

FIGURE 3. Clinical courses of patient 2. Serum levels of CEA and CA19-9 were inversely associated with the severity of chronic graft-versus-host disease (cGVHD).

lesions in the liver and the lungs. The pulmonary lesions were defined as measurable targets. After engraftment on day 10, she developed maculopapular rash on the trunk on day 20, which was histopathologically diagnosed as grade II acute GvHD. Mild but significant disease progression was detected on the follow-up CT scan on day 30 (Fig. 4). Because the cutaneous GvHD had resolved spontaneously by day 45, we started tapering of cyclosporine from day 50. The follow-up CT scans of the chest on day 60 showed a significant decrease in the size of target lesions. Thereafter, lung metastatic lesions progressed gradually again after the disappearance of acute GvHD, and donor lymphocyte containing 6.4×10^7 /kg CD3+ cells were infused on day 181. She developed extensive chronic GvHD involving the skin and the lung, and size of the metastatic lesions decreased again. As of March 2004 (17 months after RIST), the best and final responses are both PR. Serum levels of CEA and CA19-9 were inversely associated with the development of GvHD (Fig. 5).

Patient 4

A 52-year-old woman with advanced colon cancer received RIST from an HLA-identical sibling in January 2003. Her multiple metastatic lesions included the liver, the lung,

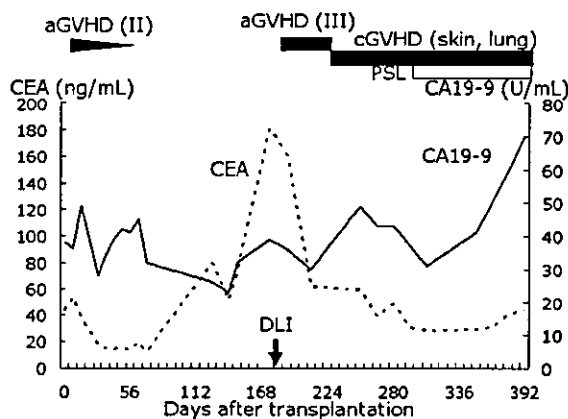


FIGURE 4. Evaluation of metastatic lesions in the lung of patient 3. Repeated computed tomography scans of the chest showed that metastatic lesions shrank after the development of GvHD.

the peritoneal, multiple lymph nodes, and the residual colon. Liver metastases and lymph nodes were defined as measurable lesions. New metastatic lesions appeared in the lung on day 60, and the best response was PD. We tapered cyclosporine rapidly to enhance a GvT effect. With the development of grade II skin GvHD on day 38, the metastatic lesion of the supraclavicular lymph node decreased in size, and serum levels of CEA and CA19-9 decreased (Table 1). She was stable until day 88, when she accidentally fell on the floor. She suffered from fatal head injury. An autopsy revealed complete disappearance of the metastatic lesion in the supraclavicular lymph node. The other lesions were stable in size. The final response was PD.

DISCUSSION

Allo-SCT has a considerable risk of transplant-related mortality. Development of optimal preparative regimens for colorectal cancer is an important issue for future clinical trials. With RIST procedure, all of the four patients achieved durable engraftment within 30 days of transplant. These findings suggest that our reduced-intensity regimen is sufficient to assure engraftment in RIST for metastatic colorectal cancer. Because most patients with advanced colorectal cancer are heavily treated with chemotherapeutic agents such as fluorouracil and irinotecan (24), the risk of graft rejection will be low compared with other solid tumors, which are rarely treated by cytotoxic agents.

RRT should be critically evaluated in developing allo-SCT. All of our patients had been treated heavily by surgery or cytotoxic chemotherapy before RIST. However, we demonstrated that RRT was mild in all the organs and that all the patients tolerated the procedure well. Grade 3 to 4 toxicity according to the Bearman's criteria (25) were not observed in any patients. We omitted the use of methotrexate to enhance a GvT effect. Because methotrexate causes mucosal damages, this might have contributed to the amelioration of gastrointestinal damages in this study. Our experience indicates that fludarabine/busulfan-based preparative regimens are safe and tolerable for patients with advanced colorectal cancer.

Concerning the efficacy of RIST for colorectal cancer, all the patients showed some evidence of antitumor effects. Serum levels of CEA and CA19-9 decreased significantly, either after engraftment (patient 1) or development of GvHD (patient 2 and 3). There might be a debate as to whether serum levels of CEA and CA19-9 can be reliable surrogate markers of treatment response (26). However, one patient (patient 3) achieved durable PR (23). In another patient (patient 1), postmortem examination showed marked reduction of the tumor size. Although patient 4 had supraclavicular lymph node, this lesion disappeared after development of acute GvHD. Although different conditioning regimens and GvHD prophylaxis methods were used in this study, these findings indicate that allo-SCT is promising for metastatic colorectal cancer.

We have demonstrated the feasibility of allo-SCT for colorectal cancer; however, there are some problems to be discussed. First, the precise mechanism of the GvT effect on solid tumors including colorectal cancer remains unknown. Disease regression associated with cyclosporine withdrawal, complete donor chimerism, and GvHD provides evidence

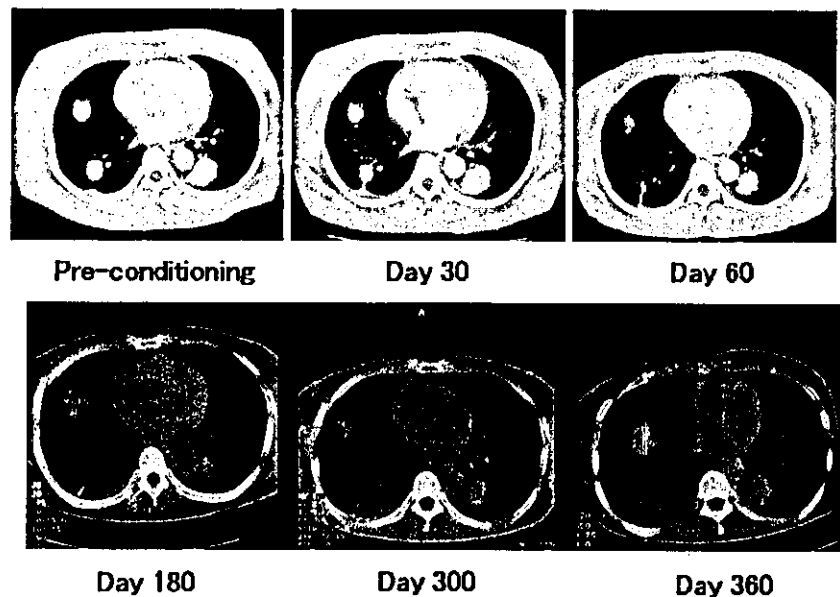


FIGURE 5. Clinical courses of patient 3. Serum levels of CEA and CA19-9 decreased after the development of GvHD.

that cytotoxic donor T cells play an important role in GvT effects. Recent studies on RIST for RCC have suggested that distinct T-cell populations recognizing tumor-specific antigens or minor histocompatibility antigens are involved in the GvT effect (27–29). Despite our attempt to detect anti-CEA-specific cytotoxic T lymphocyte by enzyme-linked immunosorbent spot assay, the laboratory system using HLA-A24-restricted peptides has not been established. Our effort to establish the system continues. Cloning of cytotoxic T cells and identification of target minor antigens are essential in the development of RIST for colorectal cancer. On the other hand, some investigators suggested that the local cytokine storm associated with the early phase of allogeneic transplantation plays an important role in GvHD (30). Furthermore, it is interesting that tumor markers declined promptly after engraftment in patient 1, suggesting the existence of an anticolorectal cancer mechanism other than the GvT effects associated with GvHD. Allo-SCT using CD34-positive cell selection lowered the possibilities of subclinical GvHD immediately after engraftment. The GvT effect is thus unlikely to be associated with GvHD. The simultaneous decline in CEA might be attributable to a cytokine storm or immune dysregulation associated with engraftment.

Second, we should identify what types of cancer respond to alloimmunity. RCC, which is believed to be immunogenic, is promising in allogeneic immunotherapy (15). Cancers derived from the target organs of GvHD such as colorectal cancer (31) and cholangiocellular carcinoma are also promising. Because allogeneic immune responses lead to epithelial damage of the gastrointestinal tract, colorectal cancer should reasonably respond to alloimmunity. Another supporting observation is that T-cell sensitization for GvHD occurs close to the Peyer's patch to induce strong allogeneic immune responses in the colon (32). Although few reports have been published on RIST for colorectal cancer, the report by Hentschke et al. (31) and the present study showed the association between GvHD and GvT effects in this cancer.

Third, we should establish the evaluation methods of treatment response after allo-SCT, which might be different from those after chemotherapy (33). The evaluation of immunotherapy frequently involves tumor markers. Because reliability of serum tumor markers is questionable (34), we recommend introducing the RECIST criteria to immunotherapy, thus enabling a comparison with chemotherapy. There are some controversies concerning the reliability of RECIST criteria in the response evaluation after cytotoxic chemotherapy against gastrointestinal tumors (23, 35, 36), and its application to immunotherapy requires careful consideration (33). In the RECIST criteria, pretreatment measurable lesions are identified, and their sum of longest diameters is compared before and after treatment. Even without enlargement of any of the measurable lesions, the emergence of a new lesion indicates PD, as shown in patient 4. This evaluation method is reasonable in chemotherapy, which has a prompt posttreatment response and transient effect. However, RIST requires several months until manifestation of efficacy, which may continue long after RIST (15). The longer duration until efficacy develops is problematic in progressive solid tumors. The tumor progression early after RIST occurs by nature, as shown in patient 3 and 4, until explicit treatment effect several months later. If the RECIST is applied in such cases, the evaluation results are PD. How can we evaluate cases with early progression and subsequent regression simultaneously with GvHD down to the preRIST size? Physicians involved in RIST have the impression that RIST has altered the natural disease progression and therefore has been effective. In contrast, most oncologists would believe PD. The integration of the evaluation concepts between RIST physicians and oncologists is an important and challenging issue. The ultimate goal of survival should be evaluated as a primary endpoint in a phase III trial.

Last, the development of tumor-specific treatments is warranted. At present, with the high probability of GvT effects in concert with GvHD, we permit GvHD symptoms to

TABLE 1. Tumor responses and outcomes

No	Age/Sex	Metastatic lesions	CEA (ng/ml)		CA19-9 (U/ml)		Tumor response according to RECIST ^a		Postmortem examination	Outcomes	
			Pretransplant	Maximum	Minimum	Pretransplant	Maximum	Minimum			Maximum
1	44/M	Peritoneum	45.7	131	25.9	1388	2507	90	NA ^b	Reduction of peritoneal metastasis	Died of GVHD on day 62
2	52/F	Lung, liver	10360	10640	4175	5340	15150	3950	SD	NA	Died of PD on day 178
3	59/F	Lung, liver	48.6	181	12.4	38	70	23	PR	NA	Alive on day 390
4	52/F	Lung, liver, peritoneum, colon	9.3	14.2	6.8	158	529	219	PD ^c	Disappearance of lymph node metastasis. The other lesions remained stable ^d	Died of accident on day 88

^a Tumor responses were defined according to the RECIST criteria. The lesions were evaluated monthly using CT scans.

^b The patient had no measurable lesions.

^c New lesions appeared in the chest CT on day 60, leading to the diagnosis of PD.

^d The lesion of left supraclavicular lymph node shrunk with the development of acute GVHD. No lesion was found at postmortem examination. GVHD, graft versus host disease; NA, not applicable; PR, partial response; PD, progressive disease.

some extent to maintain clinical efficacy of RIST. We may even modify the criteria for initiation of GvHD treatment (37). However, GvHD increases morbidity and mortality, leaving this method difficult in elderly patients (38). The problem might be overcome with an adjuvant tumor-specific immunotherapy (39), ex vivo priming of donor lymphocytes against tumor cells (40), use of highly immunosuppressive conditioning regimens (41), and the protection of GvHD target organs using cytokines (42).

In conclusion, the present study suggests the promising results of RIST in colorectal cancer. Because GvT effects are likely to be associated with GvHD, the optimization of conditioning regimens and GvHD management are necessary through phase II trials in colon cancer. Along with studies on GvT effects, the development of specific treatments, separate from GvHD, are needed.

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Research

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Clinical response in Japanese metastatic melanoma patients treated with peptide cocktail-pulsed dendritic cells

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Abstract

Background: Metastatic, chemotherapy-resistant melanoma is an intractable cancer with a very poor prognosis. As to immunotherapy targeting metastatic melanoma, HLA-A2⁺ patients were mainly enrolled in the study in Western countries. However, HLA-A24⁺ melanoma patients-oriented immunotherapy has not been fully investigated. In the present study, we investigated the effect of dendritic cell (DC)-based immunotherapy on metastatic melanoma patients with HLA-A2 or A24 genotype.

Methods: Nine cases of metastatic melanoma were enrolled into a phase I study of monocyte-derived dendritic cell (DC)-based immunotherapy. HLA-genotype analysis revealed 4 cases of HLA-A*0201, 1 of A*0206 and 4 of A*2402. Enriched monocytes were obtained using OptiPrep™ from leukapheresis products, and then incubated with GM-CSF and IL-4 in a closed serum-free system. After pulsing with a cocktail of 5 melanoma-associated synthetic peptides (gp100, tyrosinase, MAGE-2, MAGE-3 and MART-1 or MAGE-1) restricted to HLA-A2 or A24 and KLH, cells were cryopreserved until used. Finally, thawed DCs were washed and injected subcutaneously (s.c.) into the inguinal region in a dose-escalation manner.

Results: The mean percentage of DCs rated as lin⁺HLA-DR⁺ in melanoma patients was 46.4 ± 15.6%. Most of DCs expressed high level of co-stimulatory molecules and type1 phenotype (CD11c⁺HLA-DR⁺), while a moderate number of mature DCs with CD83 and CCR7 positive were contained in DC products. DC injections were well tolerated except for transient liver dysfunction (elevation of transaminases, Grade I-II). All 6 evaluable cases except for early PD showed positive immunological responses to more than 2 melanoma peptides in an ELISPOT assay. Two representative responders demonstrated strong HLA-class I protein expression in the tumor and

very high scores of ELISPOT that might correlate to the regression of metastatic tumors. Clinical response through DC injections was as follows: 1 CR, 1 PR, 1 SD and 6 PD. All 59 DC injections in the phase I study were tolerable in terms of safety, however, the maximal tolerable dose of DCs was not determined.

Conclusions: These results suggested that peptide cocktail-treated DC-based immunotherapy had the potential for utilizing as one of therapeutic tools against metastatic melanoma in Japan.

Background

Despite many attempts in the last few years to target cancer-specific antigens, a breakthrough in terms of clinical response has yet to be achieved mainly because of a scarcity of effective genuine cancer antigens, immunological evasion, or an immunosuppressive state.

Melanoma-associated antigens are categorized as class I human leukocyte antigen (HLA)-restricted cancer/testis antigens [1] which are considered to be tolerable to the immune system because they are also expressed in normal tissues. However, malignant melanoma is the most well known cancer in which multiple tumor-specific antigens have been defined and utilized in vaccination strategies as peptide vaccines or peptide-pulsed DC vaccines [2-9].

From a clinical point of view, several vaccination strategies for stage IV melanoma using a combination of several (more than 3) peptides with a restriction to HLA-A2 have been reported to date [10,11]. However, little immunotherapeutic study regarding HLA-A24-restricted multiple peptides has been conducted because HLA-A24 is not a common allele in Caucasians. Several studies have demonstrated the identification of many HLA-A24-restricted CTL epitopes from various cancer-related antigens including p53, CEA, telomerase, tyrosinase, MAGE proteins etc. [12-18]. When it comes to melanoma, our group demonstrated the feasibility of using a combination of 5 melanoma-associated peptides with restriction of HLA-A24 (peptide cocktail) as a specific cancer vaccine in an immunotherapeutic trial (Akiyama et al, Anticancer

Res., 2004). Based on basic research results, a phase I clinical trial of HLA-A2 or A24-restricted melanoma peptide cocktail-pulsed dendritic cell-based immunotherapy has been performed. Here we describe the safety and efficacy of DC-based immunotherapy against metastatic melanoma.

Materials and methods

Patient characteristics and eligibility criteria

Nine patients with metastatic melanoma were enrolled in a phase I clinical trial of a peptide cocktail-pulsed DC-based vaccine approved by the Institutional Review Board (No. 12-93 and 12-94) of the National Cancer Center, Tokyo. All patients gave written informed consent. All patients had received prior surgery, chemotherapy and radiation (Table 1). Three subjects had metastatic lesions in the brain and been given radiation to control them. Inclusion criteria were: i) biopsy-proven stage IV metastatic melanoma, ii) age ≥ 18 years, iii) performance status ≤ 2 , iv) HLA-A2 or A24 phenotype and v) measurable target lesions. Exclusion criteria were: i) prior therapy < 4 weeks before trial entry, ii) untreated CNS lesion, iii) pregnancy, iv) autoimmune disease, and v) concurrent corticosteroid/immunosuppressive therapy. All the patients, who gave written informed consent, received subcutaneously (s.c) 3 DC vaccines at the inguinal region weekly and toxicity was checked. DCs were injected in dose-escalation design at a dose level per cohort of 1.0, 2.0 and 5.0 $\times 10^7$ /body/shot (Table 1). The injected DC number was calculated from the percentage of Lin⁻HLA-DR⁺ gated populations in a FACS analysis.

Table 1: Phase I study of DC-based therapy against melanoma

Patient No.	Age	Sex	Previous therapy	Measurable lesions	DC Injection (times)	Side effect	DTH		Response
							peptide	KLH	
1	41	F	ST, CT, RT, IFN β	lung, LN	1 $\times 10^7$ (10)	Hepatic (II)	-	++	PR
2	75	M	ST, CT, IFN β	LN	1 $\times 10^7$ (10)	-	+	+	SD
3	49	F	ST, CT, IFN β , RT	lung, liver	1 $\times 10^7$ (3)	-	-	-	(PD)*
4	49	M	ST, CT	lung, liver	2 $\times 10^7$ (6)	-	-	-	PD
5	50	M	ST, CT, IFN β	lung, liver, LN	2 $\times 10^7$ (6)	Hepatic (I)	-	-	PD
6	69	M	ST, CT, IFN β	LN	2 $\times 10^7$ (10)	-	+	+	CR
7	61	M	ST, CT, RT	liver, LN	5 $\times 10^7$ (8)	Hepatic (I)	+	++	PD
8	64	F	ST, CT, RT	lung	5 $\times 10^7$ (3)	Fever (I)	-	-	(PD)
9	66	F	ST, CT,	lung, LN	5 $\times 10^7$ (3)	-	-	-	(PD)

* The (PD) patients represent those who received fewer than 4 DC injections because of an early progression of the disease.

Preparation of DCs and peptides

Leukapheresis products from 7 L of processed blood were washed and centrifuged using density-adjusted OptiPrep™ (Axis-Shield PoC, Oslo, Norway), then the monocyte layer at the top was retrieved. Cells were transferred to an X-fold culture bag (Nexell, Irvine, CA) and cultured in the presence of GM-CSF at 50 ng/ml (CellGenix, Freiburg, Germany) and IL-4 at 50 ng/ml (CellGenix) in X-VIVO15 serum-free medium (Biowhittaker, Walkersville, MD). After 7 days, harvested cells were pulsed with a cocktail of 5 melanoma-specific synthetic peptides (25 µg/ml each) restricted to HLA A2 or A24 and KLH (25 µg/ml, Intracell, Frederick, MD). DC-enriched cells were washed and cryopreserved in Cryocyte bags (Baxter Healthcare Co., Deerfield, IL) until used. The purity of CD14⁺ cells was evaluated with a flow cytometer (FACSCalibur, Becton-Dickinson Co., CA) before and after OptiPrep™ separation. The percentage of DCs was rated as the lin⁻HLA-DR⁺ population (lineage antibodies including CD3, CD14, CD16, CD19, CD20, CD56; Becton-Dickinson Co.). The additional DC-related markers were determined on gated lin⁻HLA-DR⁺ cells. The following peptides restricted to HLA-A2 or A24 were synthesized according to GMP standards by Multiple Peptide Systems, CA. HLA-A2: MART-1₂₇₋₃₅ (AAGIGILTV), gp100₂₀₉₋₂₁₇ (IMDQVPFSV), tyrosinase₃₆₈₋₃₇₆ (YMDGTMSQV), MAGE-2₁₅₇₋₁₆₆ (YLQLVFGIEV), MAGE-3₂₇₁₋₂₇₉ (FLWGPRLV); HLA-A24: gp100₁₅₂₋₁₆₀ (VWKTWGQYW), tyrosinase₂₀₆₋₂₁₄ (AFLPWHRLF), MAGE-1₁₃₅₋₁₄₃ (NYKHCFPEI), MAGE-2₁₅₆₋₁₆₄ (EYLQLVFGI), MAGE-3₁₉₅₋₂₀₃ (IMPKAGLLI).

Characterization of tumor specimens before DC vaccines

Skin metastatic lesions were obtained from patients who gave written informed consent. The expression of melanoma tumor antigens was investigated using RT-PCR as described previously [19]. HLA protein expression was also evaluated using an immunohistochemical (IHC) analysis with anti-HLA-A2 or A24 monoclonal antibody (One Lambda Inc., Canoga Park, CA). A phenotypical analysis of lymphocytes infiltrating the tumor site was also performed using IHC.

Clinical and immunological monitoring

Adverse effects were evaluated according to the NCI Common toxicity criteria after 3 DC injections. Standard conventional definitions of major (complete or partial) objective responses were used. Stable disease (SD) was defined as less than a 25% change in size with no new lesions lasting at least 4 weeks. Clinical response was rated as maximal through the DC vaccinations. The patients received up to 10 injections on the condition that at least one measurable lesion showed more than stable disease (SD) response and/or an ELISPOT assay performed after 4 injections indicated a positive response for more than 1 melanoma-associated peptides. PBMC samples were har-

vested before and 29, 78, 134 and 190 days after the 1st DC injection, and frozen prior to use for immunological monitoring tests. All patients were followed up for 2 years after the enrollment into the study.

ELISPOT assay

The ELISPOT assay was performed using in vitro re-stimulations. Briefly, PBMCs were incubated in a 24-well culture plate at 4×10^6 per ml and divided into non-adherent and adherent cells. Adherent cells were treated with a peptide cocktail and β 2-microglobulin for 2 hrs, and co-cultured with non-adherent cells in the presence of IL-2 at 15 U/ml and IL-7 at 10 ng/ml. On day 7, non-adherent cells were re-stimulated with peptide-pulsed adherent cells. On day 14, responder cells (1×10^4 /well) were incubated with peptide-pulsed target cells (1×10^5 /well; .221A201 cells for HLA-A2 peptide or TISI cells for HLA-A24 peptide) in a 96-well culture plate coated with anti-IFN- γ antibody (MABTECH AB, Nacka, Sweden) overnight. Finally positive spots stained with anti-IFN- γ antibody were measured using the KS ELISPOT system (Carl Zeiss AG, Oberkochen, Germany). HLA-A2-restricted Influenza M1 peptide (GILGFVFTL) or HLA-A24-restricted EBNA3A peptide (RYSIFFDY) was used as a negative control.

Tetramer staining

PBMCs were re-stimulated twice in vitro and utilized for tetramers staining. CD8⁺-enriched T cells were obtained by the depletion of CD4⁺ T cells using Dynabeads M-450 CD4 (DynaL, Oslo, Norway) and used for tetramers staining. The staining was performed according to the method reported by Kuzushima et al [20]. The PE-labeled tetramers used in the present study were as follows: HLA-A*0201 MART1 (Beckman Coulter Inc., San Diego, CA), HLA-A*0201 gp100, HLA-A*2402 tyrosinase, HLA-A*2402 MAGE-1, HLA-A*2402 HIV (RYLRDQQLL) and HLA-A*0201 Influenza M1 tetramers (MBL, Nagoya, Japan).

Intracellular cytokine staining

PBMCs were stimulated with 25 ng/ml of PMA (Sigma) and 1 µg/ml of ionomycin (Sigma) for 5 hrs in a 96-well culture plate. Breferrdin A (10 µg/ml) was also added to cultures in the last hour. After the stimulation, cells were stained with FITC-anti-CD4 MoAb, and subsequently intracellular staining was performed with fix/permealization buffer and PE-labeled anti-IFN- γ or anti-IL-4 MoAb (Pharmingen, San Diego, CA). Finally, the ratio of Th1 (IFN- γ ⁺) and Th2 (IL-4⁺) was calculated in PBMC samples obtained before and after DC vaccination.

DTH reactions

The HLA-A2 or A24 peptide cocktail solution diluted to a dose of 5 µg/ml (each peptide) and KLH (50 µg/ml) were injected intradermally on the patient's forearm and the

Table 2: Immunological monitoring in melanoma patients

Patient No.	HLA	Tumor antigen, HLA expression	ELISPOT	Tetramer	Th1/Th2 balance
1	A*2402	3/5 (Tyr, M1, M2), A24(+)	3/5 (Tyr, M1, M2)	Tyrosinase (0.34%)	5.19 (1.45) ^a
2	A*0201	A2(+)	2/5 (MART1, gp100)	MART1 (0.64%)	3.68 (1.49)
3	A*2402	A24(-)	N. D. ^b	N. D.	-
4	A*0206	A2(-)	2/5 (MART1, M2)	-	3.05 (2.57)
5	A*0201	A2(-)	2/5 (MART1, M2)	MART1 (1.48%)	2.83 (3.68)
6	A*2402	2/5 (M2, M3), A24(+)	2/5 (M2, M3)	-	3.76 (2.00)
7	A*0201	4/5 (MART1, Tyr, gp100, M2), A2(+)	2/5 (gp100, M2)	-	2.64 (1.79)
8	A*2402	A24(-)	N. D.	N. D.	-
9	A*0201	A2(+)	1/5 (gp100) ^c	N. D.	N. D.

^aThe value in the parenthesis shows Th1/Th2 ratio prior to DC vaccination. ^bN. D. ; not done.

^cThe value shows the one obtained prior to DC vaccines.

redness and induration at the injection site was measured. PPD was used as a positive control.

Statistical analysis

Statistical differences were analyzed using Student's paired two-tailed *t*-test. Values of $p < 0.05$ were considered significant.

Results

DC characterization

The mean percentage of DCs rated as lin⁺HLA-DR⁺ in melanoma patients was $46.4 \pm 15.6\%$, not different from that in healthy volunteers (data not shown). The frequencies of the DC-related markers were determined on gated lin⁺HLA-DR⁺ cells: HLA-class I $97.5 \pm 0.9\%$, CD80 $87.6 \pm 6.9\%$, CD86 $85.5 \pm 7.4\%$, CD1a $55.2 \pm 24.2\%$, CD83 $29.9 \pm 13.3\%$, CCR7 $32.4 \pm 13.7\%$, DC SIGN $78.2 \pm 19.3\%$, CD11c⁺HLA-DR⁺ $90.6 \pm 6.0\%$, CD123⁺HLR-DR⁺ $0.99 \pm 1.3\%$. Most of DCs expressed high level of co-stimulatory molecules and type1 phenotype (CD11c⁺HLA-DR⁺), while a moderate number of mature DCs with CD83 and CCR7 positive were contained in DC products. On the other hand, the T cell-stimulating activity of DCs investigated in the MLR assay using allogeneic T cells was as strong as that of DCs obtained from healthy volunteers (data not shown).

Characterization of tumor specimen

An analysis of melanoma antigen expression by RT-PCR was performed in 3 cases. The expression of more than 2 antigens in the tumor was verified in all cases. HLA protein expression was positive in 5 out of 9 cases (Table 2). Patient 1 who showed a remarkable clinical response (PR), was representative of HLA protein-positive cases (Fig. 1). In contrast, in patient 7, HLA-A2 protein expression in the tumor was lost in the course of treatment.

ELISPOT assay

CTL precursors of more than 2 melanoma peptides were recognized after DC vaccines in 6 of 9 cases. Two HLA-A2⁺ cases (patients 5 and 9) showed HLA-A2 peptide-specific CTL responses before the vaccination. Patients 1 and 6, which showed remarkable clinical responses, exhibited many CTL precursors against a HLA-A24 restricted peptide-cocktail (Table 3, Figure 2). Notably, in patient 1, a remarkable increase in the CTL response to the HLA-A24 peptide cocktail was seen in accordance with the regression of metastatic tumor of the lung (Fig. 3). On the other hand, patient 7 also demonstrated a high CTL precursor frequency, but showed no significant clinical response.

Tetramer staining

After CD4⁺ T cell depletion, the frequency of CD8⁺ cells was more than 85%. The proportion of PE-labeled tyrosinase-HLA-A24 tetramer-positive cells among gated CD8⁺ cells was 0.34% in patient 1 (Table 2). HIV-A24 tetramer (negative control)-positive cells were not detected. The percentage of PE-labeled MART1-HLA-A2 tetramer-positive cells was 0.64% and 1.48% in patients 2 and 5, respectively. On the other hand, that of Influenza M1-HLA-A2 tetramer (negative control)-positive cells was 0.04%.

Th1 and Th2 balance after DC vaccination

In 5 of 6 evaluable cases, the balance of Th1 and Th2 shifted more to Th1 after 4 DC injections compared with prior to vaccination. (Table 2). The amplitude of the shift seemed to be larger in clinical responders (patients 1, 2, 6) than non-responders (patients 4, 5, 7) (% of ratio increase; 264 ± 86 vs. 114 ± 35).

DTH

Three of 6 evaluable cases showed positive DTH to a peptide-cocktail after DC injections (Table 1). On the other hand, 4 of 6 cases developed a DTH response to KLH pro-

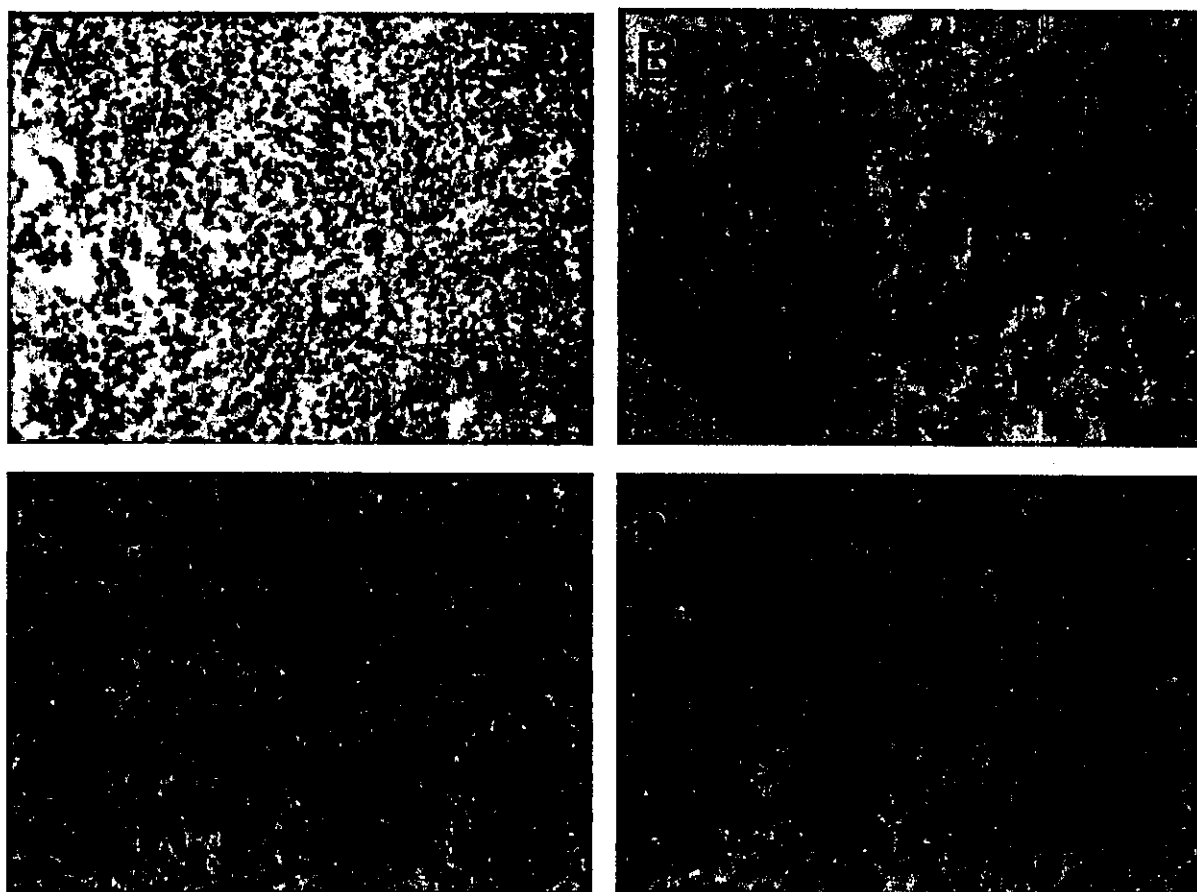


Figure 1

Immunohistochemical analysis of metastatic tumor tissue from responder patient 1 and non-responder patient 7. A; H-E stain and B; anti-HLA-A24 MoAb from patient 1. C; anti-HLA-A2 MoAb before DC vaccination and D; anti-HLA-A2 MoAb after 4 DC injections from patient 7. Magnification $\times 200$.

tein. There were stronger reactions to KLH in patients 1 and 7.

Adverse effects of DC vaccine

Safety was assessed after 3 DC injections in all 9 cases. Three of 9 patients developed mild hepatic dysfunction (grade I-II), however it was only transient and disappeared in spite of the continuance of DC injections. Rheumatoid factor and anti-nuclear antibody were negative before the injection, but increased to 1:160 and 1:40, respectively after the injections finished in patient 1. No clinical symptoms of autoimmune disease were found in patient 1 (Table 1).

Clinical response

Clinical response was rated as maximal through the DC vaccinations. In 6 evaluable cases except for 3 cases of early PD cases due to a rapid progression of the disease, 1CR (patient 6), 1PR (patient 1), 1SD and 3 PD were obtained (Table 1). Large metastatic lesions in the lung and hilar nodes in patient 1 dramatically decreased in size after 4 DC injections, and almost disappeared after treatment finished (Fig. 3). Moderate sized cervical metastatic lesions in patient 6 finally started to decrease after 8 DC injections and disappeared surprisingly rapidly after the finish of DC therapy. In contrast, patient 7 who exhibited good immunological responses in the ELISPOT assay and

Table 3: Peptide cocktail-specific CTL precursor frequency during DC vaccination

Patient No.	DC Injection (times)	before	Spot No./CD8 ⁺ T cell (%) ^a			
			day29	day78	day134	day190
1	1 × 10 ⁷ (10)	1.19/0.45	6.96/0.06	8.82/0.63	8.81/0.08	5.4/0.08
2	1 × 10 ⁷ (10)	0.07/0.05	0.07/0.2	0.02/0	0.02/0	0.29/0.03
3	1 × 10 ⁷ (3)	N.D. ^b	N.A. ^c	N.A.	N.A.	N.A.
4	2 × 10 ⁷ (6)	0.39/0.53	1.29/0.03	1.12/0	N.A.	N.A.
5	2 × 10 ⁷ (6)	1.74/0.05	0.51/0.2	1.25/0.04	N.A.	N.A.
6	2 × 10 ⁷ (10)	0.21/0.27	0.31/0.28	1.18/0.24	7.80/0.19	9.82/0.30
7	5 × 10 ⁷ (8)	0.62/0.20	6.52/0.1	7.33/0.11	N.A.	N.A.
8	5 × 10 ⁷ (3)	N.D.	N.A.	N.A.	N.A.	N.A.
9	5 × 10 ⁷ (3)	3.09/1.24	N.D.	N.A.	N.A.	N.A.

The percentages represent IFN- γ positive spot No. divided by total CD8⁺ cell No. from 1 × 10⁴ PBMCs. ^aEach value represents the percentage with peptide cocktail/without peptide cocktail. ^bN.D.; not done, ^cN.A.; sample not available.

DTH, showed no shrinkage of the tumor, resulting in cessation after 6 DC injections.

Characterization of infiltrated lymphocytes in the tumor
IHC analysis of infiltrated lymphocytes in the tumor after DC vaccines was performed only in patient 1 and 7. The obvious infiltration of a larger number of CD4⁺ or CD8⁺ T cells and a small number of CD20⁺ B cells were shown in patient 1 (Fig. 4). In contrast, no significant cell infiltration was seen in patient 7 who did not develop any therapeutic effect on the tumor (data not shown).

Discussion

Clinical trials of specific immunotherapy against metastatic melanoma using peptide-pulsed Mo-derived DCs have been performed in mainly Western countries, and some fruitful results were obtained [7,10,11]. In those cases, most of the patients belonged to the HLA-A*0201 type. In the present study, we investigated the effect of peptide-pulsed DCs on 4 cases of HLA-A*2402⁺ metastatic melanoma patients besides 4 cases of HLA-A*0201⁺ patients in a clinical phase I trial. This is the first report to demonstrate that peptide-pulsed DCs were effective in some HLA-A24⁺ melanoma patients in Japan. It is well known that HLA-A*2402 is a common genotype and around 60% positive in Asians. There was one case of HLA-A*0206 patient among 5 HLA-A2⁺ patients (Table 2). Sidney et al. [21] demonstrated that over 70% of the peptides that bound A0201 with high affinity were found to bind at least two other supertype molecules like A*0202, A*0203 or A*0206. Taking it into considerations, the HLA-A*0206 patient was finally enrolled into the study. With regard to other HLA-A24⁺ solid cancers, stomach, colon and bladder cancers have been treated with peptide (MAGE-3)-pulsed DC vaccines, and showed

a limited response [22-24]. Considering that melanoma is highly immunogenic and probably a good model for tumor-specific immunotherapy despite being an unusual tumor in Asian countries, it deserves a phase I study using peptide-pulsed DCs.

In our study, peptide cocktails combining 5 peptides for each HLA type (HLA-A2 or A24) were prepared and used for DC pulsing. Our clinical study revealed positive ELISPOT responses against more than 2 peptides in all 6 evaluable cases. In previous reports, clinical DC therapy using more than 3 melanoma peptides demonstrated the induction of a specific CTL response against multiple melanoma peptides [10,11]. However,, there is still some controversy over the efficacy of multiple epitope-based vaccinations and Smith *et al.* [25] demonstrated that, although polyepitope vaccines are an effective way of priming polyvalent CTLs, continual stimulation with polypeptide vaccines might restrict CTL induction as a result of immunodominance. The results of our study are thought to answer that question, but testing of the peptide cocktail vaccine in more patients will be needed.

To refine the quality and protocol of the tumor-specific immunotherapy for clinical trials, the prediction of clinical response in an individual is important [26] and should be discussed. In our study, the correlation between immunological parameters and clinical response was investigated in a limited number of cases.

First of all, as to HLA expression in the tumor, patients 1, 2, 6 and 7 were positive, and patients 4 and 5 were negative. HLA-negative cases showed a progression of the tumor. Even in positive cases, patient 7 turned negative in the course of DC therapy, showing tumor progression.

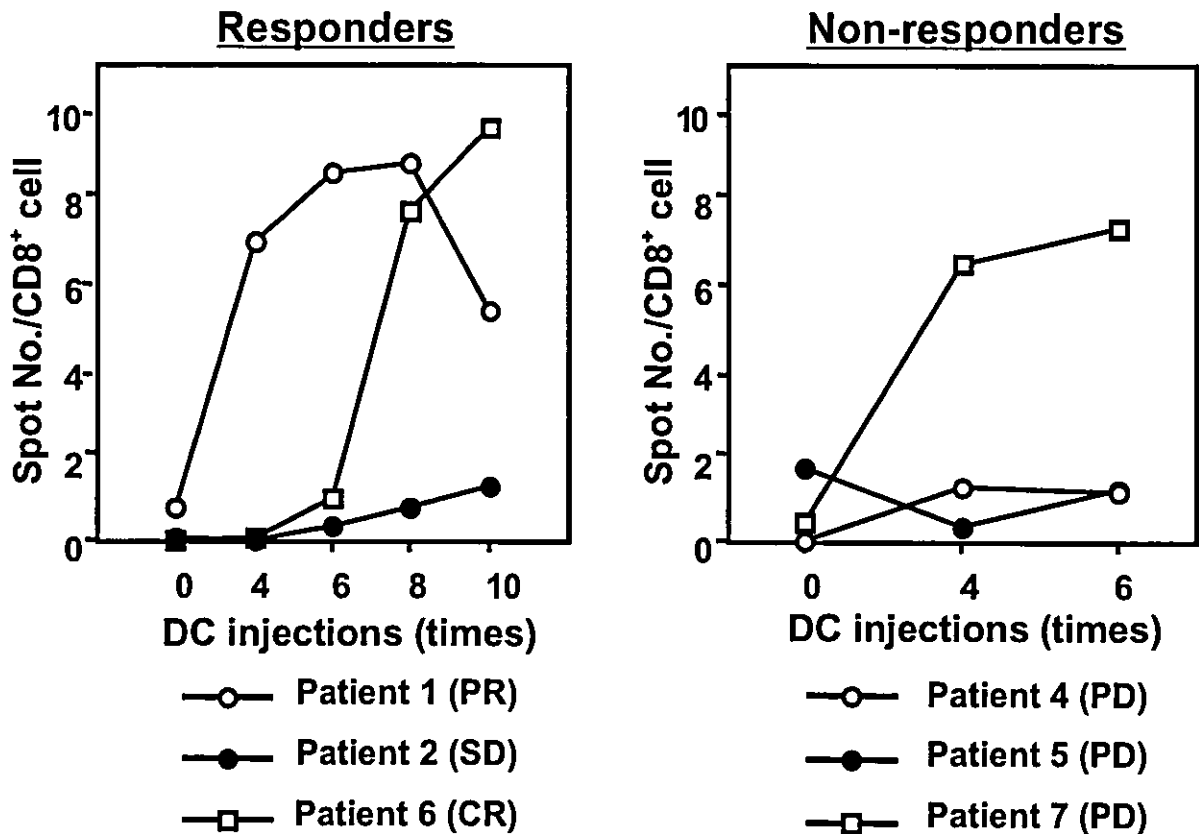


Figure 2
 CTL responses in the course of DC injections in 6 evaluable cases. Patients 1, 2 and 6 were responders and patients 4, 5 and 7 were non-responders. Responders (cases 1,6) showed remarkable CTL expansion in PBLs compared with before DC vaccination. In contrast, non-responders (patients 4,5) showed no significant CTL responses except in patient 7.

Loss of HLA expression in melanoma is reported to be a complex phenomenon associated with melanoma antigen loss [27], β 2-microglobulin gene mutation [28] or loss of heterozygosity (LOH) in chromosome 6 and may lead to tumor progression and metastasis. As to patient 7, considering that the melanoma antigen expression was maintained, the functional expression of β 2-microglobulin should be investigated. All the other HLA-positive cases showed CR, PR and SD, respectively. There was a tendency for HLA expression to be associated with tumor response, and some researchers reported a positive correlation of HLA-expression to tumor response in immunotherapy against melanoma. However, despite the positive correlation of HLA-expression in the tumor with anti-

tumor response, Nestle et al. demonstrated that HLA-expression in the tumor did not correlate to survival in melanoma patients [29].

Second, the amplitude of the CTL response in the ELISPOT assay seems to be another key factor predicting anti-tumor response. Patients 1, 6 and 7 showed large responses to peptide cocktail in ELISPOT, and patients 2, 4 and 5 showed small responses. The former exhibited a remarkable regression of tumor except patient 7. On the other hand, the latter showed a poor response. There was a likely tendency that the amplitude of the CTL response was associated with tumor regression. Also, it was difficult to predict when immunological responses like CTL induc-

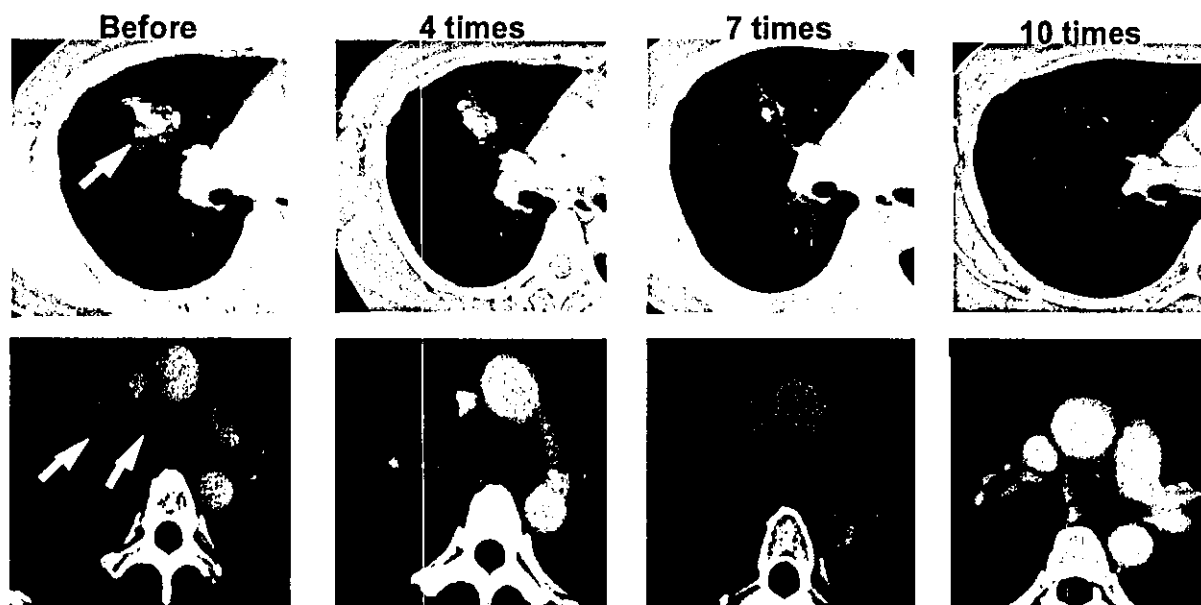


Figure 3
Impact of DC vaccines on metastatic lesions of the lung in responder patient 1. Upper and lower panels show a lung and hilar lymph node metastatic lesion (arrow), respectively. The CT scan was made before therapy and after 4, 7 and 10 DC vaccinations.

tion start to be activated *in vivo* during DC vaccination, and this question needs to be answered. In the present study, because of a limited number of patients given DC vaccines, the tendency that HLA-class I protein expression in the tumor and the amplitude of ELISPOT responses are seemingly associated with tumor regression is not convincing.

Finally, in order to improve tumor response in the present study, there are still some issues regarding clinical DC preparation. First of all, the purity of CD14⁺ cells after Opti-prep separation is still low and may not be reproducible. Therefore, other clinical grade-monocyte separation methods using an elutriator or negative selection with CD2 and CD19 MoAbs [30] should be tried. Second, considering that the amplitude of the CTL response was associated with tumor regression, and that even a remarkable increase of CTL frequency inevitably diminished in spite of the repetition of DC vaccinations, it seems to be crucial to maintain increased CTL frequency in blood leading to TIL in the tumor and expand more than enough to develop a substantial number of memory CD8⁺ CTL in lymph nodes. Such a novel method will be needed to develop an effective cancer vaccine.

Conclusions

In the present study, we investigated the effect of dendritic cell (DC)-based immunotherapy on metastatic melanoma patients with HLA-A2 or A24 genotype. Nine cases of metastatic melanoma were enrolled into a phase I study using HLA-A2 or A24-restricted peptide cocktail-pulsed DCs. All 6 evaluable cases showed positive immunological responses to more than 2 melanoma peptides in an ELISPOT assay. Clinical response through DC injections was as follows: 1CR, 1PR, 1SD and 6PD. All 59 DC injections in the phase I study were safely administered to patients. These results suggested that peptide cocktail-treated DC-based immunotherapy had the potential for utilizing as one of therapeutic tools against HLA-A2 or A24⁺ metastatic melanoma.

Abbreviations

DC, dendritic cell; HLA, human leukocyte antigen; GM-CSF, granulocyte macrophage-colony-stimulating factor; IL, interleukin; KLH, Keyhole limpet hemocyanin; CTL, cytotoxic T cell; DTH, delayed-type hypersensitivity; CR, complete remission; PR, partial remission; SD, stable disease; PD, progressive disease; RT-PCR, reverse transcription-polymerase chain reaction; IFN, interferon; PBMC, peripheral blood mononuclear cell.

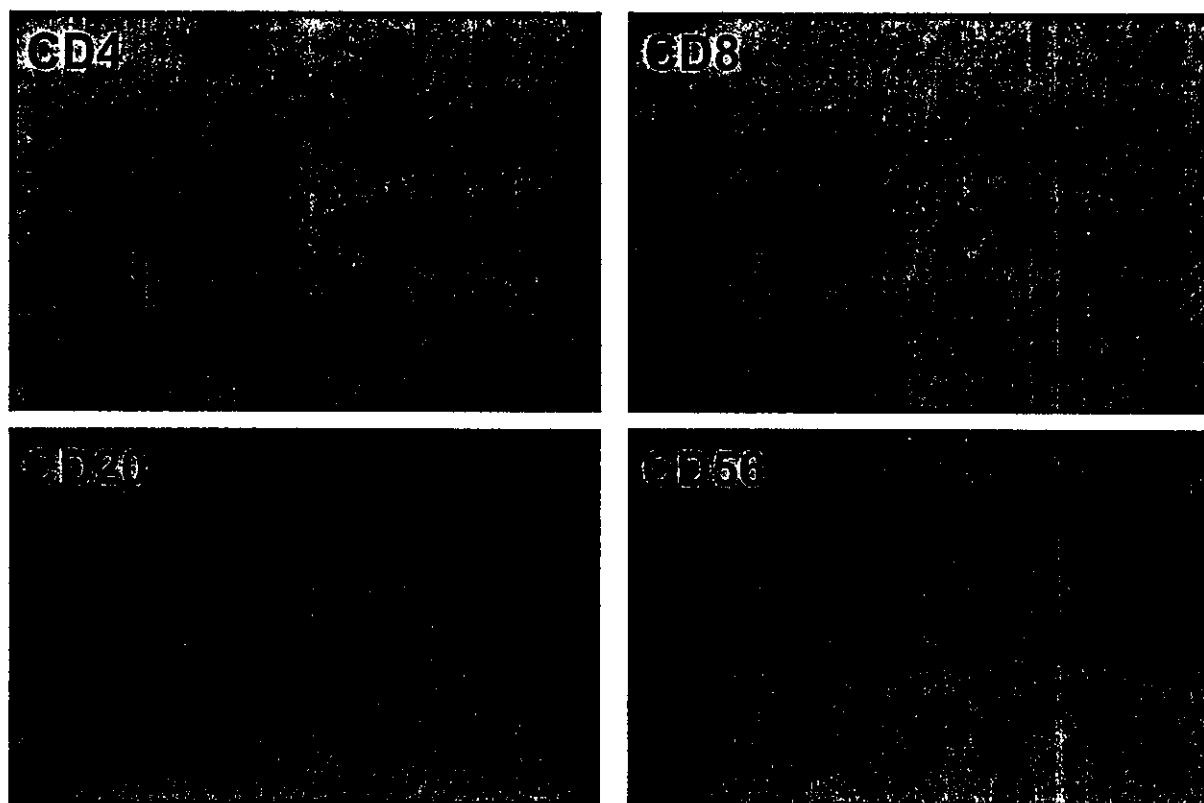


Figure 4
Phenotype analysis of lymphocytes infiltrating the tumor site in responder patient 1. Obvious infiltration of a larger number of CD4⁺ or CD8⁺ T cells and a small number of CD20⁺ B cells is shown. Indirect staining using anti-CD4, CD8, CD20 or CD56 MoAb as primary Ab and goat anti-mouse Ab as secondary Ab was performed. Magnification × 200.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YA participated in the design of the study and drafting the manuscript and were responsible for completing the study. RT, NI, MS, YH carried out apheresis and cell processing and were responsible for DC production. AY and NY were responsible for the clinical side of the study. IK, IN, KT and KM participated in the design of the study and performed biological assays. YT and KY reviewed the manuscript. All authors read and approved the final manuscript.

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