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ASSOCIATION BETWEEN PROGRAMMED DEATH-LIGANT 1 (PD-L1) EXPRESSION WITH MENINGIOMA GRADE AT PROF. DR. I.G.N.G. NGOERAH DENPASAR HOSPITAL

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ABSTRACT

Background: Meningioma is the most common primary intracranial tumor, mostly benign, yet higher-grade tumors tend to recur and behave more aggressively. The expression of *Programmed Death-Ligand 1* (PD-L1) contributes to tumor immune evasion and may serve as a prognostic biomarker as well as a potential target for *immune checkpoint inhibitor* therapy.

Objective: To analyze the association between PD-L1 expression and meningioma grade at Prof. dr. I.G.N.G. Ngoerah General Hospital.

Methods: This analytical observational study used a cross-sectional design. Samples were selected using a purposive sampling method from paraffin-embedded meningioma tissues diagnosed at the Department of Anatomical Pathology, Prof. dr. I.G.N.G. Ngoerah General Hospital. Immunohistochemistry was performed using a polyclonal anti–PD-L1 antibody (Genetex, GTX104763). PD-L1 expression was evaluated using the *Tumor Proportion Score* (TPS) and *Combined Positive Score* (CPS). Statistical analysis was conducted using the chi-square test with a significance level of $p<0.05$.

Results: A total of 41 meningioma cases were included, consisting of 20 (48.8%) grade 1, 15 (36.6%) grade 2, and 6 (14.6%) grade 3. PD-L1 expression showed an increasing trend with higher meningioma grades in both TPS and CPS evaluations. A significant correlation was observed between PD-L1 expression and tumor grade ($p<0.05$).

Conclusion: Higher PD-L1 expression was associated with higher meningioma grades, suggesting its potential role as a prognostic biomarker and as a rationale for considering immune checkpoint inhibitor therapy in high-grade or recurrent meningiomas.

Keywords: Meningioma, PD-L1, Immunohistochemistry, Tumor Proportion Score, Combined Positive Score, Grade

INTRODUCTION

Meningioma represents the most common primary intracranial neoplasm, accounting for approximately 30% of all primary brain tumors, with an estimated annual incidence of around 6 cases per 100,000 individuals worldwide.[1] These tumors originate from the arachnoid cap cells of the meninges and are typically slow-growing. The World Health Organization (WHO) classifies meningiomas into three histological grades: benign (grade 1), atypical (grade 2), and anaplastic (grade 3).[2] While the majority of meningiomas fall under WHO grade 1 and are usually curable through complete surgical resection, higher-grade variants demonstrate markedly different biological behavior. Atypical and anaplastic meningiomas are characterized by more aggressive growth patterns, increased mitotic activity, brain invasion, and a significantly higher risk of recurrence or progression.[3]

Despite advances in neurosurgical techniques and adjuvant radiotherapy, the management of recurrent or high-grade meningiomas remains a major clinical challenge.[4] Standard treatment approaches, including reoperation and radiotherapy, often provide limited long-term control, and there are currently no effective systemic therapies approved for these tumors. Consequently, there is growing interest in exploring novel molecular and immunological therapeutic strategies to improve outcomes for patients with refractory or progressive meningiomas.

In recent years, the tumor immune microenvironment has emerged as a crucial determinant of tumor development, progression, and therapeutic response.[5] One of the key pathways involved in immune evasion is the programmed cell death protein 1 (PD-1) and its ligand (PD-L1) axis. Under normal physiological conditions, PD-1/PD-L1 interaction plays a regulatory role in maintaining immune homeostasis and preventing autoimmunity by inhibiting excessive T-cell activation.[6] However, tumor cells can exploit this pathway to suppress antitumor immune responses, leading to immune tolerance and unchecked tumor growth. PD-L1 expression on tumor cells or infiltrating immune cells has been demonstrated to correlate with reduced cytotoxic T-cell activity and poor

clinical outcomes in various malignancies, including glioblastoma, non–small cell lung carcinoma, and melanoma.[7]

Several studies have investigated PD-L1 expression in meningiomas, revealing highly variable results, with reported positivity rates ranging from 12% to as high as 90%.[8] These discrepancies are attributed to differences in the antibodies used, staining protocols, scoring systems, and interpretation criteria across studies. Nevertheless, a consistent trend has emerged suggesting that PD-L1 expression tends to increase with histological grade, implying a potential link between immune evasion and tumor aggressiveness.[9] Moreover, the expression of PD-L1 may serve not only as a prognostic biomarker but also as a predictive marker for response to immune checkpoint inhibitors (ICIs), such as anti–PD-1 and anti–PD-L1 therapies, which have revolutionized the management of several solid tumors.[10]

Although the therapeutic potential of ICIs in meningioma is still under investigation, early-phase clinical trials and case reports have provided encouraging findings, particularly in patients with recurrent or high-grade meningiomas.[11] However, data on PD-L1 expression in meningiomas, especially from Southeast Asia, remain limited. In Indonesia, and specifically in Bali, available therapeutic options for patients with high-grade or recurrent meningiomas are still constrained, with most management relying heavily on surgery and radiotherapy. This underscores the urgent need for research exploring molecular and immunological aspects of these tumors in the local population.

Therefore, this study aims to evaluate PD-L1 expression in meningiomas and analyze its association with histological grade based on cases diagnosed at Prof. Dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Indonesia. Through this research, we hope to contribute to a better understanding of the immunobiology of meningiomas and provide preliminary data that may serve as a foundation for future investigations into immune checkpoint–based therapeutic approaches in the management of these tumors.

METHODS

Study Design and Sample Selection

This analytical observational study employed a cross-sectional design. The study was conducted at the Department of Anatomical Pathology, Prof. dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Indonesia, using archival formalin-fixed paraffin-embedded (FFPE) tissue blocks from patients diagnosed with meningioma between January 2023 and December 2024.

Sample Selection

The target population included all meningioma patients diagnosed histopathologically during the study period. A total of 138 eligible cases were identified (101 cases (73,2%) of grade 1, 32 cases (23,2%) of grade 2 and 5 cases (3,6%) of grade 3). 41 representative samples were selected using a purposive sampling method to ensure proportional representation of WHO grades 1-3 (20 grade 1 and 21 grades 2–3).

Immunohistochemistry Procedure

Sections 3 µm thick were cut using a Leica 2125 RM microtome, mounted on poly-L-lysine–coated Biogear slides, and air-dried for 24 hours. Automated IHC staining was performed using a Leica Bond-Max Immunostainer. The polyclonal anti–PD-L1 antibody (Genetex GTX104763, dilution 1:100, Research Use Only) was applied for 30 minutes at room temperature, followed by incubation with HRP polymer and DAB chromogen. Slides were counterstained with haematoxylin and examined using a Leica DM500 microscope.

Evaluation of PD-L1 Expression

PD-L1 expression was scored using the Tumor Proportion Score (TPS) and Combined Positive Score (CPS), where the cut-off determined using Receiver Operating Characteristic (ROC) curve. All evaluations were performed independently by two pathologists blinded to clinical data.

Statistical Analysis

Data were analyzed using SPSS version 27.0. Descriptive statistics were used to summarize demographic and clinicopathological features. The relationship between PD-L1 expression and meningioma grade was analyzed using the chi-square test, with significance set at $p < 0.05$.

Ethical Approval

This study has received approval from the Research Ethics Committee of the Faculty of Medicine, Udayana University/ Prof. dr. I.G.N.G. Ngoerah General Hospital Denpasar with ethical clearance number 2190/UN14.2.2.VII.14/LT/2025 and has been granted permission by Prof. dr. I.G.N.G. Ngoerah General Hospital with letter number DP.04.03/D.XVII.2.2.2/65061/2025.

RESULTS

The study sample are 41 meningioma cases, comprising 20 (48.8%) WHO grade 1 and 21 (51.2%) WHO grades 2–3 tumors. The patients' ages ranged from 27 to 78 years, with a mean age of approximately 53 years. The study population included both male and female patients, reflecting the expected female predominance in meningioma.

Table 1. Case distribution based on Clinicopathological Characteristics

Variable	Frequency	Percentage
Sex		
Male	6	14.6%
Female	35	85.4%
Age		
< 50 year	18	43.9%
≥ 50 year	23	56.1%
Mean±SD (min-max) = 51.66±10.18 (20-71)		
Grade meningioma		
1	20	48.8%
2 & 3	21	51.2%

Table 1 shows that from 41 meningioma samples, consisting of 6 samples from male patients (14.6%) and 35 samples from female patients (85.4%), the ages of the samples ranged from 20 to 71 years, with a mean age of 51.66 ± 10.18 years with 18 samples (43.9%) from individuals under 50 years old, while 23 samples (56.1%) from individuals aged 50 years or older and histopathological grading (by purposive sampling), 20 samples (48.8%) were classified as WHO grade 1 and 21 samples (51.2%) were classified as grades 2-3.

ROC Analysis

ROC curve analysis showed good diagnostic accuracy for both PD-L1 scoring systems. TPS had an AUC of 0,848 (cut-off 7.5%, sensitivity 81.0%, specificity 85.0%), while CPS had an AUC of 0.835 (cut-off 8.5%, sensitivity 90.5%, specificity 75.0%).

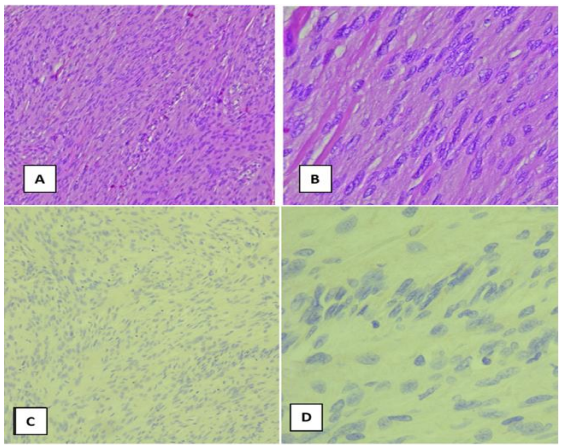

Figure 1. Meningothelial Meningioma (A. H&E, magnification 100×; B. H&E, magnification 400×). Negative PD-L1 expression in tumor cells and inflammatory cells (C. magnification 100×; D. magnification 400×).

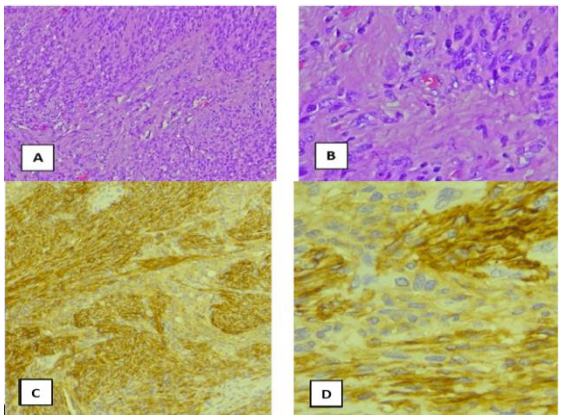

Figure 2. Atypical Meningioma (A. H&E, magnification 100×; B. H&E, magnification 400×). Positive PD-L1 expression in tumor cells (C. magnification 100×; D. magnification 400×).

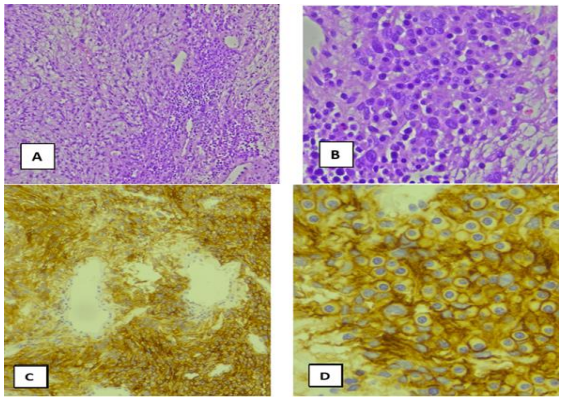

Figure 3. Lymphoplasmacyte-rich Meningioma (A. H&E, magnification 100×; B. H&E, magnification 400×). Positive PD-L1 expression in tumor cells and inflammatory cells (C. magnification 100×; D. magnification 400×).

Table 2. Association between sex and PD-L1 expression

Variable	PD-L1 (TPS)		PD-L1 (CPS)	
	Negative (n=19)	Positive (n=22)	Negatif (n=18)	Positif (n=23)
Male (n=6)	2 (10.6%)	4 (18.2%)	2 (11.1%)	4 (17.3%)
Female(n=35)	17 (89.4%)	18 (81.8%)	16 (88.9%)	19 (82.7%)
	p-value = 0.343		p-value = 0.662	

Table 2 shows that among the 6 male samples, 2 (10.6%) were negative and 4 (18.2%) were positive according to the TPS evaluation, while 2 (11.1%) were negative and 4 (17.3%) were positive according to the CPS evaluation. Among the 35 female samples, 17 (89.4%) were negative and 18 (81.8%) were positive by TPS, whereas 16 (88.9%) were negative and 19 (82.7%) were positive by CPS. Statistical analysis revealed no significant association between PD-L1 expression and sex, with p = 0.343 for TPS and p = 0.662 for CPS.

Table 3. Association between age and PD-L1 expression

Variable	PD-L1 (TPS)		PD-L1 (CPS)	
	Negative (n=22)	Positive (n=19)	Negative (n=17)	Positive (n=24)
< 50 year(n=18)	10 (45.4%)	8 (42.1%)	9 (52.9%)	9 (37.5%)
≥ 50 year (n=23)	12 (54.6%)	11 (57.9%)	8 (47.1%)	15 (62.5%)
	p-value = 0.623		p-value = 0.326	

Table 3 shows that among the 18 samples from individuals aged <50 years, 10 (45.4%) were negative and 8 (42.1%) were positive according to the TPS evaluation, while 9 (52.9%) were negative and 9 (37.5%) were positive according to the CPS evaluation. Among the 23 samples from individuals aged ≥50 years, 12 (54.6%) were negative and 11 (57.9%) were positive by TPS, whereas 8 (47.1%) were negative and 15 (62.5%) were positive by CPS. Statistical analysis showed no significant association between PD-L1 expression and age, with p = 0.623 for TPS and p = 0.326 for CPS.

Table 4. Association between grade meningioma and PD-L1 expression

Variable	PD-L1 (TPS)		PD-L1 (CPS)	
	Negative (n=21)	Positive (n=20)	Negative (n=17)	Positive (n=24)
Grade				
1 (n=20)	17 (81.0%)	3 (15.0%)	15 (88.2%)	5 (20.8%)
2&3 (n=21)	4 (19.0%)	17 (85.0%)	2 (11.8%)	19 (79.2%)
	p-value = 0.000		p-value = 0.000	

Table 4. shows that among the 20 grade 1 samples, 17 (81.0%) were negative and 3 (15.0%) were positive according to the TPS evaluation, while 15 (88.2%) were negative and 5 (20.8%) were positive according to the CPS evaluation. In contrast, among the 21 grade 2–3 samples, 4 (19.0%) were negative and 17 (85.0%) were positive by TPS, whereas 2 (11.8%) were negative and 19 (79.2%) were positive by CPS. Statistical analysis demonstrated a significant association between PD-L1 expression and meningioma grade, with p = 0.000 for both TPS and CPS

DISCUSSION

In this study, most samples, 23 (56.1%), were from individuals aged 50 years or older, while 18 samples (43.9%) were from those under 50 years of age. The mean age was 51.66 ± 10.18 years, with a range of 20 to 71 years. Previous research conducted at Prof. dr. I.G.N.G. Ngoerah General Hospital (2014–2018) similarly reported a higher incidence of meningioma among female patients. This finding is consistent with the present study, in which 35 samples (85.4%) were from females and 6 samples (14.6%) were from males.[5]

Meningioma occurs more frequently in women, which is thought to be related to higher progesterone levels. Other studies have also demonstrated the expression of oestrogen, progesterone, and androgen receptors in various types of meningiomas supporting the hypothesis that hormonal factors may contribute to meningioma development and growth.[6]

According to the World Health Organization (WHO), grade 1 meningiomas account for approximately 80.5% of all cases and are characterized by benign histological features and slow growth In contrast, grade 2 and grade 3 meningiomas represent 17.7% and 1.7%, respectively, and exhibit atypical to malignant histological features, reflecting a more aggressive clinical course.[2,7] This study have similar findings with total of 138 eligible cases consist of 101 cases (73,2%) of grade 1, 32 cases (23,2%) of grade 2 and 5 cases (3,6%) of grade 3. But for the objectives of this study, 41 samples selected using purposive sampling, 20 samples (48.8%) were classified as grade 1, while 21 samples consisted of grade 2 (39.0%) and grade 3 (12.2%).

Biologically, age-related immune system changes can influence PD-L1 expression through mechanisms such as reduced T-cell function, epigenetic alterations, and a more tolerogenic tumor microenvironment. However, in meningioma, there is currently no evidence suggesting that patient age plays a greater role than tumor grade or immune activity in determining PD-L1 expression.[7]

This study examined the potential association between age and PD-L1 expression and found no significant correlation. Similar findings were reported there is no relationship between PD-L1 expression and patient age, indicating that PD-L1 upregulation in meningioma is more likely influenced by tumor-intrinsic or microenvironmental factors rather than chronological aging.[8]

This study investigated the potential association between sex and PD-L1 expression and found no significant correlation. Similar results were reported who analyzed nine studies and found that seven out of nine showed no significant difference in PD-L1 expression between male and female patients.[9]

Furthermore, Mandala et al, conducted a large meta-analysis including 9.270 patients for overall survival (OS) and 6.193 patients for progression-free survival (PFS). Although biological differences between men and women may influence immune response and cancer progression, their analysis demonstrated that the therapeutic response to PD-1/PD-L1 checkpoint inhibition was comparable between sexes, indicating that gender does not significantly affect the efficacy or expression patterns of PD-L1 in tumors.[6]

This study demonstrated a significant correlation between PD-L1 expression and meningioma grade, as determined by both Tumor Proportion Score (TPS) and Combined Positive Score (CPS). The results showed that higher-grade meningiomas (WHO grades 2–3) expressed PD-L1 more frequently and intensely than lower-grade (grade 1) tumors. Specifically, PD-L1 positivity reached 85,0% in grades 2–3 compared to 15,0% in grade 1 based on TPS, and 79,2% versus 20,8% based on CPS, respectively (p = 0,000 for both). These findings suggest that PD-L1 expression may increase alongside tumor aggressiveness and histopathological progression.

The upregulation of PD-L1 in high-grade meningiomas reflects an adaptive immune resistance mechanism, in which tumor cells exploit immune checkpoint pathways to evade host antitumor responses. PD-L1 binds to its receptor PD-1 on activated T lymphocytes, leading to inhibition of T-cell proliferation, cytokine release, and cytotoxic activity.[7] This pathway effectively suppresses the immune system's ability to eliminate tumor cells and contributes to tumor persistence and recurrence.[8]

Previous studies have also observed a similar trend, Bi et al, found that PD-L1 expression was significantly higher in atypical and anaplastic meningiomas compared with benign subtypes.[11] Their study reported PD-L1 positivity in 48.9% of high-grade tumors versus only 6.7% in benign cases, supporting the notion that PD-L1 is associated with malignant transformation. Similarly, Han et al, reported that PD-L1–positive meningiomas demonstrated a higher Ki-67 proliferation index and were more likely to recur within two years of surgical resection, implying that PD-L1 may serve as a prognostic biomarker of aggressive biological behavior.[10]

The findings from this study also align with Zhang et al, who observed that PD-L1 expression was significantly correlated with WHO grade and tumor recurrence, suggesting its role in immune escape. Zhang further proposed that PD-L1 upregulation might be mediated by hypoxia-inducible factors (HIF-1α) and NF-κB pathway activation, both of which are known to be enhanced in rapidly proliferating or hypoxic tumor microenvironments.[12] This molecular insight supports the biological plausibility of the current study's results, as

higher-grade meningiomas typically exhibit greater cellularity, necrosis, and mitotic activity — features often associated with hypoxic signaling.[12]

Another present study used both TPS and CPS to quantify PD-L1 expression. While TPS evaluates PD-L1 staining restricted to tumor cells, CPS accounts for PD-L1 expression in both tumor and immune cells within the tumor microenvironment. Ito et al. emphasized that CPS might better reflect the overall immune landscape and therefore serve as a more sensitive biomarker for immune checkpoint inhibitor (ICI) response.[13]

However, in several cancer types, including non-small cell lung carcinoma, TPS has been shown to correlate more closely with therapeutic outcomes.[14] In this study, both TPS and CPS were significantly associated with meningioma grade, highlighting the complementary value of both scoring systems in capturing the tumor's immunological characteristics.[14]

From a clinical standpoint, the overexpression of PD-L1 in high-grade meningiomas provides a rationale for the potential use of ICIs, such as anti–PD-1 or anti–PD-L1 antibodies, in their treatment.[15] Although meningiomas are generally considered "immunologically cold" tumors, evidence from recent clinical trials suggests that a subset of PD-L1–positive or hypermutated meningiomas may benefit from immunotherapy.[21] In a phase II trial by Brastianos et al., pembrolizumab (anti–PD-1) achieved a 6-month progression-free survival (PFS-6) of 48% in recurrent and residual high-grade meningiomas, with some patients demonstrating durable disease stabilization. Importantly, PD-L1 positivity and higher tumor mutational burden were associated with better clinical responses.[15]

Likewise, Omenai et al., examined PD-L1 expression in 96 meningioma samples and found significant associations between PD-L1 positivity and higher tumor grade, as well as macrophage infiltration.[9] The study also highlighted the heterogeneity of PD-L1 staining patterns, which may vary depending on the antibody clone used. This current study utilized a polyclonal Genetex antibody (GTX104763), which, while categorized as a research-use reagent, has been shown to reliably detect PD-L1 expression in formalin-fixed paraffin-embedded tissues.[9]

The clinical relevance of PD-L1 expression in meningioma extends beyond prognosis, as it may serve as a predictive biomarker for immune checkpoint blockade efficacy.[21] PD-L1 overexpression reflects the activation of immunosuppressive pathways that could potentially be reversed by anti–PD-1/PD-L1 therapies.[8] Therefore, assessing PD-L1 expression, particularly in recurrent or high-grade meningiomas, could help identify patients who are most likely to benefit from immunotherapy, complementing traditional treatment modalities such as surgery and radiotherapy.[8]

Nevertheless, several limitations should be acknowledged. The study's retrospective design limited the ability to control for confounding variables, and the single-centre origin of the sample may restrict generalizability. In addition, the use of a polyclonal antibody rather than a diagnostic clone such as 22C3 or SP263 may introduce variability in staining intensity and interpretation. Despite these limitations, the findings are consistent with previous studies and contribute to the growing evidence supporting PD-L1 as an important biomarker in meningioma biology.

In summary, this study supports the notion that PD-L1 expression increases with meningioma grade and correlates with histopathological aggressiveness. Both TPS and CPS showed strong associations with higher-grade tumors, reinforcing the potential of PD-L1 as a prognostic and predictive biomarker. These findings add to the accumulating evidence that immunotherapy may have a therapeutic role in selected cases of PD-L1–positive or recurrent meningioma. Further multicentre studies with standardized IHC protocols, clones and larger cohorts are needed to validate PD-L1 as a biomarker for prognosis and treatment selection in meningioma patients.

CONCLUSION

This study demonstrated a significant correlation between PD-L1 expression and meningioma grade. Using both the Tumor Proportion Score (TPS) and Combined Positive Score (CPS) methods, PD-L1 expression was found to be higher in WHO grade 2–3 meningiomas compared to grade 1. Statistical analysis revealed $p = 0.000$ for both scoring systems, confirming a strong association between PD-L1 positivity and higher tumor grade.

In contrast, no significant relationship was observed between PD-L1 expression and either age or sex, suggesting that these demographic factors do not influence PD-L1 levels in meningioma.

These findings indicate that PD-L1 expression may serve as a potential prognostic biomarker for tumor aggressiveness in meningioma. The increasing expression of PD-L1 in higher grades supports its role in immune evasion and provides a rationale for exploring immune checkpoint inhibitor therapy as an adjunct treatment in recurrent or high-grade meningiomas.

Further multicentre studies with standardized immunohistochemical protocols, clones and larger cohorts are recommended to validate the prognostic and predictive significance of PD-L1 expression in meningioma.

Conflict of Interest

There are no conflicts of interest in this study.

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None.

Author Contributions

All authors have made equal contributions to the writing of this research, from the development of the conceptual framework, data collection, data analysis, to the interpretation of the research results.

References

1. Kythreotou A, Siddique A, Mauri FA, Bower M, Pinato DJ. PD-L1. J Clin Pathol. 2018;71(3):189–94. doi:10.1136/jclinpath-2017-204853
2. Louis DN, Perry A, Reifenberger G, von Deimling A, Figarella-Branger D, Cavenee WK,

et al. The 2021 World Health Organization classification of tumors of the central nervous system: a summary. Neuro Oncol. 2021;23(8):1231–51.
3. Akhtar M, Rashid S, Al-Bozom IA. PD-L1 immunostaining: what pathologists need to know. Diagn Pathol. 2021;16(1):94. doi:10.1186/s13000-021-01151-x
4. Geidel G, Parnian N, Meß C, Schlepper N, Rünger A, Heidrich I, Hansen I, et al. Differential predictive value of tissue-specific PD-L1 expression scores in adjuvant immunotherapy of melanoma. J Eur Acad Dermatol Venereol. 2024;38(10):2017–23. doi:10.1111/jdv.20177
5. Sunantara GNMCV, Sriwidyani NP, Saputra H. Gambaran klinikopatologi pasien meningioma dari tahun 2014–2018 di RSUP Sanglah Denpasar. J Med Udayana. 2021;10(3):183–8. doi:10.24843/MU.2021.v10.i03.p12
6. Malueka RG, Hartanto RA, Setyawan NH, Fauzi DNF, Damarjati KR, Rismawan A, et al. Association of hormonal contraception with meningioma location in Indonesian patients. Asian Pac J Cancer Prev. 2022;23(3):1047–51. doi:10.31557/APJCP.2022.23.3.1047
7. Ostrom QT, Cioffi G, Gittleman H, Patil N, Waite K, Kruchko C, et al. CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2012–2016. Neuro Oncol. 2019;21(Suppl 5):v1–100. doi:10.1093/neuonc/noz150
8. Karimi S, Mansouri S, Mamatjan Y, Liu J, Nassiri F, Suppiah S, et al. Programmed death ligand-1 (PD-L1) expression in meningioma: prognostic significance and its association with hypoxia and NFKB2 expression. Sci Rep. 2020;10:14111. doi:10.1038/s41598-020-70514-z
9. Omenai SA, Ajani MA, Okolo CA. Programmed death ligand 1 expression as a surrogate for determining immunotherapy in cervical carcinoma patients. PLoS One. 2022;17(2):e0263615. doi:10.1371/journal.pone.0263615
10. Han Y, Liu D, Li L. PD-1/PD-L1 pathway: current researches in cancer. Am J Cancer Res. 2020;10(3):727–42.
11. Bi WL, Nayak L, Meredith DM, Driver J, Du Z, Hoffman S, et al. Activity of PD-1 blockade with nivolumab among patients with recurrent atypical/anaplastic meningioma: phase II trial results. Neuro Oncol. 2022;24(1):101–13. doi:10.1093/neuonc/noab118
12. Zhang L, Wang L, Tan Y, Li C, Fang C. Identification of key genes of anti-programmed death ligand 1 for meningioma immunotherapy by bioinformatic analysis. Med Oncol. 2023;40(1):22. doi:10.1007/s12032-022-01869-8
13. Ito T, Okamoto I, Tokashiki K, Sato H, Okada T, Yamashita G, et al. PD-L1 expression and survival rates using TPS and CPS for nivolumab-treated head and neck cancer. Anticancer Res. 2022;42(3):1547–54. doi:10.21873/anticanres.15628
14. Frančina M, Mikuš M, Mamić M, Jovanović T, Ćorić M, Lovrić B, et al. Evaluation of PD-L1 expression in colorectal carcinomas by comparing scoring methods and their significance in relation to clinicopathologic parameters. Diagnostics (Basel). 2024;14(10):1007. doi:10.3390/diagnostics14101007
15. Brastianos PK, Kim AE, Giobbie-Hurder A, Lee EQ, Wang N, Eichler AF, et al. Phase 2 study of pembrolizumab in patients with recurrent and residual high-grade meningiomas. Nat Commun. 2022;13(1):1325. doi:10.1038/s41467-022-29052-7
16. Saygin İ, Çakir E, Kazaz SN, Güvercin AR, Eyüpoğlu İ, Ustaoğlu MM. Investigation of the status of immune checkpoint molecules (PD-L1 and PD-1) in meningiomas by immunohistochemistry. Turk J Med Sci. 2024;54(4):735–43. doi:10.55730/1300-0144.5843
17. Madala S, Rasul R, Singla K, Sison CP, Seetharamu N, Castellanos MR. Gender differences and their effects on survival outcomes in lung cancer patients treated with PD-1/PD-L1 checkpoint inhibitors: a systematic review and meta-analysis. Clin Oncol (R Coll Radiol). 2022;34(12):799–809. doi:10.1016/j.clon.2022.03.010
18. Zhang Y, Wang X, Shi M, Song Y, Yu J, Han S. Programmed death ligand 1 and tumor-infiltrating CD8+ T lymphocytes are associated with the clinical features in meningioma. BMC Cancer. 2022;22:1103. doi:10.1186/s12885-022-10249-4
19. Molavi DW. Descriptive terms in anatomic pathology. In: The Practice of Surgical Pathology. Cham: Springer International Publishing; 2018. p. 6–15. doi:10.1007/978-3-319-59211-4_2
20. Luce A, Abate M, Scognamiglio G, Montella M, Iervolino D, Campione S, et al. Immune cell infiltration and inflammatory landscape in primary brain tumours. J Transl Med. 2024;22(1):125. doi:10.1186/s12967-024-05309-1
21. Ghosh C, Luong G, Sun Y. A snapshot of the PD-1/PD-L1 pathway. J Cancer. 2021;12(9):2735–46. doi:10.7150/jca.57334