

# Clinical Significance of Personalized Neoantigen Vaccine (G1-PES) for The Treatment of Various Types of Advanced Metastatic Cancer Patients in 2001 to 2014: Treatment Case Reports



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## Abstract

Immunopeptide therapy has provided significant clinical improvements in the treatment of several malignancies. The generation 1 personalized edited sequence (G1-PES) vaccine administered to 43 severe metastatic cancer patients (terminal stage), safely and effectively in Dr. Catanazaro's clinic in 2001 to 2014. These all patients were considered for 3 to 4 months life support with no hope. Patients were on G1-PES an 18-month therapy program with the objective of achieving remission and cancer free survival within 18 months. Typically, patients received 4 cycles every 12 weeks. The safety and efficacy were assessed through adverse events, progression-free survival (PFS), overall survival (OS) and other parameters. Patients that received G1-PES were free from any serious adverse effects (SAE's), while receiving and after therapy. Typical reactions included slight fever, flu-like symptoms for 1-2 days and rash at route of administration site that lasted for 2-3 days. All of these minor reactions were self-limiting. Patients had significantly improved quality of life within 1-3 weeks of receiving therapy, with dimini-

-shing symptoms associated with their cancer and clinical evidence of cancer regression ( $p < 0.001$ ). G1-PES vaccine was feasible and safe for patients with advanced metastatic cancer. G1-PES vaccine was designed based on T cell-mediated immune response targeting tumor neoantigens as antitumor efficacy.

**Key words:** Immunotherapy, Cancer, G1-PES (Generation-1 Personalized Edited Sequence), Neoantigen, personalized vaccine, peptide vaccine, advanced malignant tumor

## Introduction

Malignant tumors are associated with high levels of morbidity and mortality worldwide with a reported 18.1 million new cases of cancer and 9.6 million cancer-related deaths in 2018 (Bray et al., 2018). The use of immunotherapeutic personalized vaccine is highly safe, effective and no-toxic for patients with many different types of cancers (Yoshida K. et al., 2011). There is no toxicities has been reported against the short peptide immunotherapy and many papers have been published for the potency of such peptides. In recent years, several clinical trials demonstrated that neo-antigens can facilitate response to checkpoint inhibition (Guo et al., 2018), thus dramatically altering our view on the clinical potential of neo-antigens in cancer immunotherapy.

**Significance** | Neoantigen cancer vaccine is highly effective to treat the various types of cancer which is conducted in 2001 to 2014 at Health and Wellness Institute Integrative Cancer Treatment under the direction of Dr. Catanazaro and his team of physicians.

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As such, neo-antigens are used to specifically direct the immune response towards cancer cells, thus minimizing the risk of developing autoimmune reaction against a patient's healthy tissue (Wang et al., 2015). On the other hand, self-antigens are used as adjuvants to boost the immune response and increase the duration of the immunity, thus minimizing the dose of antigen needed (Guo et al., 2018; Khong et al., 2016). The best self-antigens are the proteins whose expression is upregulated in tumor cells compared to normal cells (Yarchoan et al., 2017).

Studies have shown that the recognition of neo-antigens is an important driver of the clinical efficacy for standard-of-care cancer immunotherapies, whether they be via T-cell checkpoint blockade and/or adoptive T-cell therapy (CAR-T) (Yarchoan et al., 2017; Peng et al., 2019). In fact, the relevance of personalized neo-antigens in tumor control and the biological properties of these antigens has been extensively studied (Yuryev and Catanzaro, 2019).

Crucially, recent technological advances can now be utilized to identify novel neo-antigens and to isolate T-cells that recognize them in individual patients (Yuryev et al., 2019a, Peng et al., 2019). Analysis and Selection of the high confidence autologous gene products and associated proteins with up-regulation of cancer and progressive metastatic disease is crucial in identification of related matched peptides as therapeutic end products in the treatment of cancer. This personalized neo-antigen design has been employed in clinical interventions and we have treated about 500 patients with this kind of design in Health and Wellness Institute Integrative Cancer Treatment (HWIIC).

In principle, the G1-PES vaccine showed a broad anti-tumor efficacy as neoantigen vaccine could not be limited to certain tumor type as long as appropriate tumor neoantigens were identified. In this paper G1-PES (Generation-1 Personalized Edited Sequence) vaccine demonstrated the anti-tumor efficacy of neoantigen vaccine in various types of advanced metastatic cancer. The results indicated G1-PES vaccine could elicit specific T cell activation and induce broad spectrum of anti-tumor effects, without limitation to tumor type.

### Case Presentation

This was an observation based clinical study at Health and Wellness Institute Integrative Cancer Treatment (HWIIC) in USA. In this study, we reported the post treatment effectiveness of the G1-PES vaccine. This study was a clinical treatment study in-house. The treatment was provided by the clinical practitioner based upon the patient diagnosis, approved by Internal Review Committee and Independent Ethics Committee and conducted in accordance with Declaration of Helsinki and the International Conference on Harmonization Guidelines for Good Clinical Practice. All patients had signed informed consent forms before

treatment. The primary endpoints of the treatment were safety and feasibility. And the secondary endpoints were efficacy based on PFS, OS and neoantigen-specific immune responses. The safety of the study was assessed on the basis of occurrence of adverse events (AEs). The feasibility of this observation study was assessed by whether neoantigen could be identified and the vaccines could be synthesized for clinical use.

The patients were (age 40 to 70 years old) terminal stage with extensive metastatic cancer who has been treated between 2001 to 2014 in HWIIC. These patients were found to have Breast Cancer, Colon Cancer, Prostate Cancer, Malignant Melanoma, Multiple Myeloma, Leiomyosarcoma, Non Small Cell Lung Carcinoma, Squamous Cell Carcinoma Neck, Lymphoma, Brain Cancer, Bladder Cancer, Astrocytoma, Ovarian Cancer, Schwannoma, Leukemia, Angiosarcoma, Esophageal Cancer and Liposarcoma (Table 1). A positron emission tomography (PET) scan in February 2014 did not show any evidence of malignancy.

The patients were received daily 1 mg of G1-PES for 21 days in each cycle in total of 4 cycles over an 18 month period. We have reported for 43 patients who showed significant improvement in disease states. G1-PES comprised of 16~20 short length amino acid peptides. The peptides were pooled as single pool (based on HLA typing, affinity and allele frequency) and then injected subcutaneously (s.c.) at a quantity of 1 mg per peptide in upper arms and para-umbilical area respectively. Patients were scheduled to receive G1-PES with Poly ICLC, or MF59 (46 µg) as adjuvant for 21 days (i.e. 1st cycle), in total of four cycles over an 18 months period. PBIMA-G1-PES was developed by Dr. Catanzaro and his team through Harvard / Dana Farber Proteomics Bioinformatics Laboratories and NeoBioLabs in Boston. The design for patients is true personalization based upon the patient's cancer diagnosis in 2001 to 2014.

Clinical assessment, monitoring and follow-up during the treatment were conducted, including physical examination, ECOG performance, vital sign, blood test, urinalysis to assure the safety of each immunization; imaging examination at baseline and approximately every 4 months post-vaccination to assess clinical efficacy; and serum electrophoresis (antibodies), inflammation markers, cancer biomarkers (tumor antigens), flow cytometry (T cell subsets and cytokines) conducted pre-treatment and every 8-12 weeks after treatment for the detection of specific immune response. The related adverse events (AEs) were recorded and graded for safety evaluation according to the National Cancer Institute Common Terminology Criteria for Adverse Events (version 4.0) throughout whole treatment period.

### Design of G1-PES personalized neoantigen vaccines

To identify mutations derived neoantigens, some tumor tissues and blood samples were obtained from cancer patients by surgery, biopsy or intravenous blood sampling with proteomics,

bioinformatics and HLA compatibility. In case of unavailability of tumor fresh sampling, formalin-fixed paraffin-embedded (FFPE) samples were used instead.

The bioinformatics analysis, which consists of proteomics sequencing of normal tissue/cells and tumor cells and urine for neoantigen's precision mapping, HLA affinity binding, prediction, ranking and selection, was performed by PBIMA/G1-PES formula. The personalized neoantigen peptides were manufactured in the cGMP facility standard (bacteria-free, TFA free, >95.0% purity and quantities of bacterial endotoxin less than 1EU/mg) using chemical synthesis. The solubility of peptides was determined during synthesis to select the best diluent for vaccine pool.

## Results

The results of G1-PES is shown below after receiving treatment. The treated patients showed average,  $58.37 \pm 32.25\%$  tumor regression after treatment (**Figure 1**) without any adverse effect (Table 2). The average extended survival was recorded  $5.78 \pm 2.7$  years in overall cancer patients (**Figure 2**). The result showed average,  $7.3 \pm 2.5$  score for quality of life in overall cancer patients on the 10-points scoring scale (**Figure 3**). Among 43 patients, 14 patients showed 100% tumor regression. While majority of the other patients displayed tumor regression in a range between 40 to 80%. Among all the types of cancers treated, lymphoma patients showed significantly ( $p < 0.001$ ) highest response with  $90.0 \pm 14.1\%$  tumor regression followed by the prostate cancer patients ( $p < 0.01$ ) with  $80.0 \pm 28.3\%$  tumor regression. The patients with squamous Cell Carcinoma of Neck ( $65.0 \pm 49.5\%$ ), multiple myeloma ( $60.7 \pm 31.7\%$ ), malignant melanoma ( $68.8 \pm 37.5\%$ ) and breast cancer ( $50 \pm 24.5\%$ ) showed moderate tumor regression response (**Figure 4**). The patients with non-small cell lung carcinoma ( $40.0 \pm 0.0\%$ ) and colon cancer ( $42.0 \pm 36.3\%$ ) showed statistically significant ( $p < 0.1$ ) tumor regression effects (**Figure 5**). Whereas, the patients with leiomyosarcoma ( $26.7 \pm 11.5\%$ ) and brain cancer ( $25.0 \pm 0.0\%$ ) showed mild tumor regression effects. Among all the cancer types treated, patients with lymphoma demonstrated significantly ( $p < 0.005$ ) highest extended survival rate of  $6.0 \pm 5.7$  years (**Figure 6**). Whereas, the other types of cancer showed a range between 1.5 to 3.9 years of extended survival. Among all the different types of cancer patients treated, the patients with lymphoma demonstrated significantly ( $p < 0.001$ ) improved quality of life with  $10.0 \pm 0.0$  scores (**Figure 7**). Similarly, the patients with squamous cell carcinoma of neck showed  $9.0 \pm 0.0$  score and the breast cancer patients showed  $8.6 \pm 0.5$  scores for quality of life. Patients with the other cancer types also demonstrated statistically significant improvement in quality of life with the score range between 6 to 7.5. However, the patients with brain cancer showed mild improvement in quality of life with a score of  $4.5 \pm 0.7$ . All the patients with lymphoma and squamous cell carcinoma of neck

demonstrated complete regression of tumor without recurrence. Whereas, 20 to 50% of patients with other cancer type showed recurrence of tumors after stopping the therapy (Table 2, **Figure 8**).

## Discussion

We have directly shown the ability of G1-PES vaccine, precision personalized immunotherapy to target different types of cancer patients. We have the list of over 500 patients who received this personalized therapy under their consent from 2001 to 2014 at the Dr. Catanzaro's clinic HWIIC and his treatment protocol. There were no serious adverse events experienced by any of the patients in these studies which have demonstrated the safety and efficacy of this personalized vaccine.

The Health and Wellness Institute Integrative Cancer Treatment (HWIIC) and Cancer Research Group in Seattle administered individualized isolated immunopeptides to more than 500 cancer patients, safely and effectively, as a form of adjunctive treatment in cooperation with other conventional treatments required by the patient's oncologist.

Patients in HWIIC were on an 18-month therapy program with the objective of achieving remission and cancer free survival within 18 months. Typically, patients received 4 cycles of their own isolated immunopeptides every 12 weeks. These peptides can be administered orally, intranasally and sublingually; routes of administration are determined by the scope of practice criteria.

Patients that received their own immunopeptides were free from any serious adverse effects (SAE's), while receiving and after therapy. Typical reactions included slight fever, flu-like symptoms for 1-2 days and rash at route of administration site that lasted for 2-3 days. All of these minor reactions were self-limiting. Patients had significantly improved quality of life within 1-3 weeks of receiving therapy, with diminishing symptoms associated with their cancer and clinical evidence of cancer regression. In accordance with our findings, recent clinical studies on neoantigens personalized vaccine demonstrate that it is an effective anti-cancer treatment that helps to improve vitality and quality of life of cancer patients who are failed on conventional therapy, chemotherapy, surgery and radiotherapy. The data shows complete tumor regression, with progression free survival of patient (Ott et al., 2017; Chen et al., 2019). The neoantigen personalized vaccination showed a low risk and incidence of SAEs in other study with 500 advanced cancer patients, including 174 prostate, 74 colon, 51 pancreatic and 43 gastric cancer patients (Yoshida K. et al., 2011). Moreover, favorable immune effects were observed with administration of personalized cancer peptide vaccines which included disease stability.

Table 1 | Demographic and disease characteristics at baseline

Characteristics	Patients (N=43)
<b>Age (yr)</b>	
Mean	59±10
Range	40-70
<b>Age category-no. (%)</b>	
≥ 50 yrs.	16
≤ 50 yrs	6
<b>Sex-no. (%)</b>	
Male	13 (30%)
Female	30 (70%)
<b>Metastatic sites-no. (%)</b>	
Bone	80%
Blood	90%
Brain	55%
Liver	75%
Lung	75%
Mediastinum	75%
<b>ECOG performance-status score-no. (%)*</b>	
0	0
1	43
<b>Radiotherapy-no. (%)</b>	
Yes	70%
No	30%
<b>Lines of prior systematic therapy-no. (%)</b>	
30	75%
13	25%
<b>Tumor type-no. (%)</b>	
Breast Cancer (Female)	7
Colon Cancer (three Female, two Male)	5
Prostate Cancer (Male)	5
Malignant Melanoma (two Male, two Female)	4
Multiple Myeloma (one Female, two Male)	3
Leiomyosarcoma (one Male, two Female)	3
Non Small Cell Lung Carcinoma (Female)	2
Squamous Cell Carcinoma Neck (Male)	2
Lymphoma (Male)	2
Brain tumor (Female)	2
Bladder Cancer (Male)	1
Astrocytoma (Female)	1
Ovarian Cancer (Female)	1
Schwannoma (Female)	1
Leukemia (Female)	1
Angiosarcoma (Female)	1
Esophageal Cancer (Male)	1
Liposarcoma (Female)	1

\*Eastern Cooperative Oncology Group (ECOG) performance-status scores range from 0 to 5, with 0 indicating no symptoms and higher scores indicating increasing disability.

Table 2 | Treatment related AEs in all treated patients

	Patients			
	Any Grade		Grades 3 to 4	
	No.	%	No.	%
<i>Any AE</i>	0	0	0	0
<i>Fatigue</i>	2	0	0	0
<i>Chill</i>	2	0	0	0
<i>Slight-Fever</i>	2	0	0	0
<i>Emesis</i>	0	0	0	0
<i>Muscle soreness</i>	3	0	0	0
<i>Injection site reaction</i>	3	0	0	0
<i>Dizzy</i>	0	0	0	0
<i>Nausea</i>	0	0	0	0
<i>Upper gastrointestinal heamorrhage</i>	0	0	0	0
<i>Lose weight</i>	0	0	0	0
<i>Acute allergic reaction</i>	0	0	0	0

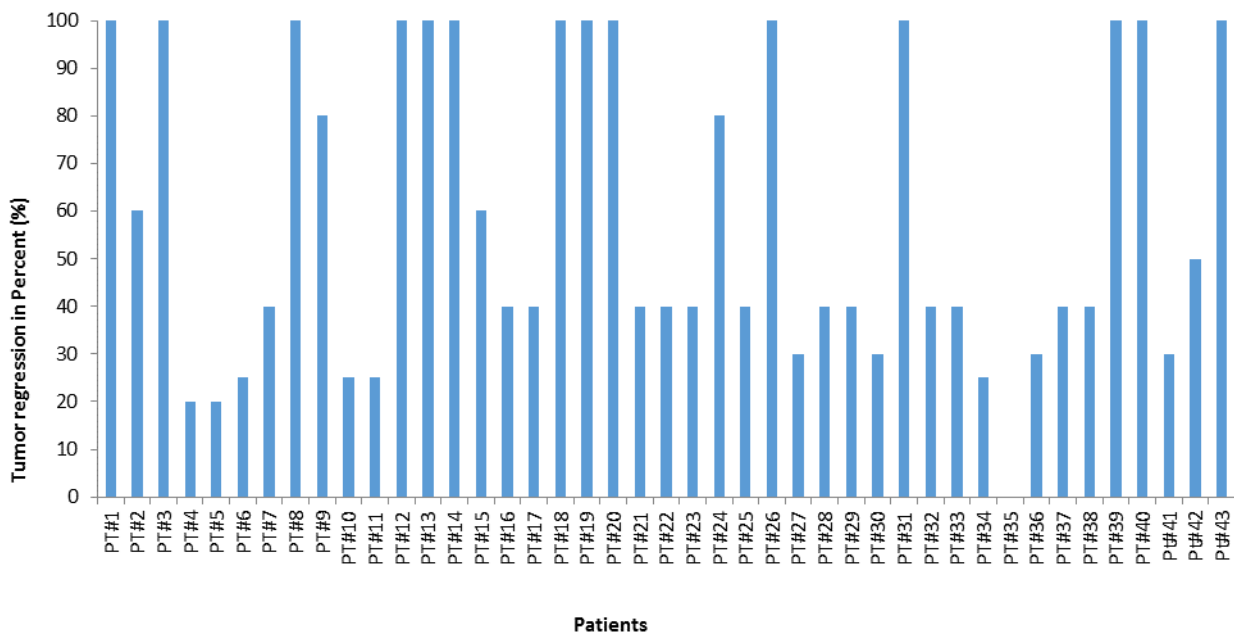


Figure 1 | Summary of treatment outcome from personalized treatment with G1-PES

Table 3 | Percentage of tumor regression in patients.

No. of Patients	Tumor Regression
14	100%
2	80%
2	60%
1	50%
14	40%
4	30%
4	25%
2	20%

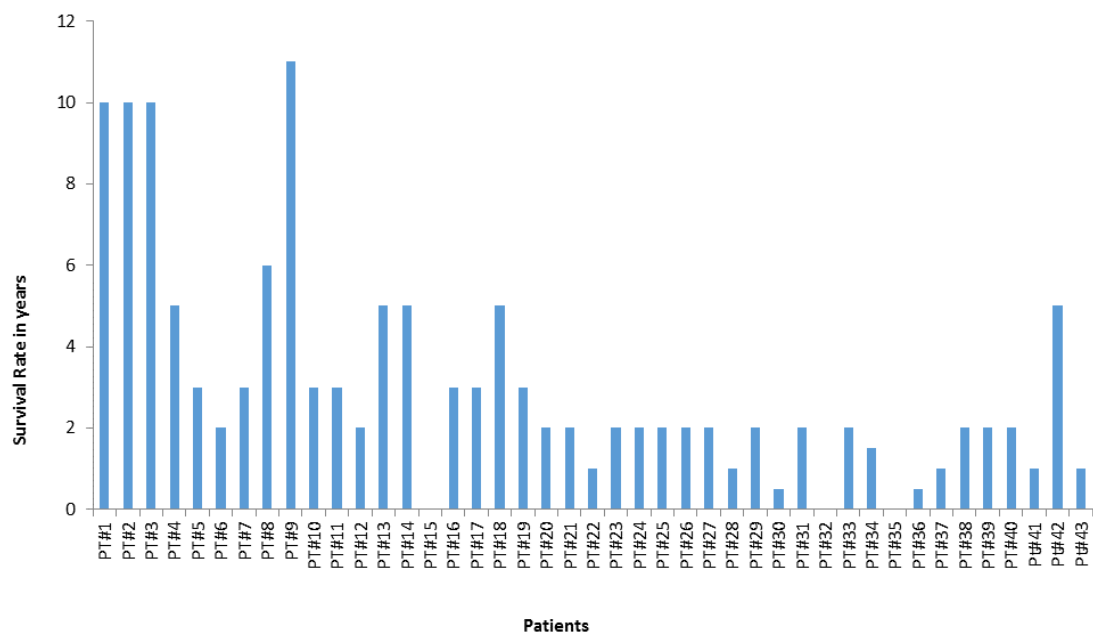


Figure 2 | Comparing the extended survival in patients

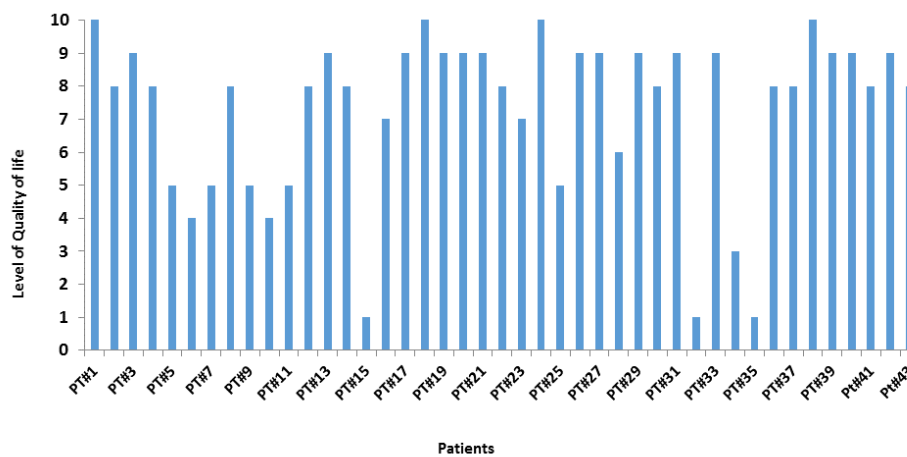


Figure 3 | Comparing Quality of Life in Patients (10 point scale)

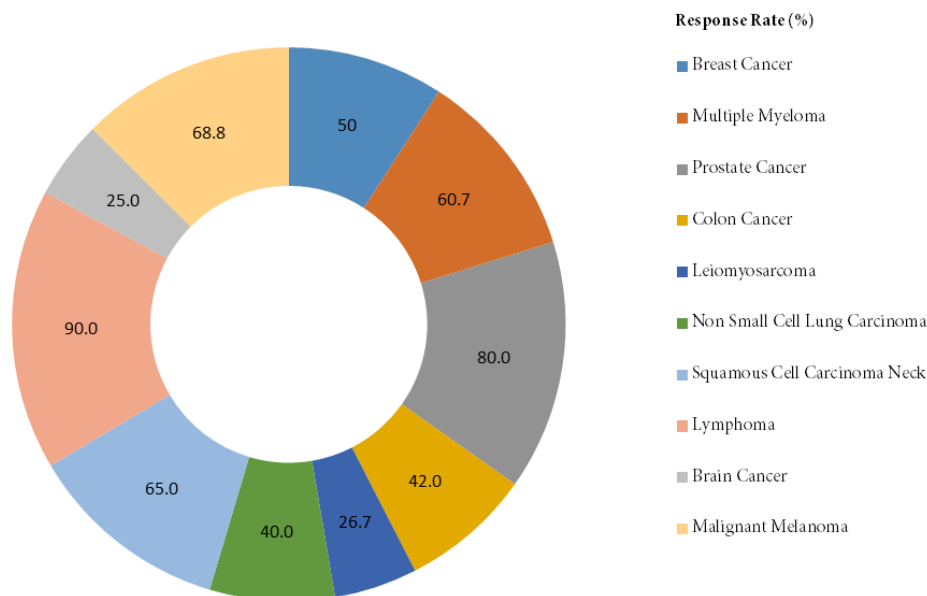


Figure 4 | Differential Response of Different Cancer Types to G1-PES Therapy

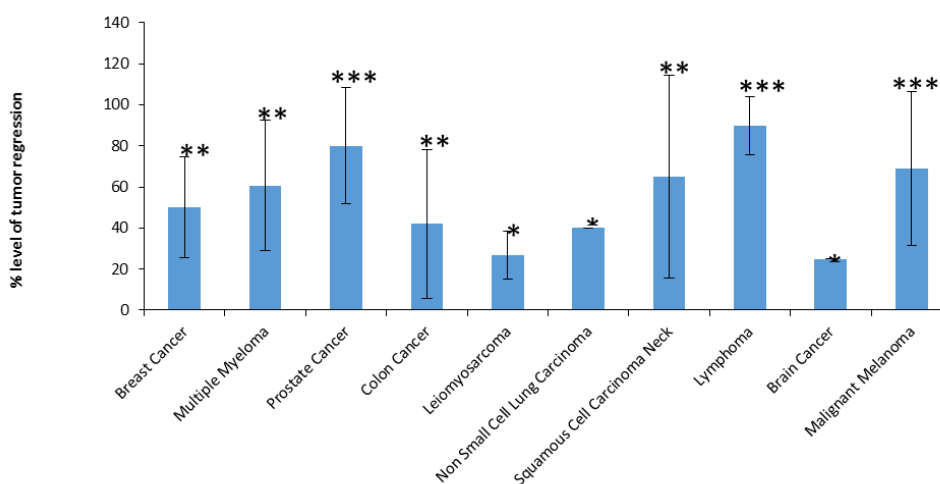


Figure 5 | Tumor Regression Effect of G1-PES on Different Tumor Types. G1-PES demonstrated  $58.37 \pm 32.25\%$  tumor regression in overall cancer patients.

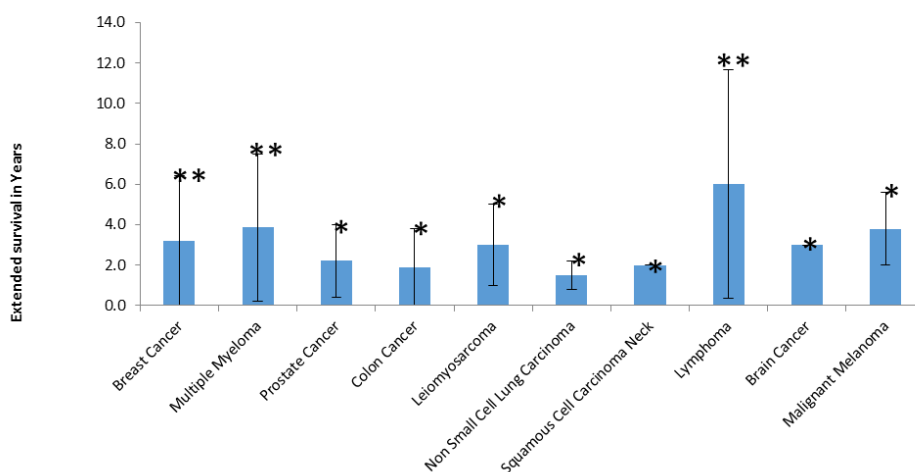


Figure 6 | Extended Survival of patients in years. G1-PES showed  $5.78 \pm 2.7$  years of extended survival in overall cancer patients.

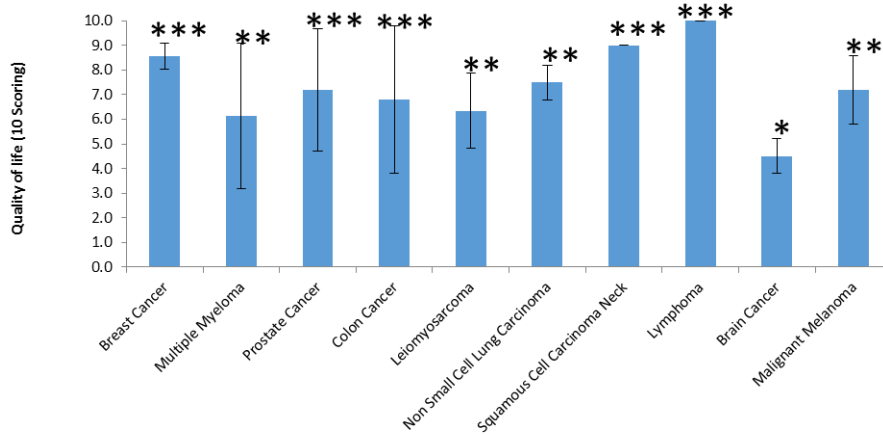


Figure 7 | Quality of life of patients based on extended survival. G1-PES treated patients scored  $7.3 \pm 2.5$  for quality of life on the 10-points scoring scale.

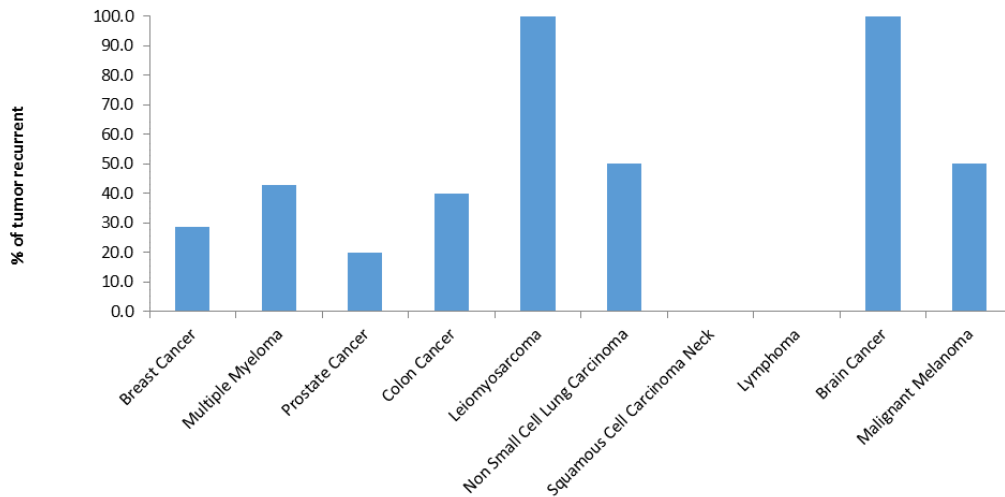


Figure 8 | Tumor Recurrence after G1-PES Therapy



Patients had follow-up evaluations within 12 weeks on clinical progress through serology, specialized imaging (PET/MRI). Within 12 weeks of initiating treatment, patients typically were 65% improved overall. Additional modalities were administered including and not limited to mind body energy, dietary, nutraceutical/bioceutical supplementation, physical and manual modalities, intravenous modalities including sodium bicarbonate (<http://cancerres.aacrjournals.org/content/69/6/2260>), DMSO, vitamin C and UV treatment in the therapy design along with the immunopeptides and are not contraindicated. Therapeutic modalities are defined and determined by the scope of practice criteria.

Patients receiving chemotherapy did not receive immunopeptides on days that they were receiving chemotherapy. Peptides were administered 2 days prior to chemotherapy administration and when patients were on aggressive daily chemotherapy cycles, immunopeptides were administered during a break in the chemotherapy treatment cycle.

Pharmacokinetic actions of personalized peptides are best seen by direct injection subcutaneously, intranodal, intravenously, intratumoral and intranasal for direct absorption and metabolism. Oral administration is not an optimal delivery due to alteration of peptide integrity by gastric and digestive activity of the gastrointestinal tract.

This case report has demonstrated the feasibility, safety and efficacy of G1-PES on patients with various types of advanced solid tumors. G1-PES monotherapy might show its efficacy through neoantigen-specific T cell response, high T cell infiltration into tumors and remodel tumor-immune microenvironment alone, suggesting its great potential as cancer immunotherapy. It is probably due to the fact that, G1-PES treatment can result in tumor necrosis, which will become an immunogenic source, providing pro-inflammatory signals (McGahan et al., 1992; Widenmeyer et al., 2011). After RFA, it may activate and/or generate a large amount of IFN- $\gamma$  and/or neoantigen, while improving the expression of other co-stimulating factors and the presenting of tumor antigen to T cells. This report provides proof-of-principle that a G1-PES vaccine can be produced and administered to a patient to generate highly specific immune responses against that individual's tumour. Additionally, the efficacy of G1-PES might be CD8+ and CD4+ T cells mediated tumour cell apoptosis (Tran, E. et al. 2014); Schumacher, T. et al. 2014) using the short peptides in the vaccine, leading to activation of both CD8+ and CD4+ T cells against tumor cells. Importantly, the proportion of tumour neoantigens inducing a T-cell response after vaccination might be due to non-antigen-directed immunotherapy, such as checkpoint blockade or tumour-infiltrating lymphocyte Therapy (Van Rooij et al. 2013; Rizvi et al. 2015; Linnemann et al. 2015; Prickett et al. 2016). Thus,

in agreement with a reported melanoma study showing T-cell responses to a dendritic-cell-based neoantigen vaccine (Carreno et al. 2015), this case report demonstrates that a personal neoantigen vaccine broadens the repertoire of neoantigen-specific T cells substantially beyond what is induced by existing immunotherapeutics.

### Conclusion

The treatment significance of G1-PES in terms of overall survival and progression-free survival has been reported. This is the first case report of multiple cancer patient in which G1-PES immunotherapy was evaluated with favorable antitumor response. In Conclusion, A summary of a random group of the patients treated shown significant efficacy for G1-PES. Among 43 patients, 14 patients showed 100% tumor regression. Majority of the other patients displayed tumor regression in a range between 40 to 80%. Patients with lymphoma, prostate cancer, malignant melanoma, squamous cell carcinoma of neck and multiple myeloma demonstrated more pronounced response rate, tumor regression, extended survival life and improved quality of life. All the patients with lymphoma and squamous cell carcinoma of neck demonstrated complete regression of tumor without recurrence. However, 20 to 50% of patients with other cancer type showed recurrence of tumors after stopping the therapy.

### Author Contribution

M.S.S.K. wrote and revised the manuscript, A.Y., J.C. has reviewed the manuscript and M.K.A.B has analysed the clinical data and statistics.

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### Competing financial interests

The author(s) declare no competing financial interests.

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