L1*, Hypoxia, Epithelial-Mesenchymal Transformation, epigenetic regulation, etc.) (54-60).

In addition, there is a certain degree of inter-tumoral heterogeneity of PD-L1 expression during tumor progression, with some variations between primary and metastatic tissues (15). PD-L1 intra-tumoral heterogeneity is also an issue (61) and dictates a limit in the reliability of small samples. It has been recently shown in a cross-validation using TMA versus whole section scores by the European Thoracic Oncology Platform (ETOP) pathologists that PD-L1 status on small biopsies did not totally represent the overall expression of PD-L1 on surgical samples (62). Actually, the ideal would be to perform more biopsies (ideally 4 cores) with larger samples containing more than 2,000 tumor cells (62-65). Interestingly, they showed that the frequency of cases presenting a major discrepancy (i.e., with one core with a TPS  $< 1\%$  and another with a TPS  $> 50\%$ ) did not exceed 2.1%. Moreover, they observed a tendency to underestimate the expression of PD-L1 on small samples, which may explain the good responses of patients with low levels or no PD-L1 expression in some trials.

Whatever, it is essential that the test used in clinical practice is the most accurate in order to comply with the indications validated by a trial and approved by the medical

authorities for patient selection. The simplest way is to use the protocol validated by the clinical trial associated with the planned therapy and standardize all the pre-analytical steps, such as fixation and tissue processing and sectioning that may influence the immunohistochemical results.

Of note, PD-L1 expression is a continuous variable and there is no to date any method to rigorously evaluate the analytical sensitivity and specificity of a given PD-L1 IHC assay; however, it is very important to try to implement as rigorously as possible both trial validated assays and LDT in routine clinical practice. Interestingly, different protocols of LDTs with the 22C3 clone used on either Ventana BenchMark Ultra, Bond III (Leica Biosystems) or DAKO Omnis autostainers are available to date (46,47,50) and offer 85–100% agreement with the 22C3 PharmDx test on 48 Link Dako/Agilent autostainer. There is also a number of recommendations for the implementation of a theranostic test that have been proposed by the College of American Pathologists (CAP) (66-69). They recommend comparing each new test with expected results (clinically and morphologically), with the results obtained in another laboratory on the same samples, and with the results obtained using previously validated assay. One suggestion for the development of a protocol is to use a set of at least 20 PD-L1 positive and 20 negative cases tested with a reference assay. Ideally, this set should be expanded on cases close to the clinically relevant positivity thresholds, currently  $\geq 1\%$  and  $\geq 50\%$  of tumor cells with membranous staining (62,70). In addition, it is essential to monitor the ongoing performance of the test by checking continuously its sensitivity and specificity, the inter-run and inter operator variability, and the positive and negative concordance rates, a minimal 90% overall concordance rate (corresponding approximately to a kappa value  $\geq 0.75$ ) as compared to the reference test being expected. In each run, since an inter-slide variability may be observed, the use of an external positive control (such as tonsil tissue containing epithelial and IC staining or cell lines) on each slide is suggested. Finally, participation to External Quality Assurance programs is crucial as well as continuous monitoring of positivity rates for clinically relevant thresholds.

## Conclusions

PD-L1 expression in tumor cells is recognized as a predictive biomarker for the first- and second-line prescription of ICI in advanced stage NSCLC. This

expression is assessed using either clinically validated assays or LDT set up in most laboratory tests along with other theranostic biomarkers. However, given the imperfect interchangeability of those tests, they have to be validated before their implementation in clinical setting and to be monitored regularly in agreement with specific recommendations regarding pre-analytical, analytical and post-analytical steps. Another major point to be awarded of is the interobserver variability of PD-L1 assessment in particularly for the 1% cut-off, as pointed out in several studies (27,30,42,53,71,72). Interobserver discrepancies tend to be higher when a multistep scoring system is used and lower for individual cut-off values. The most recent studies showed a higher concordance among the pathologists, suggesting that the increasing level of experience of pathologists in PD-L1 IHC interpretation can help in getting more reliable PD-L1 assessment. In addition to IHC staining validation, training of pathologists is thus required to increase the reproducibility of PD-L1 assessment by pathologists (31,71) and ensure reliability of PD-L1 testing in NSCLC.

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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