Tacrolimus was discontinued in 14 patients (25.5%) due to adverse effects within 100 days post-transplantion. The causes of discontinuance are shown in Table 2.

The mean peak of the tacrolimus blood level in patients who discontinued the administration was 20.8 ng/ml, against 23.7 ng/ml in patients who continued tacrolimus.

3.3 Acute GVHD

The incidence of grade III to IV acute GVHD was 23.6% for all patients. Seven (17.5%) of 40 patients who received bone marrow from an HLA-A, B or DRB1 1 locus genotypically mismatched donor developed grade III to IV acute GVHD. There was no significant difference between the incidence of grade III to IV acute GVHD for patients who underwent an HLA-A or B 1 locus mismatch transplant (18.8%) and that for patients who underwent an HLA-DRB1 mismatch transplant (16.7%) ($P = 0.96$) (Fig. 1). Of ten recipients from an HLA two or more loci mismatched donor, three (30%) developed grade III to IV acute GVHD. Three (60%) of five recipients who underwent an HLA-DR serological 1 locus mismatched transplantation developed grade III to IV acute GVHD.

Thirty-three patients received prednisolone or methylprednisolone to treat grade II to IV acute GVHD initially. Twenty-one (64%) and six (18%) of them had a complete response and a partial response, respectively. Secondary treatment such as ATG and steroid pulse therapy was needed for ten patients.

Table 2 Cause of tacrolimus discontinuance

Thrombotic microangiopathy	4
Neurological disorder	3
CMV infection	3
Nephrotoxicity	2
Veno-occlusive disease	1
Hepatotoxicity	1

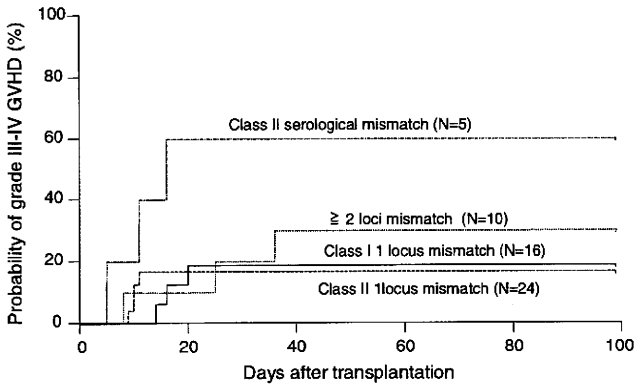

Fig. 1 Proportion of patients developing grade III–IV acute GVHD

3.4 Chronic GVHD

Of 55 patients, 46 were evaluable for chronic GVHD. Ten and 18 patients developed limited and extensive chronic GVHD, respectively. Based on Kaplan–Meier estimates, the overall incidence of chronic GVHD was 71.7%.

3.5 Relapse and survival

Early death within 100 days after transplant occurred in five patients (9.1%), all of who developed grade III or IV acute GVHD. Overall survival at 5 years was 57.4% for patients with standard risk disease and 34.8% for patients with high-risk disease (Fig. 2a). The primary causes of death are listed in Table 3. Overall, 14 (48%) out of 29 patients died of relapse. Twenty patients (36.4%) had a relapse of leukemia and the median period for relapse was 239 days (77–1,469 days). Leukemia recurred in 11 out of 33 patients who received prednisolone or methylprednisolone for the treatment of acute GVHD. Disease-free survival at 5 years was 53.2% for patients with standard

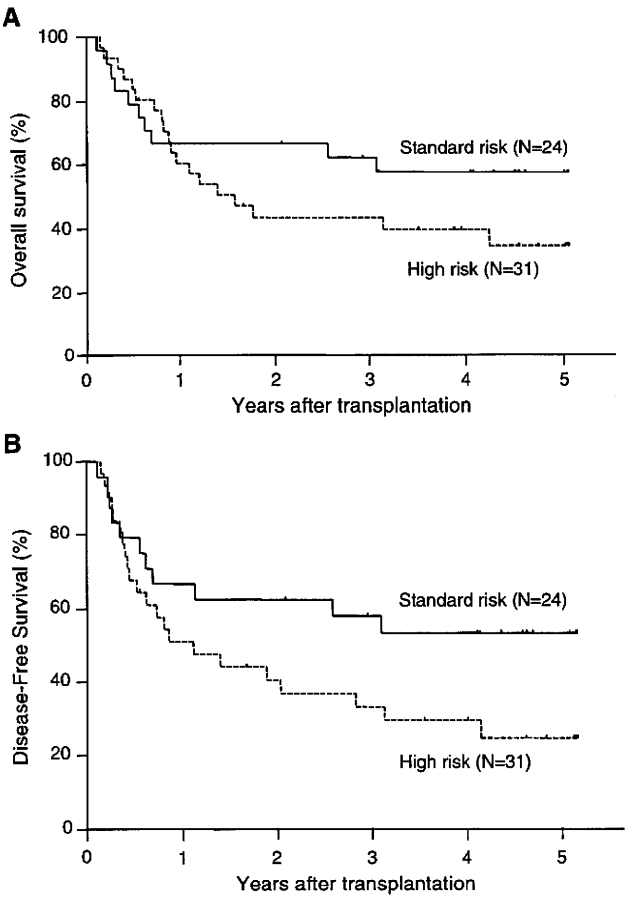

Fig. 2 Probability of overall survival (**a**) and disease-free survival (**b**) based on disease status at transplantation

Table 3 Primary causes of death

High risk disease	$N = 19$
Relapse (%)	12 (63)
GVHD (%)	1 (5)
Infection (%)	3 (16)
Others (%)	3 (16)
Standard risk disease	$N = 10$
Relapse (%)	2 (20)
GVHD (%)	3 (30)
Infection (%)	2 (20)
Others (%)	3 (30)

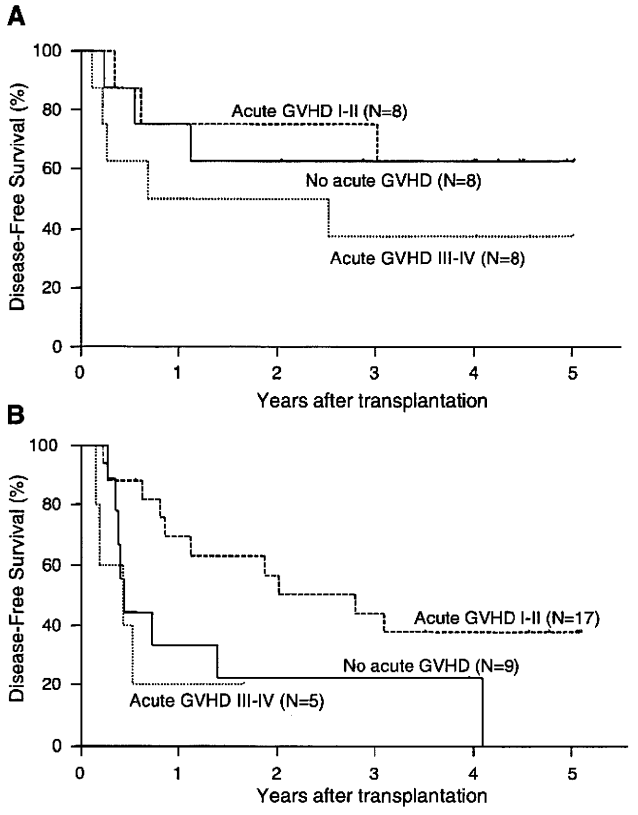

Fig. 3 Probability of disease-free survival based on the grade of acute GVHD in patients with standard risk disease (**a**) and in patients with high-risk disease (**b**)

risk disease and 24.5% for patients with high-risk disease (Fig. 2b).

The effects of acute and chronic GVHD on disease-free survival were examined. No association between acute GVHD and disease-free survival was observed in patients with standard risk disease (Fig. 3a). In patients with high-risk disease, disease-free survival was higher for patients with grade I-II acute GVHD, compared with that for patients without acute GVHD (37.8 vs. 22.2%, $P = 0.055$; Fig. 3b). Disease-free survival was significantly higher for

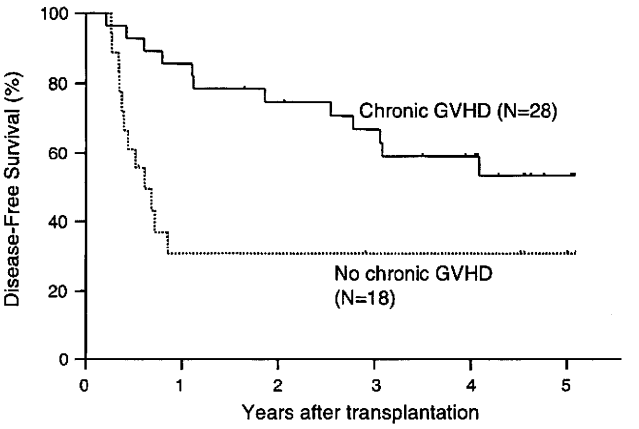

Fig. 4 Disease-free survival in patients with or without chronic GVHD

patients who developed chronic GVHD than for those who did not (53.2 vs. 30.9%, $P = 0.011$; Fig. 4).

3.6 Retrospective comparison with historical control

To compare tacrolimus with cyclosporine regarding GVHD prophylaxis, we analyzed 60 patients who received cyclosporine and short term MTX for GVHD prophylaxis and fulfilled the following criteria: (1) HLA-A, B, or DRB1 genotypically mismatched unrelated BMT, (2) first transplantation conducted between 1997 when HLA DNA typing started for a donor selection, and 2001 when the enrollment of patients in our study finished, (3) disease: leukemia or MDS, (4) age: 16–50, (5) not use of T cell-depleted marrow, (6) not use of ATG for preparative regimen. There were 35 males and 25 females with a median age of 32 years (range 16–50 years). The underlying disease was acute leukemia in 34 (56.7%), CML in 20 (33.3%), and MDS in 6 (20%). The disease status was standard risk disease in 26 (43.3%) and high-risk disease in 34 (56.7%). Forty-six patients (76.7%) received conditioning regimens with total body irradiation. Twelve (20%) and 35 (58.3%) patients underwent an HLA-A or B and HLA-DRB1 genotypically 1 locus mismatched transplantation, respectively. Thirteen patients (21.7%) received bone marrow from an HLA two or more loci mismatched donor.

The incidence of grade III to IV acute GVHD was 31.3% for all patients in the historical control. Cyclosporine exhibited significantly higher incidence of grade III to IV acute GVHD was 58.3% for patients who underwent an HLA-A or B 1 locus mismatch transplant than tacrolimus (58.3 vs. 18.8%, $P = 0.034$). However, Cyclosporine and tacrolimus showed similar incidence of grade III to IV acute GVHD for patients who underwent an HLA-DRB1 1 locus mismatch transplant (16.6 vs. 16.7%, $P = 0.93$).

4 Discussion

Since GVHD is one of the most common and life-threatening complications after allogeneic HSCT, the control of GVHD is indispensable to successful outcome after HSCT. Although the combination of cyclosporine and methotrexate is most commonly used for the prevention of acute GVHD [25], tacrolimus has been noted to be highly immunosuppressive and a potent alternative to cyclosporine [9–17, 26]. Nephrotoxicity is one of the most common problems related to tacrolimus. In previous studies, the incidence of peak serum creatinine levels greater than 2 mg/dL was 50–60% [14, 17, 27]. Meanwhile, 20 patients (36.4%) had nephrotoxicity and only two developed grade 3 or 4 nephrotoxicity in this study. The association between an increased incidence of nephrotoxicity and an increasing tacrolimus blood level that exceeded 20 ng/ml was observed in both HLA-matched sibling BMT and UR-BMT [28, 29]. The lower incidence of nephrotoxicity in this study may result from the lower target blood level of tacrolimus. Two previous reports did not show a relationship between the blood concentration of tacrolimus and the occurrence of acute GVHD [28, 29]. In a prospective randomized study, however, the use of a lower blood level (4–6 ng/ml) of tacrolimus was associated with a higher rate of acute GVHD, compared with that of a standard blood level (8–12 ng/ml) [30]. Although we determined the starting dose and the target blood level of tacrolimus as 0.03 mg/kg and 15 ng/ml, respectively, the mean peak of the tacrolimus blood level was over 20 ng/ml, suggesting that the starting dose should be reduced to 0.025–0.02 mg/kg. The peak of tacrolimus blood level did not differ between patients who discontinued or continued administration of tacrolimus. Thus, careful observations of other than tacrolimus blood level will be required for early detection of toxicities related to tacrolimus.

UR-BMT has been established as an effective treatment for patients with hematological malignancies who have no suitable related donor [3–5], and HLA mismatched UR-BMT has been considered acceptable for patients lacking an HLA matched unrelated donor. However, the disparity of HLA between the patient and the donor increases the risk of GVHD [18–21]. The present study also indicated that HLA multiple disparities induced a higher incidence of severe acute GVHD, compared with HLA 1 locus mismatch. Despite the small number of HLA-DR serological 1 locus mismatched transplantation cases, they showed a high incidence of severe acute GVHD, as previously reported [21]. The Japan Marrow Donor Program (JMDP) demonstrated that HLA-DRB1 disparity was less responsible for acute GVHD than HLA class I disparity from analysis of 1,298 recipients, most of whom received cyclosporine-based GVHD prophylaxis [19]. Our study did not detect a significant difference in the incidence of grade III to IV acute GVHD between an HLA-A or B mismatch and HLA-DRB1 mismatch (Fig. 1) suggesting that tacrolimus can reduce the risk of severe acute GVHD after an HLA-A or B 1 locus mismatch transplant as much as after an HLA-DRB1 1 locus mismatch transplant. Furthermore, we analyzed historical control used cyclosporine instead of tacrolimus for GVHD prophylaxis to compare the effect of tacrolimus on GVHD prophylaxis with that of cyclosporine. Although it was not the matched case control, the incidence of grade III to IV acute GVHD after HLA-A or B 1 locus mismatch transplant was much higher. After HLA-DRB1 1 locus mismatch transplantation, however, cyclosporine showed the similar incidence of grade III to IV acute GVHD (16.6%) to tacrolimus in our study (16.7%), suggesting that a randomized study to compare tacrolimus with cyclosporine for GVHD prophylaxis after HLA-DRB1 1 locus mismatch transplants is worthy to be conducted.

Although tacrolimus has shown to be a more effective immunosuppressant than cyclosporine, about 20% of patients who underwent HLA genotypically mismatched UR-BMT suffered from severe acute GVHD. New agents such as mycophenolate mofetil [31] and sirolimus [32] have been used for GVHD prophylaxis after UR-HSCT. More efficient GVHD prophylaxis should be established to lower the incidence of severe acute GVHD.

Relapse of leukemia was most often the primary cause of death in this study. A lesser probability of leukemia relapse in recipients with GVHD has been demonstrated than in those without GVHD, indicating that GVHD is associated with graft-versus-leukemia (GVL) effect [33–35]. We did not find any association between acute GVHD and disease-free survival in patients with standard risk disease. In patients with high-risk disease, however, disease-free survival was higher in patients with grade I-II acute GVHD than in patients without acute GVHD (Fig. 3b). Furthermore, patients who developed chronic GVHD showed significantly higher disease-free survival than patients without it (Fig. 4). In our study, 11 patients had a relapse of leukemia after the treatment of acute GVHD, suggesting that more intensive immunosuppressive therapies for GVHD wipe out the GVL effect and augment the risk of recurrent leukemia, as previously reported [35]. It has been shown that the GVL effect could be separable from GVHD [36, 37]. Alemtuzumab has shown the ability to prevent GVHD without inhibition of the GVL effect [38]. Furthermore, HLA allele mismatch combinations are being analyzed in JMDP, and high-risk combinations for severe acute GVHD have been clarified [39]. More detailed analysis may lead to better donor selection with low-risk HLA allele for severe GVHD and HLA allele expected the GVL effect.

Acknowledgments This study was supported by Health and Labour Sciences Research Grants, Research on Human Genome, Tissue Engineering, Ministry of Health, Labour and Welfare. We thank the physicians, nurses, and staff of the transplant centers who participated in this study, and the JMDP. We are also grateful to Center for Supporting Hematology–Oncology Trials (C-SHOT), to Ms. Ryouko Yamauchi for the data management, and to Ms. Haruko Nakamura and Ms. Yumi Ohashi for secretarial assistance.

Appendix

Institutions participating in this study

First Department of Internal Medicine, Sapporo Medical University, Sapporo, Japan; Department of Hematology, Sapporo Hokuyu Hospital, Sapporo, Japan; Third Department of Internal Medicine, Akita University School of Medicine, Akita, Japan; Division of Hematology, Jichi Medical University, Tochigi, Japan; Department of Hematology, Dokkyo Medical School of Medicine, Tochigi, Japan; Division of Hematology, Saiseikai Maebashi Hospital, Maebashi, Japan; Division of Hematology, Second Department of Internal Medicine, Chiba University Graduate School of Medicine, Chiba, Japan; Division of Hematology, Chiba Municipal Hospital, Chiba, Japan; Hematology Division, Tokyo Metropolitan Komagome Hospital, Tokyo, Japan; Division of Hematology, Department of Internal Medicine, Keio University School of Medicine, Tokyo, Japan; Department of Cell Therapy and Transplantation Medicine, University of Tokyo, Tokyo, Japan; Department of Hematology, Toranomon Hospital, Tokyo, Japan; Department of Hematology, Tokyo Women's Medical University, Tokyo, Japan; Department of Hematology, Yokohama City University Medical Center, Yokohama, Japan; Department of Hematology, Oncology and Rheumatology, Tokai University School of Medicine, Isehara, Japan; Department of Cellular Transplantation Biology, Kanazawa University Graduate School of Medicine, Kanazawa, Japan; Division of Hematology, Shizuoka General Hospital, Shizuoka, Japan; Division of Hematology, Department of Internal Medicine, Japanese Red Cross Nagoya First Hospital, Nagoya, Japan; Department of Hematology, Meitetsu Hospital, Nagoya, Japan; Department of Internal Medicine and Molecular Science, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan; Department of Hematology and Cell Therapy, Aichi Cancer Center Hospital, Nagoya, Japan; First Department of Internal Medicine, Kansai Medical University, Osaka, Japan; Second Department of Internal Medicine, Hyogo College of Medicine, Nishinomiya, Japan; Department of Transfusion Medicine, Hyogo College of Medicine, Nishinomiya, Japan; Division of Hematology and Oncology, Department of Medicine, Hyogo Medical Center for Adults, Akashi, Japan; Department of Hematology, Tenri Hospital, Tenri, Japan; Division of Hematology, Ehime Prefectural Central Hospital, Matsuyama, Japan.

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Transplant Infectious Disease. ISSN 1398-2273

Infectious complications in chronic graft-versus-host disease: a retrospective study of 145 recipients of allogeneic hematopoietic stem cell transplantation with reduced- and conventional-intensity conditioning regimens

S. Yamasaki, Y. Heike, S. Mori, T. Fukuda, D. Maruyama, R. Kato, E. Usui, K. Koido, S. Kim, R. Tanosaki, K. Tobinai, T. Teshima, Y. Takaue. Infectious complications in chronic graft-versus-host disease: a retrospective study of 145 recipients of allogeneic hematopoietic stem cell transplantation with reduced- and conventional-intensity conditioning regimens.
Transpl Infect Dis 2008: **10**: 252–259. All rights reserved

Abstract: To assess infectious complications associated with chronic graft-versus-host disease (cGVHD) after allogeneic hematopoietic stem cell transplantation (HSCT) with reduced- and conventional-intensity conditioning regimens (RIC, $n = 91$; CIC, $n = 54$, respectively), we retrospectively analyzed data from 145 consecutive patients with cGVHD after allogeneic HSCT from a human leukocyte antigen-matched related or unrelated donor. In the present retrospective analysis, 57% (83/145) of patients with cGVHD developed infections, with a mortality rate of 27% (22/83). The incidences of bacteremia ($n = 28$), central venous catheter-related infections ($n = 11$), bacterial pneumonia ($n = 4$), invasive aspergillosis ($n = 7$), and adenoviral hemorrhagic cystitis ($n = 8$) were significantly higher in patients with prednisolone dose ≥ 1 mg/kg at the time of diagnosis of cGVHD. The present results suggest that infections associated with cGVHD, especially after high-dose prednisolone, are predictive of poor outcome regardless of whether the patient received RIC or CIC.

S. Yamasaki[1], Y. Heike[1], S. Mori[1], T. Fukuda[1], D. Maruyama[1], R. Kato[1], E. Usui[1], K. Koido[1], S. Kim[1], R. Tanosaki[1], K. Tobinai[1], T. Teshima[2], Y. Takaue[1]

[1]Division of Hematology/Hematopoietic Stem Cell Transplantation, National Cancer Center Hospital, Tokyo, Japan, [2]Center for Cellular and Molecular Medicine, Kyushu University Hospital, Fukuoka, Japan

Key words: infectious complication; chronic graft-versus-host disease; allogeneic hematopoietic stem cell transplantation; reduced-intensity conditioning; HLA-matched donor

Correspondence to:
Yuji Heike, MD, PhD, Division of Hematology/Hematopoietic Stem Cell Transplantation, National Cancer Center Hospital, 5-1-1 Tsukiji, Chuo-ku, Tokyo 104-0045, Japan
Tel: + 81 3 3542 2511
Fax: + 81 3 3545 3567
E-mail: yheike@ncc.go.jp

Received 26 May 2007, revised 11 July, 23 July, 4 September 2007, accepted for publication 12 September 2007

DOI: 10.1111/j.1399-3062.2007.00291.x
Transpl Infect Dis 2008: **10**: 252–259

Infectious complications contribute to morbidity and mortality following allogeneic hematopoietic stem cell transplantation (HSCT). Well-known factors affecting susceptibility to infections include donor type, conditioning regimen, development of graft-versus-host disease (GVHD), and environmental factors. Reduced-intensity conditioning (RIC) regimens are thought to lower the risk of infections because they involve relatively little damage to vital organs (1). However, our experience indicates that with both RIC and conventional-intensity conditioning (CIC) regimens, the incidence of bacterial infections during neutropenia and *Aspergillus* infections is high after allogeneic HSCT (2, 3). Thus, it appears that RIC alone is not sufficient to improve the safety of allogeneic HSCT.

GVHD and the treatment of GVHD with immunosuppressive drugs are also well-known predominant risk factors for the development of opportunistic infections (4–6). In the case of acute GVHD, inpatients can be given comprehensive prophylaxis, including environmental control, to prevent infections over the short term. In contrast, chronic GVHD (cGVHD) is most often a late complication of allogeneic HSCT, and is usually treated on an outpatient basis. Consequently, the resources that can be used to control infections in patients with cGVHD are limited, and prophylaxis should be considered as a long-term approach, taking into account the safety and emergence of drug-resistant pathogens. In Japanese patients, the incidence of cGVHD after allogeneic HSCT is reportedly as high as 50%, with 20% of those who develop cGVHD contracting concurrent infections (7). At present, more transplantation procedures are being performed with peripheral blood stem cell (PBSC) products, in older patients, and with

unrelated donors. The available evidence suggests that all of these factors would result in greater numbers of patients with cGVHD. Thus, management of cGVHD is one of the greatest challenges to physicians practicing HSCT.

In the present study, we evaluated infectious complications associated with cGVHD in patients who received an RIC or a CIC regimen before undergoing PBSC transplantation (PBSCT) from a human leukocyte antigen (HLA)-matched relative (related PBSCT) or bone marrow transplantation (BMT) from an HLA-matched unrelated volunteer (unrelated BMT).

Patients and methods

Patient characteristics

We retrospectively analyzed data from 145 consecutive adult patients with hematologic malignancies who had received allogeneic HSCT with an RIC ($n = 91$) or CIC ($n = 54$) regimen between January 2000 and December 2004 at our institution. All of these 145 patients had sustained engraftment, had survived for >100 days following transplantation, and had developed cGVHD. The following types of patients were excluded: patients who suffered from disease progression before the development of cGVHD and received donor lymphocyte infusion, and patients with a history of previous allogeneic HSCT. Significant differences were observed between the RIC and CIC groups in terms of the age of the patients and donors, the gender of the patients, diagnosis, disease risk (8), time from diagnosis to transplantation, donor type and source of stem cells, and GVHD prophylaxis. The patient characteristics are summarized in Table 1. Typing for HLA-A, -B, and -DR antigens of the donor and recipient was performed using low-resolution DNA typing. The frequency with which allogeneic PBSCT is performed in Japan has been increasing since it became eligible for reimbursement from health insurance organizations in the year 2000, and our banking system only approves donation of bone marrow. The clinical characteristics of cGVHD, including use of immunosuppressive drugs at diagnosis and initial treatment, are summarized in Table 2. The present study was approved by the Ethics Committee of our institution, and all 145 subjects provided informed consent.

Conditioning regimen and supportive care

The CIC regimen consisted of cyclophosphamide (CY, 120 mg/kg), in combination with either 12 Gy total-body irradiation (TBI, $n = 25$) or busulfan (BU, 16 mg/kg; $n = 29$). The RIC regimen consisted of BU (8 mg/kg) in combination with either fludarabine (Flu, 180 mg/m^2; $n = 70$) or 2-chlorodeoxyadenosine (2-CdA, 0.66 mg/kg; $n = 21$); 14 patients received either anti-thymocyte globulin (ATG, 5–10 mg/kg; $n = 6$) or 4 Gy TBI ($n = 8$). All patients received cyclosporine (CSP, 3 mg/kg/day; $n = 137$) or tacrolimus (TAC, 0.03 mg/kg/day; $n = 8$), with ($n = 78$) or without ($n = 67$) short courses of methotrexate (MTX; related PBSCT, 10 mg/m^2 on day 1, and 7 mg/m^2 on days 3 and 6; unrelated BMT, 10 mg/m^2 on days 3, 6, and 11) as GVHD prophylaxis. All patients received prophylactic ciprofloxacin (200 mg orally 3 times daily) for prevention of infections until neutrophil recovery. Trimethoprim-sulfamethoxazole (80 mg of trimethoprim once daily) was administered for the prevention of *Pneumocystis* pneumonia and encapsulated bacterial infection, from the first day of the conditioning regimen until day 3, and from day +30 until 6 months after transplantation, or for prolonged periods in patients with cGVHD. Patients also received oral or intravenous fluconazole (100 mg once daily) for prevention of infection by *Candida* species, and low-dose acyclovir (600 mg until engraftment, and then 100 mg/day orally), starting at the same time as the conditioning regimens and continuing until cessation of administration of immunosuppressive drugs (9). Cytomegalovirus (CMV) antigenemia was monitored weekly until cessation of the administration of immunosuppressive drugs. Testing for CMV antigenemia consisted of direct immunoperoxidase staining of leukocytes with a peroxidase-labeled monoclonal antibody. Quantitative real-time polymerase chain reaction was not performed.

Definition of outcome

Patients with grades II–IV acute GVHD were treated with prednisolone (PSL) according to a standard regimen (10). Chronic GVHD was assessed and graded according to the standard criteria (11). The diagnosis and staging of cGVHD were also assessed according to the working report published by the National Institutes of Health Consensus Development Project (12). Relapse was defined either by morphologic evidence of the disease in the peripheral blood, marrow, or extramedullary sites, or by recurrence and persistence of pre-transplant chromosomal abnormalities in cytogenetic analysis of the marrow cells.

Infectious complications

A documented infection was defined as signs and symptoms associated with microbiological documentation of a pathogen from the site of infection. Culture-documented bacteremia, fungemia, or viremia was considered to be a definite infection, regardless of symptoms. On the other hand, clinical infection was defined as signs or symptoms consistent with an infection, but without microbiological confirmation. Central venous catheter (CVC)-related

Patient characteristics and transplant outcomes

	RIC ($n = 91$)	CIC ($n = 54$)	P
Median age of patients (range)	55 (26–68)	37 (18–53)	< 0.0001
Median age of donors (range)	50 (17–69)	34 (19–54)	< 0.0001
Male/female patient	57[1]/34	22/32	0.015
Female donor for male patient	19	10	0.83
Diagnosis AML (+ MDS)	27 (9)	17 (4)	0.0029
MDS	17	4	
CML	7	12	
ALL	1	8	
ML	36	13	
Others[2]	3	0	
Disease risk group (standard/advanced)[3]	14/77	21/33	0.0023
Median time interval[4] (range), (months)	19 (2–178)	10 (1–100)	0.014
KPS[5] ≤ 80%	10	5	0.41
HCT-SCI[6] ≥ 2	13	7	0.99
Prior infectious complications	6	3	0.99
Prior autologous transplantation	5	2	0.99
Donor type and source of stem cells			
Related PBSC/Unrelated BM	82/9	34/20	0.0002
GVHD prophylaxis			
CSP orTAC alone/MTX with CSP orTAC	66/25	1/53	< 0.0001
Acute GVHD grade II/III/IV	24/23/3	18/8/2	0.072
Median onset day (range) of grades II–IV acute GVHD[7]	39 (12–97)	32 (14–91)	0.48
Prior use of PSL for acute GVHD			
0.5–<1.0/1.0–<2.0/ ≥ 2.0 mg of PSL/kg	5/34/18	4/13/9	0.27
Relapse/progressive disease following cGVHD	16	10	0.99
Cause of death	30	20	0.27
Infection	15[8]	7[8]	
Chronic GVHD	9[8]	8[8]	
Lungs/gastrointestinal tract/MOF/Others[9]	3/1/3/2	3/3/2/0	
Others[10]	3	6	
Progression	8	2	
Median follow-up (range), (months)	39 (5–73)	45 (15–79)	0.20

[1]Number of patients, unless indicated otherwise.
[2]Others = myelofibrosis ($n = 1$), chronic lymphocytic leukemia ($n = 1$), and multiple myeloma ($n = 1$).
[3]Patients who were considered standard risk with a diagnosis of AML + MDS or AML, or ALL in first complete remission, CML in first chronic phase, or untreated refractory anemia in MDS. All other conditions were considered to indicate advanced risk.
[4]Time from diagnosis to transplantation.
[5]KPS was evaluated before the start of the conditioning regimen, and was graded according to Karnofsky performance status score.
[6]HCT-SCI was evaluated before the start of the conditioning regimen, and was graded according to hematopoietic cell transplantation-specific comorbidity index (ref. 8).
[7]Time from occurrence of grades II–IV acute GVHD to transplantation.
[8]Total number of patients differs because 8 patients (RIC, 5; CIC, 3) died of both infection and chronic GVHD.
[9]Others = renal ($n = 1$) and liver ($n = 1$).
[10]Others = RIC: cerebral infarction ($n = 1$), secondary hepatocellular carcinoma ($n = 1$), infection following secondary allogeneic cord blood stem cell transplantation; CIC: acute myocardial infarction ($n = 1$), cerebral infarction ($n = 1$), drug-induced interstitial pneumonia ($n = 1$), infection following chemotherapy ($n = 1$), and suicide ($n = 2$).
RIC, reduced-intensity regimen; CIC, conventional-intensity regimen; AML, acute myeloid leukemia; MDS, myelodysplastic syndrome; CML, chronic myeloid leukemia; ALL, acute lymphoblastic leukemia; ML, malignant lymphoma; PBSC, peripheral blood stem cell; BM, bone marrow; CSP, cyclosporine; TAC, tacrolimus; MTX, methotrexate; GVHD, graft-versus-host disease; PSL, prednisolone; cGVHD, chronic graft-versus-host disease; MOF, multiple organ failure.

Table 1

Clinical characteristics of cGVHD

	RIC	CIC	*P*
Median onset day (range)[1]	100 (79–479)	109 (93–348)	0.51
Limited/extensive	5/86	1/53	0.41
De novo/quiescent/progressive	27/38/26	24/9/21	0.16
KPS score 1/2/3	61/16/8	46/2/2	0.045
Skin score 1/2/3	27/33/8	17/12/3	0.15
Mouth score 1/2/3	40/29/3	23/9/1	0.87
Eyes score 1/2/3	30/14/7	15/9/1	0.38
Gastrointestinal tract score 1/2/3	28/4/12	19/1/7	0.84
Liver score 1/2/3	7/23/44	6/13/24	0.89
Lungs score 1/2/3	6/8/4	8/7/1	0.26
Joints and fascia score 1/2/3	13/2/0	8/5/1	0.13
Genital tract score 1/2/3	1/0/0	0/0/0	0.99
Eosinophilia $>0.5 \times 10^9$/L	30	22	0.37
Platelets $<100 \times 10^9$/L	26	20	0.36
Others[2]	5	2	0.39
Immunosuppressive drugs at diagnosis of cGVHD			
CSA/TAC	66/3	37/3	0.76
<0.5/0.5–<1.0/1.0–<2.0/ ≥ 2.0 mg of PSL/kg	17/9/11/2	9/2/3/1	0.57
Initial treatment for cGVHD			
Addition or increased dose of CSA/TAC	69/7	41/4	0.99
<0.5/0.5–<1.0/1.0–<2.0/ ≥ 2.0 mg of PSL/kg	18/14/15/4	10/7/6/2	0.74
Median follow-up from diagnosis of cGVHD (range) (months)	39 (5–73)	45 (15–79)	0.26

[1]Time from occurrence of cGVHD to transplantation.
[2]Others = pleural effusion ($n = 4$), pericardial effusion ($n = 3$), ascites ($n = 3$), and polymyositis ($n = 1$).
RIC, reduced-intensity regimen; CIC, conventional-intensity regimen; cGVHD, chronic graft-versus-host disease; KPS, Karnofsky performance status; CSP, cyclosporine; TAC, tacrolimus; PSL, prednisolone.

Table 2

infections consisted of exit site infections without bacteremia. Bacterial pneumonia was included in the category of definite infections, and was diagnosed by chest x-ray examination or computed tomography (CT) and identification of a bacterial pathogen on culture of sputum, bronchoalveolar lavage fluid, pleural fluid, or blood specimen. Fungal infections, including proven or probable invasive fungal infections, were diagnosed by identification of a fungal pathogen on culture or *Aspergillus* antigen and CT examination according to consensus criteria (13). Pneumonia of unknown origin was included in the category of undefined pneumoniae, which were diagnosed by chest x-ray and/or CT. There was no significant difference in CMV serostatus between the RIC and CIC groups (data not shown). A polymicrobial infection of 1 organ or several adjacent organs was considered to be a single infection. Death associated with a documented infection was defined as the death of a patient with findings consistent with an infection, or as detection of the pathogen in an autopsy specimen.

Statistical analysis

Comparisons of variables were performed using the 2-tailed Fisher exact test or the χ^2 test. Continuous variables were compared by the Mann–Whitney *U*-test. All *P*-values were 2-sided, and the type I error rate was fixed at $P < 0.05$.

Results

Transplant outcomes

The transplant outcomes are summarized in Table 1. Twenty-two patients (RIC, $n = 15$; CIC, $n = 7$) died of infections, of whom 8 patients (RIC, $n = 5$; CIC, $n = 3$) died of

both infections and chronic GVHD, with cGVHD at a median follow up of 40 months from transplantation (RIC, 39 vs. CIC, 45 months). The median onset of cGVHD was 112 days (RIC, 100 vs. CIC, 109 days), and 47 patients (RIC, $n = 26$; CIC, $n = 21$) developed progressive-type cGVHD at a median follow up of 32 months from diagnosis of cGVHD (RIC, 39 vs. CIC, 45 months). The severity of the Karnofsky performance status (KPS) score was significantly greater in the RIC group ($P = 0.045$).

Infectious complications

A total of 134 infectious episodes occurred in 83 patients (RIC, 51 vs. CIC, 32; $P = 0.73$), as shown in Table 3. Of these, 28 patients (RIC, 18 vs. CIC 10; $P = 0.83$) developed bacteremia, the causative organisms (43 positive cultures) of which are summarized in Table 4. Gram-positive bacteremia (27 positive cultures) was more common than gram-negative bacteremia (16 positive cultures). The bacteremia was caused by 2, 3, and 4 types of organisms in 4, 4, and 1 patient, respectively. The incidence of bacteremia was significantly higher in patients with the following factors: cGVHD including progressive types ($n = 15$, $P = 0.0027$), a KPS score ≥ 2 ($n = 11$, $P = 0.0062$) and a gastrointestinal (GI) score ≥ 2 ($n = 13$, $P < 0.0001$); PSL dose ≥ 1 mg/kg at the time of diagnosis ($n = 9$, $P = 0.00090$) and for the initial treatment of cGVHD ($n = 11$, $P = 0.0050$). CVC-related infections ($n = 11$) were caused by *Staphylococcus epidermidis* ($n = 4$), *Staphylococcus* species ($n = 2$), *Stenotrophomonas maltophilia* ($n = 2$), *Acinetobacter iwoffii* ($n = 1$), *Corynebacterium* species ($n = 1$), or methicillin-resistant *Staphylococcus aureus* (MRSA, $n = 1$). The incidence of CVC-related infections was significantly higher in patients with PSL dose ≥ 1 mg/kg at the time of diagnosis of cGVHD ($n = 4$, $P = 0.026$). Bacterial pneumonia was observed in 4 patients, and the isolated organisms were as follows: *Pseudomonas aeruginosa* ($n = 1$), *Hemophilus influenzae* ($n = 1$), *S. epidermidis* ($n = 1$), and *Staphylococcus* species ($n = 1$). The incidence of bacterial pneumonia ($n = 4$) was significantly higher in patients with PSL dose ≥ 1 mg/kg at the time of diagnosis ($n = 3$, $P = 0.0051$) and for the initial treatment of cGVHD ($n = 3$, $P = 0.021$). Invasive aspergillosis (IA) and *Candida* infections developed in 7 and 3 patients, respectively. All patients with IA had been given ≥ 0.5 mg of PSL/kg at the time of diagnosis of cGVHD. The incidence

Infectious complications associated with cGVHD

	Total (median onset, range, days)	RIC	CIC	*P*
Bacterial infections				
Bacteremia	28 (175, 104–1629)	18 (5)[1]	10 (2)	0.83
CVC-related	11 (123, 101–1774)	5 (0)	6 (0)	0.33
Pneumonia	4 (311, 101–1045)	3 (2)	1 (1)	0.99
Others[2]	16 (302, 102–1065)	7 (4)	9 (2)	0.11
Fungal infections				
Candida infection	3 (128, 101–358)	1 (0)	2 (0)	0.56
Invasive aspergillosis	7 (181, 112–1232)	6 (0)	1 (0)	0.26
Viral infections				
Adenoviral hemorrhagic cystitis	8 (192, 111–538)	5 (0)	3 (0)	0.99
CMV colitis	1 (343)	0 (0)	1 (0)	0.37
Cutaneous VZV	18 (502, 106–1684)	12 (0)	6 (0)	0.80
Influenza	4 (483, 355–898)	1 (0)	3 (0)	0.15
Others[3]	2 (133, 103–164)	1 (0)	1 (0)	0.99
CMV antigenemia	15 (140, 104–448)	11 (0)	4 (0)	0.42
Pneumoniae of unknown origin	32 (283, 101–1735)	18 (4)	14 (4)	0.41

[1]Number of infectious episodes (number of deaths) is shown.
[2]Others = sepsis of unknown origin (4 episodes), dermatitis (3), hemorrhagic cystitis (2), otitis media (2), meningitis (2), cholecystitis (1), pseudomembranous enterocolitis (1), and urinary tract infection (1).
[3]Others = herpes simplex viral esophagitis (1 episode) and meningitis (1).
cGVHD, chronic graft-versus-host disease; RIC, reduced-intensity regimen; CIC, conventional-intensity regimen; CVC, central venous catheter; CMV, cytomegalovirus; VZV, varicella zoster virus.

Table 3

Bacteremia associated with cGVHD

	RIC ($n = 18$)	CIC ($n = 10$)
Gram-positive organisms	16[1]	11
Staphylococcus epidermidis	7	2
Streptococcus species	2	3
Enterococcus species	3	0
Staphylococcus species	0	3
Bacillus species	0	1
Corynebacterium species	1	0
MRSA	0	1
Gram-positive cocci	3	1
Gram-negative organisms	10	6
Bacteroides species	3	2
Pseudomonas aeruginosa	2	2
Klebsiella species	2	0
Enterobacter species	0	1
Escherichia coli	0	1
Gram-negative rods	3	0

[1]Number of positive cultures.
cGVHD, chronic graft-versus-host disease; RIC, reduced-intensity regimen; CIC, conventional-intensity regimen; MRSA, methicillin-resistant *Staphylococcus aureus*.

Table 4

of IA was significantly higher in patients with cGVHD including a GI score ≥ 2 ($n = 4$, $P = 0.015$), PSL dose ≥ 1 mg/kg at the time of diagnosis ($n = 4$, $P = 0.0037$), and for the initial treatment of cGVHD ($n = 7$, $P < 0.0001$). Eighteen patients developed cutaneous varicella zoster virus (VZV); all responded promptly to acyclovir. Eight patients developed adenoviral hemorrhagic cystitis (HC); 2 of these 8 patients developed continuously complicated lethal bacteremia. The incidence of adenoviral HC was significantly higher in patients with cGVHD including a KPS score ≥ 2 ($n = 5$, $P = 0.0071$) and a GI score ≥ 2 ($n = 4$, $P = 0.026$); PSL dose ≥ 1 mg/kg at the time of diagnosis ($n = 4$, $P = 0.0069$); and for the initial treatment of cGVHD ($n = 5$, $P = 0.0060$). *De novo* CMV antigenemia before or after development of cGVHD was observed in 62 and 15 patients, respectively. Sixteen and 8 patients, respectively, died of bacterial infections and pneumoniae of unknown origin.

Discussion

In the present retrospective analysis, 57% (83/145) of patients with cGVHD developed infections, with a mortality rate of 27% (22/83). Although the limitations of this study were the retrospective study design and the differences in baseline characteristics in both the RIC and CIC groups, these results illustrate the importance of establishing more effective management of infectious complications associated with cGVHD, which are predictive of poor outcome for both RIC and CIC regimens.

In patients with cGVHD, the major source of bacteremia was heterogeneous, gram-positive organisms such as *S. epidermidis* and *Streptococcus* species, which were more common than gram-negative organisms, and bacteremia caused by *Pseudomonas aeruginosa*, including multidrug-resistant *P. aeruginosa*, occurred only in patients with cGVHD involving a GI tract score ≥ 2. Additionally, *Streptococcus pneumonia* sepsis was a risk factor for non-relapse mortality, as reported previously (4), and pneumococcal vaccination of transplant recipients was found to be relatively ineffective in the presence of cGVHD. In other studies with RIC regimens, the incidence of bacteremia appeared to be significantly lower than in the present study, but this may a result of the shorter follow-up periods in those studies (14, 15). Moreover, 29% (7/24) of the present patients with cGVHD involving a GI tract score ≥ 2 had received ≥ 2 mg of PSL/kg before developing cGVHD, and all 7 of these patients developed bacteremia. Although 50% (14/28) of patients with bacteremia received antibiotic

drugs and all 14 of these patients received intravenous immunoglobulin to maintain IgG levels at >400 mg/dL for prophylaxis of encapsulated bacteria and *Pneumocystis*, these results suggest that patients with cGVHD having a GI tract score ≥ 2, especially after high-dose PSL, are more likely to develop bacteremia than patients with cGVHD not having a GI tract score ≥ 2. This was probably due to colonization of the GI tract resulting from translocation into the bloodstream or disruption of the ecologic GI equilibrium involving GI bacterial overgrowth (e.g., use of antibiotic decontamination), increased permeability of the GI mucosal barrier (e.g., GVHD-induced mucosal damage), or deficiencies in the host immune defenses (e.g., use of immunosuppressive drugs). Thus, a review of strategies for prevention of bacteremia may lead to improvement of patient outcomes after allogeneic HSCT. That is, in patients with cGVHD having a GI tract score ≥ 2, restrictions on the use of broad-spectrum antibiotics may help reduce GI bacterial overgrowth, including overgrowth by antibiotic-resistant organisms, resulting from failure of the GI barrier. In contrast, we recognize the difficulty in identifying bacteremia using culturing blood. Our patients were immunocompromised hosts who presented with undifferentiated fever; therefore, blood culture results were often delayed well into the course of empirical therapy. There is a need to develop suitable strategies for screening of bacteremia associated with cGVHD in patients who receive allogeneic HSCT with either RIC or CIC regimens.

Most of the present patients with cGVHD who developed *Candida* infection or IA received ≥ 0.5 mg of PSL/kg before developing cGVHD and the incidence of IA was significantly higher in patients with cGVHD having a GI score ≥ 2, especially after high-dose PSL. The number of patients with fungal infections was small, but high-dose PSL may be effective for improving the prophylaxis for such infections. Furthermore, the duration of prophylaxis still remains unclear as randomized clinical trials have yet to be conducted.

All the present patients with adenoviral HC developed grades II–IV acute GVHD and received PSL for GVHD therapy, which differs considerably from what has been reported previously(16). The incidence of adenoviral HC was significantly higher in patients with cGVHD having a KPS score ≥ 2, a GI score ≥ 2, and high-dose PSL at the time of diagnosis and for the initial treatment of cGVHD. Although the present study was limited in its ability to detect risk factors for adenoviral HC, because of low patient numbers and lack of prospective investigation of viral infection, the present results suggest that patients who receive high-dose PSL before and after developing cGVHD should be frequently checked for abdominal and urinary symptoms, and that urinary tests should be regularly performed during ongoing use of immunosuppressive drugs. In addition, we identified only 1 patient with cGVHD who suffered from CMV colitis, indicating that it is useful to monitor and treat CMV antigenemia intensively in patients receiving immunosuppressive drugs, especially before development of cGVHD. In contrast, 12% of the present patients with cGVHD developed cutaneous VZV with a median onset of 502 days (range, 106–1684), despite low-dose acyclovir prophylaxis during at least the first year after allogeneic HSCT. Nonetheless, there were no cases of breakthrough VZV infection. This suggests that low-dose acyclovir prophylaxis effectively prevented breakthrough VZV infection, but that reestablishment of antiviral therapy was needed to protect against cutaneous VZV in patients with cGVHD.

In summary, the present data indicate that infections associated with cGVHD, especially after high-dose PSL, are predictive of poor outcome, whether RIC or CIC is used. Accordingly, there is a need for clinical trials to develop new strategies for screening and prevention of infections associated with cGVHD in patients who receive allogeneic HSCT with either RIC or CIC regimens.

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Int J Hematol
DOI 10.1007/s12185-008-0163-7

ORIGINAL ARTICLE

Reduced-intensity unrelated donor bone marrow transplantation for hematologic malignancies

Sung-Won Kim · Keitaro Matsuo · Takahiro Fukuda · Masamichi Hara · Kosei Matsue · Shuichi Taniguchi · Tetsuya Eto · Mitsune Tanimoto · Atsushi Wake · Kazuo Hatanaka · Shinji Nakao · Yoji Ishida · Mine Harada · Atae Utsunomiya · Masahiro Imamura · Yoshinobu Kanda · Kazutaka Sunami · Fumio Kawano · Yoichi Takaue · Takanori Teshima

Received: 25 March 2008 / Revised: 7 August 2008 / Accepted: 18 August 2008

Abstract To review a current experience of unrelated bone marrow transplantation (BMT) with reduced-intensity conditioning (RIC) regimens, we conducted a nationwide survey with 77 patients (age, 25–68 years). The backbone RIC regimen was a combination of fludarabine or cladribine, busulfan or melphalan and total body irradiation at 2–4 Gy. Five patients died early, but 71 (92%) achieved initial neutrophil recovery. Thereafter, 36 patients (47%) died of therapy-related complications, 23 (30%) of whom died within day 100. Grades II–IV acute graft-versus-host disease (GVHD) occurred in 34 of the 68 evaluable patients (50%). In a multivariate analysis, a regimen containing antithymocyte globulin (ATG) was significantly associated with a decreased risk of acute GVHD ($P = 0.041$). Thirty-three patients are currently alive with a median follow-up of 439 days (28–2002 days), with an OS of 50% at 1 year. In conclusion, unrelated BMT with RIC regimens can be a curative treatment in a subset of patients.

S.-W. Kim · T. Fukuda · Y. Takaue
Hematology and Hematopoietic Stem Cell Transplantation Division, National Cancer Center Hospital, Tokyo, Japan

K. Matsuo
Division of Epidemiology and Prevention, Aichi Cancer Center Research Institute, Nagoya, Japan

M. Hara
Department of Hematology, Ehime Prefectural Central Hospital, Matsuyama, Japan

K. Matsue
Division of Hematology/Oncology, Kameda Medical Center, Kamogawa, Japan

S. Taniguchi · A. Wake
Department of Hematology, Toranomon Hospital, Tokyo, Japan

T. Eto
Department of Hematology, Hamanomachi Hospital, Fukuoka, Japan

M. Tanimoto
Department of Hematology and Oncology, Okayama University Graduate School of Medicine and Dentistry, Okayama, Japan

K. Hatanaka
Department of Internal Medicine, Rinku General Medical Center, Izumisano, Japan

S. Nakao
Department of Hematology, Kanazawa University Graduate School of Medical Science, Kanazawa, Japan

Y. Ishida
Division of Hematology/Oncology, Iwate Medical University School of Medicine, Morioka, Japan

M. Harada
Department of Medicine and Biosystemic Science, Kyushu University, Fukuoka, Japan

A. Utsunomiya
Department of Internal Medicine, Imamura Bun-in Hospital, Kagoshima, Japan

M. Imamura
Department of Hematology and Oncology, Hokkaido University Graduate School of Medicine, Sapporo, Japan

Y. Kanda
Division of Hematology, Saitama Medical Center, Jichi Medical University, Saitama, Japan

Keywords Unrelated transplantation · Reduced-intensity conditioning · Hematologic malignancy

1 Introduction

Allogeneic hematopoietic stem cell transplantation (HSCT) is a possible curative approach for patients with various hematologic malignancies. Recently, the application of reduced-intensity conditioning (RIC) regimens, mostly incorporating fludarabine as a backbone agent, has been explored for patients whose age or concomitant medical conditions contraindicate the use of conventional myeloablative regimens [1–3]. Since only 30–40% of patients have an appropriate family donor available [4], the establishment of an unrelated donor transplantation program with RIC regimens is urgently needed.

Graft rejection, regimen-related toxicities and graft-versus-host disease (GVHD) have been the major problems in unrelated HSCT with RIC [5–13]. In unrelated transplantation, engraftment is influenced by the source of stem cells and superior results have been observed with peripheral blood stem cells (PBSC) compared to bone marrow [9, 14]. Nevertheless, PBSC has not yet been approved as a graft source for unrelated transplantation in Japan [15]. The level of regimen-related toxicities directly depends on the intensity of the regimen, and the incidence of GVHD increases with unrelated donors compared to related donors. Although attempts have been made to overcome these problems, a suitable procedure for unrelated bone marrow transplantation (BMT) with RIC regimens has not yet been established. To accumulate further expertise, we conducted a nationwide survey of Japanese patients with hematologic malignancy who had undergone BMT from an HLA-matched or -mismatched unrelated donor with RIC regimens. Although the present data were obtained from a limited population of patients, these findings may show a current status of unrelated BMT with RIC.

K. Sunami
Department of Internal Medicine,
National Hospital Organization Okayama Medical Center,
Okayama, Japan

F. Kawano
Department of Internal Medicine,
National Hospital Organization Kumamoto Medical Center,
Kumamoto, Japan

T. Teshima (✉)
Center for Cellular and Molecular Medicine,
Kyushu University, 3-1-1 Maidashi,
Higashi-ku, Fukuoka 812-8582, Japan
e-mail: tteshima@cancer.med.kyushu-u.ac.jp

2 Patients and methods

2.1 Data sources

This survey collected the data of 77 consecutive patients in 17 participating hospitals who received unrelated BMT with RIC for hematologic malignancies between 2000 and 2004. Data were derived from questionnaires distributed to each hospital. Additional questionnaires were sent to confirm the follow-up data, including the occurrence of GVHD. The minimum data required for inclusion of a patient in this study were age, sex, histological diagnosis, status at transplant, donor information, conditioning regimen, date of transplant, donor chimerism status, therapy-related complications, date of last follow-up, disease status at follow-up, date of disease progression (PD)/death and cause of death.

This study was approved by institutional review board of each individual center. All patients provided written informed consent according to the Declaration of Helsinki. Unrelated donors provided consent through the Japan Marrow Donor Program as part of its standard procedures. The indications, conditioning regimens, management of GVHD and supportive care for BMT were left to the discretion of each institution. Patients who had previously received allogeneic HSCT and those younger than 20 years were not included. Patients younger than 50 years who had organ dysfunction and/or have previously received high-dose chemotherapy with autologous HSCT were also included.

2.2 Definitions

RIC regimens were defined as previously reported [6, 9, 10], and conditioning regimens that included either beyond 4 Gy of total body irradiation (TBI), 8 mg/kg of busulfan or 140 mg/m^2 of melphalan were excluded from the study. Alleles at the HLA-A, -B, and -DRB1 loci were identified by middle-resolution DNA typing as described previously [16]. Risk status at transplantation was categorized as either standard risk or high risk. Standard-risk diseases included acute leukemia in first complete remission, chronic myeloid leukemia in first chronic phase, and refractory anemia of myelodysplastic syndrome (MDS). Other diseases were categorized as high-risk disease. Graft failure was analyzed in patients who survived more than 28 days posttransplant according to the criteria reported by Petersdorf et al. [17]. Briefly, the definition included failure of the absolute neutrophil count (ANC) to surpass 500/mm^3 before relapse, death or second transplantation, as well as a decrease in the ANC to less than 100/mm^3 on at least three consecutive determinations with a finding of severe hypoplastic marrow. The degree of donor chimerism among peripheral blood T cells was assessed several times

between day 28 and day 100 after HSCT using fluorescence in situ hybridization (FISH) to detect X and Y chromosomes for recipients of grafts from sex-mismatched donors, and polymerase chain reaction-based analyses of polymorphic microsatellite regions for recipients of sex-matched or sex-mismatched transplants. Mixed chimerism was defined as the detection of 5–90% of donor cells in the peripheral blood. Acute and chronic GVHD were graded according to the consensus criteria [18, 19]. Patients who survived 100 days were evaluable for the assessment of chronic GVHD. Overall survival (OS) was measured as the time from the day of transplantation until death from any cause, and progression-free survival (PFS) was the time from the day of transplantation until PD/relapse or death from any cause. Patients who died from transplantation-related causes were classified as non-relapse mortality (NRM) regardless of their disease status.

2.3 Statistical analysis

The primary endpoint of this study was OS and chimerism. The secondary endpoints were PFS, NRM, PD, and the incidence of acute and chronic GVHD. Descriptive statistical analysis was performed to assess patient baseline information. Patients were divided into two groups: age 60 or above and less than 60. OS and PFS were calculated using the Kaplan–Meier method. The cumulative incidence of acute GVHD was calculated using the method described by Gooley et al. [20] to eliminate the effect of competing risks. The competing event for acute GVHD was defined as death without grades II–IV acute GVHD. For each endpoint, a Cox proportional hazard model was used for univariate and multivariate analyses. The factors included in the analysis were HLA disparity (mismatch vs. identical), recipient age (age 60 or above vs. less than 60), use of TBI (yes vs. no), use of ATG (yes vs. no), diagnosis of AML (yes vs. no), risk status (high vs. standard) and acute GVHD (II–IV vs. 0–I). Acute GVHD in the model was treated as a time-varying covariate. We defined statistical significance as a P value less than 0.05. All statistical analyses were performed using STATA version 8 (College Station, TX).

3 Results

3.1 Patients and diagnoses

The patients' characteristics are listed in Table 1. The median age of the patients was 54 years (range, 25–68 years) as a whole. Twenty-one patients (27%) had acute myelogenous leukemia (AML), 2 (3%) had acute lymphoblastic leukemia, 5 (7%) had chronic myeloid leukemia, 20 (26%) had MDS or myeloproliferative disease (refractory anemia, $n = 8$; refractory anemia with excess blasts, $n = 9$; others, $n = 3$), 19 (25%) had non-Hodgkin lymphoma (follicular lymphoma, $n = 12$; diffuse large B-cell lymphoma, $n = 4$; mantle cell lymphoma, $n = 2$; peripheral T-cell lymphoma, unspecified, $n = 1$), 7 (9%) had adult T-cell leukemia/lymphoma, and 3 (4%) had multiple myeloma. Sixty-three patients (82%) had high-risk disease at the time of allogeneic BMT.

3.2 Conditioning regimens

Conditioning regimens are shown in Table 2. None received ex vivo T-cell depleted transplantation.

3.3 HSCT procedure and supportive care

Forty-seven patients (61%) were transplanted from a matched, 24 (31%) were from a 1 allele-mismatched, and 6 (8%) were from a 2 or 3 allele-mismatched unrelated donor. All patients received bone marrow as a source of stem cells. The prophylaxis of GVHD was either cyclosporine- or tacrolimus-based. Thirty-nine patients (51%) received cyclosporine with methotrexate, including five patients who received an ATG-containing preparative regimen. Nine patients (12%) received cyclosporine alone, including five patients who received ATG. Each patient received cyclosporine with mycophenolate mofetil and cyclosporine with prednisolone, respectively. Twenty-five patients (33%) received tacrolimus with methotrexate, including one patient who received ATG. Two patients (3%) received tacrolimus alone, including one who received ATG. Granulocyte colony-stimulating factor was administered intravenously from day +1 or +6 until neutrophil engraftment in all patients.

3.4 Engraftment and chimerism

Five patients died before the engraftment evaluation, with a median survival time of 15 days (range, 2–17 days). Seventy-one patients (92%) achieved initial neutrophil recovery, but three patients (two AMLs and one MDS) later experienced secondary graft failure; one each with AML and MDS after unrelated BMT from an HLA-1 allele-mismatched donor received a second transplantation when they failed to achieve subsequent complete donor-type chimerism, but both died of infectious complications. The other patient with AML after unrelated BMT from an HLA-6 allele-matched donor achieved initial complete chimerism, but later developed secondary graft failure upon the administration of ganciclovir for cytomegalovirus antigenemia. However, this patient achieved the spontaneous recovery of autologous marrow function and is currently surviving beyond 2,000 days.

Table 1 Patient characteristics

Variable	Younger than 60 years ($n = 60$)	60 years or older ($n = 17$)
Patient age (range, median)	25–59, 52	60–68, 63
Disease		
Acute myelogenous leukemia	16 (27%)	5 (29%)
Acute lymphoblastic leukemia	2 (3%)	0
Chronic myeloid leukemia	5 (8%)	0
Myelodysplastic syndrome or myeloproliferative disease	12 (20%)	8 (47%)
Malignant lymphoma	16 (27%)	3 (18%)
Adult T-cell leukemia/lymphoma	7 (12%)	0
Multiple myeloma	2 (3%)	1 (6%)
Risk status		
Standard	13 (22%)	1 (6%)
High	47 (78%)	16 (94%)
HLA disparity		
Matched	37 (62%)	10 (59%)
One-mismatched	19 (32%)	5 (29%)
Two or more mismatched	4 (7%)	2 (12%)
Donor–recipient sex match		
Male–male	20 (33%)	11 (65%)
Male–female	16 (27%)	2 (12%)
Female–male	9 (15%)	4 (24%)
Female–female	15 (25%)	0
GVHD prophylaxis		
Cyclosporine ± methotrexate	38 (63%)	10 (59%)
Tacrolimus ± methotrexate	21 (35%)	6 (35%)
Others	1 (2%)	1 (6%)
Median nucleated cell dose infused ($\times 10^8$/kg, range)	2.80 (0.39–5.52)[a]	2.92 (0.76–4.30)

HLA Human leukocyte antigen, *GVHD* graft-versus-host disease

[a] The data of two patients were excluded because infused nucleated cell dose was unknown

Chimerism was evaluated in 68 patients (88%), with short tandem repeats analysis ($n = 52$), variable number of tandem repeats analysis ($n = 5$) and FISH analysis in the case of sex mismatch ($n = 11$). Complete donor chimerism was confirmed in 58 (85%) within day 100. Mixed chimerism was confirmed in nine patients (13%), but two later reverted to recipient type. One patient failed to achieve donor-type chimerism due to disease relapse on day 20. The incidence of complete donor chimerism was similar in those younger and older than 60 years (85 and 86%), with a similar incidence of mixed chimerism (15 and 14%). No patients received donor lymphocyte infusion.

3.5 GVHD

Acute GVHD occurred in 41 of the 68 evaluable patients (60%), grades II–IV in 34 (50%) and grades III–IV in 14 patients (21%). Chronic GVHD occurred in 26 of the 42 evaluable patients (62%), with extensive type in 23 (55%). The incidence of grades II–IV acute GVHD was the same in patients younger and older than 60 years (50%). The incidence of grades III–IV acute GVHD (22 and 14%) and extensive chronic GVHD (56 and 50%) was similar. In unrelated BMT, from HLA-6 allele-matched ($n = 40$), HLA-1 allele-mismatched ($n = 23$), and HLA-2 or 3 allele-mismatched ($n = 5$) donors, grades II–IV acute GVHD occurred, respectively, in 18 (45%), 10 (43%) and 3 patients (60%), and chronic GVHD occurred in 15 (38%), 9 (39%) and 2 patients (40%). In univariate and multivariate analyses, an ATG-containing regimen was significantly associated with a decreased risk of the onset of grades II–IV acute GVHD (data not shown).

3.6 Survival

Thirty-three patients are currently alive with a median follow-up of 439 days (28–2,002 days), with an OS of 50% at 1 year and 46% at 2 years. The OS of patients younger than 60 years was 49% at 2 years (95% confidence interval [CI], 34–62%), and this could not be defined in older patients (95% CI, 15–45%). Patients younger than 60 years

Table 2 Conditioning regimens

Conditioning regimens	Younger than 60 years ($n = 60$)	60 years or older ($n = 17$)
TBI-containing		
Fludarabine 180 mg/m^2 (or cladribine 0.66 mg/kg), oral busulfan 8 mg/kg, TBI 4 Gy	30 (50%)	6 (35%)
Fludarabine 125–180 mg/m^2, melphalan 80–140 mg/m^2, TBI 4 Gy	5 (8%)	3 (18%)
Fludarabine 180 mg/m^2 (or cladribine 0.66 mg/kg), oral busulfan 8 mg/kg, TBI 2 Gy	2 (3%)	0 (0%)
Fludarabine 180 mg/m^2, TBI 4 Gy	0 (0%)	1 (6%)
ATG-containing		
Fludarabine 180 mg/m^2 (or cladribine 0.66 mg/kg), oral busulfan 8 mg/kg, ATG	5 (8%)	4 (24%)
Fludarabine 180 mg/m^2, cyclophosphamide 60 mg/kg, ATG	1 (2%)	0 (0%)
Fludarabine 180 mg/m^2, ATG	1 (2%)	0 (0%)
TBI and ATG-containing		
Fludarabine 180 mg/m^2, oral busulfan 8 mg/kg, TBI 4 Gy, ATG	1 (2%)	1 (6%)
Non-TBI and non-ATG		
Fludarabine 180 mg/m^2, oral busulfan 8 mg/kg	6 (10%)	2 (12%)
Fludarabine 125–180 mg/m^2, melphalan 140 mg/m^2	5 (8%)	0 (0%)
Fludarabine 180 mg/m^2, oral busulfan 8 mg/kg, cyclophosphamide 60 mg/kg	2 (3%)	0 (0%)
Fludarabine 180 mg/m^2, oral busulfan 8 mg/kg, thiotepa 10 mg/kg	1 (2%)	0 (0%)
Fludarabine 180 mg/m^2, cyclophosphamide 60 mg/kg	1 (2%)	0 (0%)

TBI Total body irradiation, *ATG* antithymocyte globulin (ATG-Fresenius 10 mg/kg or thymoglobulin 5 mg/kg)

tended to show better survival than older patients ($P = 0.124$). The HLA disparity (match vs. mismatch), TBI vs. non-TBI, ATG vs. non-ATG-containing regimen, and disease category (AML vs. MDS or myeloproliferative disease vs. lymphoid malignancies) was not significantly associated with OS (data not shown). Patients with standard risk tended to show better survival than those with high risk ($P = 0.129$). In univariate and multivariate analyses, no variables were significantly associated with OS (data not shown).

3.7 NRM and PD

Thirty-six patients (47%) died of therapy-related complications, with a cumulative incidence of NRM at 1 year of 43% (95% CI, 31–56%). Of the patients who died of therapy-related complications, 23 (30%) died within day 100 of transplantation and 13 (17%) died thereafter. The NRM at 1 year in patients younger and older than 60 years was 38% (95% CI, 25–53%) and 61% (95% CI, 36–85%), respectively, as shown in Fig. 1. The causes of NRM were infection (23%), regimen-related toxicity (14%) and GVHD (9%). GVHD-related mortality was found in 26%. Infection was the major cause of death in patients younger than 60 years. Regimen-related toxicity, mainly pulmonary complications, was the major cause of treatment failure for patients older than 60 years. In univariate and multivariate analyses, no variables were significantly associated with

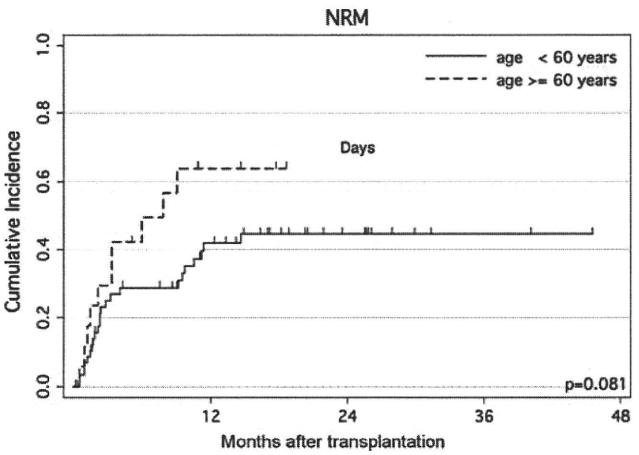

Fig. 1 Non-relapse mortality stratified according to patient age, younger or older than 60 years

NRM (data not shown). Relapse or progression of primary disease after unrelated BMT with RIC regimens was observed in 13 patients (17%; 10 patients younger than 60 years and 3 older than 60 years). There were no relapsed patients after transplantation in standard risk group. The incidence of death due to relapse or progression of primary disease was 14%. In univariate and multivariate analyses, no variables were significantly associated with PD although patients with grades II–IV acute GVHD showed a relatively lower incidence of PD (data not shown).

4 Discussion

This report reviews the current experience of unrelated BMT with RIC regimens in Japan, with particular focus on the risk factors for engraftment, GVHD, NRM, survival and PD. Although the engraftment rate has been reported to be lower when RIC unrelated transplantation was performed with bone marrow compared to peripheral blood cells [9, 10], we observed that sustained engraftment was achieved in 99% of evaluable patients, with complete donor chimerism confirmed in 85%. The incidence of graft failure was not different from that in RIC transplantation from related donors in Japan; 3.7% in recipients with an HLA-matched donor and 5.7% in those with a 1-locus-mismatched donor [21]. Complete donor chimerism in our study was comparable with that reported from the National Marrow Donor Program (85 vs. 84%) [22]. In our study, two-thirds of patients successfully received 2–4 Gy TBI-containing regimens, which were aimed at the enhancement of engraftment, as suggested in a previous report with patients with aplastic anemia [23], while 2 of the 12 patients who received an ATG-containing regimen had late graft failure, similar to a previous report which noted an incidence of 19% [5]. It has been reported that the Japanese population is more homogenous than others in terms of the distribution of HLA. Thus, it would be possible that the impact of minor HLA disparities on engraftment may become prominent after RIC transplantation.

Despite the observed satisfactory engraftment rate, we confirmed a high NRM rate (47%) after unrelated BMT with variable RIC regimens, due mostly to GVHD-related complications, including infections under steroid therapy, as previously designated by Wong et al. [10]. On the other hand, the incidence of death due to relapse or progression of primary disease was low (14%). Hence, successful prophylaxis and treatment of GVHD is particularly important in this procedure, and studies with ATG [5, 24] or alemtuzumab [25–27] have reported encouraging results. Although the number of patients was still small, in our study an ATG-containing regimen resulted in a decreased incidence of acute and chronic GVHD, despite the use of a lower dose (ATG-Fresenius 10 mg/kg or Thymoglobulin 5 mg/kg) than reported elsewhere. This study showed that age older than 60 years tended to be associated with a higher risk of NRM after unrelated HSCT with RIC regimens, though this relation was not statistically significant in a multivariate analysis. This finding, however, is limited by the small sample size. Additional use of ATG may reduce the incidence of GVHD-related NRM even in older patients but ATG should be carefully incorporated since about 20% of patients who received an ATG-containing regimen developed late graft failure in our study.

This study suggested that the onset of grades II–IV acute GVHD was associated with a lower incidence of PD, although this was not statistically significant in a multivariate analysis, possibly due to the small sample size. However, GVHD in turn resulted in a higher incidence of NRM, and a desirable graft-versus-leukemia or lymphoma effect would be offset, particularly in older patients [10, 28]. Hence, our observation echoes the warning that the intentional induction of GVHD should be avoided.

Compared to the long-term follow-up data after unrelated HSCT with RIC from the NMDP reported by Giralt et al. [22], our NRM at 1 year was worse (43 vs. 30%), but OS was likely to be better (50% at 1 year and 46% at 2 years vs. 44% at 1 year, 28% at 3 years and 23% at 5 years). In their report, disease stage, performance status, stem cell source, HLA matching, and timing of transplant were the most important prognostic factors for survival after RIC unrelated donor transplantation. This study suggested that high risk and HLA-mismatched patients were associated with worse OS, although this was not statistically significant in the multivariate analysis. Interpretation of these results, however, should be careful because of relatively short period of follow-up and the small sample size in our study. Although high risk patients was 82%, rate of relapse were unexpectedly low in our study. This might be due to earlier mortality, which precludes estimate of relapse rate. Alternately, more patients (60%) received more intense conditioning composed of 8 mg/kg of busulfan or 80–140 mg/m^2 of melphalan and 4 Gy TBI in our study.

In conclusion, we confirmed that unrelated BMT with RIC regimens can be a curative therapeutic option in a subset of patients with advanced hematologic malignancy, but at the expense of a high risk of severe complications and NRM. The incorporation of low-dose TBI may be advantageous for enhancing engraftment, and a suitable prophylaxis for GVHD still remains a primary target of clinical research. Based on the observed data, a prospective trial is currently underway to determine the value of a lower dose of ATG (ATG-Fresenius 5 mg/kg) to be added to the combination of fludarabine and busulfan.

Acknowledgments We would like to thank Michihiro Hidaka, Katsuji Shinagawa, Tomomi Toubai, Yuichiro Nawa, Koichiro Yuji, Akinobu Takami, Nobuharu Fujii, Yoshinobu Takemoto, and Yoshihiro Yamasaki for their aid in collecting data and responding to the queries. This work was supported by grants from the Ministry of Health, Labor and Welfare, Japan (T.T., Y.T.)

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