A low body mass index is correlated with poor survival after allogeneic stem cell transplantation

KATARINA LE BLANC, OLLE RINGDÉN, MATS REMBERGER

Background and Objectives. The purpose of this study was to determine whether body mass index (BMI, kg body weight/height (in m^2) is related to survival in recipients of allogeneic stem cell transplantation (ASCT).

Design and Methods. Since 1977, 544 adult patients (age ranging from 18 to 64 years) diagnosed with hematologic malignancies; 172 acute myeloid leukemia, 83 acute lymphocytic leukemia, 190 chronic myeloid leukemia and 99 others, underwent myeloablative conditioning and ASCT. Low BMI (<20) was seen in 88 patients, normal BMI (20-25) in 290 and high BMI (>25) in 166 patients. The donors were 348 HLA-identical siblings, 157 matched unrelated donors and 39 HLA major mismatched donors. We assessed BMI as a risk-factor controlling for other risk-factors regarding transplant-related mortality, survival and relapse-free survival using the Cox regression model.

Results. Patients with a low BMI more often had ALL, were younger, were more often conditioned with total body irradiation and more often received monotherapy as immunosuppression against graft-versus-host disease. BMI had no effect on engraftment, transfusions and acute or chronic GVHD. Patients with BMI <20 had a higher incidence of α-streptococcal septicemia (p=0.005) than did patients with BMI $\geq$ 20, but both groups had a similar incidence of overall bacteremia. Five-year survival was 36% in those with low BMI, 47% in those with normal BMI and 55% in those with high BMI. In multivariate analysis, death was associated with BMI <20 (p=0.023). Other significant factors adjusted for were: diagnosis of acute lymphoblastic leukemia, donors other than HLA-identical siblings, disease stage beyond first complete remission or 1st chronic phase, transplantation before 1993 and total body irradiation vs. busulfan conditioning.

Interpretation and Conclusions. A low BMI (<20) was significantly correlated with an increased transplant-related mortality, a decreased survival and relapse-free survival after ASCT. BMI should be considered when analyzing outcome after ASCT.

Key words: body weight, allogeneic stem cell transplantation, leukemia, adults.

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From the Center for Allogeneic Stem Cell Transplantation, Division of Clinical Immunology, Karolinska Institutet, Huddinge University Hospital, Stockholm, Sweden.

Correspondence: Katarina Le Blanc, MD, PhD, Div. of Clinical Immunology, F79, Karolinska Institutet, Huddinge University Hospital, SE-141 86, Stockholm, Sweden. E-mail: katarina.leblanc@medhs.ki.se

Hematopoietic stem cell transplantation (HSCT) after high-dose myeloablative chemoradiotherapy has emerged during the past three decades as the treatment of choice for high-risk acute leukemia and chronic myeloid leukemia (CML).[1-6] Leukemic relapse, infections due to immunological incompetence, graft-versus-host disease (GVHD) and veno-occlusive disease of the liver (VOD) remain the major obstacles affecting the outcome of patients undergoing allogeneic HSCT.

A number of studies have identified a variety of risk factors that negatively influence the outcome of HSCT. Disease stage at the time of transplant is the single most important factor influencing outcome in all disease categories, for all donor types, stem cell sources and age categories and is associated with both an increase in transplant-related mortality as well as an increase in relapse incidence.[3-5] The second most important factor is the age of the patient. For patients over 2 years of age, transplant-related mortality increases with increasing age.[3-5] HLA mismatch is a third strong individual risk factor; thus, patients receiving well-matched sibling marrow do better than patients grafted with unrelated marrow or a mismatched graft.[6-9] Besides these factors which are generally accepted, others have remained controversial.

Ample evidence suggests that obesity in the general population is a factor contributing to a greater risk of inferior health, and premature death.[10] Regarding body weight on admission, both obesity and undernourishment have been considered as risk-factors for complications and increased relapse/non-relapse mortality in bone marrow transplant patients. Fleming *et al.*[11] found that obese adults have an inferior outcome after histocompatible allogeneic stem cell transplantation. In spite of several reports of successful outcomes in obese patients, patients are sometimes not eligible or not considered candidates for a transplant given difficulties in chemotherapy dosing to avoid overdosing, leading to increased drug toxicity and complications, such as organ failure or skin breakdown.[12,13] Obesity may also represent an independent risk factor for autologous bone marrow transplantation.[14,15]

On the other hand, weight loss and severe hypoalbuminemia during remission induction in adult patients with acute leukemia were found to be closely related to infections.[16] In an older study Deeg *et al.*[17] found no increased risk of treatment-related mortality (TRM) in the obese group but, in contrast, did find that under-

weight patients are at increased risk of death in the early period after transplant. The aim of the present study was to evaluate whether obesity or malnourishment affects the outcome of allogeneic HSCT for hematologic malignancies.

Design and Methods

Patients

From 1977 until August 2002, 544 adult patients (age ranging from 18-64 years) diagnosed with hematologic malignancies underwent allogeneic HSCT at Huddinge University Hospital. To examine outcome in relation to obesity, patients were grouped on the basis of their relative weight recorded before the beginning of the preparatory regimen. The measure of relative weight was the body mass index (BMI), which was calculated by dividing the weight (kg) by the square of the height (m^2), according to Benn.[18]

Patients were classified into three groups based on BMI: underweight patients (BMI <20); normal weight patients (BMI 20-25), and obese patients (BMI >25). The patients' and donors' characteristics are shown in Table 1 and the distribution of body weight in Figure 1. The patients with a low BMI were younger, had a younger donor, more often had bone marrow as stem cell source, were more often conditioned with total body irradiation (TBI) and more often received monotherapy as immunosuppression against GVHD (p<0.001). Minor differences between the groups included the fact that underweight patients more often had ALL, and more often received an HLA-identical sibling transplant, (p<0.05). Recipient gender did not differ between the three groups.

Table 1. Characteristics of patients and donors in 544 allogeneic stem cell transplants. The patients are divided into three groups according to body mass index (BMI).

Characteristics	*BMI <20*	*BMI 20-25*	*BMI >25*	*p value*
No. of patients (%)	88	290	166	
AML	22 (25)	87 (30)	63 (38)	ns
ALL	20 (23)	52 (18)	11 (7)	<0.03
CML	35 (40)	89 (31)	66 (40)	ns
Other malignancy	11 (13)	62 (21)	26 (16)	ns
First complete remission or chronic phase	54 (61)	160 (55)	107 (68)	ns
Donor age	33	36	40	<0.01
Donor sex, M/F	47/41	176/114	92/74	ns
Recipient age	32	38	41	<0.001
Recipient sex, M/F	50/38	171/119	99/67	ns
HLA-id sibling donor	65 (74)	179 (62)	104 (63)	<0.05
Matched unrelated donor	18 (20)	91 (31)	48 (29)	ns
Mismatched donor	5 (6)	20 (7)	14 (8)	ns
BM vs. PBSC	76/12 (86/14)	217/73 (75/25)	113/53 (68/32)	<0.01
Nucleated cell dose ($\times 10^8$/kg)	2.5 (0.1-15.5)	2.6 (0.1-27.6)	2.3 (0.2-21.1)	ns
Conditioning therapy, TBI/no TBI	79/9 (90/10)	220/70 (76/24)	109/57 (66/34)	<0.001
GVHD prophylaxis, mono- vs. combination therapy or T-cell depletion	22/66 (25/75)	31/259 (11/89)	10/156 (6/94)	<0.001

CR: complete remission; CP: chronic phase; M: male; F: female; MUD: matched unrelated donors; TBI: total body irradiation; BM: bone marrow; PBSC: peripheral blood stem cells; ns: not significant; p>0.05. The p values denote differences between the low BMI group (<20) and the other two groups combined.

Conditioning and supportive care

The majority (347/544, 64%) of patients with malignant disease received 10 Gy of TBI, with their lungs shielded to receive a median of 9 Gy, combined with cyclophosphamide (CY) 60 mg/kg for two consecutive days.[19] As an alternative, some patients (111/544, 20%) received CY combined with busulfan (BU) (4 mg/kg on four consecutive days),[20] or 12 Gy of fractionated TBI (42/544. 8%) (3 Gy on four consecutive days). In 31 patients who were given a T-cell depleted graft, 6 Gy (2 Gy for three consecutive days) of total lymphoid radiation (TLI) was administered before TBI of 7.5 Gy (lungs shielded to receive a median of 7 Gy).[21] Thirty-eight patients received a non-myeloablative conditioning regimen with TBI 2 Gy in combination with fludarabine (30 mg/m^2 for 3-5 days) (n=8), BU (4 mg/kg for two days), in combination with fludarabine (n=26), or fludarabine + CY (30 mg/kg for two days) (n=4). All patients with an unrelated or mismatched related donor were treated with antithymocyte globulin (ATG) (2-5 mg/kg/day) or OKT-3 (5 mg/day) for 2-5 days prior to transplantation.[22] Before November 1988, all patients with hematologic malignancies received 8-12 mg methotrexate (MTX) or 20 mg Ara-C intrathecally (i.t.) twice before HSCT to prevent CNS leukemia. After the transplant, i.t. MTX was given from day 32 and every other week until day 102. After 1988, only patients with ALL, AML M4 and M5 and/or a history of CNS disease, were given this treatment. Patients with previous CNS disease were given i.t. treatment until 24 months after ASCT. From 1995 to March 2002, granulocyte colony-stimulating factor was routinely given to 195 patients from day +10 until neutrophil engraftment (>0.5$\times 10^9$/L).

Nutritional treatment

Patients were encouraged to eat several meals during the day. They could chose from a variety of food. If eating was a problem because of mucositis and nausea, they were encouraged to drink. Several high-calorie fluids were offered. A special

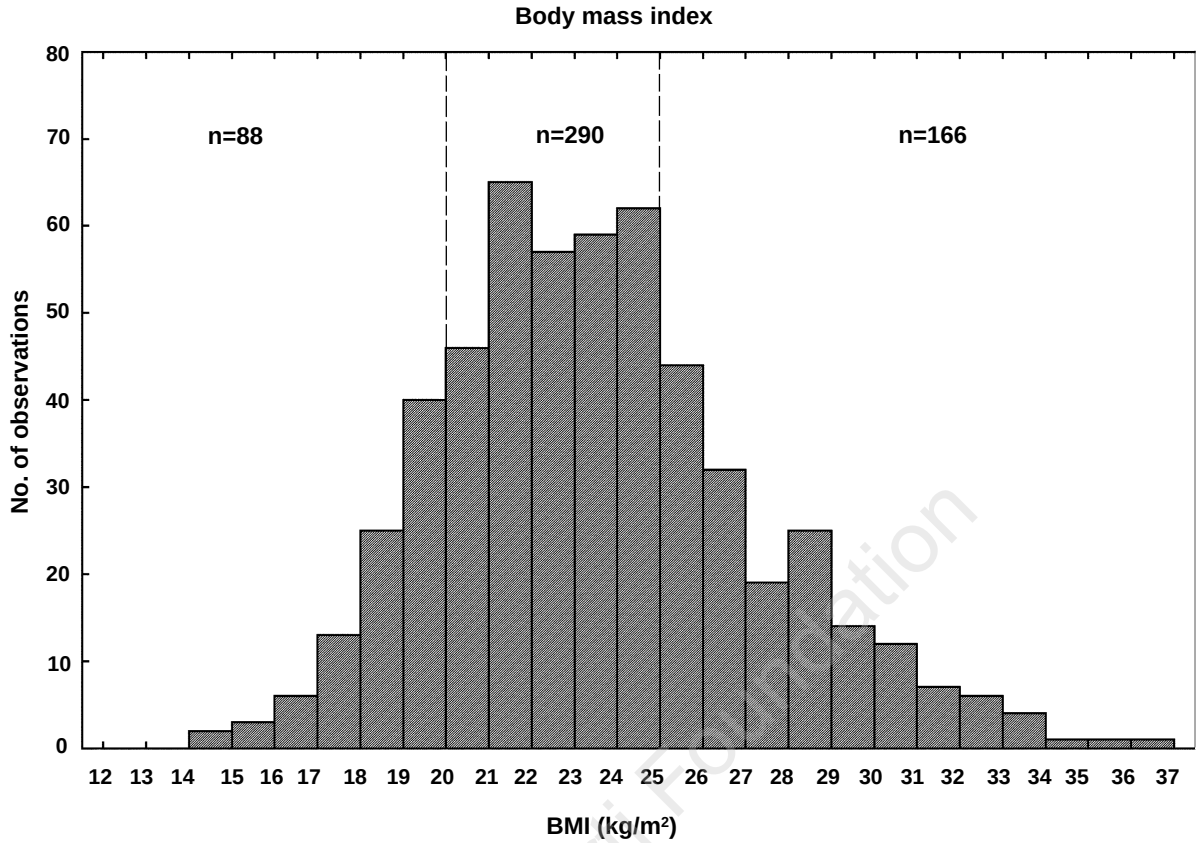

Figure 1. Weight distribution among adults undergoing ASCT for hematologic malignancies. The horizontal axis shows weight categories expressed as body mass index (BMI); the vertical axis gives the absolute number of observations. Patients were grouped as BMI <20 = underweight; BMI 20-25 = normal weight; BMI >25 overweight.

dietician took care of these patients. When needed, total parenteral nutrition (TPN) was added.

GVHD prophylaxis

Monotherapy with MTX according to the Seattle protocol, was given to 33 patients.[1,23] Twenty-one patients received cyclosporine (CsA) alone as GVHD prophylaxis.[24] The CsA dose was gradually tapered off six months after transplantation. One year after HSCT, CsA was discontinued if no signs of chronic GVHD were found. T-cell-depleted bone marrow was given to 31 patients, using previously described techniques.[21] Between August 1985 and April 1989, 204 patients received combination therapy with the first four doses of MTX given together with CsA, as described above.[21,25,26] Between May 1989 and January 1995, 79 leukemic patients were given combination therapy on an individual basis.[27] CsA was tapered after two months, if possible, and MTX was continued until day 102 after ASCT. From 1995 (n=145), a short course of MTX in combination with low dose CsA was used.[28] Ten patients were given CsA together with prednisolone and 13 were give CsA combined with micophenolate mofetil (MMF).

Statistical analysis

Results were analyzed as of November 2002. Survival by weight categories were summarized by means of Kaplan-Meier curves.[29] Log rank statistics were used to compare survival between the three categories. We also assessed the significance of weight as a risk-factor for transplant-related mortality (TRM, all deaths except relapse), relapse and chronic GVHD, while controlling for the patient's age (> or < 39 years), sibling vs. unrelated donor, year of transplant (as a continuous variable), conditioning with busulfan vs. TBI, GVHD prophylaxis, diagnosis and disease status and stem cell source (bone marrow vs. peripheral blood stem cells), using the Cox proportional hazard regression model for univariate and multivariate analysis.[30] Patients in first complete remission or first chronic phase were considered as having early disease, while all other were considered to have late disease. Patients given monotherapy with MTX or CsA were grouped together, since they showed the same incidence of acute and chronic GVHD.[24] For the same reason, patients receiving T-cell-depleted grafts were grouped with those receiving combination therapy with CsA and MTX.[21]

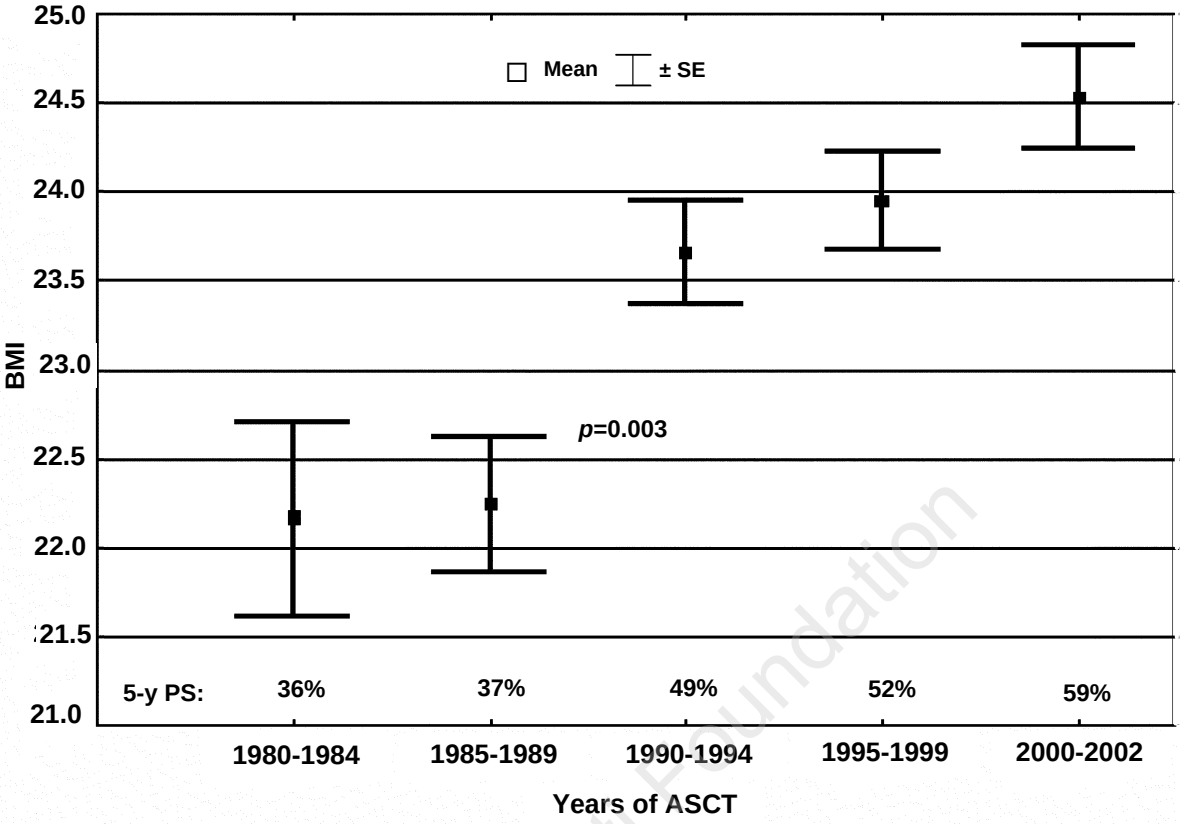

Figure 2. Mean body weight, expressed as BMI, of patients before beginning the preparation regimen, grouped by year of transplant. The increase in BMI after 1990 was statistically significant (p=0.003), mean + SD.

Results

Patients' distribution by weight

Figure 1 shows the relative frequency of the patients' weights expressed as BMI. Younger adults (<39 years) were clustered more tightly around the ideal or a low BMI; older patients showed a tendency towards higher weight. Sex distribution was equal within the groups. There was a significant increase in mean BMI over the years studied (Figure 2). In the time period 1980-89, 29% of patients had a BMI <20 before beginning their preparatory regimen and only 16% were overweight with a BMI >25. Of these only 4% were obese (BMI >30). In contrast, only 8% of patients transplanted between 2000 and 2002 were underweight and 40% were overweight, with 11% of these being obese (BMI >30).

Engraftment, transfusions, infections and GvHD

Engraftment occurred in 519 of the 544 patients (95%). No differences were recorded in time to

Table 2. Engraftment, transfusions, infections and graft-versus-host disease according to BMI.

	BMI <20	*BMI 20-25*	*BMI >25*	
Engraftment				
ANC >0.5×10⁹/L	18 (0-42)	17 (0-71)	17 (0-32)	ns
Platelets >30×10⁹/L	19 (0-210)	18 (0-210)	18 (0-116)	ns
Transfusions				
Platelets	6 (0-40)	4 (0-58)	4 (0-35)	ns
Erythrocytes	6 (0-40)	4 (0-58)	4 (0-34)	
Granulocytes	25 (26%)	49 (17%)	23 (14%)	p=0.02*
Infections				
CMV infection	44%	50%	56%	ns
CMV disease	15%	11%	7%	ns
Herpes simplex virus	31%	22%	22%	ns
Sepsis	40%	38%	40%	ns
Viridans septicemia	20%	10%	8%	p=0.005*
Graft-versus-host disease				
Acute GVHD II-IV	30%	23%	24%	ns
Chronic GVHD	57%	58%	61%	ns

**BMI <20 vs. >20; ANC: absolute neutrophil count; CMV: cytomegalovirus; GVHD: graft-versus-host disease.*

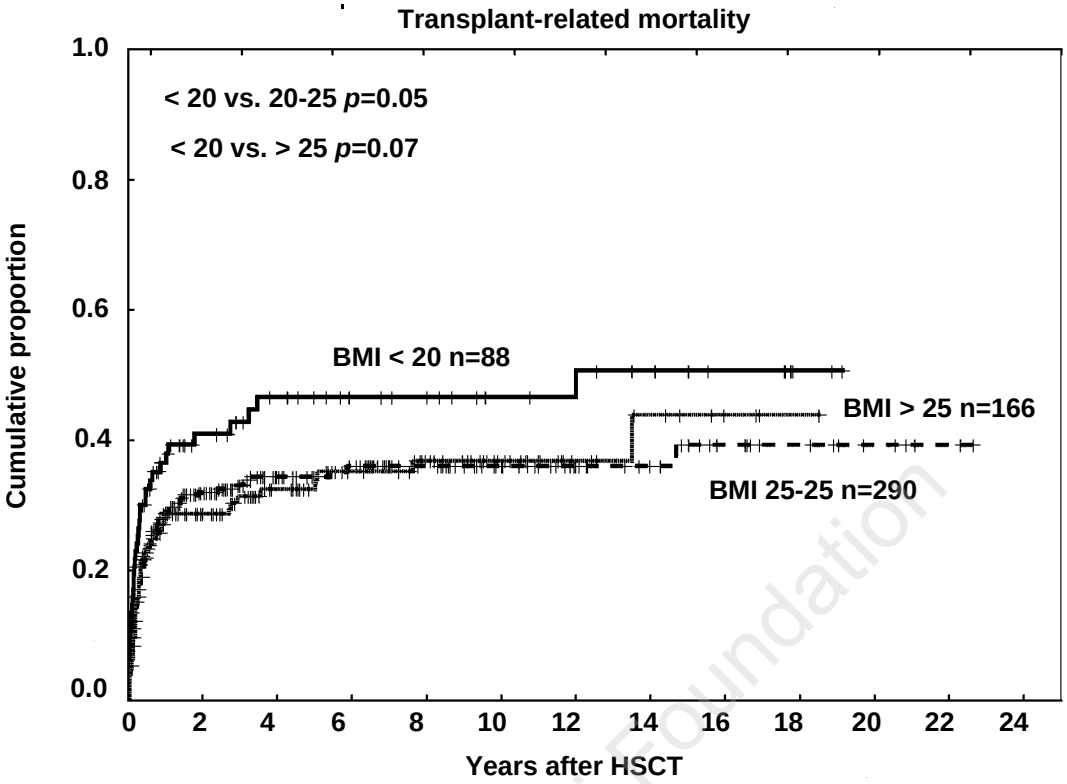

Figure 3. Cumulative incidence and time to transplant-related mortality (death from all causes except relapse) among patients with BMI <20, BMI 20-25 and BMI >25. TRM in the BMI <20 group was significantly different from that in the normal weight group (p<0.05).

granulocyte or platelet engraftment between the three weight categories (Table 2). Furthermore, body weight did not affect the need for platelet or red blood cell transfusions. However, the need for granulocyte transfusions was significantly higher in the low weight group, than in the patients with BMI >20 (p=0.02). The low weight patients were also found to have a statistically higher incidence of α-streptococcus septicemia (p=0.005) whereas the incidence of sepsis of other bacterial origin or infections with herpes viruses did not differ between the three weight groups.

The incidence of acute GVHD (grades II-IV) and chronic GVHD was not affected by body weight, since it did not differ between the three groups (Table 2). In the multivariate analysis, no association between BMI and acute or chronic GVHD was found.

Transplantation-related mortality

The overall TRM was 47% in the low BMI group, which was significantly higher than for patients of normal weight (34%; p=0.05; Figure 3). The TRM for the low weight group was also higher than the TRM of the obese patients (33%), although the difference did not reach statistical significance (p=0.07). Transplants performed with an unrelated donor or high-risk disease including patients beyond first remission or beyond first chronic phase, were the two most significant factors for TRM (p<0.01). In the multivariate analysis correct-

Table 3. Multivariate analysis of risk-factors for a) transplant-related mortality (TRM); b) overall survival; c) leukemia-free survival. Corrected for differences in patients and donor characteristics, see Table 1.

A. TRM			
Factor	RH	CI	*p* value
BMI <20	1.46	1.01-2.12	0.045
B. Leukemia-free survival			
Factor	RH	CI	*p* value
BMI <20	1.35	1.01-1.80	<0.05
C. Survival			
Factor	RH	CI	*p* value
BMI <20	1.42	1.06-1.90	0.02

RH: relative hazard; CI: confidence interval.

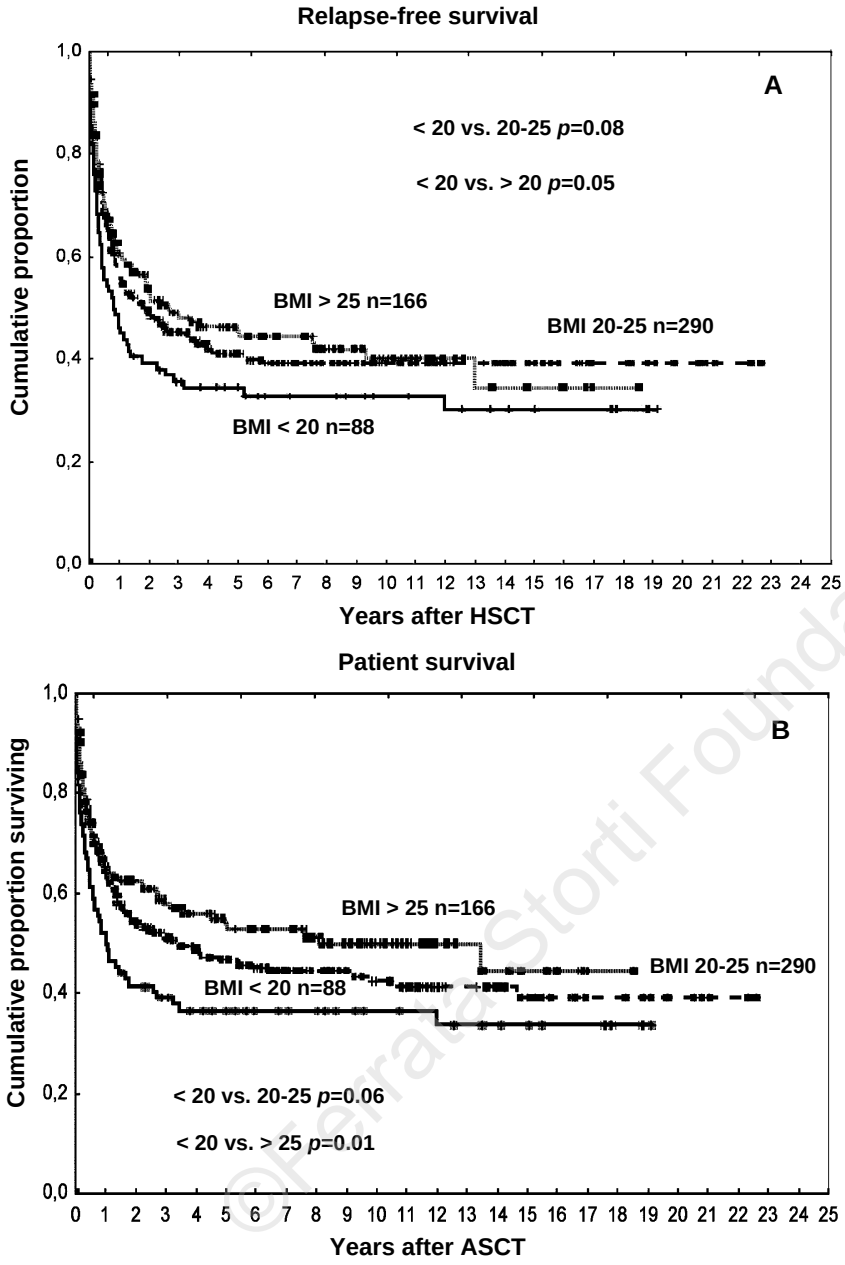

Figure 4. Relapse-free survival (a) and overall survival (b) among patients divided by weight categories: BMI <20, BMI 20-25, BMT >25. The survival curves are significantly different between the groups with the 5-year survival being 36% in those with a low BMI, 47% in normal weight patients and 55% in overweight patients.

ed for differences between the groups, the correlation between low BMI (<20) and a higher TRM was statistically significant (p=0.045) (Table 3a).

Relapse and relapse-free survival

Body weight had no impact on the risk of relapse. There were 23 relapses among patients with a low BMI, 76 relapses in the group with a BMI 20-25, and 38 relapses in the overweight group. The cumulative incidences of relapse were 39%, 39% and 34% in the three groups, respectively, with no correlation between BMI and relapse. However, body weight affected survival of patients who did not relapse, since 5-year relapse-free survival of all patients with a BMI <20 was 34% compared to 41% in the normal weight group and 46% for the overweight patients (Figure 4a). In the corrected multivariate analysis, low BMI (<20) was correlated to a lower relapse-free survival (p<0.05).

Survival and causes of death

Patients with a low BMI tended to have a lower survival (36%) than normal weight patients (47%) and a lower survival than the overweight patients (55%, p=0.01, Figure 4b). The causes of death are listed in Table 3. The two most common causes of

Table 4. Primary causes of death (n=285).

	BMI <20	*BMI 20-25*	*BMI >25*
Infection	18 (32%)	53 (34%)	25 (34%)
GVHD	9 (16%)	23 (15%)	16 (22%)
Relapse	19 (34%)	59 (38%)	21 (28%)
Other	10 (18%)	20 (13%)	12 (16%)

death were infections and relapse. There were no marked differences in the causes of death between the different weight categories. Survival had progressively improved in more recent years (Figure 2). In the corrected multivariate analysis, death was associated with BMI <20 (p=0.02, Table 3c). Other significant factors adjusted for included diagnosis of ALL, donors other than HLA-identical siblings, disease stage beyond first complete remission or first chronic phase and transplantation before 1992. Patients receiving TBI had a higher risk of death than patients who were conditioned with busulfan.

Discussion

Immediate and long-term outcomes after ASCT are influenced by numerous factors, such as advanced disease, older patient age, patient-recipient histocompatibility and cell dose.[1-9] The present study shows that a low body weight at the time of admission is also an independent risk-factor for poor outcome. BMI is a rather broad index of protein-calorie malnutrition. However, it is easy to calculate from the patients' data base and ready to use. It can also be analyzed easily in large registry data bases. In our study, patients with a BMI <20 had significantly more streptococci viridans septicemias and required more granulocyte transfusions. In multivariate analysis, adjusted for other risk-factors, low weight patients had an increased TRM, a decreased RFS and a decreased overall survival.

No published tables of ideal body weight currently account for age, percent body fat or general health status. Recognizing these limitations, we used BMI in our analysis. Only adult patients were included in the study since outcome after HSCT or high intensity chemotherapy in children appears to be less affected by nutrional status.[11,17,31] Of 544 consecutive adult patients included in our study patients in the low weight group (BMI <20) were younger than the patients in the other weight groups. Available records provided no information on duration of therapy before transplant or problems potentially associated with malnutrition, such as hypogammaglobulinemia or impaired defence mechanisms, nutrional intake or weight dynamics just prior to transplantation. Disease status, however, did not differ between the three groups, suggesting that the subjects included in the low weight group were more likely to be of a baseline low weight, rather than patients who had become underweight as a result of weight loss from their baseline weight.

We found a significant increase in mean body weight over the last 20 years. However, year of transplant was corrected for in the Cox regression analysis as a continuous variable. Indeed, survival improved in more recent years, when BMI also increased (Figure 2). Compared to in the early 1980s, older patients are now considered for transplant, and the higher mean weight could merely be consistent with the increased incidence of obesity as the population of patients ages. Furthermore, the prevalence of obesity in the general population of Sweden is increasing.[32] The higher weight in the patients may also reflect a more frequent use of prophylactic artificial nutrition during the induction period, leading to less weight loss pre-transplantation.

We found no difference in time to engraftment of platelets and granulocytes between the different weight groups, nor in the need for red cell and platelet transfusions (Table 2). However, underweight patients received significantly more granulocyte transfusions than patients of normal or high body weight. Indications for granulocyte transfusions include neutropenia (absolute neutrophil count $<0.1\times10^9$/L) with septicemia and high fever (>40°C) not responding to antibiotics, or with disseminating local infections. Malnutrition, particularly protein-calorie and fatty acid depletion, confers increased susceptibility to infections.[33] Infections may also further precipitate nutritional depletion by triggering catabolic processes and increasing the demands for energy and nutrients. The ensuing vicious cycle impairs the nutritional state as well as host defences. In accordance with this, we found a significantly higher incidence of septicemia caused by streptococci viridans, but not other bacteria, in the low weight group. The viridans streptococci are most prevalent in the oral cavity and typically cause infection only when the oral mucosa is significantly disrupted as in chemotherapy-induced mucositis. In allogeneic HSCT, chemotherapy is given at the maximum tolerated doses in an attempt to cure the disease. However, patients who fall outside ideal weight ranges may be at greater risk of relapse or drug toxicity.[14] Overweight patients treated with adjusted or ideal weight doses may be receiving insufficient treatment. Underweight patients, on the other hand, may be overdosed and suffer increased drug

toxicity. The available data did not allow us to analyze the incidence and severity of mucositis in the different weight groups, but it can be speculated that the high number of septicemia caused by streptococci viridans in the low weight group resulted from therapy-related toxicity due to overdosing.

Ineffective methods of dosing preparative chemotherapeutic agents could result in unnecessarily low dosage of chemotherapy and increase the risk of relapse in obese patients. However, the cumulative relapse incidence in our patients did not differ between the three groups. This agrees with results of a previous study by Fleming and co-workers who reported a similar relapse incidence between obese and non-obese patients in a case-controlled study of adults undergoing allogeneic HSCT.[11] Furthermore, studies of patients receiving autologous transplantation for leukemia have failed to show a correlation between patients' weight and risk of relapse.[14,15,34] This may suggest that patients of all weight categories receive enough chemotherapy for a similar cytotoxic effect on the leukemic cells. We found that low body weight was associated with an increased risk of TRM. Multivariate analysis, corrected for differences between the groups, demonstrated that the association between low weight and TRM was not explained simply by a correlation with factors such as diagnosis, histocompatibility, disease stage, conditioning regimen, or year of transplant. The cause of the increased TRM is likely to be multifactorial. Malnutrition impairs the function of the immune system and skeletal muscles. During infection and inflammation, catabolic and anorexic cytokines, such as tumor necrosis factor α (i.e.; cachectin), interleukin 1β and interleukin-6, are released. These are macrophage-derived peptides known to impair the nutritional balance.[35,36] Taken together, these factors may contribute to poorer outcome for already underweight patients. Although underweight patients have an increased risk of death in the early period after transplant, the incidence of acute GVHD grades II-IV was not higher in these patients than in the normal and overweight patients. The incidence of chronic GVHD was also similar in the three groups and no association between BMI and chronic GVHD was found in the multivariate analysis corrected for differences between the groups.

In accordance with results of a previous study by Deeg and co-workers,[17] we found that the overall prognosis of overweight patients after transplant is not significantly different from that of patients closer to ideal body weight when analyzed for relapse-free survival and overall survival. In fact, we found survival to be highest in the group of patients with a BMI >25 pre-transplant and this was significantly higher than overall survival in the low weight group (Figure 4b). Similar to previous studies on both allogeneic and autologous stem cell transplantation, we found a reduced relapse-free survival and overall survival in malnurished patients.[14,17] That a BMI <20 is an independent risk-factor for a poorer outcome after allogeneic HSCT was seen in the corrected multivariate analyses showing that a low BMI was correlated with both a lower relapse-free survival and a lower overall survival.

In conclusion, our findings indicate that strategies to improve nutritional balance should be evaluated in malnourished patients with a BMI <20 prior to HSCT. Furthermore, BMI should be included as a risk factor when analyzing outcome after HSCT.

References

1. Thomas ED, Storb R, Clift RA, Fefer A, Johnson FL, Neiman PE, et al. Bone-marrow transplantation I and II. N Engl J Med 1975; 292:832-95.
2. Goldman JM, Gale RP, Horowitz MM, Biggs JC, Champlin RE, Gluckman RE, et al. Bone marrow transplantation for chronic myelogenous leukemia in chronic phase. Increased risk of relapse associated with T-cell depletion. Ann Intern Med 1988;108:806-14.
3. Barrett AJ, Horowitz MM, Gale RP. Marrow transplantation for acute lymphoblastic leukemia: factors affecting relapse and survival. Blood 1989;74:862-71.
4. Ringdén O. Allogeneic bone marrow transplantation for hematological malignancies. Controversies and recent advances. Acta Oncol 1997;36:549-64.
5. Appelbaum FR. The current status of hematopoietic cell transplantation. Ann Rev Med 2003;54:491-512.
6. Anasetti C, Amos D, Beatty PG, Appelbaum FR, Bensinger W, Buckner CD, et al. t of HLA compatibility on engraftment of bone marrow transplants in patients with leukemia or lymphoma. N Engl J Med 1989; 320:197-204.
7. Beatty PG, Anasetti C, Hansen JA, Longton GM, Sanders JE, Martin PJ, et al. Marrow transplantation from unrelated donors for treatment of hematologic malignancies: effect of mismatching for one HLA locus. Blood 1993;81:249-53.
8. Ringdén O. Bone marrow transplantation using unrelated donors for hematological malignancies. Med Oncol 1997;14:11-22.
9. Sierra J, Storer B, Hansen J, Bjerke JW, Martin PJ, Petersdorf EW, et al. Transplantation of marrow cells from unrelated donors for treatment of high-risk acute leukemia: the effect of leukemic burden, donor HLA-matching, and marrow cell dose. Blood 1997; 89:4226-35.
10. Pi-Sunyer FX. Medical hazards of obesity. Ann Intern Med 1993; 119:655-60.
11. Fleming DR, Rayens MK, Garrison J. Impact of obesity on allogeneic stem cell transplant patients: a matched case-controlled study. Am J Med 1997;102:265-8.
12. Clarke B, Engler H. Patients with morbid obesity don't get life-saving bone marrow transplants. Obes Surg 1999;9:77-9.
13. Ritchie DS, Wirth A, Grigg AP. Successful transplant outcome in a morbidly obese patient with acute myeloblastic leukamia. Leuk Lymphoma 2001;42:1111-4.
14. Coghlin-Dickson TM, Kusnierz-Glaz CR, Blume KG, Negrin RS, Hu WW, Shizuru JA, et al. Impact of admission body weight and chemotherapy dose adjustment on the outcome of autologous bone marrow transplantation. Biol Blood Marrow Transplant 1999;5:299.
15. Meloni G, Proia A, Capria S, Romano A, Trapé G, Trisolini SM, Vignetti M, Mandelli F. Obesity and autologous stem cell transplantation in acute myeloid leukemia. Bone Marrow Transplant 2001;28:365-7.
16. Eriksson K, Cederholm T, Palmblad J. Nutrition and acute leukemia in adults. Relation between nutritional status and infectious complication during remission induction. Cancer 1998;82:1071-7.
17. Deeg HJ, Seidel K, Bruemmer B, Pepe MS, Appelbaum FR. Impact of patient weight on non-relapse mortality after marrow transplantation. Bone Marrow Transplant 1995;15:461-8.
18. Benn RT. Indices of height and weight as measures of obesity.

Br J Prev Soc Med 1970;24:64.
19. Ringdén O, Båryd I, Johansson B, Gahrton G, Groth CG, Lundgren G, et al. Increased mortality by septicemia, interstitial pneumonitis and pulmonary fibrosis among bone marrow transplant recipients receiving an increased mean dose rate of total irradiation. Acta Radiol Oncol 1983;22:423-8.
20. Ringdén O, Ruutu T, Remberger M, Nikoskelainen J, Volin L, Vindelov L, et al. A randomized trial comparing busulphan with total body irradiation as conditioning in allogeneic marrow transplant recipients with leukemia. Blood 1994;83:2723-30.
21. Ringdén O, Pihlstedt P, Markling L, Aschan J, Baryd I, Ljungman P, et al. Prevention of graft-versus-host disease with T-cell depletion or cyclosporine and methotrexate. A randomized trial in adult leukemic marrow recipients. Bone Marrow Transplant 1991;7:221-6.
22. Ringdén O, Remberger M, Persson U, Ljungman P, Aldener A, Andstrom E, et al. Similar incidence of graft-versus-host disease using HLA-A, -B and –DR identical unrelated bone marrow donors as with HLA-identical siblings. Bone Marrow Transplant 1995;15:619-25.
23. Storb R, Epstein R, Graham T, Thomas E. Methotrexate regimens for control of graft-versus-host disease in dogs with allogeneic marrow grafts. Transplantation 1970;9:240-6.
24. Ringdén O, Bäckman L, Lönnqvist B, Heimdahl A, Lindholm A, Bolme P, et al. A randomized trial comparing use of cyclosporin and methotrexate for graft-versus-host disease prophylaxis in bone marrow transplant recipients with haematological malignancies. Bone Marrow Transplant 1986;1:41-51.
25. Deeg H, Storb R, Appelbaum F, Kennedy MS, Graham TC, Thomas ED. Combined immunosuppression with cyclosporine and methotrexate in dogs given bone marrow grafts from DLA-haploidentical littermates. Transplantation 1984;37:62-5.
26. Storb R, Deeg H, Whitehead J, Appelbaum F, Beatty P, Bensinger W, et al. Methotrexate and cyclosporine compared with cyclosporine alone for prophylaxis of acute graft-versus-host disease after marrow transplantation for leukemia. N Engl J Med 1986; 314:729-35.
27. Aschan J, Ringdén O, Andström E, Ljungman P, Lönnqvist B, Remberger M. Individualized prophylaxis against graft-versus-host disease in leukemic marrow transplant recipients. Bone Marrow Transplant 1994;14:79-87.
28. Carlens S, Aschan J, Remberger M, Dilber S, Ringdén O. Low-dose cyclosporine of short duration increases the risk of mild and moderate GVHD and reduces the risk of relapse in HLA-identical sibling marrow transplant recipients with leukemia. Bone Marrow Transplant 1999;24:629-35.
29. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958;53:457-81.
30. Cox D. Regression models and life-tables. J R Stat Soc (Series B) 1972;34:187-220.
31. Weir J, Reilly JJ, McColl JH, Gibson BES. No evidence for an effect of nutritional status at diagnosis on prognosis in children with acute lymphoblastic leukemia. J Pediatr Hematol/Oncol 1998;20:534-8.
32. Rasmussen F, Johansson M, Hansen HO. Trends in overweight and obesity among 18-y old males in Sweden between 1971 and 1995. Acta Paediatrica 1999;88:365-7.
33. Palmblad J. Malnutrition associated immune deficiency syndrome: clues to mechanisms. Acta Med Scand 1987;222:1-3.
34. Dickson TM, Kusnierz-Glaz CR, Blume KG, Negri US, Hu WW, Shizuru JA, et al. Impact of admission body weight and chemotherapy dose adjustment on the outcome of autologous bone marrow transplantation. Biol Blood Marrow Transplant 1999;5:299-305.
35. Tracey KJ, Wei H, Manogue KR, Fong Y, Hese DG, Ngyuen HT, et al. Cachectin/tumor necrosis factor induces cachexia, anemia and inflammation. J Exp Med 1988;167:1211-27.
36. Cederholm T, Wretlind B, Hellström K, Andersson B, Engström L, Brismar K, et al. Enhanced generation of interleukins 1b and 6 may contribute to the cachexia of chronic disease. Am J Clin Nutr 1997;65:876-82.

Pre-publication Report & Outcomes of Peer Review

Contributions

The three authors all contributed to conception of trhe study and interpretation of data, drafting and critical revision of the manuscript. KLB wrote the first draft, OR was responsible for and took care of all the patients included in the study during the first month after transplantation. He also initiated the study of BMI. MR collected all the patients' data in his computer and did all the statistical analyses. Furthermore, he created all the survival figures.

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Disclosures

Conflict of interest: none.

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Manuscript processing

This manuscript was peer-reviewed by two external referees and by Dr. Jorge Sierra, who acted as an Associate Editor. The final decision to accept this paper for publication was taken jointly by Dr. Sierra and the Editors. Manuscript received May 27, 2003; accepted July 14, 2003.

In the following paragraphs, Dr. Sierra summarizes the peer-review process and its outcomes.

What is already known on this topic

High body weight has been reported as significant risk factor for increased procedure-related mortality after allogeneic transplantation. The effect of low weight or low body mass index on the outcome is uncertain.

What this study adds

The authors showed that a body mass index below 20 increased mortality and reduced survival after transplantation.

Caveats

This was an heterogeneous series of patients receiving related or unrelated donor transplantation for a variety of diseases. The findings should be taken with caution and reproduced in future studies including homogeneouly treated patients.