Table V. Multivariate Cox regression analysis and inverse probability of treatment weighted (IPTW) method analysis comparing transplant-related mortality (TRM), progression-free survival (PFS) and overall survival (OS) after peripheral blood stem cell transplantation (PBSCT) and bone marrow transplantation (BMT).

Outcomes	Analysis	Variables	HR (95% CI)	*P*-value
TRM at 100 d	Cox	Stem cell source: PBSCT	1·18 (0·66–2·12)	0·584
		Acute GvHD: grades II–IV	4·92 (2·57–9·42)	<0·001
	IPTW	Stem cell source: PBSCT	1·33 (0·84–2·10)	0·230
TRM at 1 year	Cox	Stem cell source: PBSCT	1·07 (0·69–1·66)	0·773
		Donor age: 40 years or older	1·98 (1·03–3·80)	0·040
		Acute GvHD: grades II–IV	2·58 (1·65–4·05)	<0·001
	IPTW	Stem cell source: PBSCT	1·17 (0·82–1·66)	0·381
Relapse	Cox	Stem cell source: PBSCT	0·95 (0·64–1·41)	0·806
		Disease risk: high	3·97 (2·66–5·94)	<0·001
		ECOG PS: 2–4	3·42 (1·73–6·77)	0·004
	IPTW	Stem cell source: PBSCT	0·95 (0·73–1·23)	0·676
PFS	Cox	Stem cell source: PBSCT	1·03 (0·77–1·37)	0·868
		Disease risk: high	2·41 (1·82–3·21)	<0·001
		ECOG PS: 2–4	2·83 (1·63–4·92)	<0·001
		Acute GvHD: grades II–IV	1·33 (1·00–1·78)	0·05
	IPTW	Stem cell source: PBSCT	1·05 (0·87–1·27)	0·589
OS	Cox	Stem cell source: PBSCT	0·99 (0·73–1·36)	0·972
		Disease risk: high	2·45 (1·79–3·34)	<0·001
		ECOG PS: 2–4	3·31 (1·88–5·84)	<0·001
		Acute GvHD: grades II–IV	1·57 (1·15–2·13)	0·004
	IPTW	Stem cell source: PBSCT	1·05 (0·85–1·29)	0·659

The following covariates were included in the Cox models as explanatory variables; patient and donor age (less than or more than 40 years), sex, sex matching, Eastern Cooperative Oncology Group performance status (ECOG PS), disease risk, cytomegalovirus (CMV) serology, stem cell source, conditioning regimen, doses of methotrexate (MTX), grades II–IV acute graft *versus* host disease (GvHD) and chronic GvHD. The values of stem cell source and significant covariates are shown in this table. Grades II–IV GvHD and chronic GvHD were included as time-dependent covariate (HR, hazard ratio).

Table VI. Causes of mortality and time of death.

	BMT (n = 104)	PBSCT (n = 75)
Number of TRM	51 (49·0)	44 (58·7)
Causes of TRM		
GvHD	4 (3·8)	13 (17·3)
Non-infectious pneumonia	6 (5·8)	6 (8·0)
Veno-occlusive disease of the liver	5 (4·8)	1 (1·3)
Infection	25 (24·0)	14 (18·7)
Haemorrhage	1 (1·0)	3 (4·0)
Others	10 (9·6)	7 (9·3)
Time of TRM		
Days 0–30	7 (6·7)	4 (5·3)
Days 31–100	14 (13·5)	20 (26·7)
After day 100	30 (28·8)	20 (26·7)
Number of deaths in relapse	53 (51·0)	31 (41·3)

TRM, transplant-related mortality; BMT, bone marrow transplantation; PBSCT, peripheral blood stem cell transplantation; GvHD, graft *versus* host disease.
Values are given as n (%).

three doses of MTX (day +1: 10 mg/m^2; day +3 and day +6: 7 mg/m^2) rather than four doses of MTX routinely used in other countries, because of the lower frequency of GvHD in Japan (Morishima *et al*, 1989). An RCT from the European Group for Blood and Marrow Transplantation (EBMT) study, in which increased incidence of acute and chronic GvHD was shown, also gave three doses of MTX (Schmitz *et al*, 2002). Omission of day +11, MTX may influence the incidence of acute and chronic GvHD (Nash *et al*, 1992; Cutler *et al*, 2001; Mehta & Singhal, 2002), although we did not find any difference among the different MTX dose groups. A recent report from the EBMT suggested that post-transplant G-CSF might increase the incidence of acute and chronic GvHD and TRM, resulting in lower leukaemia-free and OS rates after BMT (Ringden *et al*, 2004). Although the use of G-CSF postallografting is usually accepted as a standard care in Japan, we need to reconsider this indication, especially after BMT.

Notably, the observed cumulative incidence of grades II–IV acute GvHD in patients receiving HLA-identical transplants seemed lower in both groups (BMT 32·0%, PBSCT 37·4%) compared with rates reported from western countries (Powles *et al*, 2000; Bensinger *et al*, 2001; Couban *et al*, 2002; Schmitz *et al*, 2002). These data are consistent with previous reports on Japanese BMT patients (Morishima *et al*, 1989; Oh *et al*, 2002). Oh *et al* (2002) reported a multivariate analysis for adult allogeneic BMT patients showing that a Japanese cohort had a significantly lower risk of acute GvHD than white American, black American and Irish cohorts [relative risk

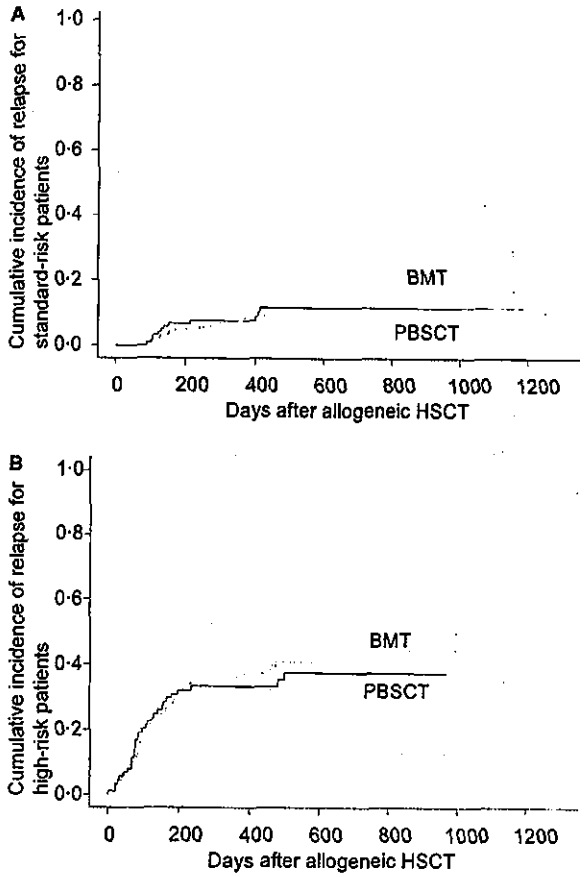

Fig 4. Cumulative incidences of relapse after allogeneic peripheral blood stem cell transplantation (PBSCT) compared with bone marrow transplantation (BMT). Cumulative incidence functions (A: standard-risk group; B: high-risk group) were predicted from the proportional subdistribution hazards model and adjusted for effects of significant covariates.

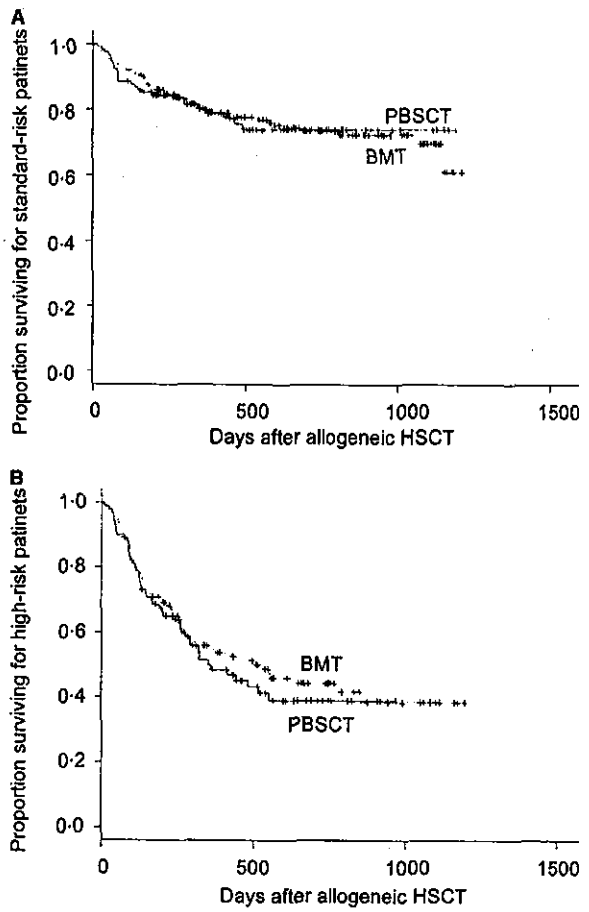

Fig 5. Probabilities of overall survival after allogeneic peripheral blood stem cell transplantation (PBSCT) compared with bone marrow transplantation (BMT). Probabilities were derived from Kaplan–Meier estimates [A: overall survival (OS) for standard risk group; B: OS for high-risk group].

(RR) = 1·77, $P < 0·01$; RR = 1·84, $P < 0·01$; RR = 2·22, $P < 0·01$ respectively]. Our data suggest that this trend might also apply to PBSCT. This difference has been speculated to reflect a lower degree of diversity for HLA and minor histocompatibility antigens among Japanese. However, a recent report revealed the influence of an interleukin-10 promotor polymorphism after allogeneic HSCT (Lin *et al*, 2003). The interleukin-10-592A/A genotype was associated with a decreased risk of grade III or IV acute GvHD. The frequency of this genotype is 67% in the Japanese population (Tegoshi *et al*, 2002), which is much higher than the frequency of 23% and 24% in two white populations (Lin *et al*, 2003). This finding may account for the decreased incidence and severity of acute GvHD in Japanese population than in white populations.

We found a significantly increased cumulative incidence of chronic GvHD among PBSCT patients in accord with several previous studies (Champlin *et al*, 2000; Bensinger *et al*, 2001; Cutler *et al*, 2001; Schmitz *et al*, 2002; Heldal *et al*, 2003). In particular, the extensive form of chronic GvHD was increased in the PBSCT cohort, whereas the incidence of the limited form was similar in the two cohorts. There is now considerable evidence that the preferential expansion of T-helper 2 (Th2) cells after allogeneic HSCT is associated with the development of chronic GvHD in both murine models and human beings (Doutrelepont *et al*, 1991; Umland *et al*, 1992; Allen *et al*, 1993; De Wit *et al*, 1993; Garlisi *et al*, 1993; Tanaka *et al*, 1997). A G-CSF-induced Th2 cytokine profile of donor T cells may be associated with increased incidence and severity of chronic GvHD (Pan *et al*, 1995). G-CSF also mobilized type 2 dendritic cells, which promote Th2 responses (Arpinati *et al*, 2000). Thus, G-CSF may have an important role in the development of chronic GHVD among PBSCT patients.

Another interesting point is the different distribution of organs affected by acute and chronic GvHD in BMT and PBSCT. Although previous reports demonstrated that skin and vaginal involvement (Bensinger *et al*, 2001; Flowers *et al*,

2002) or ocular involvement (Mohty *et al*, 2002) of chronic GvHD was more prevalent after PBSCT, the current study showed an increased incidence of skin, ocular sicca and oral mucositis, similar to Sjoegren syndrome. It is not well understood how selected organs become the targets of activated T cells. Inflammatory chemokines expressed in inflamed tissues upon stimulation by proinflammatory cytokines are specialized for the recruitment of effector cells (Moser & Loetscher, 2001). In mouse models, a comparative study of gene expression profiles of livers after experimental allogeneic and syngeneic BMT using oligonucleotide microarrays identified genes related to leucocyte trafficking that were upregulated at day 7 after allogeneic BMT when neither hepatic injury nor donor T-cell migration into the liver was evident (Ichiba *et al*, 2003). This study suggests that the interferon-γ produced by donor T cells in secondary lymphoid organs transactivates genes in target organs, stimulating the recruitment of effector cells to target organs and eventually rendering them vulnerable to effector cell attack. Thus, quantifiable and qualitative differences in immunological cells in PBSC grafts compared with bone marrow grafts may affect the chemokine environment, leading to the different distribution of affected organs. Alternately, increased numbers of affected organs in PBSC patients may simply reflect the increased severity of chronic GvHD.

Recent reports suggest that chronic GvHD with risk factors may negatively affect patients' survival (Akpek *et al*, 2001, 2003; Przepiorka *et al*, 2001). Long-term follow-up of an RCT showed that, although the cumulative incidence of chronic GvHD at 3 years was similar in BMT and PBSCT patients, chronic GvHD after PBSCT was more protracted and less responsive to treatment than after BMT (Bensinger *et al*, 2001; Flowers *et al*, 2002). With increasing numbers of long-term survivors, we need more information concerning the clinical characteristics of chronic GvHD after PBSCT (Przepiorka *et al*, 2001).

It has been postulated that a GVL effect may be observed, and the results of allogeneic HSCT may be improved in the presence of GvHD (Sullivan *et al*, 1989; Horowitz *et al*, 1990). However, the potential advantage of the GVL effect of allogeneic HSCT is often reduced by the GvHD-related morbidity and mortality (Weiden *et al*, 1981; Sullivan *et al*, 1989; Horowitz *et al*, 1990; Przepiorka *et al*, 2001; Lee *et al*, 2002). In most of the previous RCTs comparing BMT and PBSCT, the sample sizes were too small to detect meaningful survival increases (Schmitz *et al*, 1998; Blaise *et al*, 2000; Heldal *et al*, 2000; Powles *et al*, 2000). Even in the larger RCTs, survival was evaluated as a secondary end point (Bensinger *et al*, 2001; Couban *et al*, 2002; Schmitz *et al*, 2002). Bensinger *et al* (2001) and Couban *et al* (2002) have reported an OS benefit of PBSCT in patients with advanced disease. The former study included miscellaneous diseases and the observed advantage was derived from subgroup analysis, in which we were unable to draw reliable conclusions. The latter study, which involved 228 patients, included only myeloid malignancy but the improved survival was due to lower TRM with similar relapse rates, suggesting that faster haematological recovery accounts for this benefit. A meta-analysis reported by Cutler *et al* (2001), which involved 16 studies, and a large RCT from the EBMT (Schmitz *et al*, 2002) included 350 patients, and showed an increased incidence of acute and chronic GvHD, with no significant difference in relapse (Cutler *et al*, 2001; Schmitz *et al*, 2002) and survival rate (Schmitz *et al*, 2002). A recent meta-analysis suggested that any survival advantage of PBSCT is limited to patients with advanced disease (Horan *et al*, 2003). Thus, allogeneic PBSCT offered the prospect of a better outcome, but evidence for a survival benefit has been inconclusive. We must explicitly state that caution is highly advisable when interpreting *post hoc* subgroup analyses. These cannot be used for recommendations on treatment selection for individual patients, although they can be used in the development of new, empirically based research hypotheses. In addition, there might be a different impact on patient outcome after allogeneic HSCT according to stem cell source in this particular ethnic group, if the incidence of acute GvHD is lower than western countries. In the present study, multivariate analyses revealed that differences in stem cell source was not a significant factor for acute GvHD, relapse, TRM, PFS and OS despite the increased incidence of chronic GvHD after PBSCT. Early mortality within day 100 of PBSCT could be reduced because of faster engraftment (Champlin *et al*, 2000; Couban *et al*, 2002) but we did not observe this advantage. Our data showed that grades II–IV acute GvHD were significant adverse prognostic factors for TRM. The advantages of PBSCT may thus be counterbalanced by the increased incidence of GvHD. Treatment of acute and chronic GvHD was performed at the physician's discretion and immunosuppressive treatment may hamper the GVL effect in some cases. This may indicate the difficulty of separating GVL effects from GvHD clinically. We analysed the data according to each disease category and risk status, although there were no apparent differences between the two groups (data not shown). Therefore, in contrast to general belief, whether the GVL effect will improve survival after PBSCT remains unknown. Assessment of the overall benefits of PBSCT compared with BMT will require long-term follow-up of the morbidity of patients associated with chronic GvHD.

The retrospective nature, the heterogeneity of the diagnoses and the relatively short follow-up limit the power of this analysis. We cannot exclude the possibility that there are unmeasured confounders that could cause a bias between two groups. Analysis of the $CD34^+$ and $CD3^+$ cell dose was not performed because these are generally dependent on the source of stem cells, and in addition, we could not obtain enough data, especially in the BMT group. In multicentre studies, there is likely to be a variation among centres in both baseline risks and treatment effects that cannot be explained by the known prognostic factors (Frassoni *et al*, 2000; Matsuo *et al*, 2000; Loberiza *et al*, 2003). To resolve the limitations described

above, we needed an RCT in Japan. We have therefore launched a prospective, open-label RCT comparing allogeneic BMT *versus* PBSCT for adult patients with leukaemia. The primary end point of this trial is leukaemia-free survival based on time-to-event analysis. We plan the sample size per one arm to be 160, in order to detect the difference of 1·6 to 1·7 in HR for leukaemia-free survival. If this study can be completed, the impact of stem cell source on survival will be defined more accurately than the previous studies.

In summary, we observed faster engraftment and increased incidence of chronic GvHD in PBSCT compared with BMT for Japanese patients. The incidence of GvHD was lower than the western populations, but there were no differences in relapse, TRM, PFS and OS between PBSCT and BMT. These results suggest that the choice of haematopoietic stem cell source should be considered based on the data for individual ethnic populations. More detailed analysis and future trials may reveal the differential applicability of stem cells from these different sources in each disease category and hence enable us to choose appropriately between BMT and PBSCT based on reliable evidence.

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Appendix A

This study was conducted at the following institutions under the auspices of the following investigators in Japan: M. Sakai (Tokyo Metropolitan Hospital, Tokyo), T. Hamaki (National Cancer Centre, Tokyo), T. Karasuno (Osaka Medical Centre for Cancer and Cardiovascular diseases, Osaka), M. Kasai (Japanese Red Cross Nagoya first Hospital, Aichi), K. Kishi (Tokai University School of Medicine, Kanagawa), S. Okamoto (Keio University School of Medicine, Tokyo), N. Maseki (Saitama Cancer Centre Hospital, Saitama), S. Morishima (Meitetsu Hospital, Aichi), S. Yamasaki (Municipal Kitakyushu Medical Centre, Fukuoka), M. Kasai (Sapporo Hokuyu Hospital, Hokkaido), T. Kamimura (Harasanshin Hospital, Fukuoka), K. Shinagawa (Okayama University Medical School, Okayama), T. Yamane (Osaka City University, Osaka), S. Miyawaki (Saiseikai Maebashi Hospital, Gunma), Y. Miyazaki (Kansai Medical University, Osaka), T. Yamashita (National Medical Defence College, Saitama), N. Uike (National Kyushu Cancer Centre, Fukuoka), A. Maruta (Kanagawa Cancer Centre, Kanagawa), M. Misawa (Hyogo College of Medicine, Hyogo), K. Mitani (Dokkyo University School of Medicine, Tochigi), K. Kamezaki (Kyushu University Graduate School of Medical Sciences, Fukuoka), M. Masuda (Ryukyu University, Okinawa), J. Ishikawa (Osaka University, Osaka), A. Wake (Kokura Memorial Hospital, Fukuoka), A. Kohno (JA Aichi Showa Hospital, Aichi), M. Hara (Ehime Prefectural Central Hospital, Ehime), M. Kuroiwa (Hamanomachi Hospital, Fukuoka), E. Kusumi (Toranomon Hospital, Tokyo), K. Nishiwaki (Jikei University School of Medicine, Tokyo), M. Imamura (Hokkaido University Graduate School of Medicine, Hokkaido), Y. Takemoto (Jiaikai Imamura Hospital, Kagoshima), K. Fujimaki (Yokohama City University School of Medicine, Kanagawa), T. Tamaki (Rinku General Medical Centre, Osaka), Y. Takamatsu (Fukuoka University School of Medicine, Fukuoka), T. Murayama (Hyogo Medical Centre for Adults, Hyogo), M. Hirokawa (Akita University School of Medicine, Akita), T. Kobayashi (Tsuchiura Kyodo General Hospital, Ibaraki), K. Ozawa (Jichi Medical School, Tochigi), T. Ashida (Kinki University School of Medicine, Osaka), S. Imamura (Fukui Medical University, Fukui), Y. Kimura (Tokyo Medical University, Tokyo), K. Hodohara (Shiga Medical University, Shiga), H. Ago (Shimane Prefectural Central Hospital, Shimane), C. Shimazaki (Kyoto Prefectural University of Medicine, Kyoto), H. Teshima (Osaka City General Hospital, Osaka), A. Kubota (National Kyushu Medical Centre, Fukuoka), J. Tsukada (University of Occupational and Enviromental Health, School of Medicine, Fukuoka), C. Hashimoto (Yokohama City University Medical Centre), A. Yokota (Chiba Municipal Hospital, Chiba), H. Tsurumi (Gifu University, Gifu), M. Yamaguchi (Ishikawa Prefectural Central Hospital, Ishikawa), T. Endo (Hokkaido University Graduate School of Medical Sciences, Hokkaido), T. Chujo (Kanazawa University Graduate School of Medical Sciences, Ishikawa), M. Masuda (Tokyo Women's Medical College, Tokyo), S. Murakami (Social Insurance Kyoto Hospital, Kyoto), N. Emi (Nagoya University School of Medicine, Aichi), T. Fujisaki (Matsuyama Red Cross Hospital, Ehime), E. Matsuishi (Saga Prefectural Hospital Koseikan, Saga), F. Sano (St Mariannna University School of Medicine, Yokohama City Seibu Hospital, Kanagawa), Y. Torimoto (Asahikawa Medical College, Hokkaido), K. Yakushiji (Kurume University School of Medicine, Fukuoka), N. Uoshima (Matsushita Memorial Hospital, Osaka), H. Takamatsu (Kurobe City Hospital, Toyama), Y. Kobayashi (Kyoto Prefectural University of Medicine, Kyoto), K. Sunami (National Okayama Medical Centre, Okayama), K. Naito (Hamamatsu University School of Medicine, Shizuoka), H. Taguchi (Kochi Medical School, Kochi), S. Tsuchiya (Institute of Development, Aging and Cancer, Tohoku University, Miyagi), Y. Itoh (National Beppu Hospital, Oita), S. Doi (Kyoto Katsura Hospital, Kyoto), H. Kobayashi (Kyoto Prefectural Hospital, Kyoto), K. Tanimoto (Shin-koga Hospital, Fukuoka), K. Hayashi (Hoshigaoka Koseinenkin Hospital, Osaka), K. Kawachi (Takamatsu Red Cross Hospital, Kagawa), A. Urabe (NTT Kanto Medical Centre, Tokyo), R. Okamoto (Tokyo Metropolitan Komagome Hospital, Tokyo), T. Nishiura (National Kure Medical Centre, Hiroshima), H. Kimura (Kita-Fukushima Medical Centre,

Fukushima), T. Matsunaga (Sapporo Medical University School of Medicine, Hokkaido), N. Masauzi (Hakodate Municipal Hospital, Hokkaido), and T. Ishida (Sapporo Medical School, Hokkaido).

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Case Report

EBV-Positive Burkitt Lymphoma as a Late-Onset Posttransplantion Lymphoproliferative Disorder after Allogeneic Stem Cell Transplantation

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Abstract

Posttransplantation lymphoproliferative disorder (PTLD) is one of the well-recognized complications after allogeneic stem cell transplantation (SCT). It generally occurs early after SCT, and only a few reports of late-onset cases are available. We report a 58-year-old male patient who developed lymphoma 4 years after allogeneic SCT for chronic myeloid leukemia. The presence of *c-myc* translocation and Epstein-Barr virus–encoded RNA in the lymphoma cells, without rearrangement of the 3′-bcr region, confirmed the histopathologic diagnosis of Burkitt lymphoma. DNA chimerism analysis revealed that the lymphoma cells were of donor origin. The patient achieved complete response with intensive chemotherapy. To our knowledge, this is the first report of Burkitt lymphoma as a PTLD occurring after allogeneic SCT.
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Key words: Burkitt lymphoma; Posttransplantation lymphoproliferative disorder; PTLD; Allogeneic stem cell transplantation; Epstein-Barr virus

1. Introduction

Posttransplantation lymphoproliferative disorder (PTLD) is one of the well-recognized complications occurring after allogeneic stem cell transplantation (SCT) [1-5]. PTLD typically develops within 1 year after allogeneic SCT as an early-onset disorder and is frequently fatal [1,2]. Although Burkitt lymphoma has been reported as a rare subtype of PTLD in solid organ transplant recipients [3], there have been no reports of Burkitt lymphoma as a PTLD after allogeneic SCT. We report here a case of Epstein-Barr virus (EBV)-positive Burkitt lymphoma that developed after allogeneic SCT.

2. Case Report

A 54-year-old man visited the National Cancer Center Hospital because of leukocytosis, and his illness was diagnosed as chronic myeloid leukemia (CML) in the chronic phase. Allogeneic SCT from his HLA-matched brother was performed, because cytogenetic response was not obtained by administration of interferon (IFN)-α. When he received IFN-α for the treatment of CML, imatinib mesylate was not available. The preparative regimen consisted of 16 mg/kg busulfan and 120 mg/kg cyclophosphamide. Neither T-cell depletion nor the administration of antithymocyte globulin was performed. Cyclosporine-A (CsA) and short-term methotrexate were given for the prophylaxis of graft-versus-host disease (GVHD).

The peripheral blood leukocyte count reached more than 1.0×10^9/L on day +14 post-SCT. Acute grade II GVHD symptoms consisting of skin eruption and mild hyperbilirubinemia were controlled by 2 mg/kg methylprednisolone. Cytogenetic complete response (CR) was achieved on day +190. Oral administration of CsA was continued for mild extensive chronic GVHD, and it was discontinued on day +511. No recurrence of chronic GVHD was recognized throughout the patient's clinical course. On day +637, daily oral administration of 10 mg of pravastatin was started for the treatment of hyperlipidemia.

On day +1392, the patient developed lymphadenopathy in his neck and supraclavicular region, and tonsillar swelling was also noted. A biopsy specimen from his supraclavicular

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lymph node showed diffuse and dense infiltration of medium- to-large–sized, atypical lymphoid cells with hyperchromatic nuclei, and a starry sky pattern was recognized (Figures 1A and 1B). Mitotic figures were numerous. Immunohistochemical staining showed that the tumor cells were positive for CD10 and CD20 and negative for CD3, CD68, bcl-2, myeloperoxidase, latent membrane protein-1 (LMP-1), and EBV nuclear antigen-2 (EBNA-2), whereas EBV-encoded RNA-1 (EBER-1) was detected in tumor cells by in situ hybridization (Figure 1C). More than 99% of the tumor cells were Ki-67 positive.

Southern blot analysis revealed no rearrangement of the *3′-bcr* gene, a finding indicating that it was highly unlikely that the patient had lymphoid crisis of CML (data not shown). Fusion of the *c-myc* and Ig heavy chain (IgH) genes was shown by fluorescence in situ hybridization analysis (Figure 2), and the bone marrow was not infiltrated with lymphoma cells. Therefore, this case was diagnosed as EBV-positive Burkitt lymphoma, a subtype of late-onset PTLD, according to the World Health Organization (WHO) classification [2]. The clinical stage was II according to both the Ann Arbor and Murphy staging systems. DNA chimerism analysis revealed that the lymphoma cells were of donor origin (data not shown).

The patient achieved CR under intensive chemotherapy administered according to the National Cancer Institute protocol for Burkitt lymphoma, CODOX-M/IVAC [6]. At the time of this report, CR had been maintained without therapy for 17 months.

3. Discussion

PTLD is one of the well-recognized complications after allogeneic SCT; however, its cumulative incidence is reported to be relatively low: 1.0% ± 0.3% at 10 years [1]. Curtis et al reported that the incidence of PTLD varied markedly with time after SCT, with particularly high rates occurring in the first 5 months, followed by a steep decline in incidence between 6 and 12 months post-SCT [1]. In the Curtis et al report, 14 patients with late-onset PTLD occurring among 18,014 patients who underwent allogeneic SCT were documented, and the only risk factor identified for late-onset PTLD was extensive chronic GVHD. In contrast, in PTLD after solid organ transplantation, late-onset cases are not rare. The risk of PTLD development in solid organ transplant recipients varies depending on the type of allograft and immunosuppressive therapy. In solid organ transplant recipients treated with azathioprine, the mean interval between transplantation and development of PTLD is 48 months, whereas in those treated with CsA it is 15 months [2]. The reasons for the infrequency of late-onset PTLD after allogeneic SCT might include the following: almost all SCTs are performed for malignant neoplasms; some patients undergoing SCT die of disease progression or SCT-related complications; most long-term survivors after SCT are free from immunosuppressive therapy.

In the present case, the patient had been given pravastatin, an inhibitor of hydroxy-methyl-glutaryl coenzyme A reductase (or statin), which is a popular agent for the treatment of hyperlipidemia. A recent in vitro study by Kwak et al showed that statins act as direct inhibitors of the induction

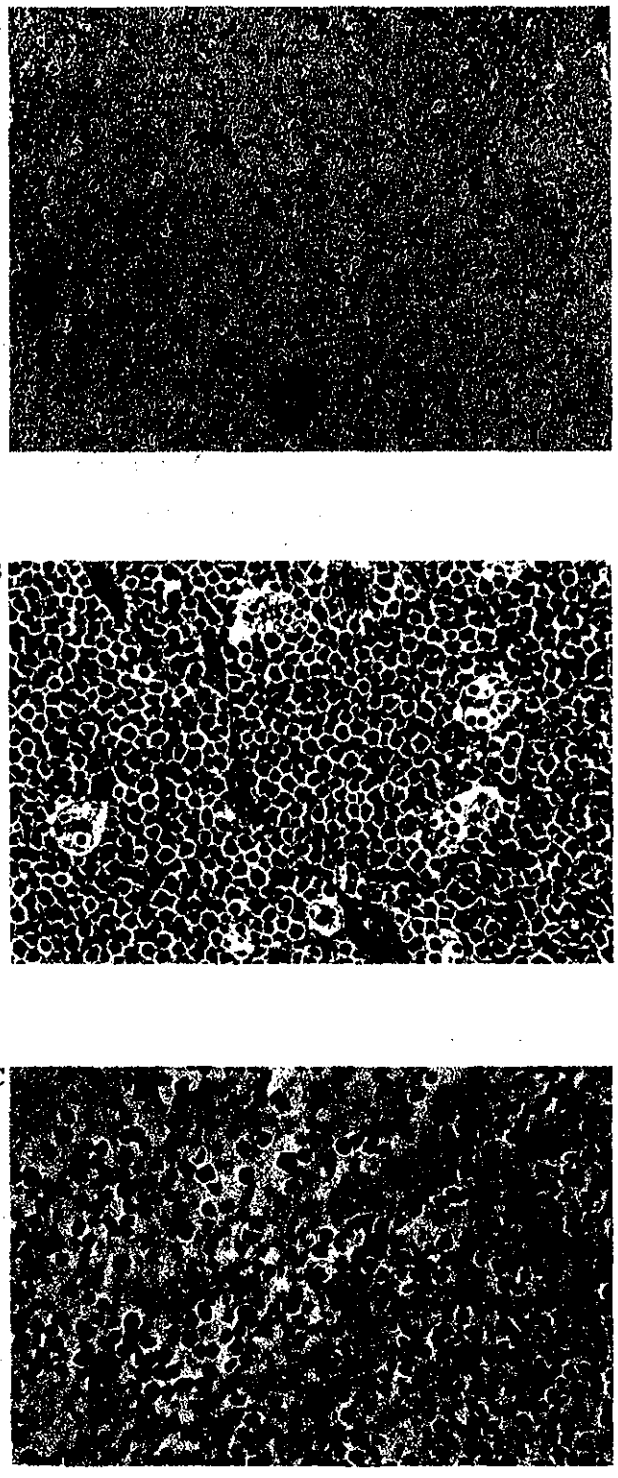

Figure 1. Histopathologic findings of the biopsied supraclavicular lymph node. A, A prominent starry sky pattern was recognized (hematoxylin and eosin, original magnification ×100); B, diffuse and dense infiltration of medium- to-large–sized atypical lymphoid cells with hyperchromatic nuclei was recognized (hematoxylin and eosin, original magnification ×400); C, Epstein-Barr virus–encoded RNA 1 was detected in neoplastic cells (in situ hybridization, original magnification ×400).

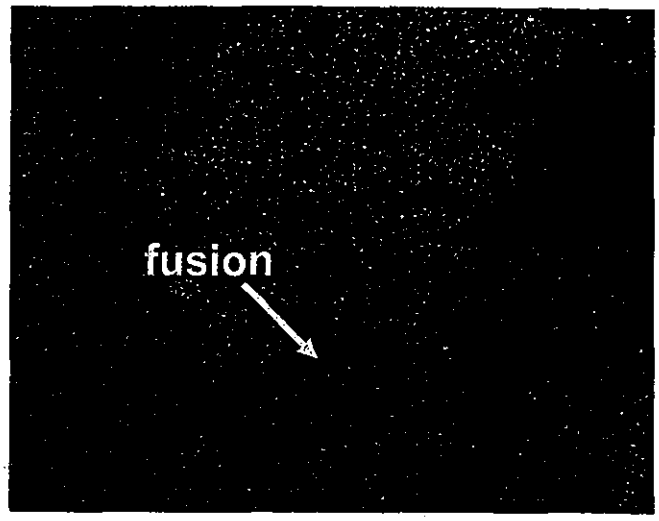

Figure 2. Fluorescence in situ hybridization analysis of the biopsied supraclavicular lymph node. The immunoglobulin (Ig)H/c-myc fusion signal was recognized. The signals represented IgH/c-myc rearrangement (yellow), c-myc (orange), IgH (green) and CEP8 (aqua). To detect IgH/c-myc rearrangements, a dual fusion translocation probe (VYSIS) was used.

of MHC class II–mediated T-cell activation [7]. They proposed recognition of statins as a new type of immunomodulator. A review by Newman et al suggested the potential carcinogenicity of long-term administration of statins in humans based on rodent carcinogenicity studies [8]; however, a recent metaanalysis of 5 large, randomized, placebo-controlled clinical trials showed no association between the use of statins and the risk of fatal or nonfatal cancers including malignant lymphoma [9].

The lymphoma cells in this case were positive for EBER-1. The majority of PTLD cases are associated with EBV infection, although approximately 20% of PTLD cases are not [2,5]. Three clinical variants of Burkitt lymphoma have been recognized: endemic, sporadic, and immunodeficiency-associated variants (including human immunodeficiency virus–associated [10] and PTLD after solid organ transplantation). Interestingly, the frequency of EBV association is quite different among the variants of Burkitt lymphoma [3,10]. Moreover, all of the reported EBV-positive Burkitt lymphoma cases, including immunodeficiency-associated cases, showed a latency I form of EBV infection [3,10], which is lacking EBNA-2 and LMP-1, although most PTLD cases show a latency III pattern. Burkitt lymphoma after solid organ transplantation and EBV-negative PTLD tend to occur later than EBV-positive cases [3,5]. Considering these findings, it is likely that the essential factor in Burkitt lymphoma development as a PTLD is *c-myc* dysregulation caused by genetic instability after prolonged mild immunosuppression, independent of EBV stimulation.

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Early Central Nervous System Complications after Reduced-Intensity Stem Cell Transplantation

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ABSTRACT

To investigate clinical characteristics of early central nervous system (CNS) complications after reduced-intensity stem cell transplantation (RIST), we reviewed the medical records of 232 patients who had undergone RIST for hematologic diseases at our institutions between September 1999 and June 2003. All patients had received purine analog–based preparative regimens. Stem cell sources comprised granulocyte colony-stimulating factor–mobilized blood from HLA-identical or 1 locus–mismatched related donors (n = 151), unrelated bone marrow (n = 44), or unrelated cord blood (n = 37). Graft-versus-host disease prophylaxis incorporated cyclosporine with or without methotrexate. Diagnosis of CNS complications was based on clinical, radiologic, and microbiological findings. CNS complications occurred in 18 patients (7.8%), with a median onset of 22 days, and were infectious (n = 1), metabolic (n = 15), or cerebrovascular (n = 2). Symptoms included seizures (n = 7), visual disturbance (n = 2), headache (n = 8), nausea (n = 8), vomiting (n = 6), impaired consciousness (n = 16), and hemiparesis (n = 3). Complications improved promptly in 10 patients, and 8 patients died without improvement within 30 days. Multivariate analysis with logistic regression identified umbilical cord blood transplantation as a significant risk factor for early CNS complications (odds ratio, 14.5; 95% confidence interval, 3.7-56.9; $P < .0001$). CNS complications are a significant problem after RIST, particularly with umbilical cord blood. Limbic encephalopathy is an unrecognized subtype of neurotoxicity after umbilical cord blood transplantation.

KEY WORDS

Allogeneic hematopoietic stem cell transplantation • Graft-versus-host disease • Umbilical cord • Cyclosporine neurotoxicity • Limbic encephalopathy

INTRODUCTION

Research in the area of neurologic complications is limited with regard to allogeneic hematopoietic stem cell transplantation (allo-HSCT). Most studies have been either retrospective or reliant on autopsy records [1–6]. Prospective evaluation of this complication has been rare [7,8]. The incidence of neurologic complications has varied from 37% to 91%, and such complications have been the cause of death in 6% to 26% of patients [1,3,8]. These findings indicate that neurologic complications represent a significant problem in conventional myeloablative allo-HSCT.

Neurologic complications occur at 3 stages of allo-HSCT: (1) after the use of conditioning agents for marrow ablation, (2) during posttransplantation pan-

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cytopenia, or (3) after immunosuppressive therapies and graft-versus-host disease (GVHD) [1–3,9]. These complications are usually categorized into 4 groups: (1) infectious, (2) cerebrovascular, (3) metabolic, or (4) immune-mediated disorders. Among these 4 types of neurotoxicity, cerebrovascular disorders and central nervous system (CNS) infection before engraftment have represented significant problems in conventional allo-HSCT [1,4,8]. Whether GVHD can affect the CNS remains controversial [10], and neurotoxicity has thus been regarded as an early complication after allo-HSCT.

A new transplantation strategy using a nonmyeloablative preparative regimen—reduced-intensity stem cell transplantation (RIST)—was developed to decrease regimen-related toxicity while preserving adequate antitumor effects [11,12]. Different pioneering conditioning regimens for RIST have been investigated, such as those including purine analogs [11–13] and total body irradiation (TBI) combined with potent immunosuppressants [14]. Although early reports on RIST emphasized safety advantages [11,15], recent studies have revealed considerable toxicities associated with this type of transplantation [16,17]. Little information is available on CNS complications after RIST. We investigated early CNS complications after RIST with regard to incidence, characteristics, and risk factors.

PATIENTS AND METHODS

Patients

Medical records of all patients who underwent RIST for treatment of hematologic diseases at the National Cancer Center Hospital or Toranomon Hospital between September 1999 and June 2003 were reviewed. Subjects comprised 232 patients (143 men and 89 women) with a median age of 54 years (range, 15-73 years). Primary diseases consisted of acute myeloid leukemia (n = 63), chronic myelogenous leukemia (n = 15), acute lymphoblastic leukemia (n = 8), malignant lymphoma (n = 67), myelodysplastic syndrome (n = 42), adult T-cell leukemia/lymphoma (n = 17), multiple myeloma (n = 10), aplastic anemia (n = 8), and others (n = 2). Hematologic malignancies were refractory to cytotoxic chemotherapy in 142 patients and were in remission or sensitive to treatment in 81 patients. Underlying diseases were not malignant in the remaining 9 patients.

Transplantation Procedures

All patients had received purine analog–based preparative regimens comprising fludarabine/cyclophosphamide (n = 12) [18], fludarabine/busulfan (n = 139) [19], fludarabine/melphalan (n = 55) [20], cladribine/busulfan (n = 25) [13], and others (n = 1). Rabbit antithymocyte globulin and TBI (4-8 Gy) were added to preparative regimens in 50 and 65 patients, respectively.

Stem cell sources were HLA-identical or 1 locus–mismatched granulocyte colony-stimulating factor–mobilized peripheral blood (n = 151), unrelated bone marrow (n = 44), or unrelated umbilical cord blood (n = 37). GVHD prophylaxis was cyclosporine alone (3 mg/kg) in RIST from an HLA-identical related donor and reduced-intensity umbilical cord blood transplantation (RI-UCBT). Patients who received transplants from a 1 locus–mismatched related donor or a matched unrelated donor received cyclosporine and short-term methotrexate. Grade II to IV acute GVHD was treated with methylprednisolone 2 mg/kg/d in addition to cyclosporine.

Diagnostic Criteria for Early CNS Complications

Early CNS complications were defined as CNS toxicity occurring within 100 days of transplantation. Diagnosis of CNS complications was made by clinical, radiologic, or microbiological findings (or a combination of these). CNS complications were categorized into 4 groups: (1) infectious, (2) cerebrovascular, (3) metabolic, and 4) immune-mediated disorders. CNS complications that occurred after relapse or progression of underlying diseases were excluded from analysis. Diagnosis of cyclosporine encephalopathy was based on the typical radiologic findings, ie, symmetrical white matter lesions mainly localized in the occipital lobe. In the case of limbic encephalopathy, the diagnosis was based on selective involvement of the medial temporal lobe on magnetic resonance imaging (MRI). Diagnosis of cerebrovascular diseases was confirmed by neuroradiologic or postmortem studies (or both). Abnormalities on imaging were defined as areas of low white-matter attenuation on computed tomographic (CT) scans and as areas of T1-weighted hypointensity and T2-weighted hyperintensity on MRI.

End Points and Statistical Analysis

The primary end point of this study was incidence of early CNS complications after RIST. A secondary objective was to investigate characteristics and risk factors for such complications. The median follow-up of surviving patients was 17.5 months (range, 8.5-52.7 months).

Univariate analysis with χ^2 and Mann-Whitney tests was performed to identify risk factors for CNS toxicity. Variables included age, sex, primary disease, disease status (refractory or sensitive to cytotoxic chemotherapy), and type of transplantation. We added multiple logistic regression analysis to assess the fractionated contribution of the above-mentioned potentially predictive factors. Variables that had a P value of

<.25 on univariate analysis were entered into the mixed-effects model. Those that contributed <10% to the overall ability of the model to influence serum levels of fluconazole were sequentially eliminated. The level of significance was set at $P < .05$.

RESULTS

Incidences and Types of CNS Complications after RIST

A total of 18 patients (7.8%) developed early CNS complications. Subtypes comprised infectious (invasive aspergillosis; n = 1), metabolic (n = 15; cyclosporine neurotoxicity, n = 4; limbic encephalopathy, n = 4; hemophagocytic syndrome, n = 1; leukoencephalopathy, n = 1; idiopathic, n = 5), and cerebrovascular (subdural hematoma, n = 1; subarachnoid hemorrhage, n = 1) complications. No patient was diagnosed with immune-mediated CNS toxicity.

Clinical and Laboratory Features at Onset of CNS Complications

Backgrounds of the patients who developed CNS complications are shown in Table 1. Except for a patient with aplastic anemia, the remaining 17 patients had refractory hematologic diseases.

Clinical and laboratory findings at the onset of CNS complications are shown in Table 2. The median onset was 22 days (range, 1-74 days). Seizures developed in 7 patients (generalized, n = 6; focal, n = 1). Other symptoms included headache (n = 8), nausea (n = 8), vomiting (n = 6), impaired consciousness (n = 16), and hemiparesis (n = 3). Two of 11 evaluable patients developed visual disturbance (blurred vision). Cyclosporine blood levels were higher than target levels (250-350 ng/mL) in 4 patients. Nine patients displayed fever at the onset of CNS complications, and 2 patients were receiving steroid therapy for acute GVHD. Concomitant conditions in the 15 patients with metabolic encephalopathy included systolic hypertension (>170 mm Hg) in 6 patients, diastolic hypertension (>100 mm Hg) in 6, hyponatremia in 8, hypomagnesemia in 6, and hypocholesterolemia in 4. Cerebrospinal fluid obtained from 5 patients showed normal levels of protein and cell counts. No pathogens such as bacteria, fungi, or viruses were cultured from cerebrospinal fluid.

Imaging Studies

Seventeen patients underwent cranial imaging studies: CT only in 6, MRI only in 4, and both CT and MRI in 7. Results are shown in Table 2. Of the 14 patients with metabolic encephalopathy who underwent imaging studies, 7 displayed some abnormal findings. Lesions were located bilaterally in the occipital lobes (n = 3), temporal lobes (n = 3), or periventricular white matter (n = 1). Three patients who had received UCBTs were diagnosed with limbic encephalopathy on the basis of imaging studies (Figure 1).

Treatment and Outcomes

Cyclosporine was continued (n = 4) or withheld (n = 14) for 1 to 14 days. Two patients received antihypertensive agents. Corticosteroids were used in 16 patients. In most patients, subsequent treatment with cyclosporine was well tolerated without recurrence of neurotoxicity.

Eight patients died within 30 days of developing CNS complications. Causes of death included disease progression (n = 1), subarachnoid hemorrhage (n = 1), GVHD (n = 3), and infection (n = 3). CNS complication was a primary cause of death in 2 cases (invasive aspergillosis, n = 1; subarachnoid hemorrhage, n = 1).

Risk Factors

In univariate analysis, the development of CNS complications was associated with the use of umbilical cord blood ($P < .0001$) and the status of underlying disease (chemorefractory hematologic diseases versus others; $P = .032$). Multivariate analysis showed that the use of umbilical cord blood was significantly correlated with CNS complications after RIST (odds ratio, 14.5; 95% confidence interval, 3.7-56.9; $P < .0001$).

DISCUSSION

In this study, CNS complications occurred in 7.8% of RIST recipients, and mortality with 30 days of its development reached 44%. These findings indicate that early CNS complications are a common and important problem in both RIST and conventional allo-HSCT [1,3,4,8]. However, significant differences existed in clinical characteristics of CNS complications between RIST and conventional myeloablative allo-HSCT.

The incidence of CNS complications was lower in RIST than in conventional allo-HSCT, in which 11% to 44% of patients develop such complications [2,6,7]. In conventional transplantation, the most common causes of CNS complications are cerebrovascular disease and infection after conventional transplantation [1,4,8], and these are mostly attributable to regimen-related toxicity [21,22] or profound myelosuppression before engraftment [1,3,4]. However, in RIST, regimen-related toxicities are minimal, and myelosuppression is short. Acute GVHD, as the most important complication in RIST [16], rarely affects the CNS [23]. RIST has, at the very least, improved the safety of allo-HSCT by decreasing the incidence of CNS complications.

Table 1. *Backgrounds of Patients Who Developed CNS Complications after RIST*

Patient No.	Type of CNS Complication	Age (y)	Sex	Primary Disease	History of CNS Involvement	No. of Chemotherapy Regimens before Transplantation	Preparative Regimen	GVHD Prophylaxis	Stem Cell Source
1	Cerebrovascular	57	M	ALL	Yes	1	Flu/BU/ATG	Cyclosporine	HLA-identical sibling
2	Cerebrovascular	32	F	Malignant lymphoma	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
3	Infectious	40	M	MDS	No	2	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
4	Metabolic	21	M	Aplastic anemia	No	1	Flu/BU/ATG	Cyclosporine	HLA-identical sibling
5	Metabolic	67	M	Malignant lymphoma	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
6	Metabolic	67	M	MDS	No	1	Flu/BU/TBI 4 Gy/ATG	Cyclosporine/Methotrexate	Matched unrelated donor
7	Metabolic	51	M	AML	No	2	Flu/BU/TBI 4 Gy	Cyclosporine	Umbilical cord blood
8	Metabolic	52	M	MDS	No	2	Flu/ATG	Cyclosporine	Mismatched related donor
9	Metabolic	49	M	ALL	No	1	Flu/BU	Cyclosporine	HLA-identical sibling
10	Metabolic	48	F	AML	Yes	3	Flu/BU/ATG	Cyclosporine/Methotrexate	Mismatched related donor
11	Metabolic	57	F	AML	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
12	Metabolic	66	M	Malignant lymphoma	No	2	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
13	Metabolic	63	M	MDS	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
14	Metabolic	54	M	AML	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
15	Metabolic	55	M	Malignant lymphoma	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
16	Metabolic	62	F	ATL	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
17	Metabolic	46	M	ATL	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood
18	Metabolic	54	F	ATL	No	1	Flu/Mel/TBI 4 Gy	Cyclosporine	Umbilical cord blood

AML indicates acute myeloblastic leukemia; MDS, myelodysplastic syndrome; ALL, acute lymphoblastic leukemia; ATL, adult T-cell leukemia/lymphoma; Flu, fludarabine; BU, busulfan; ATG, antithymocyte globulin; TBI, total body irradiation; CNS, central nervous system.

Table 2. *Clinical, Laboratory, and Radiologic Characteristics at the Onset of CNS Complications*

Patient No.	Type of CNS Complication	Cause	Onset (day)	Clinical Findings: Impaired Consciousness	Seizures	Visual Disturbance	Fever (>38.0°C)	Blood Pressure (Systolic; mm Hg)	Blood Pressure (Diastolic; mm Hg)	Cyclosporine (ng/mL)*	Laboratory Findings: Creatinine (mg/dL)	Hemoglobin (g/dL)	Na (mEq)	K (mEq)	Mg (mEq)	T-Chol (mg/dL)	Radiologic Examination: CT	T2-Weighted MRI	Electroencephalogram	Outcomes
1	Cerebrovascular		16	No	No	No	No	170	87	386	0.6	9.0	139	4.3	1.5	NA	NA	Subdural hematoma	NA	Improved
2	Cerebrovascular		40	Yes	Yes	Yes	Yes	152	98	NA	1.6	7	137	3.5	1.3	217	Brain edema, subarachnoid hemorrhage	NA	NA	Dead
3	Infection		68	Yes	No	No	No	108	64	NA	1.2	7.5	136	3.4	0.6	140	Mass in the parietal lobe	NA	NA	Dead
4	Metabolic encephalopathy	Cyclosporine	8	No	No	No	Yes	142	74	316	0.8	6.5	140	4.0	1.5	NA	NA	Bilateral parietal and occipital lobes	NA	Improved
5	Metabolic encephalopathy	Limbic encephalopathy	22	Yes	Yes	No	No	170	108	219	0.3	8.2	124	3.5	1.2	143	NA	Bilateral temporal lobes	NA	Improved
6	Metabolic encephalopathy	Cyclosporine	22	Yes	Yes	Not evaluable	Yes	182	100	266	1.2	7.5	141	2.5	1.8	NA	Low-density area in the bilateral occipital lobes	NA	NA	Improved
7	Metabolic encephalopathy	Cyclosporine	22	Yes	Yes	Not evaluable	No	120	80	348	1.5	6.5	139	4.8	1.3	107	Normal	Bilateral occipital lobes	NA	Improved
8	Metabolic encephalopathy	Cyclosporine	7	Yes	Yes	Not evaluable	Yes	170	78	342	0.8	4.1	138	3.6	1.3	145	Normal	NA	NA	Improved
9	Metabolic encephalopathy	Hemophagocytic syndrome	46	Yes	No	Yes	No	130	64	NA	0.7	9.7	139	4.1	NA	110	NA	Normal	NA	Dead
10	Metabolic encephalopathy	Leukoencephalopathy	12	Yes	No	No	Yes	110	56	NA	1.1	6.5	134	4.0	NA	NA	Normal	Bilateral frontal and parietal lobes (periventricular area)	NA	Dead
11	Metabolic encephalopathy		20	Yes	No	No	No	154	100	584	0.8	8.2	130	2.9	NA	157	Normal	NA	NA	Dead
12	Metabolic encephalopathy		13	Yes	No	Not evaluable	Yes	190	120	511	1.5	8.1	130	4.2	NA	162	Normal	Normal	Normal	Improved
13	Metabolic encephalopathy	Limbic encephalopathy	24	Yes	No	No	No	158	85	68	0.8	9.7	131	4.3	NA	NA	Normal	Bilateral temporal lobes	Diffuse slow waves	Improved
14	Metabolic encephalopathy		22	Yes	Yes	Not evaluable	Yes	168	86	416	0.8	7.8	134	3.9	1.3	107	Normal	Normal	Diffuse slow waves	Dead
15	Metabolic encephalopathy		41	Yes	No	No	Yes	180	120	52	NA	NA	NA	NA	NA	NA	Normal	NA	Diffuse slow waves	Dead
16	Metabolic encephalopathy	Limbic encephalopathy	26	Yes	Yes	Not evaluable	Yes	174	98	37	2.4	7.4	127	3.4	1.4	130	Normal	Bilateral temporal lobes	Spike wave in frontal lobes	Dead
17	Metabolic encephalopathy		18	Yes	No	Not evaluable	No	150	100	156	0.4	9.7	113	3.7	NA	NA	Normal	Normal	Diffuse slow waves	Improved
18	Metabolic encephalopathy		74	Yes	No	No	No	130	80	NA	2.2	12.1	119	5.4	NA	NA	NA	NA	NA	Improved

NA indicates not applicable; T-chol, total cholesterol.
*Continuous infusion of cyclosporin was given at target levels of 250-350 ng/mL.

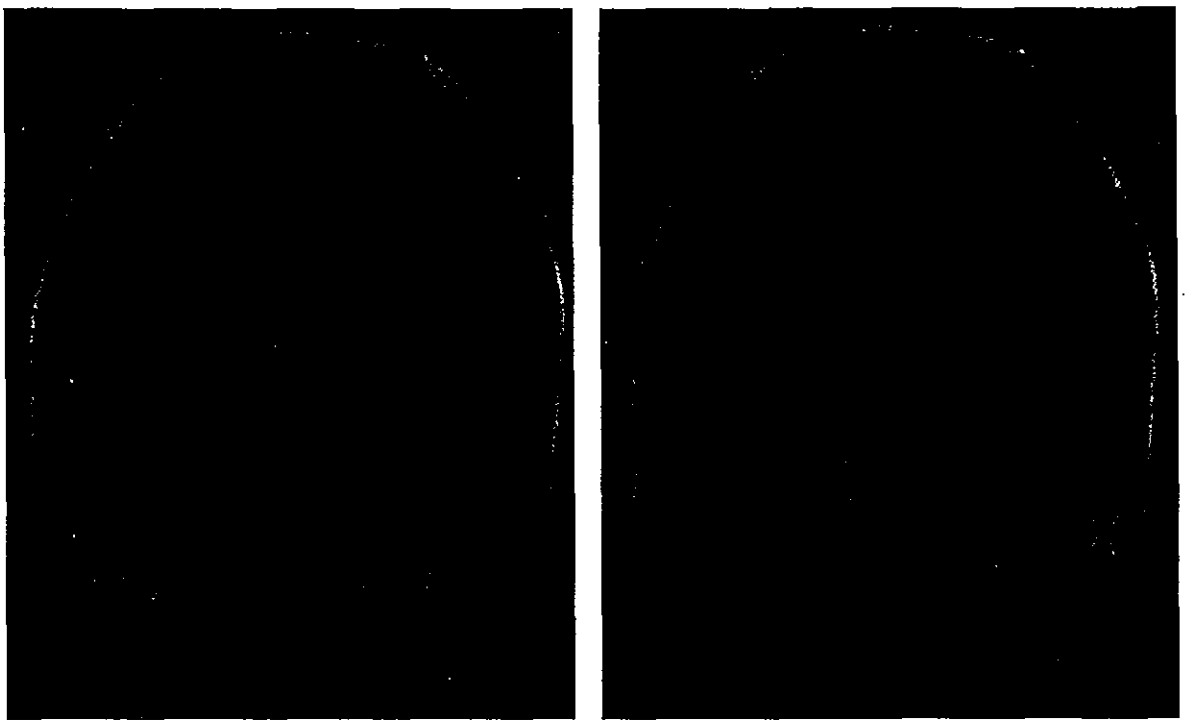

Figure 1. T2-weighted magnetic resonance image of the brain showing high-intensity signals in bilateral temporal lobes. The patient was diagnosed with limbic encephalopathy.

In contrast to conventional allo-HSCT, the incidence of metabolic encephalopathy is increased with RIST. In this study, 15 of 18 CNS complications were metabolic. Of these patients, 4 were diagnosed with cyclosporine encephalopathy on the basis of typical clinical and imaging findings. The incidence of cyclosporine encephalopathy was 1.7% after RIST, which is comparable to that after conventional allo-HSCT in young patients [24]. The median onset was 15 days (range, days 7-22). Three patients displayed seizures and altered mental status that improved after discontinuation of cyclosporine. Blood levels for cyclosporine were normal in all of the 4 patients. Risk factors for cyclosporine encephalopathy have been reported [24,25], and hypertension (2/4), hypocholesterolemia (1/2), and hypomagnesemia (3/4) were observed in our study. These findings are comparable to previous reports on cyclosporine neurotoxicity [24,25]. The growing use of RIST has increased the chance of cyclosporine being administered to elderly patients. Our study does not support the hypothesis that cyclosporine neurotoxicity increases in elderly patients, but further investigation of the safety issues for cyclosporine is warranted. General management such as blood pressure control and electrolyte replacement may be important in preventing adverse effects of cyclosporine.

No findings in the remaining 11 patients with metabolic encephalopathy suggested cyclosporine encephalopathy. However, it should be noted that all 11 patients received a fludarabine-based preparative regimen and that fludarabine has a considerable neurotoxicity [26–32]. These findings suggest that fludarabine might have contributed to the development of CNS toxicity in this study. Except for 1 patient with leukoencephalopathy and hemophagocytic syndrome–related CNS complications, the other 10 patients had undergone UCBT. The incidence of CNS complications after RI-UCBT was 24%. Cord blood as a stem cell source was an independent risk factor in multivariate analysis (odds ratio, 14.5; 95% confidence interval, 3.7-56.9; $P < .0001$). Few studies on CNS complications after myeloablative UCBT have been reported. This complication is possibly characteristic of RI-UCBT. All 10 patients developed altered mental status, including 3 with generalized seizures. Brain imaging in 3 patients showed abnormal signals around the hippocampus, whereas images were normal in the other 6 patients. Hippocampal encephalopathy in the 3 patients involved both white and gray matter and was thus distinct from leukoencephalopathy. Similar findings after RI-UCBT have recently been reported [33]. Although an association with tacrolimus administration has been suggested, none of our patients received tacrolimus, thus indicating other causes. Possibilities include infection, regimen-related toxicity, and immune reaction associated with the use of cord blood. Eight patients who developed metabolic encephalopathy after RI-UCBT had received fludarabine, melphalan, and TBI as a preparative regimen.

This has a higher intensity than most reduced-intensity regimens and might have caused CNS toxicities.

Conversely, CNS complications do not represent a significant concern in bone marrow or peripheral blood transplantation with similar reduced-intensity regimens. Because adult RI-UCBT recipients receive a relatively low dose of $CD34^+$ cells, it would raise the concern that there might have been delayed engraftment, leading to an increase in subclinical or undetected CNS viral infections. However, this possibility seemed unlikely. In RI-UCBT with fludarabine, melphalan, and intermediate-dose TBI as a preparative regimen and cyclosporine as GVHD prophylaxis [34], the median day of neutrophil engraftment was 17.5 days. This is comparable to RIST with granulocyte colony-stimulating factor–mobilized blood [11,13]. Furthermore, neither cerebrospinal findings nor blood cultures identified CNS infection in our study, and no patient had GVHD at the onset of CNS complications. Because 4 of the 10 patients who underwent RI-UCBT died soon after the development of CNS complications, symptoms might represent an early manifestation of a systemic disorder predisposing for multiple organ dysfunction syndrome, increasing the risk of transplant-related mortality [35]. However, the association of CNS complications with engraftment is noteworthy in RI-UCBT. We did not use antithymocyte globulin or corticosteroids for preparative regimens or GVHD prophylaxis, respectively, although these practices have been commonly used in previous studies on UCBT [36]. Both agents display strong immunosuppressive properties. The fluid accumulation often observed during this period may have accentuated the tendency for brain edema to develop, as seen in patients with renal decompensation. In RI-UCBT with our regimens [34], the cumulative incidence of complete donor chimerism at day 60 was 93%, and the median time to complete donor chimerism was 22 days. Grade II to IV acute GVHD occurred in 27% of patients. Approximately 60% of RI-UCBT recipients had a noninfectious fever before engraftment (median onset, day 9). Manifestations included a high-grade fever, eruption, and diarrhea, and corticosteroids were effective for ameliorating these reactions. These findings suggest that they might be associated with a cytokine storm induced by massive proliferation of cells with a unique cytokine profile and that the CNS toxicity was attributable to these immune responses. We therefore treated the CNS toxicity with corticosteroids. Because CNS toxicity is associated with considerable morbidity and mortality, optimal preventive measures for CNS complications after RI-UCBT should be established. Intensification of GVHD prophylaxis, such as with methotrexate, might prove beneficial for this purpose.

This investigation was a retrospective study based on medical records. Pathologic examinations were not used in most patients, and diagnosis of CNS complications was established on the basis of clinical and radiologic findings. Mild neurotoxicity associated with allo-HSCT was likely neglected, and incidences might have been underestimated in this study. Compared with autopsy studies, approximately half of the patients with neurologic complications had been diagnosed during life [4]. Further prospective evaluation is warranted to clarify incidences and clinical characteristics for CNS complications after RIST and to establish optimal preventive and therapeutic measures.

In conclusion, we have demonstrated that CNS complications are a common and frequently fatal complication after RIST, particularly after the use of umbilical cord blood. Metabolic encephalopathy is the most common subtype of CNS complication after RIST, and it frequently manifests as limbic encephalopathy in RIST with umbilical cord blood.

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Regimen-related toxicity following reduced-intensity stem-cell transplantation (RIST): comparison between Seattle criteria and National Cancer Center Common Toxicity Criteria (NCI-CTC) version 2.0

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Summary:

Acute regimen-related toxicity (RRT) is minimal in reduced-intensity stem-cell transplantation (RIST). However, the Seattle RRT grading (Bearman *et al*), developed in the context of conventional-intensity transplantation, is frequently applied to RIST. We compared the National Cancer Institute Common Toxicity Criteria (NCI-CTC) version 2.0 with the Seattle criteria after RIST in 86 patients. RRT *within 30 days of transplant* graded by both sets of criteria were significantly associated with the outcome confirming the predictive value of both the systems. A total of 15 patients died of disease progression, and 12 of transplant-related mortality: RRT ($n=2$), graft-versus-host disease (GVHD) ($n=7$), infection ($n=1$), and others ($n=2$). GVHD-related deaths primarily resulted from infections after steroid treatment ($n=6$) and bronchiolitis obliterans ($n=1$). This study shows that NCI-CTC is appropriate in toxicity evaluation of RIST, and that its application to RIST enables a toxicity comparison between RIST and other types of cancer treatments. Since GVHD is a significant problem in RIST, *modifications* are required to evaluate immunological complications following RIST.

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Reduced-intensity stem-cell transplantation (RIST) is associated with lower acute regimen-related toxicity (RRT).[1–6] The recognition and grading of toxicity caused by RIST is important in practice and in designing clinical trials.

After conventional-intensity stem-cell transplantation (CIST), patients can die of disease progression or complications of therapy. RRT is toxicity that is directly attributable to the conditioning regimen, but usually excludes graft-versus-host disease (GVHD), infection, and hemorrhage. It is often difficult to separate RRT from other toxicities. The Seattle group proposed a toxicity grading system specifically for allogeneic HSCT based upon a retrospective review of 195 patients who underwent CIST.[7] RRT in RIST is minimal and a significant proportion of morbidity and mortality is secondary to GVHD.[8] However, the Seattle criteria have been used to evaluate RIST.

The National Cancer Institute Common Toxicity Criteria version 2.0 (NCI-CTC ver. 2.0) has been widely used for development and evaluation of chemotherapeutic agents. If NCI-CTC ver. 2.0 can be applied to RIST, toxicity comparison between RIST and various other cancer treatments would be possible. We studied 86 patients who underwent RIST to see if NCI-CTC ver. 2.0 could be used to predict transplant-related mortality (TRM) and overall survival (OS) after RIST.

Patients and methods

Patients

The medical records of all of the patients ($n=86$) who underwent RIST at the National Cancer Center Hospital between January 1999 and April 2002 were reviewed. All patients and donors gave their written informed consent in accordance with the requirements of the Institutional Review Board of the National Cancer Center Hospital.

The median age was 51 years (range, 4–67). The underlying disease was AML ($n=26$), lymphoma ($n=21$), MDS ($n=11$), CML ($n=5$), ALL ($n=2$), other hematologic diseases ($n=3$), and solid tumors ($n=18$). The hematological malignancies were refractory to chemotherapy in 33 cases, and were in remission or sensitive to

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treatment in the remaining 35 cases. All of the patients with solid tumors were refractory to conventional treatments.

Preparative regimens

The preparative regimens comprised busulfan 4 mg/kg daily for 2 days with fludarabine 25 mg/kg daily for 6 days ($n = 64$)[9] or cladribine 0.11 mg/kg daily for 6 days ($n = 22$).[5] Rabbit antithymocyte globulin (ATG, Thymoglobulin, IMTIX-SANGSTAT, Lyons, France) 2.5 mg/kg for 2 or 4 days and TBI (4 Gy) were added to the preparative regimen in 49 and three patients, respectively.

Stem-cell source

A total of 64 patients had an HLA-identical related donor and 17 had a one-locus mismatched related donor.[10] Peripheral blood was used for these 81 patients. Five patients received bone marrow from a matched unrelated donor (MUD).

Prophylaxis and treatment of GVHD

Patients who were transplanted from an HLA-identical related donor received cyclosporin alone (3 mg/kg). Those who were transplanted from an HLA-mismatched related donor or MUD received cyclosporin and short-course methotrexate.

The diagnosis of GVHD was made on clinical grounds in conjunction with biopsy of the skin and digestive tract. Acute and chronic GVHD were graded according to the consensus criteria.[11,12] Grade II–IV acute GVHD was treated with 2 mg/kg/day of methylprednisolone in addition to cyclosporin.

Management of infections

All of the patients stayed in reverse isolation in a laminar airflow-equipped room, and received prophylaxis with trimethoprim/sulfamethoxazole or pentamidine inhaler, ciprofloxacin, and fluconazole against *Pneumocystis carinii*, bacterial, and fungal infection, respectively. Herpes virus prophylaxis with acyclovir was also given as previously described.[13] CMV pp65 antigenemia was routinely monitored once a week. When antigenemia was detected, preemptive therapy with ganciclovir was initiated as previously reported.[14]

Toxicity grading

The Seattle criteria assess post transplant RRT in eight organs: the heart, bladder, kidneys, lungs, liver, mucosa, central nervous system (CNS), and gut. As the criteria exclusively assess RRT, they exclude adverse events attributable to GVHD and infection. Similarly, renal failure is excluded when it coincides with the administration of known nephrotoxic agents. RRT was graded with the Seattle criteria on the day of initiation of conditioning regimens and days 0, 7, 14, and 28 (and on day 100 for lungs) post transplant (Table 1).

NCI-CTC ver. 2.0 assesses more than 260 adverse events in 24 organ systems. To make a comparison, 16 items in NCI-CTC ver. 2.0 equivalent to those in the Seattle criteria were regraded. These included arrhythmia, cardiovascular dysfunction, hematuria, renal dysfunction/creatinine levels, lung toxicity, serum levels of bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP), weight gain/ascites, neurological dysfunction, mucositis, and diarrhea (Table 2). All of the observed adverse events were evaluated daily with NCI-CTC ver. 2.0 from the day of initiation of conditioning regimens until day 30 post transplant (and on day 100 for lungs).

Two or more independent physicians graded RRT based on the medical records. If there was discordance between their diagnoses, another physician (MK) made a final diagnosis.

Statistical analysis

The probability of OS was determined with the Kaplan–Meier method as of June 31, 2002. The median follow-up period after transplantation was 252 days (range, 82–1046 days). Surviving patients were censored on the last day of follow-up.

A univariate analysis using the χ^2 test and Mann–Whitney test were performed to identify the risk factors for RRT. A multivariable Cox proportional-hazards analysis was conducted to determine whether the development of RRT was independent of other clinical variables in predicting overall mortality. In RIST for solid tumors and malignant lymphoma, some lesions persist following preparative regimens. Sizes of these lesions frequently show a transient increase until the development of alloimmune responses. When patients die without disease progression, it is difficult to determine whether these deaths are attributable to disease progression or TRM. We therefore used overall mortality instead of nonrelapse deaths.

Clinical variables examined in a univariate analysis were entered in a backward, stepwise Cox proportional-hazards model to identify predictors of mortality. Variables with a *P*-value of less than 0.50 were entered into the model, and those with a *P*-value of less than 0.10 were retained. The *P*-values less than 0.05 were considered to be significant.

Results

Toxicity grading

Grade 3–4 toxicity by the Seattle criteria was observed in the lung (5%), CNS (2%), kidney (1%), and heart (1%) (Table 3). The maximal toxicity of grades 0, 1, 2, 3, and 4 was noted in eight (9%), 38 (44%), 35 (41%), four (5%), and one patient (1%), respectively.

Grade 3–4 toxicity by NCI-CTC ver. 2.0 was observed in all of the organs (Table 4): liver (31%), lung (21%), stomatitis (13%), gastrointestinal tract (9%), heart (6%), CNS (6%), kidney (2%), and bladder (1%). The maximal toxicity of grades 0, 1, 2, 3, and 4 was observed in two