

Prediction of veristrat test in first-line therapy of pemetrexed based regimen for advanced lung adenocarcinoma patients

Bo Jia

Beijing Cancer Hospital

Zhi Dong

Beijing Cancer Hospital

Di Wu

Beijing Cancer Hospital

Jun Zhao

Beijing Cancer Hospital

Meina Wu

Beijing Cancer Hospital

Tongtong An

Beijing Cancer Hospital

Yuyan Wang

Beijing Cancer Hospital

Minglei Zhuo

Beijing Cancer Hospital

Jianjie Li

Beijing Cancer Hospital

Yang Wang

Beijing Cancer Hospital

Jie Zhang

Beijing Cancer Hospital

Xinghui Zhao

Beijing Cancer Hospital

Sheng Li

Beijing Cancer Hospital

Junfeng Li

Beijing Cancer Hospital

Menglei Ma

Beijing Cancer Hospital

Chen Chen

Chinese PLA General Hospital

Xue Yang

Beijing Cancer Hospital

Jia Zhong

Beijing Cancer Hospital

Hanxiao Chen

Beijing Cancer Hospital

Jingjing Wang

Beijing Cancer Hospital

Yujia Chi

Beijing Cancer Hospital

Xiaoyu Zhai

Beijing Cancer Hospital

Song Cui

Bioyong Technologies Inc

Rong Zhang

Bioyong Technologies Inc

Qingwei Ma

Bioyong Technologies Inc

Jian Fang

Beijing Cancer Hospital

Ziping Wang (✉ wangzp2007@126.com)

Beijing Cancer Hospital <https://orcid.org/0000-0002-6763-7431>

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Abstract

Background: Although advanced non-squamous non-small cell lung cancer (NSCLC) patients have significantly better survival outcome on pemetrexed based treatment, a subset of patients still show intrinsic resistance and progress rapidly. Therefore we aim to use a blood-based protein signature (VeriStrat, VS) to analyze whether VS could identify the subset of patients who had poor efficacy on pemetrexed therapy.

Methods: This study retrospectively analyzed 72 advanced lung adenocarcinoma patients who received first-line pemetrexed/platinum or combined with bevacizumab treatment.

Results: Plasma samples from these patients were analyzed using VS and classified as Good (VS-G) or Poor (VS-P) group. The relationship between efficacy and VS status was further investigated. Of 72 patients included in this study, 35 (48.6%) were treated with pemetrexed plus platinum and 37 (51.4%) were treated with pemetrexed/platinum combined with bevacizumab. Among all patients, 60 (83.3%) and 12 (16.7%) patients were classified as VS-G and VS-P, respectively. VS-G patients had significantly better median progression free survival (PFS) (Unreached vs. 4.2 months; $P=0.001$) than VS-P patients. Besides, partial response (PR) rate was higher in VS-G than that in VS-P group (46.7% vs 25.0%, $P=0.212$). Subgroup analysis showed that PFS was also significantly longer in the VS-G than that in VS-P group no matter for patients received chemotherapy alone or chemotherapy plus bevacizumab.

Conclusions: Our study indicates that VS could be considered as a novel and valid method to predict efficacy of pemetrexed based therapy and identify a subset of advanced lung adenocarcinoma patients who have intrinsic resistance to pemetrexed based regimen.

1. Introduction

Lung cancer is the most common cancer worldwide and most patients are diagnosed with advanced stage[1, 2]. Over the past decades, although the treatment for non-small cell lung cancer (NSCLC) patients has been improved noticeably, especially a significant progress has been made in immunotherapy and targeted therapy, but chemotherapy remains the cornerstone for advanced NSCLC patients.

Pemetrexed based therapy has been the standard first-line chemotherapy regimen for advanced non-squamous NSCLC patients without epidermal growth factor receptor (EGFR) sensitizing mutations, anaplastic lymphoma kinase (ALK) or c-ros oncogene 1 receptor kinase (ROS1) rearrangement. First-line pemetrexed based chemotherapy showed significant better outcomes than other chemotherapy regimens for these patients especially with gemcitabine/platinum[3-5]. Bevacizumab was a recombinant humanized monoclonal antibody which could bind vascular endothelial growth factor-A (VEGF-A), inhibit its binding to VEGF receptor-2, and then inhibit the biological effects of VEGF. As an anti-angiogenesis targeted drug, bevacizumab has been approved for the first-line treatment of advanced, metastatic or recurrent non-squamous NSCLC patients[6]. However some patients still showed primary resistance to these treatment regimens and progressed rapidly. It was unclear why these patients responded

heterogeneously and it was necessary to find a method to predict the efficacy, and identify a subset of patients who might be resistant to pemetrexed based chemotherapy or combined with bevacizumab. Therefore these patients could have a chance to receive other treatment methods such as immunotherapy, targeted therapy, and other chemotherapy regimens.

VeriStrat (VS), a blood-based test could divide patients into either VS Good (VS-G) or VS Poor (VS-P) group, which might potentially help oncologists in a puzzle about the matter in their clinical practice. Previous studies have shown that VS was a valid method to predict the efficacy of chemotherapy or targeted therapy for advanced NSCLC patients[7-11]. However, so far there has been no study using VS method for the prediction of first-line pemetrexed based chemotherapy plus for Chinese advanced lung adenocarcinoma patients without EGFR sensitizing mutations, ALK or ROS1 rearrangement. Therefore we conducted a study to explore whether VS could be used in the first-line setting to identify advanced adenocarcinoma patients who have better outcomes or resistance on pemetrexed chemotherapy.

2. Materials And Methods

2.1 Patents

Patients were enrolled in this study if they had stage IIIB or IV lung adenocarcinoma, had no previous systemic anticancer therapy and showed measurable lesions. All patients received chemotherapy or combined with bevacizumab. Chemotherapy regimens include pemetrexed (500mg/m² q21d) in combination with cisplatin (75mg/m² q21d) or carboplatin (AUC=5 q21d). The dose of bevacizumab was 7.5mg/kg, q21d. The primary endpoint was progression free survival (PFS). Other endpoints include partial response and objective response rate (ORR). PFS was calculated from the date of initiation of chemotherapy to the date of progression or death from any cause. The tumor response was assessed by RECIST version 1.1.

2.2. Samples and VeriStrat test

Serum samples were collected and stored frozen. Samples were anonymized and shipped to Bioyong (Beijing,China). VeriStrat analysis was conducted on 72 serum samples by Bioyong (Beijing, China) in a blinded to clinical and treatment data. Matrix Assisted Laser Desorption Ionization Time of Flight Mass Spectrometry (MALDI-TOF-MS) was a new type of soft ionization biomass spectrometry developed in recent years and was the most commonly used frontier technology in proteomics research. MALDI-TOF mass spectrometry could be used to detect protein polypeptide components in patients' serum, and the molecular weight and content could be drawn into protein polypeptide fingerprints. VeriStrat (VS) could eventually discover and capture new specific protein features by comparing the differences in atlases between different case groups and by bioinformatics analysis. VeriStrat (VS) testing was performed as described[7, 12]. This test use Clin-TOFII mass spectrometer(based on MALDI mass spectrometry) (Bioyong,Beijing,China). Samples were thawed on ice and diluted 1:10 in HPLC-grade water, then combined with equal volume of matrix solution.(25mg/ml sinapinic acid prepared in 50% acetonitrile/0.1% trifluoroacetic acid).Spot 2 uL sample-matrix mixture on polished stainless steel MALDI

plates three times. Acquire data on Clin-TOFII Mass Spectrometer (Bioyong,Beijing,China)in linear mode. Export ASCII files from spectra, and run VeriStrat Algorithm on ASCII files. A Vetistrat label of Good or Poor was produced for each sample when all replicates from a sample gave the same classification. An indeterminate classification status was assigned to samples with discordant findings in the replicates. Only patients with classifications of VeriStrat good (VSG) or VeriStrat Poor(VSP) were included in this study cohort.

2.3. Statistical analysis

Baseline characteristics between VS-G and VS-P group were compared using T test for age or using X2 test for all other variables. Tumor response was compared using X2 test in two groups. PFS was compared using univariate analysis. A Cox model was used to adjust differences in PFS between groups for other confounding variables (gender, stage, smoking status, and treatment).

3. Results

3.1. Patient Characteristics

Table 1 shows the patients' clinical characteristics in this study. Of the 72 patients, 60 (83.3%) were classified as VS-G and 12 (16.7%) as VS-P. Patients' characteristics were well balanced between VS-G and VS-P group (P>0.05 for all).

Table 1. Patients' Characteristics according to VS Classification

	All Patients (%)	VS-G (%)	VS-P (%)	p ¹
Age (years)				0.682
Median (range)	58 (34 – 81)	58 (34 – 81)	58 (46 – 74)	
Gender				1.000
Female	24 (33.3)	20 (33.3)	4 (33.3)	
Male	48 (66.7)	40 (66.7)	8 (66.7)	
ECOG				1.000
0	42 (58.3)	35 (58.3)	7 (58.3)	
1	30 (41.7)	25 (41.7)	5 (41.7)	
Stage				1.000
IIIB	14 (19.4)	12 (20.0)	2 (16.7)	
IV	58 (80.6)	48 (80.0)	10 (83.3)	
Smoking				0.595
Yes	41 (56.9)	35 (58.3)	6 (50.0)	
No	31 (43.1)	25 (41.7)	6 (50.0)	
Treatment				0.916
Chemotherapy	35 (48.6)	29 (48.3)	6 (50.0)	
Chemotherapy+Bev	37 (51.4)	31 (51.7)	6 (50.0)	

ECOG, Eastern Cooperative Oncology Group; Bev, Bevacizumab. ¹Two groups were compared using T test for age or using X² test for all other characteristics.

3.2. Tumor Response

Table 2 illustrates the tumor response in two groups. The partial response (PR) rate was higher in VS-G group than that in VS-P group (46.7% vs 25.0%, P=0.212). There were no significant differences of stable disease (SD) rate (P=0.343) and progression disease (PD) rate (P=0.526) between VS-G and VS-P group. For patients who received chemotherapy alone, PR rate was 31.0% and 0.0% in VS-G and VS-P groups respectively. There were no significant differences of SD rate (P=0.377) and PD rate (P=0.442) between two groups. For patients with chemotherapy and bevacizumab treatment, PR rate was also higher in VS-G than that in VS-P groups (61.3% for VS-G vs. 50.0% for VS-P). SD rate was 35.5% and 50.0% (P=0.653) in VS-G and VS-P group with the PD rate of 3.2% and 0.0% (P=1.000) respectively. The difference did not reach a statistical significance likely because of the limited number of patients in this study (Table 2).

Table 2. Tumor response according to VS Classification

	VS-G (%)		VS-P (%)		P ¹
PR	28 (46.7)		3 (25.0)		0.212
SD	28 (46.7)		8 (66.7)		0.343
PD	3 (5.0)		1 (8.3)		0.526
PR+SD	56 (93.3)		11 (91.7)		1.000

	Chemotherapy		P ¹	Chemotherapy+Bev		P ¹
	VS-G(%)	VS-P(%)		VS-G(%)	VS-P(%)	
PR	9 (31.0)	0 (0.0)	0.304	19(61.3)	3 (50.0)	0.670
SD	17 (58.6)	5 (83.3)	0.377	11 (35.5)	3 (50.0)	0.653
PD	2 (6.9)	1 (16.7)	0.442	1 (3.2)	0 (0.0)	1.000
PR+SD	26 (89.7)	5 (83.3)	0.546	30 (96.8)	6 (100.0)	1.000

PR, partial response; SD, stable disease; PD, progression disease; Bev, Bevacizumab. ¹Tumor response was compared using X² test in two groups.

3.3. Survival

Of 72 patients in this study, 25 patients experienced disease progression. The median follow-up time for all patients was 7.4 months (0.9 – 18.8 months). A significant improved median PFS was observed for patients in VS-G group compared with that in VS-P group (Unreached vs. 4.2 months; P=0.001) (Figure 1). Median OS was not reached in either group. For 35 patients received chemotherapy, median PFS was significantly superior for patients in VS-G than that in VS-P group (Unreached vs. 4.0 months; P=0.001) (Figure 2). For 37 patients treated with chemotherapy and bevacizumab, median PFS was also significantly longer in the VS-G than that in VS-P group (Unreached vs. 4.8 months, p=0.042) (Figure 3). Patients who did not relapse or progress at the last follow-up were referred to as censored data. Interaction between PFS and VS classification was tested using the Cox model. After adjusting for gender, stage, smoking status and treatment by multivariate analysis, the interaction between PFS and VS classification was also statistically significant (P=0.011) (Table 3).

Table 3. Association of Treatment with Progression-free Survival (PFS)

	Univariate Analysis	Multivariate Analysis	
	p ¹	HR (95% C.I.)	p ²
Treatment Chemotherapy vs. Chemotherapy+bevacizumab	0.890	0.734 (0.325 - 1.656)	0.457
Gender Male vs. Female	0.344	0.998 (0.262 - 3.803)	0.998
Smoking Status Smoking vs. Non-smoking	0.379	0.646 (0.201 - 2.077)	0.463
Stage IV vs. IIIB	0.059	0.265 (0.061 - 1.150)	0.076
VeriStrat Good vs. Poor	0.001	0.214 (0.088 - 0.522)	0.011

HR, hazard ratio; C.I., confidence interval. ¹P-value was estimated by univariate analysis. ²HR, 95% C.I. and P-value were estimated in Cox proportional hazards model.

4. Discussion

This is the first study indicating that a blood-based protein signature (VS) could be considered as a novel and valid method to predict efficacy of pemetrexed/platinum or combined with bevacizumab in the first-line treatment for Chinese advanced lung adenocarcinoma patients.

The concept of combination therapy refers to that using the best combination of existing treatment methods according to the specific conditions of patients, such as body condition, pathological type, invasion range (pathological stage) and development trend, to greatly improve the cure rate, prolong the survival period and improve the quality of life of patients. Surgery, radiotherapy, and systemic therapy are the 3 modalities of combination therapy for cancer patients. Systemic therapy, including chemotherapy, targeted therapy and immunotherapy, is suitable for the treatment of advanced NSCLC patients. Recently, although a significant progress has been made in immunotherapy and targeted therapy, chemotherapy remains the cornerstone for advanced NSCLC patients[13-20]. Pemetrexed is a third generation cytotoxic agent. It can inhibit cell replication and tumor growth by disrupting folate-dependent normal cellular metabolism. Several clinical trials demonstrated that first-line pemetrexed based therapy was associated with significant better survival outcome than other chemotherapy regimens for advanced lung adenocarcinoma patients. Besides, the combination of bevacizumab could further improve survival for these patients. Therefore, pemetrexed/platinum combined with bevacizumab has been the standard first-line chemotherapy regimen for advanced non-squamous NSCLC patients. But some patients still showed poor response to pemetrexed based regimen[21, 22]. Currently, for lacking of clinical evidence, no specific biomarkers have been applied in clinical practice. Therefore it is urgently needed to find promising biomarkers to predict efficacy of cytotoxic agents.

In 2007, David Carbone etc initially established a VeriStrat method that can be used to predict the first-line efficacy of EGFR tyrosine kinase inhibitor (TKI) for advanced NSCLC patients who did not receive EGFR

mutation test before treatment. In this study, the median survival was 306 days in VS-G group of 69 patients, far more than 107 days in VS-P group of 27 patients[4]. A series of follow up studies demonstrated that VS is predictor of therapeutic benefit from EGFR TKI therapy[23]. In PROSE study, VS method was utilized to predict second-line single-drug chemotherapy for advanced lung cancer (pemetrexet/docetaxel). The results show that among the 129 patients receiving single-drug chemotherapy, OS and PFS were significantly lower in VS-P group than in VS-G group [24]. Another study examined the performance of VeriStrat in three independent clinical trials from 481 patients treated with platinum-based chemotherapy in first line. Patients classified as VS-G had significantly longer PFS and OS than VS-P patients. These results demonstrated that VS is a strong predictive test in NSCLC patients treated with platinum-based regimens in the first line[10]. However, so far there has been no study using this VS method for the prediction of first-line pemetrexed plus platinum-based chemotherapy or combined with bevacizumab for Chinese advanced lung adenocarcinoma patients.

To address these issues, we conducted a retrospective analysis of plasma samples from lung adenocarcinoma patients with stage IIIB or IV, who received first-line pemetrexed based chemotherapy. Our study showed that median PFS was unreached in VS good group, significantly superior than that in VS poor group, the PFS of which was 4.2 months. For 35 patients received chemotherapy, an improved PFS was still observed for patients in VS-G vs. VS-P group (median PFS: Unreached vs. 4.0 months) A recent study included 76 non-squamous patients treated with a combination of carboplatin or cisplatin with pemetrexed. Patients classified as VS-G had longer PFS and OS than VS-P: 6.5 vs 1.6 months and 10.8 vs 3.4 months, respectively.[11] The PFS in our study was longer than previously reported data likely because pemetrexed maintenance therapy was administered in our study. PARAMOUNT study demonstrated that continuation maintenance therapy with pemetrexed was an effective and well tolerated treatment option for patients with advanced non-squamous NSCLC with good performance status who did not progress after induction therapy with pemetrexed plus cisplatin[25]. In PARAMOUNT study, the median PFS was 4.1 months for pemetrexed and 2.8 months for placebo[26]. The result in our study was consistent with that in PARAMOUNT study.

In POINTBREAK study, PFS was significantly improved with pemetrexed/carboplatin plus bevacizumab and pemetrexed/bevacizumab maintenance therapy (median PFS, 6.0 v 5.6 months; P = 0.012)[27]. In AVAPEAL study, bevacizumab plus pemetrexed maintenance was also associated with a significant PFS benefit compared with bevacizumab alone (median, 3.7 v 7.4 months; P < 0.001)[28]. Updated survival analysis of the AVAPERL study showed maintenance with bevacizumab-pemetrexed was associated with a nonsignificant increase in OS over bevacizumab alone[29]. A recent study (WJOG 5610L) reported in 2019 American Society of Clinical Oncology annual meeting demonstrated that bevacizumab and pemetrexed maintenance therapy could not prolong OS compared with bevacizumab maintenance therapy alone (median, 23.3 vs 19.6 months; P=0.069). In our study, for 37 patients treated with chemotherapy and bevacizumab, PFS was also significantly longer in the VS-G compared with VS-P group (median PFS: Unreached vs. 4.8 months). Our study indicated that VS is also predictive for chemotherapy and bevacizumab combined therapy. Although this study clearly identified patients who might have worse outcome on pemetrexed based therapy. These data are not compelling enough to deny

pemetrexed therapy to VS-P patients. But perhaps in these VS-P patients, alternative treatment approaches could be considered.

Several limitations of our study are worthy of note. First, 72 were eligible for inclusion and analysis, and only a small subset of participants (12/72, 16.7%) tested as VS-P. This limited the power of the analysis we performed. Further, OS data was not available. Because OS is typically not calculated until more than 50% of patients experienced events, and median OS was not reached in either group. But our study still indicates that VS could be considered as a novel and valid method to predict efficacy of pemetrexed based therapy and identify a subset of advanced lung adenocarcinoma patients who have intrinsic resistance to pemetrexed based regimen.

5. Conclusions

Our study indicates that VS could be considered as a novel and valid method to predict efficacy of pemetrexed based therapy with Chinese advanced lung adenocarcinoma patients and identify a subset of patients who have intrinsic resistance to pemetrexed based regimen.

Declarations

Ethics approval and consent to participate The study was approved by the Medical Ethics Committee of Peking University Cancer Hospital. All patients signed "Informed consent of obtaining the patient sample to conduct a scientific study" and all authors had no access to patient's identities.

Consent for publication: All authors have read and agreed to the published version of the manuscript.

Availability of data and material The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

Competing interests: Authors Song Cui, Rong Zhang, Qingwei Ma were employed by the company Bioyong Technologies Inc. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Authors' Contributions: Conceptualization, B.J. and ZP.W.; methodology, XH.Z, S.L., JF.L., ML.M., C.C., S.C., R.Z. and QW.M; formal analysis, B.J.; investigation, B.J., J.F. and ZP.W.; data curation, Z.D., D.W., J.Z., MN.W., TT.A., YY.W., ML.Z., JJ.L., Y.W., J.Z., X.Y., J.Z., HX.C., JJ.W.,YJ.C., and XY.Z.; writing—original draft preparation, B.J.; writing—review and editing, B.J.; supervision, ZP.W.; project administration, ZP.W.; funding acquisition, B.J. and ZP.W.

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References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. *CA Cancer J Clin* 2016; 66: 7-30.
2. Chen W, Zheng R, Baade PD et al. Cancer statistics in China, 2015. *CA Cancer J Clin* 2016; 66: 115-132.
3. Scagliotti GV, Parikh P, von Pawel J et al. Phase III study comparing cisplatin plus gemcitabine with cisplatin plus pemetrexed in chemotherapy-naive patients with advanced-stage non-small-cell lung cancer. *J Clin Oncol* 2008; 26: 3543-3551.
4. Xu H, Xu F, Zhu W et al. Comparing first-line treatment patterns and clinical outcomes of patients with pan-negative advanced non-squamous non-small cell lung cancer. *Thorac Cancer* 2018; 9: 1005-1011.
5. Ciuleanu T, Brodowicz T, Zielinski C et al. Maintenance pemetrexed plus best supportive care versus placebo plus best supportive care for non-small-cell lung cancer: a randomised, double-blind, phase 3 study. *Lancet* 2009; 374: 1432-1440.
6. Patel J, Socinski M, Garon E et al. PointBreak: a randomized phase III study of pemetrexed plus carboplatin and bevacizumab followed by maintenance pemetrexed and bevacizumab versus paclitaxel plus carboplatin and bevacizumab followed by maintenance bevacizumab in patients with stage IIIB or IV nonsquamous non-small-cell lung cancer. *J Clin Oncol* 2013; 31: 4349-4357.
7. Carbone DP, Ding K, Roder H et al. Prognostic and predictive role of the VeriStrat plasma test in patients with advanced non-small-cell lung cancer treated with erlotinib or placebo in the NCIC Clinical Trials Group BR.21 trial. *J Thorac Oncol* 2012; 7: 1653-1660.
8. Gadgeel S, Goss G, Soria JC et al. Evaluation of the VeriStrat((R)) serum protein test in patients with advanced squamous cell carcinoma of the lung treated with second-line afatinib or erlotinib in the phase III LUX-Lung 8 study. *Lung Cancer* 2017; 109: 101-108.
9. Fidler MJ, Fhied CL, Roder J et al. The serum-based VeriStrat(R) test is associated with proinflammatory reactants and clinical outcome in non-small cell lung cancer patients. *BMC Cancer* 2018; 18: 310.
10. Grossi F, Genova C, Rijavec E et al. Prognostic role of the VeriStrat test in first line patients with non-small cell lung cancer treated with platinum-based chemotherapy. *Lung Cancer* 2018; 117: 64-69.
11. Grossi F, Rijavec E, Genova C et al. Serum proteomic test in advanced non-squamous non-small cell lung cancer treated in first line with standard chemotherapy. *Br J Cancer* 2017; 116: 36-43.
12. Taguchi F, Solomon B, Gregorc V et al. Mass spectrometry to classify non-small-cell lung cancer patients for clinical outcome after treatment with epidermal growth factor receptor tyrosine kinase inhibitors: a multicohort cross-institutional study. *J Natl Cancer Inst* 2007; 99: 838-846.
13. Bhattacharjee S, Roche B, Martienssen R. RNA-induced initiation of transcriptional silencing (RITS) complex structure and function. *RNA biology* 2019; 16: 1133-1146.

14. Ghosh D, Venkataramani P, Nandi S, Bhattacharjee S. CRISPR-Cas9 a boon or bane: the bumpy road ahead to cancer therapeutics. *Cancer cell international* 2019; 19: 12.
15. Ghosh D, Nandi S, Bhattacharjee S. Combination therapy to checkmate Glioblastoma: clinical challenges and advances. *Clinical and translational medicine* 2018; 7: 33.
16. Bhattacharjee S, Nandi S. Rare Genetic Diseases with Defects in DNA Repair: Opportunities and Challenges in Orphan Drug Development for Targeted Cancer Therapy. *Cancers* 2018; 10.
17. Bhattacharjee S, Nandi S. Synthetic lethality in DNA repair network: A novel avenue in targeted cancer therapy and combination therapeutics. *IUBMB life* 2017; 69: 929-937.
18. Bhattacharjee S, Nandi S. DNA damage response and cancer therapeutics through the lens of the Fanconi Anemia DNA repair pathway. *Cell communication and signaling : CCS* 2017; 15: 41.
19. Bhattacharjee S, Nandi S. Choices have consequences: the nexus between DNA repair pathways and genomic instability in cancer. *Clinical and translational medicine* 2016; 5: 45.
20. Rahman M, Nasrin F, Bhattacharjee S, Nandi S. Hallmarks of Splicing Defects in Cancer: Clinical Applications in the Era of Personalized Medicine. *Cancers* 2020; 12.
21. Ricciuti B, Brambilla M, Cortellini A et al. Clinical outcomes to pemetrexed-based versus non-pemetrexed-based platinum doublets in patients with KRAS-mutant advanced non-squamous non-small cell lung cancer. *Clin Transl Oncol* 2019.
22. Xu YL, Jiang XM, Zhang LL et al. Establishment and Characterization of Pemetrexed-resistant NCI-H460/PMT Cells. *Anticancer Agents Med Chem* 2019; 19: 731-739.
23. Stinchcombe TE, Roder J, Peterman AH et al. A retrospective analysis of VeriStrat status on outcome of a randomized phase II trial of first-line therapy with gemcitabine, erlotinib, or the combination in elderly patients (age 70 years or older) with stage IIIB/IV non-small-cell lung cancer. *J Thorac Oncol* 2013; 8: 443-451.
24. Gregorc V, Novello S, Lazzari C et al. Predictive value of a proteomic signature in patients with non-small-cell lung cancer treated with second-line erlotinib or chemotherapy (PROSE): a biomarker-stratified, randomised phase 3 trial. *Lancet Oncol* 2014; 15: 713-721.
25. Paz-Ares L, de Marinis F, Dediu M et al. Maintenance therapy with pemetrexed plus best supportive care versus placebo plus best supportive care after induction therapy with pemetrexed plus cisplatin for advanced non-squamous non-small-cell lung cancer (PARAMOUNT): a double-blind, phase 3, randomised controlled trial. *Lancet Oncol* 2012; 13: 247-255.
26. Paz-Ares LG, de Marinis F, Dediu M et al. PARAMOUNT: Final overall survival results of the phase III study of maintenance pemetrexed versus placebo immediately after induction treatment with pemetrexed plus cisplatin for advanced nonsquamous non-small-cell lung cancer. *J Clin Oncol* 2013; 31: 2895-2902.
27. Patel JD, Socinski MA, Garon EB et al. PointBreak: a randomized phase III study of pemetrexed plus carboplatin and bevacizumab followed by maintenance pemetrexed and bevacizumab versus paclitaxel plus carboplatin and bevacizumab followed by maintenance bevacizumab in patients with stage IIIB or IV nonsquamous non-small-cell lung cancer. *J Clin Oncol* 2013; 31: 4349-4357.

28. Barlesi F, Scherpereel A, Rittmeyer A et al. Randomized phase III trial of maintenance bevacizumab with or without pemetrexed after first-line induction with bevacizumab, cisplatin, and pemetrexed in advanced nonsquamous non-small-cell lung cancer: AVAPERL (MO22089). J Clin Oncol 2013; 31: 3004-3011.
29. Barlesi F, Scherpereel A, Gorbunova V et al. Maintenance bevacizumab-pemetrexed after first-line cisplatin-pemetrexed-bevacizumab for advanced nonsquamous nonsmall-cell lung cancer: updated survival analysis of the AVAPERL (MO22089) randomized phase III trial. Ann Oncol 2014; 25: 1044-1052.

Figures

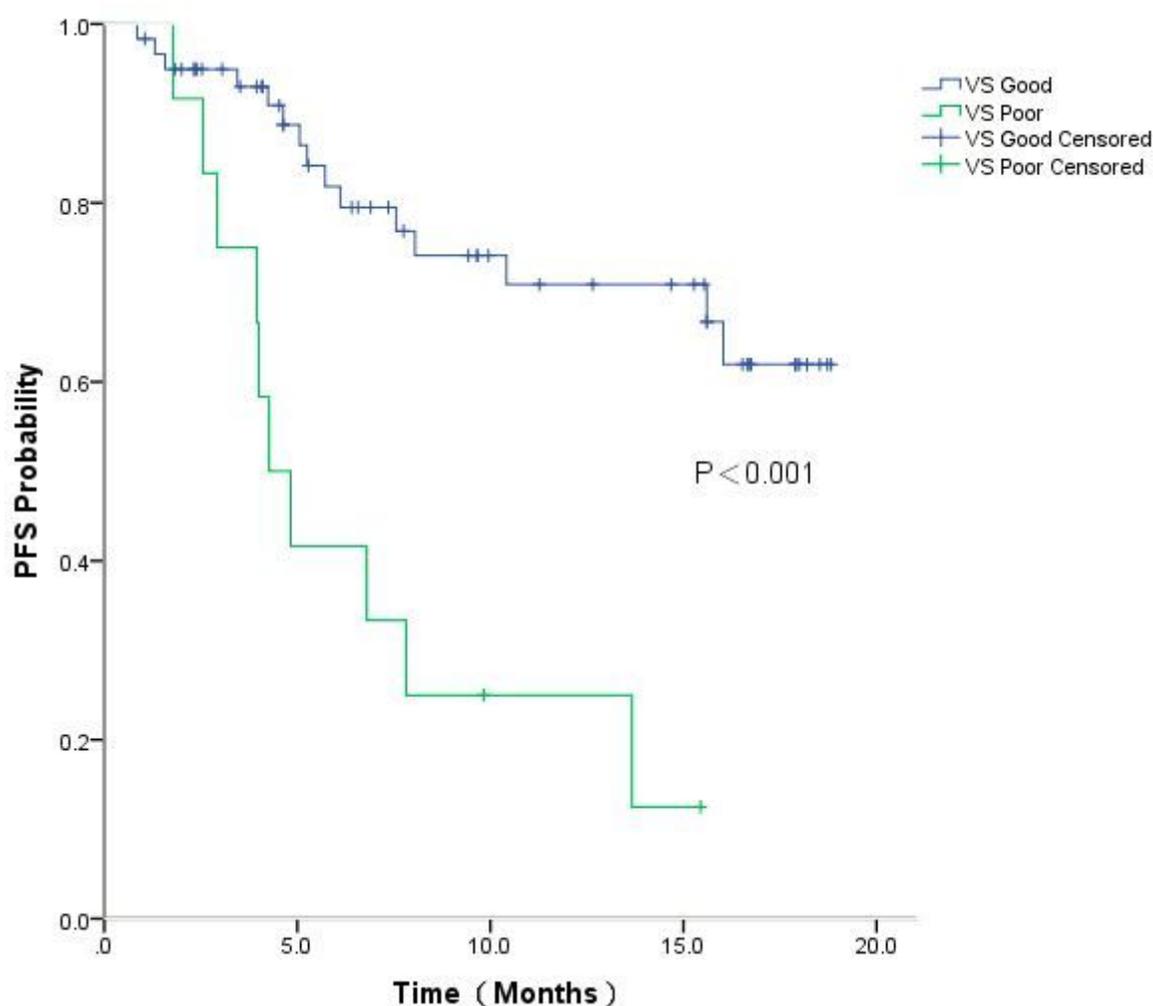


Figure 1

Progression-free Survival (PFS) by VS Classification for all patients

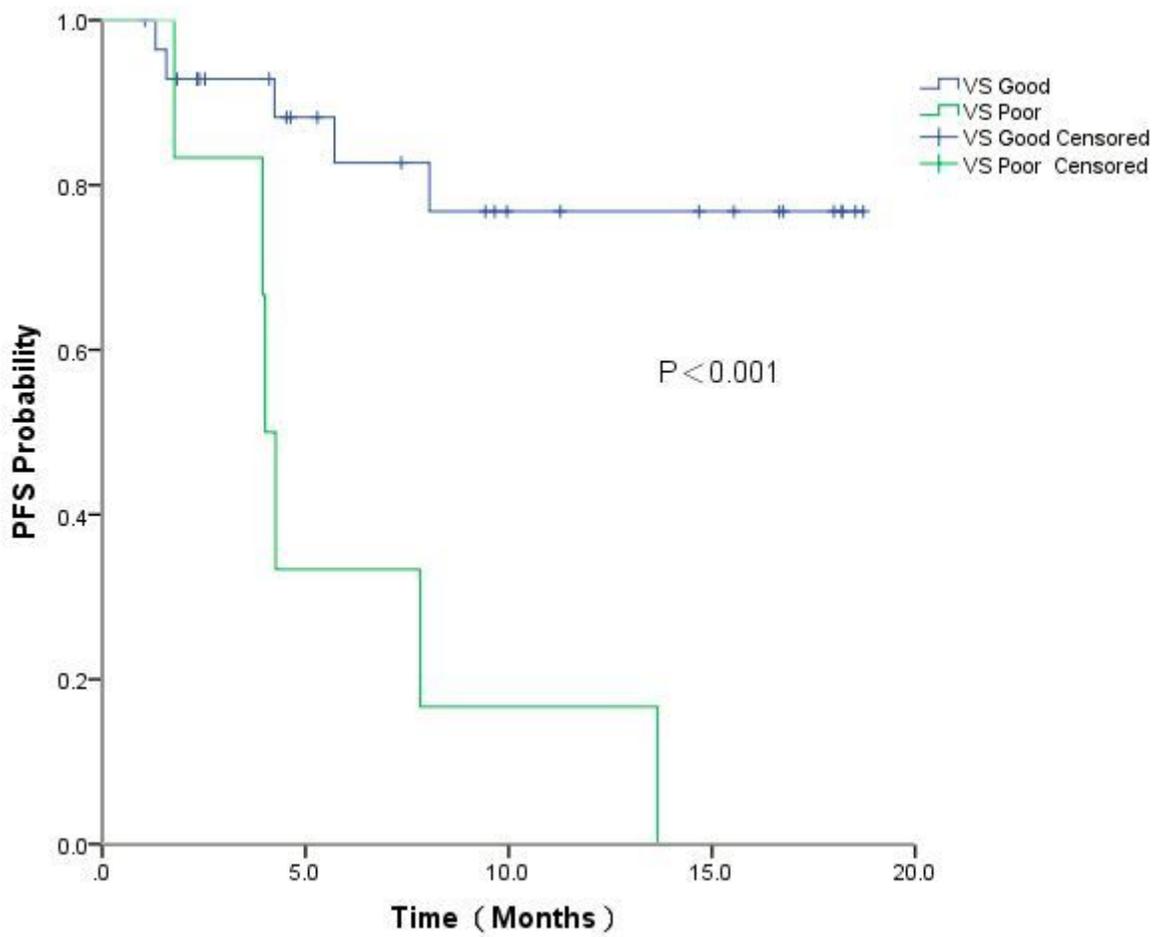


Figure 2

Progression-free Survival (PFS) by VS Classification for patients received chemotherapy alone

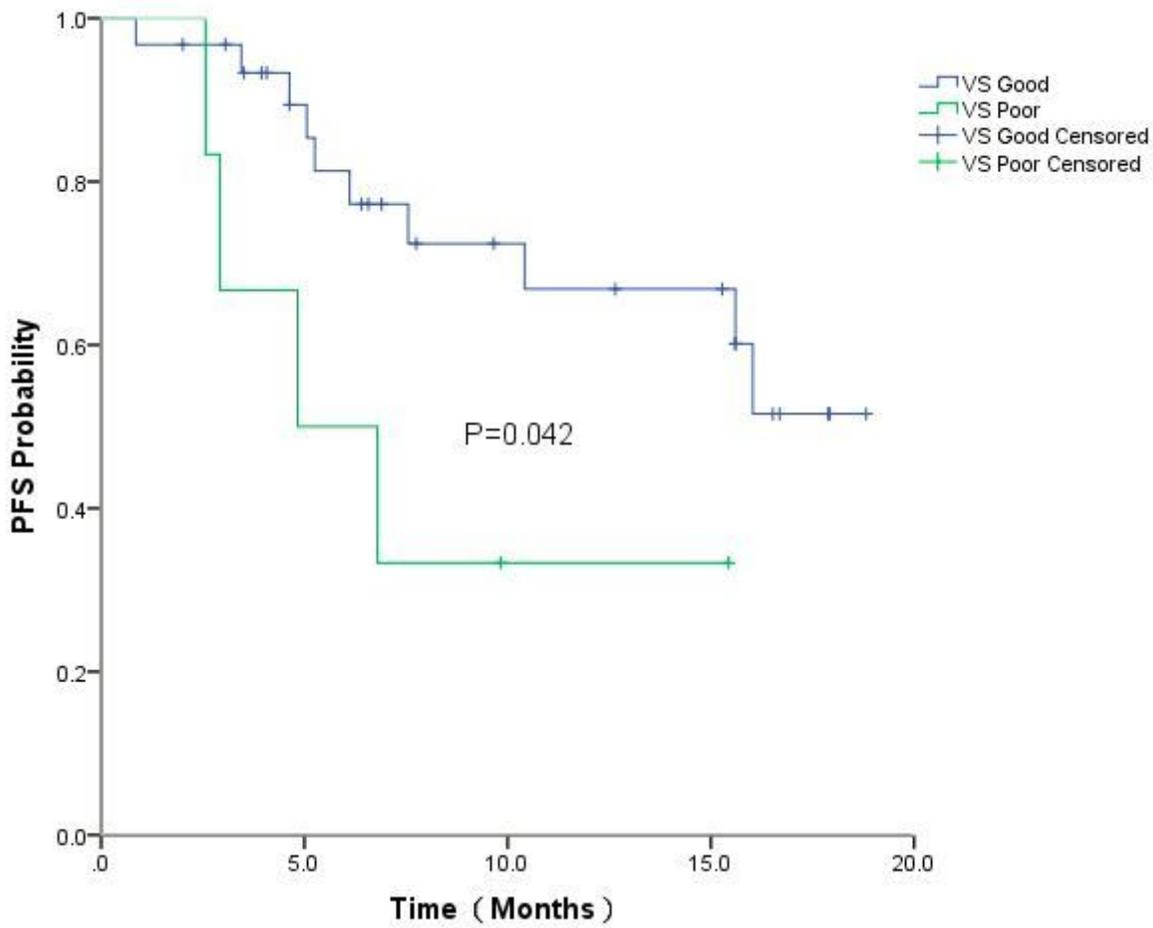


Figure 3

Progression-free Survival (PFS) by VS Classification for patients received chemotherapy and bevacizumab