

SPECIAL REPORT

Use of haploidentical stem cell transplantation continues to increase: the 2015 European Society for Blood and Marrow Transplant activity survey report

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Hematopoietic stem cell transplantation (HSCT) is an established procedure for many acquired and congenital disorders of the hematopoietic system. A record number of 42 171 HSCT in 37 626 patients (16 030 allogeneic (43%), 21 596 autologous (57%)) were reported by 655 centers in 48 countries in 2015. Trends include continued growth in transplant activity over the last decade, with the highest percentage increase seen in middle-income countries but the highest absolute growth in the very-high-income countries in Europe. Main indications for HSCT were myeloid malignancies 9413 (25%; 96% allogeneic), lymphoid malignancies 24 304 (67%; 20% allogeneic), solid tumors 1516 (4%; 3% allogeneic) and non-malignant disorders 2208 (6%; 90% allogeneic). Remarkable is the decreasing use of allogeneic HSCT for CLL from 504 patients in 2011 to 255 in 2015, most likely to be due to new drugs. Use of haploidentical donors for allogeneic HSCT continues to grow: 2012 in 2015, a 291% increase since 2005. Growth is seen for all diseases. In AML, haploidentical HSCT increases similarly for patients with advanced disease and for those in CR1. Both marrow and peripheral blood are used as the stem cell source for haploidentical HSCT with higher numbers reported for the latter.

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INTRODUCTION

Hematopoietic stem cell transplantation (HSCT) is an established procedure for many acquired and congenital disorders of the hematopoietic system, including disorders of the immune system, and as enzyme replacement in metabolic disorders.^{1–4} The annual activity survey of the European Society of Blood and Marrow Transplantation (EBMT), describing the status of HSCT in Europe and affiliated countries, has become an instrument used to observe trends and to monitor changes in technology use.^{5–12} The survey captures the numbers of HSCT performed in the preceding year by each participating team, divided by indication, donor type and stem cell source. The standardized structure of the survey over many years and the excellent commitment of the participating teams allow us to observe changes over time and to evaluate factors associated with these changes. More recently, the survey has included additional information on novel cell therapies with hematopoietic stem cells for non-hematopoietic use, as well as on the use of non-hematopoietic stem and progenitor cells. This coincides with the recent interest of the World Health Organization (www.who.org) in cell and tissue transplants, and further stresses the need for adequate and timely information.¹³ The analysis of the survey data spanning over 25 years and amassing data on more than 600 000 transplants in over 550 000 patients, has shown a continued and constant increase in the annual

numbers of HSCT and transplant rates (number of HSCT/10 million inhabitants) for both allogeneic and autologous HSCT.

This report is based on the 2015 survey data. In addition to transplant rates and indications, this report focuses on the use of haploidentical donors for transplantation including disease entities and stem cell sources.

PATIENTS AND METHODS

Data collection and validation

Participating teams were invited to report data for 2015 by indication, stem cell source and donor type as listed in Table 1. The survey allows the possibility to report additional information on the numbers of subsequent transplants performed as a result of relapse, rejection or those that are part of a planned sequential transplant protocol. Supplementary Information on the numbers of donor lymphocyte infusions, reduced intensity HSCT and the numbers of pediatric HSCT is also collected. New in this year's survey is the more detailed report on cellular therapies (Table 2). Quality-control measures included several independent systems: confirmation of validity of the entered data by the reporting team, selective comparison of the survey data with minimum essential data (MED-A) data sets in the EBMT Registry database and cross-checking with the National Registries.

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Table 1. Numbers of HSCTs in Europe 2015 by indication, donor type and stem cell source

	Transplant activity 2015																						
	No. of patients																						
	Allogeneic								Autologous														
	Family				Unrelated				BM only				BM + PB				Total						
HLA-id		Twin		Haplo ≥ 2MM		Other family		BM		PB		Cord		BM only		BM + PB		Cord		Allo		Auto	
BM	PB	Cord	All	BM	PB	BM	PB	BM	PB	BM	PB	Cord	BM	PB	Cord	BM	PB	Cord	BM	PB	Cord	Allo	Auto
Myeloid malignancies	412	2439	5	9	310	603	28	68	0	525	4425	170	9	410	0	8994	419	9413	419	413	6602	6189	413
AML	290	1750	5	6	208	460	15	52	0	330	2940	133	9	404	0	6189	413	6602	413	413	6602	6189	413
First complete remission	201	1077	5	3	100	196	10	29	0	203	1537	79	6	349	0	3440	355	3795	355	355	3795	3440	355
Not first complete remission	64	485	0	3	81	199	4	21	0	90	864	37	3	50	0	1848	53	1901	53	53	1901	1848	53
AML therapy related	11	57	0	0	4	18	0	1	0	9	115	6	0	2	0	221	2	223	2	2	223	221	2
AML from MDS/MPN	14	131	0	0	23	47	1	1	0	28	424	11	0	3	0	680	3	683	3	3	683	680	3
CML	26	115	0	0	14	12	12	2	0	27	196	6	0	3	0	398	3	401	3	3	401	398	3
Chronic phase	14	48	0	0	2	5	0	1	0	14	78	1	0	1	0	163	1	164	1	1	164	163	1
Not first chronic phase	12	67	0	0	12	7	0	1	0	13	118	5	0	2	0	235	2	237	2	2	237	235	2
MDS or MD/MPN	87	442	0	3	68	108	12	9	0	146	971	28	0	3	0	1874	3	1877	3	3	1877	1874	3
MPN	9	132	0	0	20	23	1	5	0	22	318	3	0	0	0	533	0	533	0	0	533	533	0
Lymphoid malignancies	338	1410	5	11	222	356	16	41	1	392	1984	114	26	19424	0	4890	19450	24340	19450	24340	4890	19450	24340
Acute lymphatic leukemia	264	641	5	2	101	185	15	27	1	309	851	93	3	81	0	2494	84	2578	84	84	2578	2494	84
First complete remission	164	457	0	2	49	92	9	12	1	146	556	43	1	65	0	1531	66	1597	66	66	1597	1531	66
Not first complete remission	100	184	5	0	52	93	6	15	0	163	295	50	2	16	0	963	18	981	18	18	981	963	18
CLL	9	83	0	0	7	13	0	3	0	7	131	2	0	36	0	255	36	291	36	36	291	255	36
Plasma cell disorders: MM	6	194	0	2	13	14	0	1	0	20	285	3	5	10856	0	538	10861	11399	538	538	11399	538	0
Plasma cell disorders: other	0	15	0	2	0	1	0	0	0	2	9	0	0	326	0	29	326	355	29	29	355	29	0
Hodgkin's lymphoma	12	130	0	2	55	61	1	2	0	9	166	4	8	2062	0	442	2070	2512	442	442	2070	442	0
Non-Hodgkin's lymphoma	47	347	0	3	46	82	0	8	0	45	542	12	10	6063	0	1132	6073	7205	1132	1132	6073	1132	0
Solid tumors	5	2	1	1	2	19	0	1	0	2	4	1	47	1430	1	38	1478	1516	38	38	1478	38	0
Neuroblastoma	3	1	1	0	2	12	0	0	0	0	1	1	27	459	1	21	487	508	21	21	487	21	0
Soft tissue sarcoma/Ewing	0	0	0	0	0	5	0	1	0	0	2	0	10	205	0	8	215	223	8	8	215	8	0
Germinal tumors	0	0	0	0	0	0	0	0	0	0	0	0	1	350	0	0	351	351	0	0	351	0	0
Breast cancer	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	29	29	0	0	29	0	0
Other solid tumors	2	1	0	1	0	2	0	0	0	2	1	0	9	387	0	9	396	405	9	9	396	9	0
Non-malignant disorders	648	241	28	4	64	131	72	49	4	419	227	98	9	214	0	1985	223	2208	223	223	2208	1985	223
BM failure: SAA	185	105	5	3	16	22	11	3	1	124	79	12	0	0	0	566	0	566	0	0	566	566	0
BM failure: other	68	24	4	0	8	20	9	12	1	73	31	11	0	0	0	261	0	261	0	0	261	261	0
Thalassemia	148	66	9	1	5	12	17	7	1	55	19	1	1	3	0	341	4	345	4	4	345	341	4
Sickle cell disease	92	11	6	0	10	4	3	1	0	14	5	0	0	0	0	146	0	146	0	0	146	146	0
Primary immune deficiencies	130	26	3	0	19	65	27	22	1	120	77	37	2	6	0	527	8	535	8	8	535	527	8
Inh. disorders of metabolism	23	5	1	0	6	7	5	3	0	30	14	35	4	0	0	129	4	133	4	4	133	129	4
Auto immune disease	2	4	0	0	0	1	0	1	0	3	2	2	2	205	0	15	207	222	15	15	207	15	0
Others	31	10	1	0	8	16	5	1	0	17	27	7	0	26	0	123	26	149	123	123	149	123	26
Total patients	1434	4102	40	25	606	1125	121	160	5	1355	6667	390	91	21504	1	16030	21596	37626	21596	21596	37626	16030	21596
Re/additional transplants	55	257	0	2	96	257	4	12	0	71	497	21	7	3266	0	1272	3273	4545	1272	1272	3273	1272	3273
Total transplants	1489	4359	40	27	702	1382	125	172	5	1426	7164	411	98	24770	1	17302	24869	42171	24869	24869	42171	17302	24869

Abbreviations: BM = bone marrow; HSCT = hematopoietic stem cell transplant; MDS = myelodysplastic; MPN = myeloproliferative neoplasm; MM = multiple myeloma; PB = peripheral blood; SAA = severe aplastic anaemia. Bold text implies the subtotals.

Table 2. Numbers of cellular therapies in Europe 2015 by indication, donor type and cell source

Number of patients	DLI		MSC		NK cells		Selected/ expanded T cells or CIK		TREGS		Genetically modified T cells		Dendritic cells		Expanded CD34+ cells		Genetically modified CD34+ cells		Other		
	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	Allo	Auto	
GvHD			396				3		29		1				3						
Graft enhancement	803		44	1	2		14								5						24
Autoimmune disease			4	40																	
Genetic disease			2								1								8		
Infection			4				119														6
Malignancy			1		11	1	32	5	1	5	8	4	5	20			19				3
DLI for residual disease	410																				
DLI for relapse	1285																				
DLI per protocol	442																				
Regenerative medicine			16	7											1						3
Total	2940	467	48	13	1	168	5	30	5	9	5	5	20	9	0	19	8	33	97		

Abbreviations: DLI = donor lymphocyte infusions; MSC = mesenchymal stem cells; NK = natural killer; TREGS = regulatory T cells. Bold text implies the totals.

Teams

Six hundred and eighty-seven centers from 48 countries were contacted for the 2015 survey (39 European and 9 affiliated countries), of which 655 teams reported. This corresponds to a 95% return rate and includes 552 active EBMT member teams. Thirty-two active teams failed to report in 2015.

Contacted teams are listed in the online Supplementary Appendix in alphabetical order by country, city and EBMT centre code, with their reported numbers of first and total HSCT, and of first allogeneic and autologous HSCT as Supplementary Material. The World Health Organization regional office definitions (www.who.org) were used to classify countries as European or Non-European. Nine non-European countries participated in the 2015 EBMT survey: Algeria, Iran, Israel, Jordan, Lebanon, Nigeria, Saudi Arabia, South Africa and Tunisia. Their data (2776 HSCT in 2657 patients) from 29 actively transplanting teams make up 6.6% of the total data set and is included in all analyses.¹³

Patient and transplant numbers

Wherever appropriate, patient numbers corresponding to the number of patients receiving a first transplant and transplant numbers reflecting the total number of transplants performed are listed.

The term sibling donor includes HLA identical siblings and twins, but not siblings with HLA mismatches. Unrelated donor transplants include HSCT from unrelated donors with peripheral blood and marrow as a stem cell source, but not cord blood HSCT. In the 2015 survey, we collected separately the numbers of haplo-identical and other family member HSCT. Haplo-identical being described as any family member with two or more loci mismatch within the loci HLA-A, -B, -C, -DRB1 and -DQB1 in GvH and/or HvG direction. Other family member donors are those related donors who are mismatched to a lesser degree than a full haplotype. Additional non-first transplants may include multiple transplants defined as subsequent transplants within a planned double or triple autologous or allogeneic transplant protocol, and retransplants (autologous or allogeneic) defined as unplanned HSCT for rejection or relapse after a previous HSCT.

Transplant rates

Transplant rates, defined as the total number of HSCT per 10 million inhabitants, were computed for each country without adjustments for patients who crossed borders and received their HSCT in a foreign country. Population numbers were obtained from Eurostats for 2015 for the European countries, (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_ure)

and the US census bureau database for the non-European countries (<http://www.census.gov/population/international/data/idb/rank.php>).

Analysis

Wherever appropriate, the absolute numbers of transplanted patients, transplants or transplant rates are shown for specific countries, indications or transplant techniques. Myeloid malignancies include AML, myelodysplastic or myelodysplastic/myeloproliferative neoplasm (MPN), MPN and CML. Lymphoid malignancies include ALL, CLL, Hodgkin's disease, non-Hodgkin lymphoma and plasma cell disorders. The non-malignant disorders include bone marrow failure, thalassemia, sickle cell disease, primary immune disease inherited disease of metabolism and autoimmune disease AID. Others include histiocytosis and other rare disorders not included in the above.

RESULTS

2015 data

Participating teams in 2015. Of the 655 teams, 412 (62%) performed both allogeneic and autologous transplants; 227 (35%) restricted their activity to autologous HSCT and 11 teams (2%) to allogeneic transplants only. Five teams (1%) reported having performed no transplants in 2015 due to renovation or temporary closure of the transplant unit. Of the 655 active centers, 131 (20%) centers performed transplants on both adult and pediatric patients. An additional 106 (16%) centers were dedicated pediatric transplant centers and 417 (64%) centers performed transplants on adults only.

Numbers of patients and transplants

In 2015, 42 171 transplants were reported in 37 626 patients (first transplant); of these, 17 302 HSCT (41%) were allogeneic and 24 869 (59%) autologous (Table 1). When compared with that in 2014, the total number of transplants increased by 3.3% (2.1% allogeneic HSCT and 4.1% autologous HSCT).¹² Furthermore, there were 4545 second or subsequent transplants, 1272 allogeneic and 3273 autologous. The total number of patients transplanted under the age of 18 in both dedicated and joint adult-pediatric units was 4490 (3338 allogeneic and 1152 autologous HSCT). Of these, 3015 patients (67%, 2570 allogeneic and 896 autologous) reporting a total of 3466 transplants were performed in dedicated pediatric centers. A total of 4545 transplants were second or multiple transplants. Among these,

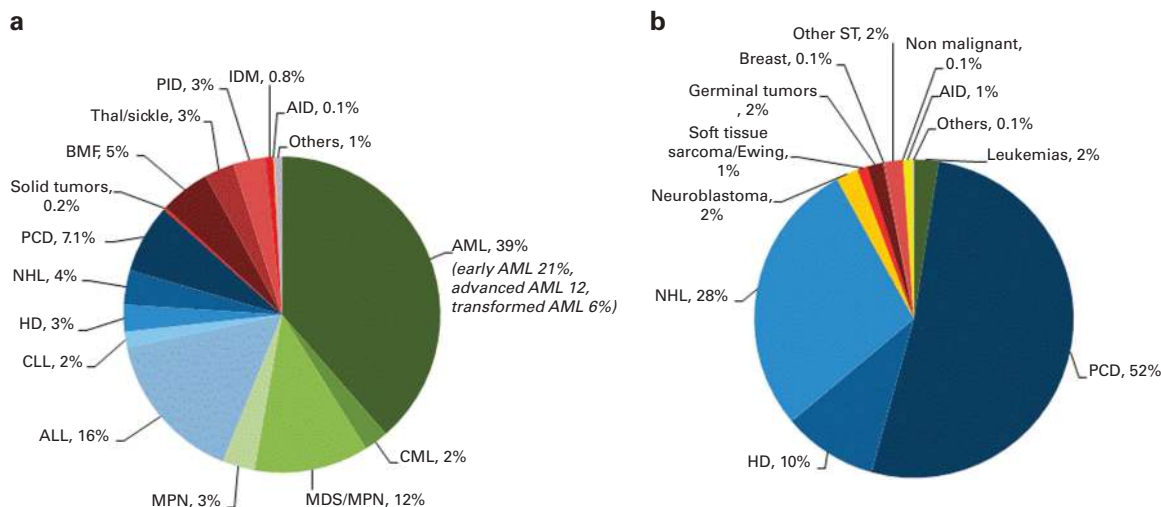


Figure 1. Relative proportion of indications for HSCT in Europe in 2015. (a) Proportions of disease indications for allogeneic HSCT in Europe in 2015. (b) Proportions of disease indications for autologous HSCT in Europe in 2015.

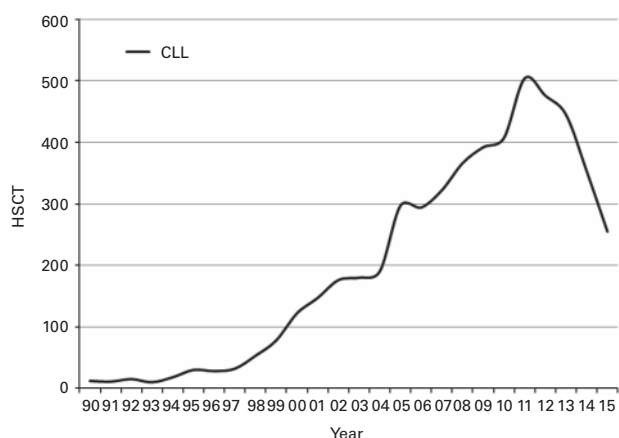


Figure 2. The rise and fall in absolute numbers of allogeneic HSCT for CLL in Europe 1990–2015.

3273 were autologous, the majority of which were probably part of multiple transplant programs, for example, as for plasma cell disorders. In total, 1272 were allogeneic HSCTs mainly to treat relapse or graft failure. In addition, 794 HSCTs were reported as allogeneic HSCT after a previous autologous HSCT and were mainly for lymphoma or plasma cell disorders.

Indications

Indications for HSCT in 2015 are listed in detail in Table 1. Main indications were myeloid malignancies (AML, CML, myelodysplastic/MPN and MPN): 9413 (25% of total; 96% of which were allogeneic); lymphoid malignancies (ALL, CLL, Hodgkin's disease, non-Hodgkin lymphoma and plasma cell disorder): 24 340 (65%; 20% allogeneic); solid tumors: 1516 (4%; 3% allogeneic); non-malignant disorders: 2208 (6%; 90% allogeneic) and others: 149 (0.4%). As seen in previous years, the majority of HSCT for lymphoid malignancies were autologous, whereas most transplants for leukemia were performed using stem cells from allogeneic donors. Autologous HSCT for non-malignant disorders predominantly include patients with autoimmune disorders (207).

Figures 1a and b show as a pie graph the distribution of disease indications for allogeneic (Figure 1a) and autologous (Figure 1b), respectively. Of interest, we show that for allogeneic HSCT AML is

the most frequent indication (39%); of these, 21% were for patients in CR1, 12% for patients with more advanced disease and 6% for patients with transformed AML, either therapy related or from myelodysplastic /MPN. Compared with that in 2014, there were increases in allogeneic HSCT for AML by 7.9% and MPN 3.5% and a major decrease by 28% was seen in allogeneic HSCT use for CLL (Figure 2), dropping from 504 patients in 2011 to 255 in 2015. Among allogeneic HSCT, 6933 were performed using non-myeloablative conditioning. This is an increase of 1% since in 2014 and is 40% of all allogeneic HSCT. For autologous HSCT, there was an increase in myeloma by 8.1% and Hodgkin lymphoma by 2.1%; proportions for most other diseases remained stable.

Important trends in 2015 include continued increase in patients treated with allogeneic and autologous HSCT as shown in Supplementary Figure 1, and increasing use among allogeneic HSCT recipients of unrelated donor transplantation,¹⁴ although it might appear that the growth rate is slowing down (Supplementary Figure 2). Figure 3a shows the continued use of alternative donor transplantation and among these an impressive increase of the use of haploidentical donors to 2012 patients in 2015 across Europe, an increase of 291% since 2005. The highest growth is seen in myeloid malignancies (1008), with lymphoid malignancies 636, nonmalignant disorders 316 and 52 others. Figure 3b shows that the growth of haploidentical donor HSCT is seen more in patients with myeloid malignancy, but also in lymphoid malignancy and non-malignant disorders, although to a lesser degree. Among myeloid malignancies, the majority ($n = 735$) are patients with AML. Of note, there are equal proportions of patients with AML receiving haploidentical donor HSCT transplanted in CR1 and with more advanced disease (Figure 3c). Stem cell source for haploidentical donor HSCT is shown in Figure 3d, peripheral blood is used more frequently than marrow. The decreasing use of unrelated cord blood as donor source is shown in Figure 3a for total HSCT, or by main indication in Figure 3e. This decrease is in sharp contrast to the rise seen in haploidentical donor HSCT. As shown in Figure 3e, this decrease pertains to myeloid and lymphoid malignancies but not to nonmalignant disorders where the use of unrelated cord blood is stable over time.

Transplant rates

Supplementary Figures 3a and b show transplant rates by country for allogeneic and autologous HSCT comparing rates in 2015 on

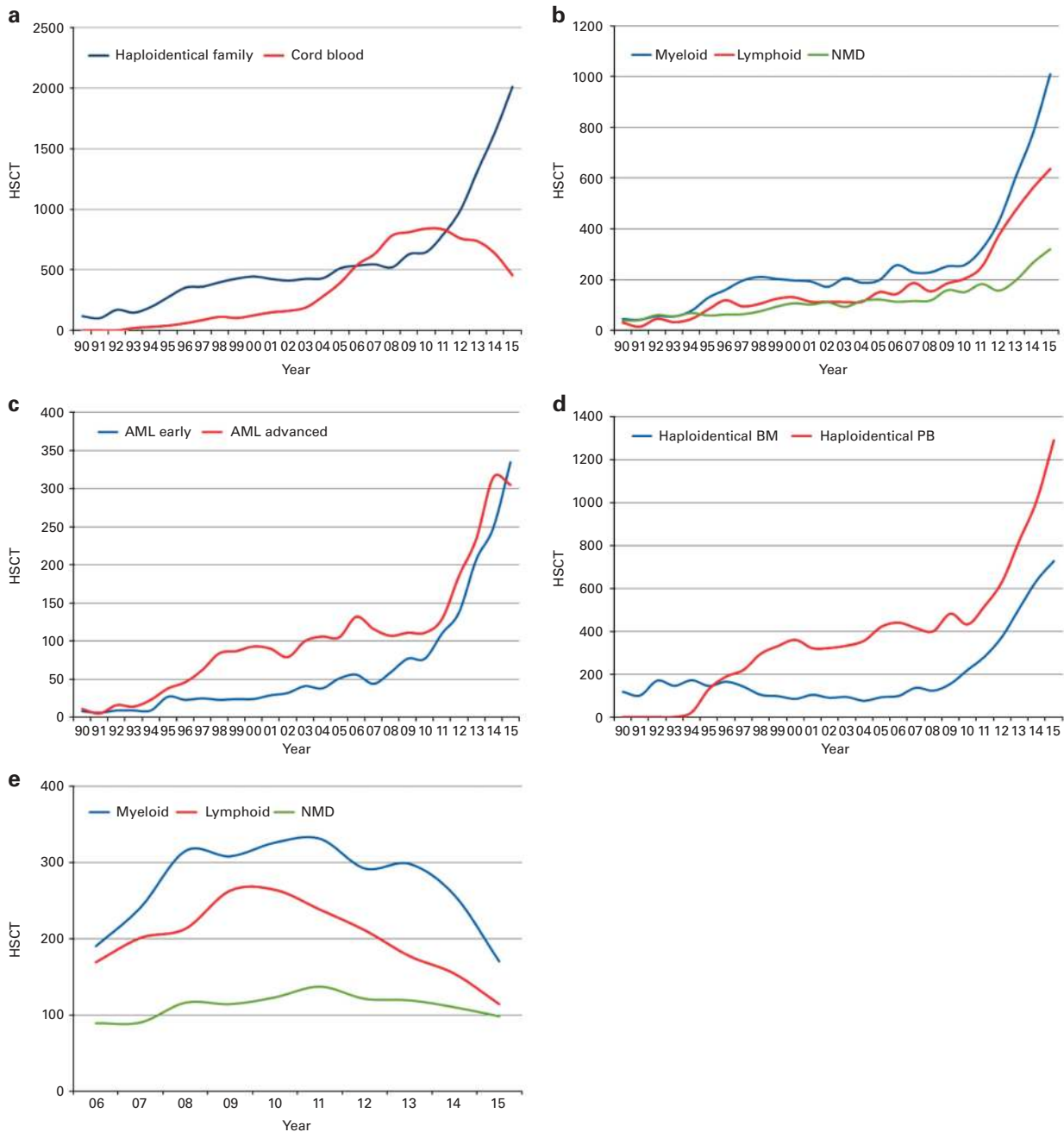


Figure 3. Change in the absolute numbers of haploidentical and cord blood HSCT in Europe 1990–2015. **(a)** Change in donor selection from cord blood HSCT to haploidentical HSCT. **(b)** Increase in the use of haploidentical donors by main indication group. **(c)** Haploidentical HSCT by AML early disease and advanced disease. **(d)** Haploidentical HSCT by cell source; bone marrow versus peripheral blood. **(e)** Trend in the use of unrelated cord blood HSCT by main indication group 2006–2015.

maps of Europe. Median transplant rates per 10 million inhabitants were 153.1 (range, 4.4–460.9) for allogeneic HSCT and 251.8 (range, 1.0–759.9) for autologous HSCT in 2015. For the purpose of this analysis, we have grouped countries according to World Bank income group gross national income per capita in USD in 2015, (<http://data.worldbank.org/data-catalog/world-development-indicators>). All European countries fall within the group of either middle-income or high-income category; thus, we created a third group to split the high-income countries into very wealthy countries defined as >40 000 USD gross national income per capita. Median transplant rates in 2015 for the 3 groups are as follows: 262, 179, and 34 for very-high-, high- and medium-income

countries (allogeneic HSCT, transplants per 10 million inhabitants), and 396, 295 and 56 for autologous HSCT, respectively. Figure 4 shows growth rates in allogeneic and autologous HSCT use by income category as relative growth, that is, % increase from 2005 to 2015 or as absolute increase in transplant rates from 2005 to 2015 normalized for size of the population. Figure 4a and b shows that % increase is highest for middle income countries (gross national income per capita < 12 500 USD) for both allogeneic and autologous HSCT, and lowest for the very-high-income countries. The higher income countries had already achieved a high level of transplant rates in 2005. To the contrary, the absolute growth, that is, increase in access of patients to transplant centers is highest in

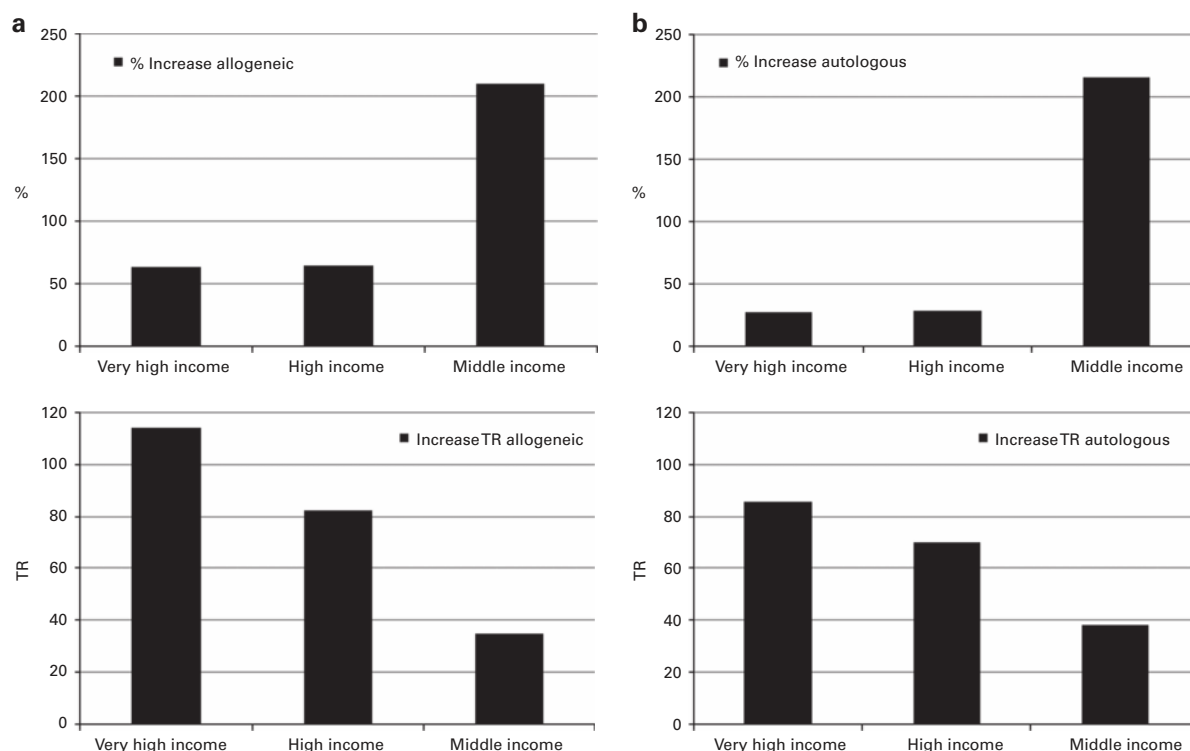


Figure 4. Effect of income group on changes in transplant activity and transplant rates 2005–2015. (a) Percentage increase in transplant activity for allogeneic HSCT (top left), increase in transplant rates for allogeneic HSCT (bottom left). (b) Percentage increase in transplant activity for autologous HSCT (top right), increase in transplant rates for autologous HSCT (bottom right).

the very-high-income countries in the period of 2005–2015, again for both allogeneic and autologous HSCT.

Additional cellular therapies

A total of 35 countries (330 teams) reported having performed 3882 cellular therapies in 2015. Of these, 2940 patients received donor lymphocyte infusions (Table 2). Indications were graft enhancement: 803 (27%), residual disease: 410 (14%), relapsed disease: 1285 (44%), and per protocol 442 (15%).

Other cellular therapies were given either within the context of a HSCT or not. The majority were mesenchymal stem cells given for GvHD treatment (396) or for graft enhancement (45). Seventy-four patients received mesenchymal stem cells for various other indications. The largest additional group of cellular therapies were selected or expanded T cells given to treat infectious complications (119 patients) or for anti-malignant effects (37). Other cellular therapies including natural killer cells,¹⁴ regulatory T-cells (35), genetically modified T-cells,¹⁴ dendritic cells (25) and expanded or genetically modified hematopoietic stem cells (36) were reported more rarely. One hundred and twenty patients received cellular products for purposes of regenerative medicine.^{15,16}

DISCUSSION

The EBMT activity survey has been conducted annually since 1990.⁶ The 2010 survey reported for the first time >30 000 patients transplanted in a given year¹⁷ and >40 000 transplants in 2014. Again, transplant numbers continue to increase unabated across Europe.

HSCT for some indications continues to increase but not for others. Of interest is the decreasing use of allogeneic HSCT for CLL and a growth in allogeneic HSCT using haploidentical donors, an increase over 200% in the last 5 years. The drop in allogeneic HSCT for CLL is remarkable and reminds us of the drop seen in CML transplants once kinase inhibitors became available.^{18,19} Whether

this drop is going to be permanent or whether this is temporary will depend on the long-term results of kinase inhibitors and possibly bcl2 inhibitors developed to treat CLL.

The continuing use of haploidentical donors is impressive and it becomes apparent that haploidentical donor HSCT is not only used for advance disease stages but also for early disease stages as exemplified by AML (Figure 3c). The use of peripheral blood as a stem cell source has surpassed the use of marrow (Figure 3d), although the original studies describing haploidentical donor HSCT with post-transplant cyclophosphamide as GvHD prophylaxis have been using mainly marrow.²⁰ The use of unrelated cord blood, a competitor for alternative donor HSCT when identical siblings and well-matched unrelated donors are not available, continues to decrease but only for malignant disorders.²¹ Cord blood transplant rates for nonmalignant diseases remain stable, reflecting the practice mainly in pediatric centers.

We looked at development of transplant technology in countries in Europe by economic strength of the societies and, for this purpose, show growth of allogeneic and autologous HSCT as relative and as absolute growth for countries in the middle-, high- and very-high-income categories. We here confirm that the relative growth is more significant in middle income countries, but that the highest absolute growth over the last decade is seen in the category of very-high-income countries. This exemplifies that autologous and allogeneic HSCT remains an expensive technology broadly available in wealthy societies.

We have added data on the use of cellular therapies, most of which is donor lymphocyte infusions given to treat relapse or residual disease in over 2900 patients. Other cellular therapies have been given to over 900 patients, the largest group of which is mesenchymal stromal cells to treat GvHD. Although we have established confidence in the reported transplant numbers we cannot exclude a certain degree of underreporting, particularly in the most advanced fields of cellular therapies of patients included in studies across Europe.

In conclusion, this year's activity survey shows continued increase in the use of HSCT across Europe. Some trends are visible and are discussed here. The study reflects current practice and results may be useful to healthcare planning and health policy makers.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

- 1 Copelan EA. Hematopoietic stem-cell transplantation. *N Engl J Med* 2006; **354**: 1813–1826.
- 2 Appelbaum FR. Hematopoietic-cell transplantation at 50. *N Engl J Med* 2007; **357**: 1472–1475.
- 3 Ljungman P, Bregni M, Brune M, Cornelissen J, deWitte T, Dini G *et al*. European Group for Blood and Marrow. Allogeneic and autologous transplantation for haematological diseases, solid tumours and immune disorders: current practice in Europe 2009. *Bone Marrow Transplant* 2010; **45**: 219–234.
- 4 Gratwohl A, Baldomero H, Aljurf M, Pasquini MC, Bouzas LF, Yoshimi A *et al*. Hematopoietic stem cell transplantation: a global perspective. *JAMA* 2010; **303**: 1617–1624.
- 5 Gratwohl A, Pasquini MC, Aljurf M, Atsuta Y, Baldomero H, Foeken L *et al*. One million haemopoietic stem-cell transplants: a retrospective observational study. *Lancet Haematol* 2015; **2**: e91–e100.
- 6 Gratwohl A, Baldomero H, Schwendener A, Gratwohl M, Apperley J, Frauendorfer K *et al*. The EBMT activity survey 2008 impact of team size, team density and new trends. *Bone Marrow Transplant* 2011; **46**: 174–191.
- 7 Gratwohl A. Bone marrow transplantation activity in Europe 1990. Report from the European Group for Bone Marrow Transplantation (EBMT). *Bone Marrow Transplant* 1991; **8**: 197–201.

- 8 Gratwohl A, Baldomero H, Horisberger B, Schmid C, Passweg J, Urbano-Ispizua A. Accreditation Committee of the European Group for Blood and Marrow Transplantation (EBMT). Current trends in haematopoietic stem cell transplantation in Europe. *Blood* 2002; **100**: 2374–2386.
- 9 Gratwohl A, Baldomero H, Schwendener A, Rocha V, Apperley J, Frauendorfer K *et al*. The EBMT activity survey 2007 with focus on allogeneic HSCT for AML and novel cellular therapies. *Bone Marrow Transplant* 2009; **43**: 275–291.
- 10 Gratwohl A, Schwendener A, Baldomero H, Gratwohl M, Apperley J, Niederwieser D *et al*. Changes in use of hematopoietic stem cell transplantation; a model for diffusion of medical technology. *Haematologica* 2010; **95**: 637–643.
- 11 Passweg JR, Baldomero H, Peters C, Gaspar HB, Cesaro S, Dreger P *et al*. Hematopoietic SCT in Europe: data and trends in 2012 with special consideration of pediatric transplantation. *Bone Marrow Transplant* 2014; **49**: 744–750.
- 12 Passweg JR, Baldomero H, Bader P, Bonini C, Cesaro S, Dreger P *et al*. Hematopoietic stem cell transplantation in Europe 2014: more than 40 000 transplants annually. *Bone Marrow Transplant* 2016; **51**: 786–792.
- 13 World Health Organisation. Transplantation. WHO: Geneva, Switzerland, 2015. <http://www.who.int/topics/transplantation/en/>.
- 14 Foeken LM, Green A, Hurley CK, Marry E, Wiegand T, Oudshoorn M. Monitoring the international use of unrelated donors for transplantation: the WMDA annual reports. *Bone Marrow Transplant* 2010; **45**: 811–818.
- 15 Bonini C, Mondino A. Adoptive T-cell therapy for cancer: the era of engineered T cells. *Eur J Immunol* 2015; **45**: 2457–2469.
- 16 Tolar J, Le Blanc K, Keating A, Blazar BR. Concise review: hitting the right spot with mesenchymal stromal cells. *Stem Cells* 2010; **28**: 1446–1455.
- 17 Passweg JR, Baldomero H, Gratwohl A, Bregni M, Cesaro S, Dreger P *et al*. The EBMT activity survey: 1990-2010. *Bone Marrow Transplant* 2012; **47**: 906–923.
- 18 Jeyakumar D, O'Brien S. The next generation of targeted molecules for the treatment of chronic lymphocytic leukemia. *Oncology (Williston Park)* 2016; **30**: 1008–1015.
- 19 Passweg JR, Baldomero H, Bader P, Bonini C, Cesaro S, Dreger P *et al*. Impact of drug development on the use of stem cell transplantation: a report by the European Society for Blood and Marrow Transplantation (EBMT). *Bone Marrow Transplant* 2016; **52**: 191–196.
- 20 Luznik L, O'Donnell PV, Symons, Chen AR, Leffell MS, Zahurak M *et al*. HLA-haploidentical bone marrow transplantation for hematologic malignancies using nonmyeloablative conditioning and high-dose, posttransplantation cyclophosphamide. *Biol Blood Marrow Transplant* 2008; **14**: 641–650.
- 21 Brunstein CG, Fuchs EJ, Carter SL, Karanes C, Costa LJ, Wu J *et al*. Blood and Marrow Transplant Clinical Trials Network. Alternative donor transplantation after reduced intensity conditioning: results of parallel phase 2 trials using partially HLA-mismatched related bone marrow or unrelated double umbilical cord blood grafts. *Blood* 2011; **118**: 282–288.



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