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Phase III Randomized Study of Rituximab/Carmustine, Etoposide, Cytarabine, and Melphalan (BEAM) Compared With Iodine-131 Tositumomab/BEAM With Autologous Hematopoietic Cell Transplantation for Relapsed Diffuse Large B-Cell Lymphoma: Results From the BMT CTN 0401 Trial

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ABSTRACT

Purpose

This clinical trial evaluated standard-dose radioimmunotherapy with a chemotherapy-based transplantation regimen followed by autologous hematopoietic cell transplantation versus rituximab with the same regimen in patients with relapsed diffuse large B-cell lymphoma (DLBCL).

Patients and Methods

Patients with chemotherapy-sensitive persistent or relapsed DLBCL were randomly assigned to receive iodine-131 tositumomab (dosimetric dose of 5 mCi on day −19 and therapeutic dose of 0.75 Gy on day −12), carmustine 300 mg/m² (day −6), etoposide 100 mg/m² twice daily (days −5 to −2), cytarabine 100 mg/m² twice daily (days −5 to −2), and melphalan 140 mg/m² (day −1; B-BEAM) or rituximab 375 mg/m² on days −19 and −12 and the same chemotherapy regimen (R-BEAM).

Results

Two hundred twenty-four patients were enrolled, with 113 patients randomly assigned to R-BEAM and 111 patients assigned to B-BEAM. Two-year progression-free survival (PFS) rates, the primary end point, were 48.6% (95% CI, 38.6% to 57.8%) for R-BEAM and 47.9% (95% CI, 38.2% to 57%; P = .94) for B-BEAM, and the 2-year overall survival (OS) rates were 65.6% (95% CI, 55.3% to 74.1%) for R-BEAM and 61% (95% CI, 50.9% to 69.9%; P = .38) for B-BEAM. The 100-day treatment-related mortality rates were 4.1% (95% CI, 0.2% to 8.0%) for R-BEAM and 4.9% (95% CI, 0.8% to 9.0%; P = .97) for B-BEAM. The maximum mucositis score was higher in the B-BEAM arm (0.72) compared with the R-BEAM arm (0.31; P < .001).

Conclusion

The B-BEAM and R-BEAM regimens produced similar 2-year PFS and OS rates for patients with chemotherapy-sensitive relapsed DLBCL. No differences in toxicities other than mucositis were noted.

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INTRODUCTION

The Parma study established the use of high-dose chemotherapy with autologous bone marrow transplantation as the standard of care for relapsed chemotherapy-sensitive diffuse large B-cell lymphoma (DLBCL).[1] However, even in patients with chemotherapy-sensitive DLBCL, relapse of lymphoma remains the major cause of transplantation failure.[2-4] To address this problem, different chemotherapeutic agents have been combined such as carmustine, etoposide, cytarabine, and melphalan (BEAM); carmustine, etoposide, cytarabine, and cyclophos-

phamide; and cyclophosphamide, etoposide, and carmustine.[5-7] Total-body irradiation (TBI) has been combined with cyclophosphamide or with cyclophosphamide and etoposide in various studies.[8,9] Although lymphoma is a radiation-sensitive tumor, the TBI used in many of these regimens has proven to be more toxic, especially in older patients.[9] None of these chemotherapy-only or TBI-containing regimens has proven to be superior.

In an attempt to further improve outcome, the addition of monoclonal antibodies to the transplantation regimen has been explored. Initially, the use of rituximab in the peritransplantation period

seemed to improve the progression-free survival (PFS) compared with patients who did not receive rituximab.[10,11] However, as the use of rituximab in first-line therapy was extended to all patients, the advantage of peritransplantation rituximab faded.[12,13]

Radioimmunotherapy has properties that would make it an ideal candidate for addition to a transplantation regimen. The major adverse effect of radioimmunotherapy is myelosuppression, which can be overcome with the infusion of hematopoietic stem cells. Therefore, several phase I and II studies have been performed using either high doses of yttrium-90 (^{90}Y)–ibritumomab tiuxetan (Zevalin; Spectrum Pharmaceuticals, Henderson, NV)[14,15] or iodine-131 (^{131}I)–tositumomab (Bexxar; GlaxoSmithKline, Philadelphia, PA)[16] as part of the transplantation regimen. Alternatively, phase I and II studies of standard outpatient doses of ^{90}Y–ibritumomab tiuxetan[17] or ^{131}I-tositumomab[18] added to standard transplantation regimens have been performed. With promising results in the phase I and II studies, standard-dose ^{131}I-tositumomab with BEAM (B-BEAM) was included in this phase III trial.

Herein, we report the results of the Blood and Marrow Transplant Clinical Trials Network (BMT CTN) 0401 study, which was a phase III trial comparing outcomes of patients with relapsed chemotherapy-sensitive DLBCL receiving rituximab plus BEAM (R-BEAM) versus B-BEAM with autologous hematopoietic cell transplantation (AHCT).

PATIENTS AND METHODS

Study Design

From January 2006 to July 2009, a prospective phase III multicenter trial was conducted in 37 transplantation centers of the BMT CTN (Appendix Table A1, online only). Patients who met eligibility criteria were randomly assigned to receive either tositumomab and ^{131}I-tositumomab (dosimetric dose of 5 mCi on day −19 and therapeutic total-body dose of 0.75 Gy on day

−12), carmustine 300 mg/m^2 (day −6), etoposide 100 mg/m^2 twice daily (days −5 to −2), cytarabine 100 mg/m^2 twice daily (days −5 to −2), and melphalan 140 mg/m^2 (day −1; B-BEAM) or rituximab (375 mg/m^2 on days −19 and −12) with the BEAM regimen (R-BEAM). The primary hypothesis to be tested in patients with chemotherapy-sensitive persistent or relapsed DLBCL was that the addition of ^{131}I-tositumomab to a standard high-dose chemotherapy transplantation regimen with BEAM would improve the 2-year PFS compared with the addition of rituximab to the same chemotherapy transplantation protocol. Secondary end points included overall survival (OS), time to progression, complete response (CR) and partial response (PR) at day +100, relapse rates, time to hematologic recovery, maximum mucositis score on day +21, 100-day treatment-related mortality, and the development of secondary myelodysplastic syndrome (MDS) or acute myelogenous leukemia (AML).

The protocol was approved by the protocol review committee of the National Heart, Lung, and Blood Institute, the local institutional review board, and appropriate radiation safety and scientific review boards. All patients signed the approved informed consent in effect for the study in accordance with the Declaration of Helsinki.

Eligibility Criteria

Patients enrolled onto this study were age 18 to 80 years; had a Karnofsky score ≥ 70, persistent or recurrent DLBCL, and chemotherapy-sensitive disease; and had received one to three prior chemotherapy regimens. Patients were eligible who had persistent DLBCL after induction chemotherapy but were chemotherapy sensitive (first PR), had experienced relapse after an initial CR but had a PR to salvage chemotherapy, or had a CR to salvage chemotherapy (second [CR2]). Patients also needed ≤ 20% involvement of their bone marrow with lymphoma with no evidence of MDS in the pretransplantation bone marrow. All patients had their pathology reviewed locally and had a specimen that was CD20$^+$ with no evidence of transformed follicular lymphoma. Mobilization therapy was used as per institutional guidelines, but all patients received at least one dose of rituximab 375 mg/m^2 within 3 months of the first apheresis collection. Patients were required to have an adequate autograft collection (target ≥ 2.0 × 10^6 CD34$^+$ cells/kg; minimum 1.5 × 10^6 CD34$^+$ cells/kg) to be eligible for the protocol.
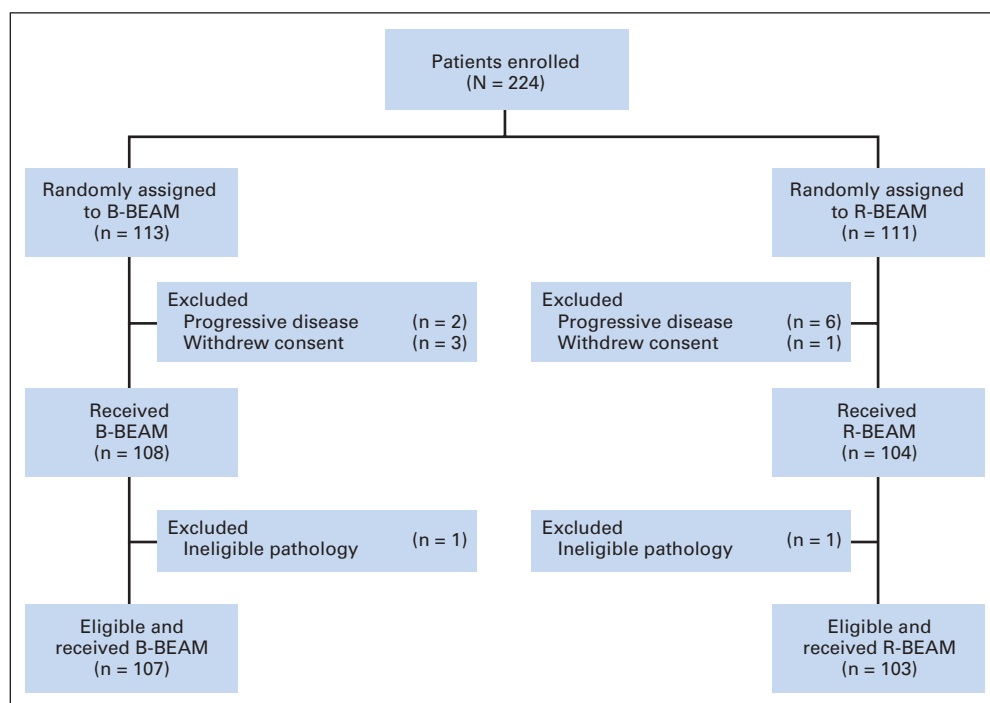

Fig 1. CONSORT diagram outlining the number of patients at each step of the trial. B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.

Patients

Two hundred twenty-four patients with persistent or relapsed DLBCL were enrolled onto the clinical trial. Median follow-up of the study population is 25.5 months (range, 13.8 to 55.8 months).

Treatment

The CONSORT diagram is outlined in Figure 1. Enrolled patients were randomly assigned to R-BEAM or B-BEAM with AHCT infusion 24 hours later. The patients assigned to the B-BEAM arm received orally administered saturated solution of potassium iodide, two drops given three times daily starting 1 day before the dosimetric dose, and this was continued for 14 days after the therapeutic dose. The murine monoclonal anti-CD20 (tositumomab) was radioiodinated with sodium ^{131}I by the iodogen method, purified, and tested as previously described.[19] Within 1 hour after the dosimetric dose of ^{131}I-tositumomab and before urination, a whole-body quantitative gamma camera image was obtained for baseline readings. Additional scans were performed on day 2, 3, or 4 and day 6 or 7 after the dosimetric dose. Using this information, the radioactive clearance from each patient was obtained to determine the radioactive millicurie activity of ^{131}I-tositumomab required to deliver the desired therapeutic dose 1 week later. The methodology for determining the patient-specific millicurie activity was performed in accordance with the Medical Internal Radiation Dose Primer for Absorbed Dose Calculations.[20] The day of AHCT was designated as day 0. Filgrastim 5 μg/kg subcutaneously was administered starting on day +5 and continued until neutrophil recovery of $\geq$ 500/μL for 3 consecutive days was obtained. Patients received supportive care during the transplantation as per institutional guidelines.

End Points

The study had an 80% power to detect a 20% difference in the primary end point with an α = .05. The primary end point of the clinical trial was 2-year PFS. PFS was defined as time to disease relapse or progression, initiation of nonprotocol antilymphoma therapy, or death, measured from the time of AHCT, with patients censored at time of last contact. Supporting data for disease status and nonprotocol antilymphoma therapy during the trial were centrally reviewed by an outcome adjudication committee blinded to treatment assignment. Secondary end points were OS, time to progression, CR and PR at day + 100, relapse rates, time to hematologic recovery, incidence of grade 3 to 5 adverse events (Common Terminology Criteria for Adverse Events, version 3),[21] maximum mucositis score on day +21 measured by the Oral Mucositis Assessment Scale,[22] 100-day treatment-related mortality, and the development of secondary MDS or AML. Hematologic recovery was defined as follows: neutrophil recovery was defined as the first of 3 consecutive days of an absolute neutrophil count $\geq$ 500/μL; platelet recovery was defined as the first of 7 consecutive days with a platelet count $\geq$ 20,000/μL with no transfusions; and RBC recovery was defined as the first of 30 days with a hemoglobin $\geq$ 8.0 g/dL without a transfusion. OS was defined as the time from transplantation to death from any cause.

Definition of disease response was based on the 2007 Cheson criteria.[23] Disease assessments were performed before AHCT, at 100 days after AHCT, and at 1 and 2 years after AHCT. Patients received computed tomography and/or positron emission tomography/computed tomography of the chest, abdomen, and pelvis; physical examinations; CBC; chemistry profile; and a bone marrow biopsy to confirm CR at these time points.

Statistical Analysis

The data cutoff for analysis was November 14, 2011. Primary analysis was performed using the intent-to-treat principle (ie, patients were classified according to their original assigned treatment, even if they did not receive all prescribed interventions). Both PFS and OS were calculated using the Kaplan-Meier method.[24] CIs were calculated using the logit transformation and the Greenwood variance estimate.[25] Differences between the Kaplan-Meier curves were assessed using the log-rank test.[26] The significance of demographic and treatment features was assessed using stratified survival analysis and univariate, multivariable Cox proportional hazards regression analysis or the corresponding hazard analysis for competing risks.[27] All calculations were analyzed

using SAS (version 9.2; SAS Institute, Cary, NC) and R (version 2.10.0; www.r-project.org/) statistical software. Statistical significance was set at $P <$ .05; all P values were two-sided. Covariates used for the Cox regression model of PFS and OS were treatment arm, sex, ethnicity, race, age at transplantation, performance status, interval from diagnosis to transplantation, disease in CR at transplantation, number of prior chemotherapy regimens, total bilirubin, ALT, AST, and pulmonary diffusion capacity (DLCO). Backward selection and stepwise selection methods were used for model building. Proportional hazards were tested for all the variables in the model. Interactions were tested between treatment arm and any covariates, and no significant interactions were found.

Monitoring for accrual and toxicity according to sequential probability ratio stopping guidelines was performed by the National Heart, Lung, and Blood Institute–appointed Data and Safety Monitoring Board. No stopping rules were reached during the protocol accrual period.

RESULTS

Patients

Of the randomly assigned patients, 104 (93.7%) of 111 assigned to B-BEAM received a transplantation and 108 (95.6%) of 113 assigned to R-BEAM received a transplantation. Of the 12 patients who did not receive a transplantation, eight had progressive disease and four withdrew consent (three patients on the B-BEAM arm and one patient on the R-BEAM arm; Fig 1). The median age of the patients was 58 years, and 63% of the patients were male. Patient characteristics were similar in the two random assignment groups (Table 1).

Table 1. Demographic and Clinical Characteristics of Patients With DLBCL Enrolled Onto the BMT CTN 0401 Trial

Characteristic	B-BEAM (n = 111)		R-BEAM (n = 113)	
	No. of Patients	%	No. of Patients	%
Received transplantation	104		108	
Eligible for study	103		107	
Male	68	61.3	74	65.5
Age, years				
Median	56.8		58.5	
Range	19.8-74.9		24.0-76.6	
Race, white	99	89.2	103	91.2
KPS				
100	29	26.1	26	23
90	67	60.4	63	55.8
80	12	10.8	19	16.8
70	3	2.7	5	4.4
Disease status at transplantation				
PR1	21	18.9	15	13.3
REL1	35	31.5	45	39.8
CR2	55	49.5	53	46.9
No. of prior therapies				
1	2	1.8	7	6.2
2	93	83.8	83	73.5
3	16	14.4	23	20.4

Abbreviations: B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; BMT CTN, Blood and Marrow Transplant Clinical Trials Network; CR2, second complete remission; DLBCL, diffuse large B-cell lymphoma; KPS, Karnofsky performance score; PR1, first partial response; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan; REL1, first relapse (chemotherapy sensitive).

PFS and OS

Probabilities of 2-year PFS were 48.6% (95% CI, 38.6% to 57.8%) and 47.9% (95% CI, 38.2% to 57%) for the R-BEAM and B-BEAM arms, respectively ($P = .94$; Fig 2A). The probabilities of 2–year OS were 65.6% (95% CI, 55.3% to 74.1%) and 61% (95% CI, 50.9% to 69.6%) for the R-BEAM and B-BEAM arms, respectively ($P = .38$; Fig 2B).

Patients in CR after salvage chemotherapy (CR2) had an improved 2-year OS and PFS compared with patients with chemotherapy-sensitive first PR or chemotherapy-sensitive relapse. However, there were no differences in any of the groups by treatment arm. The 2-year PFS for CR2 patients receiving R-BEAM was 61.9% (95% CI, 47% to 73.8%) compared with 52.7% (95% CI, 38.8% to 64.9%) for patients receiving B-BEAM ($P = .61$; Fig 2C). The 2-year PFS for patients with chemotherapy-sensitive disease at relapse was 38.0% (95% CI, 25.8% to 50.1%) for patients receiving R-BEAM compared with 44.6% (95% CI, 31.4% to 57.0%) for patients receiving B-BEAM ($P = .88$; Fig 2D).

Disease Progression/Relapse and Treatment-Related Mortality

The most common cause of treatment failure was progression/relapse of lymphoma, with a cumulative incidence of relapse/progression at 2 years after transplantation of 48.1% (95% CI, 38.1% to 58.1%) in the R-BEAM arm compared with 45% (95% CI, 35.2% to 54.8%) in the B-BEAM arm ($P = .68$; Fig 3A). The 100-day treatment-

related mortality was low in both arms, with a rate of 4.1% (95% CI, 0.2% to 8.0%) in the R-BEAM arm compared with 4.9% (95% CI, 0.8% to 9.0%) in the B-BEAM arm ($P = .97$; Fig 3B).

Engraftment

Engraftment was similar, with an absolute neutrophil count $\geq 500/\mu L$ by day +28 in 93.5% (95% CI, 88.6% to 98.4%) of patients in the R-BEAM arm compared with 96.1% (95% CI, 92.2% to 100%) of patients in the B-BEAM arm ($P = .40$). Platelet recovery to $\geq 20,000/\mu L$ with transfusion independence by day +100 was present in 81.3% (95% CI, 73.9% to 88.7%) of patients in the R-BEAM arm compared with 84.5% (95% CI, 77.4% to 91.6%) of patients in the B-BEAM arm ($P = .58$).

Toxicities

Grade 3 to 5 toxicities are listed in Table 2. The only toxicity that was different between the treatment groups was the mucositis score as measured by Oral Mucositis Assessment Scale.[28] The median maximum mucositis score was 0.72 in the B-BEAM arm compared with 0.31 in the R-BEAM arm ($P < .001$). One case of MDS was reported in each arm of the trial, and one additional case of AML was reported in the R-BEAM arm.

Causes of Death

At the time of data analysis, deaths had been reported in 81 patients— 42 patients (52%) in the B-BEAM arm and 39 patients
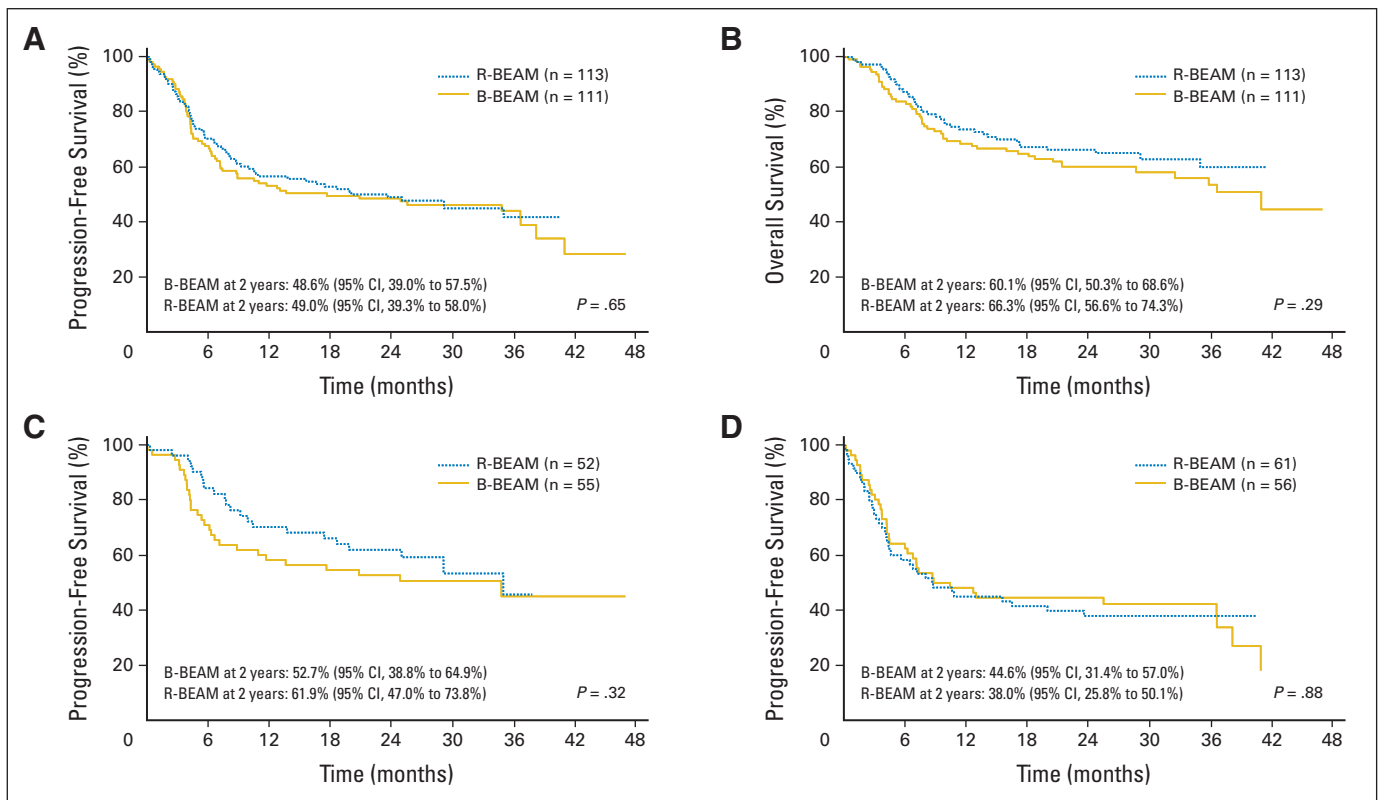

Fig 2. (A) Progression-free survival (PFS) according to random assignment groups. (B) Overall survival according to random assignment groups. (C) PFS of patients in second complete response according to random assignment groups. (D) PFS of patients with chemotherapy-sensitive relapse according to random assignment groups. B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.
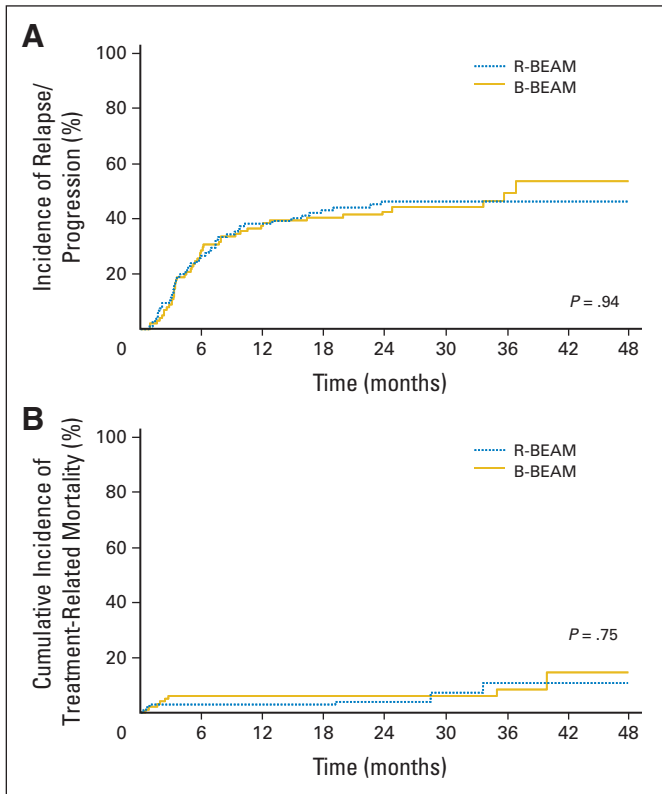
Fig 3. (A) Cumulative incidence of disease progression or relapse according to random assignment groups. (B) Cumulative incidence of transplantation-related mortality according to random assignment groups. B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.

(48%) in the R-BEAM arm. The most common causes of death were progression/relapse (n = 64), organ failure (n = 4), and adult respiratory distress syndrome (n = 3). There was no significant difference in the distribution of primary causes of death between the two arms (P = .86).

Multivariate Cox Model for PFS and OS

The multivariate analysis for the primary end point of PFS is shown in Table 3. The only significant covariate in the model was

Table 2. Grade 3 to 5 Nonhematologic Toxicities Within 2 Years After Transplantation (> 10% of patients)

| | B-BEAM | | R-BEAM | | |
	No. of Patients	%	No. of Patients	%	P
Toxicity					
Any grade 3-5 toxicity	67	65	46	43	< .01
Mucositis WHO grade 3-5	53	52	19	18	< .01
Hypotension	11	10.7	13	12.1	.83
Hypoxia	20	19.4	17	15.9	.59
Dyspnea	29	28.2	25	23.4	.44
Diarrhea	9	8.7	14	17.8	.38

Abbreviations: B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.

Table 3. Multivariate Analysis of PFS

Covariate	Hazard Ratio	95% CI	P
Treatment arm			
R-BEAM	1.00		.66
B-BEAM	1.08	0.76 to 1.54	
Disease status at transplantation			
CR	1.00		.008
Not in CR	1.63	1.14 to 2.33	

Abbreviations: B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; CR, complete remission; PFS, progression-free survival; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.

disease status at the time of transplantation. The patients in CR at transplantation had an improved PFS compared with patients with a chemotherapy-sensitive persistent or relapsed lymphoma (P = .008). The treatment arm was not significant in the model (P = .66). The multivariate analysis for OS is shown in Table 4. The disease status at the time of transplantation was again the most important characteristic predicting for OS (P < .001).

DISCUSSION

The use of high-dose chemotherapy and AHCT has been the standard of care for chemotherapy-sensitive relapsed DLBCL since the Parma Trial demonstrated the improved outcomes compared with standard salvage chemotherapy.[1] The results of the Collaborative Trial in Relapsed Aggressive Lymphoma (CORAL) study demonstrated that for patients with relapsed DLBCL in the rituximab era,

Table 4. Multivariate Analysis for OS

Covariate	Hazard Ratio	95% CI	P
Treatment arm			
R-BEAM	1.00		.55
B-BEAM	1.14	0.73 to 1.78	
Disease status at transplantation			
CR	1.00		< .001
Not in CR	2.42	1.47 to 3.96	
Age at transplantation, years			
< 50	1.00		.027
≥ 50	1.93	1.08 to 3.47	
Interval from diagnosis to transplantation, months			
< 15	1.00		.001
≥ 15	0.47	0.30 to 0.75	
Sex			
Female	1.00		.045
Male	1.65	1.01 to 2.70	
AST or ALT, units/L			
< 25	1.00		.042
≥ 25	0.62	0.39 to 0.98	

Abbreviations: B-BEAM, iodine-131 tositumomab plus carmustine, etoposide, cytarabine, and melphalan; CR, complete remission; OS, overall survival; R-BEAM, rituximab plus carmustine, etoposide, cytarabine, and melphalan.

the benchmarks have been modified.[29,30] In the CORAL study, only one half of the patients with relapse were able to proceed on to transplantation after salvage rituximab-containing chemotherapy. Therefore, on an intent-to-treat basis, patients with prior rituximab exposure and early relapse (< 12 months after diagnosis) who were enrolled onto the study had a 2-year PFS of only 23%. However, for such patients who responded to salvage therapy and then went on to transplantation, the 2-year event-free survival was only 40%.[30] Similar outcomes have been reported in other studies of patients who fail a rituximab-containing regimen.[11]

With low PFS and OS after standard high-dose chemotherapy and AHCT, new areas of research have focused on the modification of the transplantation regimen. One major focus has been the addition of radioimmunotherapy as part of the conditioning regimen for transplantation. Multiple phase I and II studies using either ^{131}I-tositumomab or ^{90}Y–ibritumomab tiuxetan combined with chemotherapy have been published.[14-18] On the basis of these favorable early results, the BMT CTN developed the current study, which randomly assigned patients to rituximab/BEAM versus ^{131}I-tositumomab and BEAM.

Despite the promising phase I and II studies using radioimmunotherapy as part of the transplantation preparative regimen, this phase III study did not demonstrate a benefit for the addition this radioimmunotherapy to the transplantation regimen for patients with chemotherapy-sensitive relapsed DLBCL. However, the study was only powered to detect a large difference in PFS. The only variable that was predictive for an improved outcome with transplantation was the documentation of CR of the DLBCL before the transplantation procedure. The major cause of failure on this trial was relapse of the DLBCL. Although few cases of MDS were identified, further follow-up will be needed to monitor for late cases.

The other phase I and II radioimmunotherapy-containing transplantation regimens that have demonstrated the best outcomes have been those using higher doses of radioimmunotherapy. Studies evaluating higher doses of ^{90}Y–ibritumomab tiuxetan used either a higher set dose of 0.8 to 1.2 mCi/kg[31] or a dose calculated to deliver a set dose to critical organs ranging from 10 to 15 Gy.[14,15] Higher doses of ^{131}I-tositumomab have also been used either alone[32] or in association with high-dose etoposide and cyclophosphamide[16] for transplantation. In these studies, the patients received a median dose of 20 to 27 Gy to critical organs. These studies had patients with a variety of histologic types of lymphomas and were small studies; however, the CR rates were higher. A phase III randomized trial using one of these regimens would be needed to evaluate the efficacy of the higher doses of radioimmunotherapy in the transplantation regimen using a homogeneous population of patients.

Future efforts for the improvement of AHCT for patients with relapsed DLBCL will need to focus on improved salvage therapy to get a higher proportion of patients into CR, as well as consideration of post-transplantation consolidation or maintenance therapy to reduce relapse rates. Few phase III maintenance studies in the post-transplantation setting have been completed. One study by Thompson et al[33] evaluated interkeukin-2 in the post-transplantation setting. This study showed that post-transplantation interleukin-2 given at the published dose and schedule had no significant effect on PFS or OS. More recently, the results of the second random assignment from the CORAL study also demonstrated no benefit from rituximab maintenance in the post-transplantation setting.[12,30]

There have recently been several novel agents that have demonstrated activity in relapsed DLBCL that may be candidates for oral maintenance therapy in the post-transplantation setting. These include agents inhibiting the B-cell receptor signaling pathway such as spleen tyrosine kinase[34] or Bruton's tyrosine kinase.[35] Another possible oral agent for consideration of use for post-transplantation maintenance therapy is lenalidomide because it does have single-agent activity for DLBCL and affects the microenvironment of the lymph node and bone marrow.[36] Future clinical trials will be needed to evaluate these options for improving the outcome of transplantation for patients with relapsed DLBCL.

AUTHOR CONTRIBUTIONS

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Appendix

Table A1. List of Participating Transplantation Centers

Centers
Baylor College of Medicine/The Methodist Hospital
Blood and Marrow Transplant Program at Northside Hospital
City of Hope National Medical Center
City of Hope Samaritan
Dana-Farber Cancer Institute/Brigham and Women's Hospital
Duke University Medical Center–Adult BMT
Emory University
Fox Chase–Temple University–BMT Program
Fred Hutchinson Cancer Research Center
Hackensack University Medical Center
Indiana BMT at Beech Grove
Jewish Hospital BMT Program
Loyola University Medical Center
Medical College of Wisconsin
Memorial Sloan-Kettering Cancer Center
Moffitt Cancer Center
Oregon Health and Science University
Rocky Mountain BMT Program
Scripps Clinic/Green Hospital
Stanford Hospital and Clinics
Texas Transplant Institute
Tufts Medical Center
University of California San Diego Medical Center
University Hospitals of Cleveland/University Hospitals Case Medical Center
University of Alabama at Birmingham
University of Florida College of Medicine (Shands)
University of Kansas Hospital
University of Michigan Medical Center
University of Minnesota
University of Nebraska Medical Center
University of Oklahoma Medical Center
University of Pennsylvania Abramson Cancer Center
The University of Texas MD Anderson Cancer Research Center
University of Wisconsin Hospital and Clinics
University of Utah Medical School
Vanderbilt University Medical Center/VA Tennessee Valley Healthcare System
Virginia Commonwealth University MCV Hospitals
Wichita CCOP

Abbreviations: BMT, bone marrow transplantation; CCOP, Community Clinical Oncology Program; MCV, Medical College of Virginia; VA, Veterans Affairs.