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## ANNUAL REPORT

# 2018 Annual Report of the European Liver Transplant Registry (ELTR) – 50-year evolution of liver transplantation

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1 Paul Brousse Hospital, Univ Paris-Sud, Inserm U935, Villejuif, France

2 King's College Hospital, London, UK

3 The Queen Elizabeth Hospital, Birmingham, UK

4 Medizinische Hochschule Hannover, Hannover, Germany

5 Centro de Trapianti di Fegato, Torino, Italy

6 Charité- Campus – Virchow Klinikum, Berlin, Germany

7 Addenbrooke's Hospital, Cambridge, UK

8 St James's & Seacroft University Hospital, Leeds, UK

9 C. U. K. GHs Essen, Essen, Germany

10 Hospital Universitario LA FE, Valencia, Spain

11 Cliniques Universitaires Saint Luc, Brussels, Belgium

12 Universitätsklinikum Hamburg Eppendorf, Hamburg, Germany

13 C.H.U. Rennes, Hopital De Pontchaillou, Rennes, France

14 Hospital Clinic I Provincial de Barcelona, Barcelona, Spain

15 Hopital Beaujon, Clichy, France

16 C.H.R.U. De Strasbourg, Strasbourg, France

17 University of Bologna, Bologna, Italy

## SUMMARY

The purpose of this registry study was to provide an overview of trends and results of liver transplantation (LT) in Europe from 1968 to 2016. These data on LT were collected prospectively from 169 centers from 32 countries, in the European Liver Transplant Registry (ELTR) beginning in 1968. This overview provides epidemiological data, as well as information on evolution of techniques, and outcomes in LT in Europe over more than five decades; something that cannot be obtained from only a single center experience.

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## Key words

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The order of the co-authors from 2 to 40 was determined according to the decreasing number of liver transplants recorded in the ELTR.

The list with all the centers is available at the following link: <http://www.eltr.org/spip.php?page=centers-tous>

- 18 Department of Surgery, Medical University of Vienna, Vienna, Austria
  - 19 Sahlgrenska University Hospital, Gothenborg, Sweden
  - 20 Royal Free Hospital, London, UK
  - 21 Universitätsklinikum Heidelberg, Heidelberg, Germany
  - 22 Medical University of Warsaw Banacha, Warsaw, Poland
  - 23 Hospital 12 De Octubre, Madrid, Spain
  - 24 Ospedale Cisanello, Pisa, Italy
  - 25 Huddinge Hospital, Huddinge, Sweden
  - 26 University Hospital, Innsbruck, Austria
  - 27 University of Edinburgh Royal Infirmary, Edinburgh, UK
  - 28 Hospital Universitari De Bellvitge, Barcelona, Spain
  - 29 Papa Giovanni 23 Hospital, Bergamo, Italy
  - 30 University Medical Center Groningen, Groningen, The Netherlands
  - 31 Inonu Universitesi, Malatya, Turkey
  - 32 Hôpital Henri Mondor, Créteil, France
  - 33 Universitaire Ziekenhuizen Leuven, Leuven, Belgium
  - 34 Rikshospitalet, Oslo, Norway
  - 35 Transplant Center, Institute for Clinical and Experimental Medicine (IKEM), Prague, Czech Republic
  - 36 Hopital Saint Eloi, Montpellier, France
  - 37 Hospital De Cruces, Baracaldo Vizcaya, Spain
  - 38 Ospedale Niguarda Ca Granda, Milano, Italy
  - 39 Hospital Universitario Reina Sofia, Cordoba, Spain
  - 40 Chirurgische Klinik und Poliklinik, Klinikum rechts der Isar, Munich, Germany
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## Introduction

### Background of the European Liver Transplant Registry

Created in 1986, the ELTR has collected the data of liver transplantation (LT) from 175 centers all over Europe since 1968. The registered data represents more than 95% of the overall European data compared with the published official figures [1].

### Questionnaire

The ELTR questionnaire includes data on indications for LT, donors and recipients characteristics, technical aspects of LT (with reduced, split, domino, live and nonheart beating donors), initial and current regimen of immunosuppression, patient outcomes, and cause of death or graft failure. The ELTR has developed an online application (Electronic Data Capture – EDC) for collecting data. A Web-based module was developed to allow for real-time data capture. Software, questionnaires, validation routines, and statistics are located on a central server, which can be accessed by the participating centers with a standard internet browser [2].

To avoid an overlap in case of multiple diagnoses, the ELTR has two variables to report the diagnosis

(Disease1 & Disease2) and an open field for specification in case a diagnosis is not available in the official pull-down menu, or in case there are more than two combined diagnoses. A standard procedure was stated accordingly for the data entry and their analysis in each condition.

### Quality control of the data

The data-entry process is dynamically controlled. The data are subjected to routine checks for completeness, consistency, and range. Comprehensive logical intra- and inter-updates are performed. In addition, a control of the good adequacy between ELTR questionnaire and patient charts is performed by randomly conducted audit visits to the centers. The ELTR audit visits have been continuously conducted since 1998 with, initially 10 randomly selected centers per year up to the year 1999, and five centers per year since 2000. Two auditors perform the visit with the condition that both are not from the visited country. Ten percent of center's files, with a minimum of 20 and a maximum of 50, are analyzed to check data for completeness and consistency. The audit visits serve also to train staff members, and to introduce amendments in the procedure. It is also the opportunity to meet

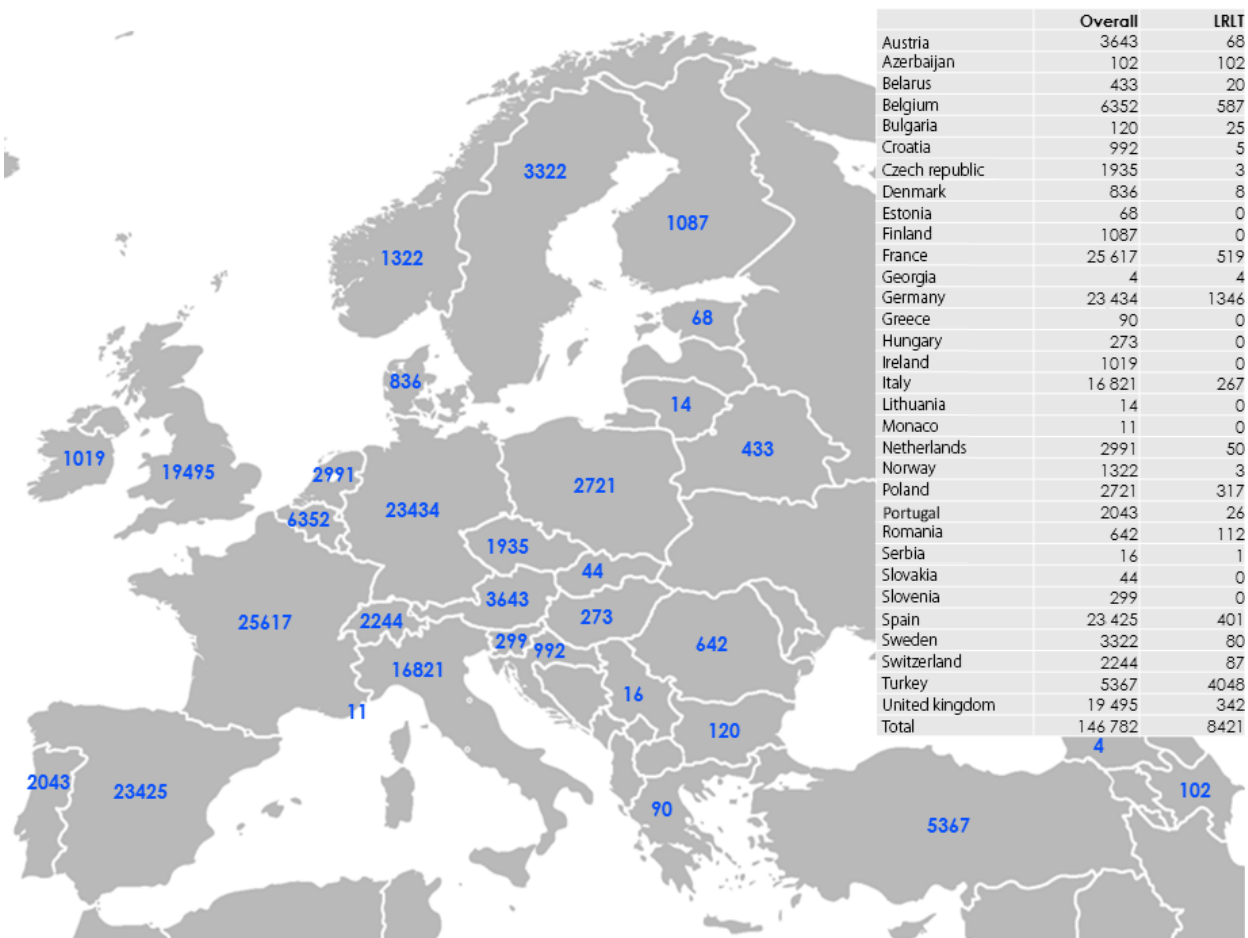
with the staff of centers, something that is valuable for creating a team spirit. The ELTR is considered as the pioneer of external audit visits of a scientific registry. The audit report is sent confidentially to the head of the center with all the discrepancies noted, and the recommendations necessary to improve the data entry included. The results of all center audits are presented during the ELTR biennial workshops, where all the contributing centers are invited. A recent analysis of the ELTR audit data (38 centers from 16 countries, 57 575 variables from 1458 patient files, from 2010 to 2016) showed that the overall rates of completeness and consistency were 94.5% and 97.3% respectively. Audit visits are an indicator of the quality of data, and represent one of the pillars of the ELTR. These results have indicated that ELTR data are reliable, and the scientific results of ELTR can be considered credible and representative of LT in Europe [3–6].

### Partnership with organ sharing organizations (OSOs)

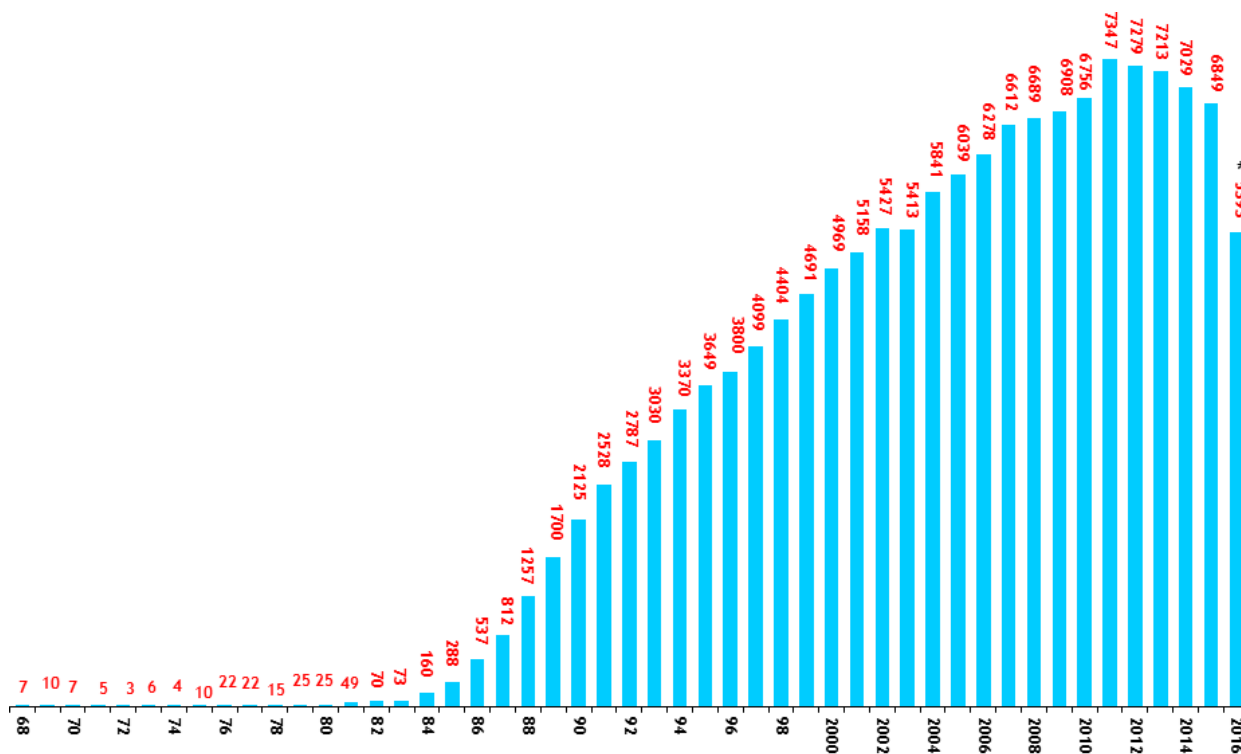
The ELTR has established agreements with the main national and international OSOs: United Kingdom Transplant Service Support Authority – UK NHS Blood and Transplant, Spanish Organizacion Nacional de Trasplantes – ONT, Scandinavian Scandiatransplant – SKT, Dutch Transplant Foundation – NTS, Eurotransplant Foundation – ET, French Agence de la Biomédecine – ABM to exchange data collected from European Centers and to cross check common data between OSO and ELTR.

### Source of the data

There are two sources of ELTR data; 72% of data (63% of centers) are shared with the OSOs and 28% of data (37% of centers) are directly entered into the ELTR EDC platform. Some variables were added to the



**Figure 1** Number of LTs performed in each country, overall and living related liver transplantation (LRLT)(May 1968–December 2016).



\* This decrease is owed to the fact that some centers did not yet send their updating.

Figure 2 Evolution of 147 161 LTs performed in Europe since May 1968.

questionnaire, and some definitions have changed since the registry was created in 1986. To adapt the ELTR to these evolutions, an experts committee was appointed to oversee the standardization of the questionnaire. The European Liver and Intestine Transplant Association (ELITA) board and the OSOs share this concern and are also attentive to all the evolutions.

### Previous ELTR achievements

The ELTR regularly carries out thematic studies related to the different fields of LT. These studies minimize the potential biases, by assessing interactions between confounding factors and identification of independent predictors among all the ELTR variables that can have an impact on the outcome. A sample of these studies is cited in the references of the manuscript. With reports concerning LT for specific hepatic diseases [7–24], analysis of the impact of the type of preservation solution [25], and of the immunosuppressive regimen on the patient outcome [26], ELTR has helped develop risk models for mortality following liver-transplantation [27,28]. Owing to the large cohort of patients, the exhaustiveness, and quality of the data, and the long

follow-up provided by the ELTR, the results are really representative of LT in Europe.

The objective of this paper is to report these results and their evolution in adults as well as in pediatric recipients.

### Patients and methods

The whole data since 1968 was considered initially to show the evolution of results of LT in Europe since its initial development. The rest of analysis was then undertaken considering two different periods: (i) January 1988 to December 2016 (147 161 LT – 127 851 patients) [January 1988 was chosen corresponding to the introduction and widespread use of cyclosporine-based immunosuppression, and standardization of the surgical procedure], (ii) the last 15-year period data from January 2002 to December 2016 (99 562 LT – 91 183 patients) to give a more recent evaluation of LT results in Europe.

Data were generally analyzed as a whole (except for some variables), without making a distinction between adult and pediatric population, the latter representing 10% of LT in Europe.

**Table 1. Primary indication of LT in Europe and the corresponding graft and patient survival rate.**

Indication of LT	From 1988 to 2016										Last 15 years									
	N	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	20 years, %	N	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	
																				N
Acute hepatic failure	9485	7	0.1	Graft Patient	9268	66	58	52	45	37	6240	7	0.1	Graft Patient	6080	70	62	55	46	
Fulminant or Subfulminant hepatitis	7485	6	0.1	Graft Patient	7291	66	59	53	46	38	4606	5	0.1	Graft Patient	4466	71	64	57	50	
Virus A	163	2	0.1	Graft Patient	160	61	57	52	43	32	111	2	0.1	Graft Patient	109	65	61	61	61	
Virus B	917	12	1	Graft Patient	909	69	62	57	50	40	578	13	1	Graft Patient	571	74	67	64	52	
Virus C	127	2	0.1	Graft Patient	125	65	53	39	32	25	80	2	0.1	Graft Patient	78	68	50	35	61	
Virus D	14	0.2	0.01	Graft Patient	14	76	67	46	46	46	4	0.1	0.004	Graft Patient	4	100	100	67	67	
Other known	797	11	1	Graft Patient	776	68	61	56	49	40	565	12	1	Graft Patient	547	71	64	57	100	
Other unknown	3647	49	3	Graft Patient	3585	65	58	53	46	39	1966	43	2	Graft Patient	1922	71	65	59	50	
Paracetamol	743	10	1	Graft Patient	671	69	59	50	45	32	531	12	1	Graft Patient	477	74	64	53	43	
Other drug related: specify	715	10	1	Graft Patient	668	74	65	58	54	43	472	10	1	Graft Patient	476	78	70	63	59	
Toxic (hondrug)	362	5	0.3	Graft Patient	359	63	58	51	44	29	299	6	0.3	Graft Patient	297	63	58	48	48	
Traumatic acute hepatic failure	430	0.3	0.3	Graft Patient	430	48	39	35	31	31	346	0.4	0.4	Graft Patient	346	52	41	36	54	
Postoperative	173	40	0.1	Graft Patient	173	30	20	17	17	43	138	40	0.2	Graft Patient	138	33	21	17	44	
Post-traumatic	257	60	0.2	Graft Patient	257	61	52	48	45	45	208	60	0.2	Graft Patient	208	65	55	49	30	
Subacute hepatic failure	1570	1	1	Graft Patient	1570	65	57	54	54	54	1288	1	1	Graft Patient	1288	69	60	54	54	
Virus A	10	1	0.01	Graft Patient	10	67	50	50	50	50	8	1	0.01	Graft Patient	8	71	48	48	66	
Virus B	130	8	0.1	Graft Patient	127	80	65	54	20	49	113	9	0.1	Graft Patient	111	80	68	63	66	
Virus C	184	12	0.1	Graft Patient	184	75	56	32	18	28	161	13	0.2	Graft Patient	161	75	55	33	66	
Virus D	6	0.4	0.005	Graft Patient	6	67	67	67	67	67	4	0.3	0.004	Graft Patient	4	75	75	75	34	
Other known	62	4	0.05	Graft Patient	61	76	66	66	66	66	54	4	0.1	Graft Patient	53	80	68	68	50	
Other unknown	278	18	0.2	Graft Patient	267	77	71	64	64	64	207	16	0.2	Graft Patient	198	80	71	67	58	
Paracetamol	5	0.3	0.004	Graft Patient	5	67	67	67	65	53	4	0.3	0.004	Graft Patient	4	100	100	76	64	
Other drug related: specify	60	4	0.05	Graft Patient	56	62	55	49	41	41	51	4	0.1	Graft Patient	47	66	57	53	66	
Toxic (non drug)	24	2	0.02	Graft Patient	23	78	68	54	27	27	17	1	0.02	Graft Patient	16	87	80	80	25	
Other acute hepatic failure: specify	811	52	1	Graft Patient	808	65	54	46	40	29	669	52	1	Graft Patient	666	67	53	46	48	

**Table 1. Continued.**

Indication of LT	From 1988 to 2016					Last 15 years														
	N patients	% of the disease	Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	20 years, %	N patients	% of the disease	Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	
Fulminant or subfulminant or subacute hepatitis	11 625	9									7638	8								
Viral	1551	13	1	Graft Patient	1535	70	60	53	45	36	1054	14	1	Graft Patient	1046	73	63	57	46	
Virus B	1047	9	1	Graft Patient	1529	75	66	58	52	43	691	9	1	Graft Patient	1043	78	68	61	55	
Drug-related	1523	13	1	Graft Patient	1032	76	69	63	57	47	1058	14	1	Graft Patient	682	75	67	64	51	
Paracetamol	748	6	1	Graft Patient	1420	73	66	57	52	43	535	7	1	Graft Patient	989	73	65	55	50	
Other drugs	775	7	1	Graft Patient	676	69	59	50	45	32	523	7	1	Graft Patient	988	77	70	62	60	
Toxic (nondrug)	386	3	0.3	Graft Patient	748	68	61	49	44	35	316	4	0.3	Graft Patient	480	78	70	63	59	
Unknown or others	5595	48	4	Graft Patient	747	72	66	56	50	42	3461	45	4	Graft Patient	508	72	65	56	56	
				Graft Patient	382	64	59	51	44	29	8439	9	9	Graft Patient	508	76	70	61	61	
				Graft Patient	381	69	65	58	51	45	3382	45	4	Graft Patient	312	69	65	56	56	
				Graft Patient	5497	66	59	53	47	39	8242	84	74	Graft Patient	3386	71	63	57	46	
				Graft Patient	5488	72	66	61	55	48	8221	90	81	Graft Patient	3382	77	70	64	55	
				Graft Patient	12 917	82	73	62	50	38	8439	9	9	Graft Patient	8242	84	74	63	52	
				Graft Patient	12 883	87	79	71	59	46	4274	5	5	Graft Patient	8221	90	81	73	62	
				Graft Patient	955	72	62	54	47	39	693	8	1	Graft Patient	679	73	62	54	49	
				Graft Patient	955	79	69	62	56	48	3050	36	3	Graft Patient	679	80	69	63	58	
				Graft Patient	5698	83	76	66	54	41	4248	50	5	Graft Patient	2971	86	78	68	59	
				Graft Patient	5688	87	80	71	58	45	448	5	0.5	Graft Patient	2966	90	83	74	64	
				Graft Patient	5682	83	71	58	45	31	4172	85	73	Graft Patient	4172	85	73	59	46	
				Graft Patient	5663	89	80	71	60	46	448	5	0.5	Graft Patient	4160	91	82	74	60	
				Graft Patient	582	80	74	68	58	50	448	5	0.5	Graft Patient	420	79	71	66	62	
				Graft Patient	577	86	82	78	69	64	4274	5	5	Graft Patient	416	86	80	77	71	
				Graft Patient	6248	82	77	73	68	63	4274	5	5	Graft Patient	4180	85	81	77	68	
				Graft Patient	6234	88	85	83	80	76	207	5	0.2	Graft Patient	4174	91	88	87	85	
				Graft Patient	257	81	74	66	57	52	207	5	0.2	Graft Patient	206	82	74	62	78	
				Graft Patient	257	89	84	80	70	66	3403	80	4	Graft Patient	206	90	86	78	78	
				Graft Patient	5107	82	77	74	70	64	3403	80	4	Graft Patient	3326	86	82	78	74	
				Graft Patient	5095	89	85	83	81	78	138	3	0.2	Graft Patient	3322	92	89	88	86	
				Graft Patient	192	80	77	67	63	61	21	0.5	Graft Patient	136	83	78	66	66		
				Graft Patient	192	88	85	75	71	69	21	0.5	Graft Patient	136	90	88	75	75		
				Graft Patient	41	87	80	54	36	21	21	0.02	Graft Patient	21	79	63	42	42		
				Graft Patient	41	87	87	76	76	69	261	6	0.3	Graft Patient	21	79	79	59	75	
				Graft Patient	335	82	77	74	69	69	261	6	0.3	Graft Patient	258	85	81	79	75	
				Graft Patient	335	88	84	80	77	72	244	6	0.3	Graft Patient	258	90	87	85	80	
				Graft Patient	316	83	75	68	54	44	244	6	0.3	Graft Patient	233	83	75	70	21	
				Graft Patient	314	88	81	78	68	62	231	89	83	Graft Patient	231	89	83	82	75	
				Graft Patient	63 140	80	67	55	43	32	45 566	50	50	Graft Patient	44 806	82	68	55	42	
				Graft Patient	63 062	84	71	59	47	36	18 135	40	20	Graft Patient	44 758	85	72	59	46	
				Graft Patient	24 030	82	70	55	41	29	18 135	40	20	Graft Patient	17 849	83	71	55	40	
				Graft Patient	24 005	85	74	58	43	31	2027	4	2	Graft Patient	17 830	86	75	59	43	
				Graft Patient	2850	81	71	60	48	38	3826	8	4	Graft Patient	1978	83	74	63	45	
				Graft Patient	2843	86	77	68	57	48	3826	8	4	Graft Patient	1974	88	80	72	57	
				Graft Patient	5746	80	70	64	56	48	3826	8	4	Graft Patient	3774	82	72	66	57	
				Graft Patient	5739	84	74	68	61	52	3770	86	76	Graft Patient	3770	86	76	70	62	

**Table 1. Continued.**

Indication of LT	From 1988 to 2016						Last 15 years									
	N patients	% of the disease	% of the Total	Survival rate	N	% of the disease	% of the Total	Survival rate	N patients	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %
Virus C related cirrhosis	15 187	24	12	Graft 15 062 Patient 15 051	77	60	47	37	26	41	30	Graft 10 396 Patient 10 387	78	59	46	36
Virus BD related cirrhosis	1939	3	2	Graft 1899 Patient 1895	89	84	79	74	67	81	73	Graft 1403 Patient 1401	89	64	51	40
Virus BC related cirrhosis	829	1	1	Graft 819 Patient 818	78	64	54	42	31	84	73	Graft 552 Patient 551	80	89	83	78
Virus BCD related cirrhosis	174	0.3	0.1	Graft 170 Patient 170	88	78	62	47	47	60	47	Graft 130 Patient 130	88	78	67	39
Virus related cirrhosis-Other viruses: specify	1994	3	2	Graft 1780 Patient 1766	90	80	67	45	45	64	49	Graft 1208 Patient 1203	89	81	69	39
Combined virus C and alcoholic cirrhosis	1996	3	2	Graft 1980 Patient 1980	82	65	50	36	24	55	41	Graft 1515 Patient 1516	83	66	51	38
Combined virus B and alcoholic cirrhosis	489	1	0.4	Graft 485 Patient 484	87	74	61	53	53	61	64	Graft 379 Patient 379	88	77	68	44
Posthepatic cirrhosis-Drug related	77	0.1	0.1	Graft 77 Patient 77	78	63	46	33	33	46	33	Graft 44 Patient 44	84	65	48	45
Other cirrhosis: specify	2732	4	2	Graft 2728 Patient 2727	79	64	55	47	38	55	47	Graft 1837 Patient 1836	78	66	55	48
Cryptogenic (unknown) cirrhosis	5618	9	4	Graft 5514 Patient 5507	78	67	56	46	34	56	46	Graft 3741 Patient 3737	83	69	57	45
Primary liver tumors	21 135	87	17	Graft 20 976 Patient 20 971	81	60	47	36	28	50	39	Graft 17 206 Patient 17 202	83	64	49	37
Hepatocellular carcinoma and cirrhosis	18 349	87	14	Graft 18 225 Patient 18 220	82	62	48	36	28	48	36	Graft 15 510 Patient 15 506	84	65	49	40
Hepatocellular carcinoma and noncirrhotic liver carcinoma – Fibrolamellar Biliary tract	734	3	1	Graft 726 Patient 726	77	49	34	24	18	51	39	Graft 423 Patient 423	81	61	44	24
Hepatocellular carcinoma – Fibrolamellar Biliary tract	51	0.2	0.04	Graft 51 Patient 51	76	38	33	27	27	33	27	Graft 26 Patient 26	85	45	47	45
Hepatocellular carcinoma (Klatskin)	395	2	0.3	Graft 394 Patient 394	65	34	26	16	13	41	21	Graft 244 Patient 244	67	35	25	25
Hepatic cholangiocellular carcinoma	530	3	0.4	Graft 526 Patient 526	66	32	23	16	14	35	24	Graft 306 Patient 306	76	47	41	17
Hepatoblastoma	377	2	0.3	Graft 372 Patient 372	83	75	71	70	61	23	16	Graft 325 Patient 325	84	77	73	73
Epithelioid hemangioendothelioma	216	1	0.2	Graft 213 Patient 213	85	72	67	61	58	77	71	Graft 158 Patient 158	85	73	65	60
Angiosarcoma	17	0.1	0.01	Graft 17 Patient 17	35	38	33	27	20	67	60	Graft 3 Patient 3	67	79	71	65
Other liver malignancies: specify	466	2	0.4	Graft 452 Patient 452	70	46	40	33	28	77	71	Graft 211 Patient 211	82	62	57	45
Secondary liver tumors	639	3	0.5	Graft 636 Patient 636	75	48	32	24	19	44	36	Graft 393 Patient 393	79	57	44	33
Carcinoid	341	53	0.3	Graft 339 Patient 339	78	52	34	24	19	34	26	Graft 183 Patient 183	83	64	51	38
					82	55	36	27	22	36	27	Graft 183 Patient 183	87	67	54	41



**Table 1. Continued.**

Indication of LT	From 1988 to 2016										Last 15 years									
	N patients	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	20 years, %	N patients	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	
Other neuroendocrine	188	29	0.1	Graft	188	74	51	40	34		140	35	0.2	Graft	140	76	56	44	36	
				Patient	188	80	56	43	35					Patient	140	83	61	45	37	
Colorectal	73	11	0.1	Graft	72	73	24	3			53	13	0.1	Graft	53	81	24			
				Patient	72	80	26	3						Patient	53	85	29			
GI noncolorectal	18	3	0.01	Graft	18	60	35	20	10		8	2	0.01	Graft	8	45	23	23	23	
				Patient	18	60	35	20	10					Patient	8	45	23	23	23	
Nongastrointestinal	19	3	0.01	Graft	19	61	41	20			9	2	0.01	Graft	9	76	57			
				Patient	19	72	50	27						Patient	9	100	80			
Metabolic disease	7414		6	Graft	7188	82	73	64	55	48	5336		6	Graft	5166	83	74	63	52	
				Patient	7163	87	79	71	63	56				Patient	5147	88	80	71	60	
Wilson disease	1241	17	1	Graft	1200	83	78	71	64	56	904	17	1	Graft	879	85	79	72	65	
				Patient	1191	89	86	81	76	69				Patient	875	92	87	82	77	
Hemochromatosis	622	8	0.5	Graft	610	74	63	48	36	28	399	7	0.4	Graft	390	77	65	47	40	
				Patient	609	77	66	51	38	29				Patient	389	80	69	50	41	
Alpha-1 – Antitrypsin deficiency	717	10	1	Graft	678	83	75	66	58	44	478	9	1	Graft	457	84	76	68	54	
				Patient	678	87	81	72	65	56				Patient	457	88	81	73	61	
Glycogen storage disease	145	2	0.1	Graft	142	87	84	77	68	68	118	2	0.1	Graft	115	88	83	69	61	
				Patient	142	94	92	86	76	76				Patient	115	95	92	81	81	
Homozygous Hypercholesterolemia	36	0.5	0.03	Graft	36	86	81	65	65	65	29	1	0.03	Graft	29	85	80			
				Patient	36	86	81	65	65	65				Patient	29	85	80			
Tyrosinemia	122	2	0.1	Graft	119	85	75	73	71	65	65	1	0.1	Graft	62	87	84	84	84	
				Patient	118	91	86	84	84	84				Patient	62	90	87	87	87	
Familial amyloidotic polyneuropathy	1261	17	1	Graft	1241	82	73	62	50	38	866	16	1	Graft	847	83	73	62	50	
				Patient	1231	88	79	68	56	46				Patient	837	90	81	69	50	
Primary hyperoxaluria	332	4	0.3	Graft	326	79	72	62	53	50	264	5	0.3	Graft	258	78	73	61	33	
				Patient	326	84	77	68	58	58				Patient	258	84	79	67	25	
Protoporphyrin	19	0.3	0.01	Graft	19	77	77	70	61	51	8	0.1	0.01	Graft	8	69	69			
				Patient	19	77	77	70	61	51				Patient	8	69	69			
Other porphyria	17	0.2	0.01	Graft	17	81	65	65	65	65	13	0.2	0.01	Graft	13	83	83			
				Patient	17	87	65	65	65	65				Patient	13	91	82			
Nonalcoholic steatohepatitis (NASH)	749	10	1	Graft	706	83	72	51			748	14	1	Graft	705	83	72	52		
				Patient	705	86	75	54						Patient	704	86	75	55		
Crigler-Najjar	93	1	0.1	Graft	88	86	74	72	72	72	65	1	0.1	Graft	60	84	70	66		
				Patient	88	94	89	89	89	89				Patient	60	95	91	91		
Cystic fibrosis	277	4	0.2	Graft	272	83	68	63	57	46	233	4	0.3	Graft	228	86	73	68		
				Patient	271	85	74	64	57	45				Patient	227	88	76	70		
Byler disease	251	3	0.2	Graft	250	85	81	78	71	71	137	3	0.2	Graft	136	88	82	74	59	
				Patient	250	94	92	89	85	85				Patient	136	94	92	90	79	
Other metabolic disease	1532	21	1	Graft	1484	81	71	63	55	49	1009	19	1	Graft	979	83	72	63	54	
				Patient	1482	86	77	71	63	57				Patient	977	88	79	72	65	
Budd Chiari	1069		1	Graft	1052	73	65	57	49	39	715		1	Graft	704	77	67	58	49	
				Patient	1051	79	72	65	57	49			0	Patient	704	82	74	65	57	
Benign liver tumors or Polycystic disease	1824		1	Graft	1804	85	80	70	60	52	1516		2	Graft	1499	87	81	71	60	
				Patient	1804	88	84	75	65	56				Patient	1499	90	86	76	64	
Hepatic adenoid	38	2	0.03	Graft	38	65	47	40	40	40	30	2	0.03	Graft	30	70	44	44		
				Patient	38	71	55	55	55	55				Patient	30	73	52	52		
Adenomatosis	51	3	0.04	Graft	49	81	81	81	81	81	45	3	0.05	Graft	43	81	81	81		
				Patient	49	87	87	87	87	87				Patient	43	88	88	88		
Hemangioma	71	4	0.1	Graft	71	75	69	64	64	64	45	3	0.05	Graft	45	73	64	64	64	
				Patient	71	80	77	71	71	71				Patient	45	75	69	69	69	

**Table 1. Continued.**

Indication of LT	From 1988 to 2016										Last 15 years									
	N patients	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	20 years, %	N patients	% of the disease	% of the Total	Survival rate	N	1 year, %	5 years, %	10 years, %	15 years, %	
Focal nodular hyperplasia	12	1	0.01	Graft	12	75	64	21			10	1	0.01	Graft	10	80	80	27		
Polycystic disease	1493	82	1	Graft	1478	87	82	32	62	52	1293	85	1	Graft	1280	88	83	73	61	
Nodular regenerative hyperplasia	25	1	0.02	Patient	25	88	71	36	36	36	17	1	0.02	Patient	17	100	83	83	65	
Other benign tumors: specify	134	7	0.1	Graft	131	79	71	60	49	44	76	5	0.1	Graft	74	82	73	56	56	
Parasitic disease	101		0.1	Graft	101	77	69	58	40	20	71		0.1	Graft	71	81	70	70	62	
Schistosomia (Bilharzia)	2	2	0.002	Patient	2	50	50	50	50	27	1	1	0.001	Patient	1	84	73	73		
Alveolar echinococcosis	58	57	0.05	Graft	58	88	80	66	66	66	49	69	0.1	Graft	49	90	78	78		
Cystic hydatidosis	11	11	0.01	Patient	11	72	57	29	29	29	8	11	0.01	Patient	8	74	49	80		
Other parasitic disease: specify	30	30	0.02	Patient	30	60	56	44	22	22	13	18	0.01	Patient	13	60	60	60		
Other liver disease	2380		2	Graft	2325	73	64	56	50	42	1302		1	Graft	1264	75	67	59	43	
TPN-induced cholestasis	11	0.5	0.01	Patient	11	71	54	61	55	47	10	1	0.01	Patient	10	68	46	49		
Hepatopulmonary syndrome	19	1	0.01	Graft	18	78	78	78			19	1	0.02	Graft	18	78	78	78		
Other liver diseases, nonspecified	2350	99	2	Patient	2296	73	64	56	50	42	1273	98	1	Graft	1233	75	67	59	43	
<b>Total</b>	<b>127 851</b>		<b>100</b>		<b>2289</b>	<b>77</b>	<b>69</b>	<b>61</b>	<b>55</b>	<b>47</b>	<b>91 183</b>		<b>100</b>		<b>1232</b>	<b>80</b>	<b>72</b>	<b>64</b>	<b>49</b>	

Kaplan–Meier analysis was used to estimate graft and patient survival stratified by conditions group; statistical analyzes were performed using the log-rank test ( $P < 0.05$  as significant) with SAS® Version 9.1.3 Enterprise Guide version 5.1 (Copyright© 2012 by SAS Institute Inc., Cary, NC, USA). The dynamics of data control was continued during the statistical analyzes. Calculation of survival rates was determined by the actuarial method.

### Results

From May 1968 to December 2016, the ELTR has collected data concerning 146 782 LTs in 132 466 patients, from 169 Centers, and 32 countries (Fig. 1). These data give a comprehensive overview of the status and evolution of LT in Europe. Both the number of transplant centers and the annual number of LT's performed in Europe have gradually increased since the ELTR was created (Fig. 2). However, after an exponential increase from the eighties, a plateau seems to have been reached in recent years with about 7300 LTs performed all over Europe annually.

### Main indications of LT in Europe

The main indications for LT in Europe with the corresponding graft and patient survival rates at 1, 5, 10, and 15 years in the whole ELTR population and in the last 15 years cohort are listed in Table 1. Twenty-year survival is provided for the whole ELTR population. Cirrhosis was the most frequent indication (50%), mainly related to either viral infection (22% with 12% of hepatitis C virus (HCV) infection and 5% of hepatitis B virus (HBV) infection), or to alcohol abuse (19%). Combined viral and alcoholic (ALD) cirrhosis represented 2.4% of indications, with 2% of HCV-ALD. Cirrhosis is followed by three major indications: primary liver tumors (17%, predominantly hepatocellular carcinoma – HCC, 15%), cholestatic liver diseases (10%), and acute hepatic failure (9.1%, 2% of which are virus-related, 2.4% drug related, 0.3% toxic nondrug related and 4.4% of unknown cause). The most common etiologies of the underlying cirrhosis in HCC patients were HCV (43%), ethanol abuse (27%), and HBV (16%). Cholestatic diseases included primary biliary cirrhosis (5%) and primary sclerosing cholangitis (5%). Biliary atresia (4%)

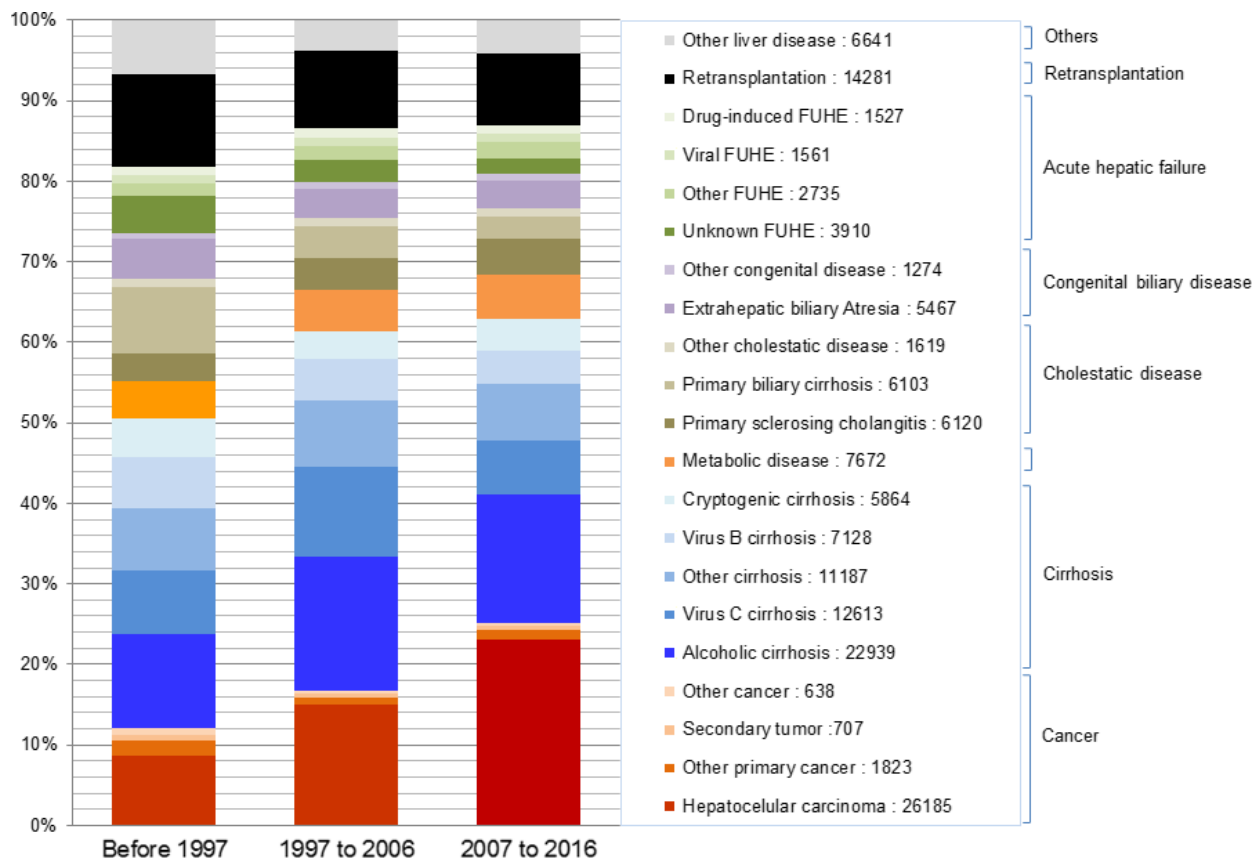


Figure 3 Evolution of indication according to three eras.

represented the major congenital biliary disease. Metabolic diseases represented 6% of all the indications with three major indications being familial amyloidotic polyneuropathy, Wilson disease, and alpha-1-antitrypsin deficiency (1% each). Budd-Chiari and benign liver tumors (mainly polycystic disease) represented only 1% of the indications for LT. Secondary liver tumors (mainly neuroendocrine) represented 0.5% of LT's.

*Indications for Pediatric liver transplants*

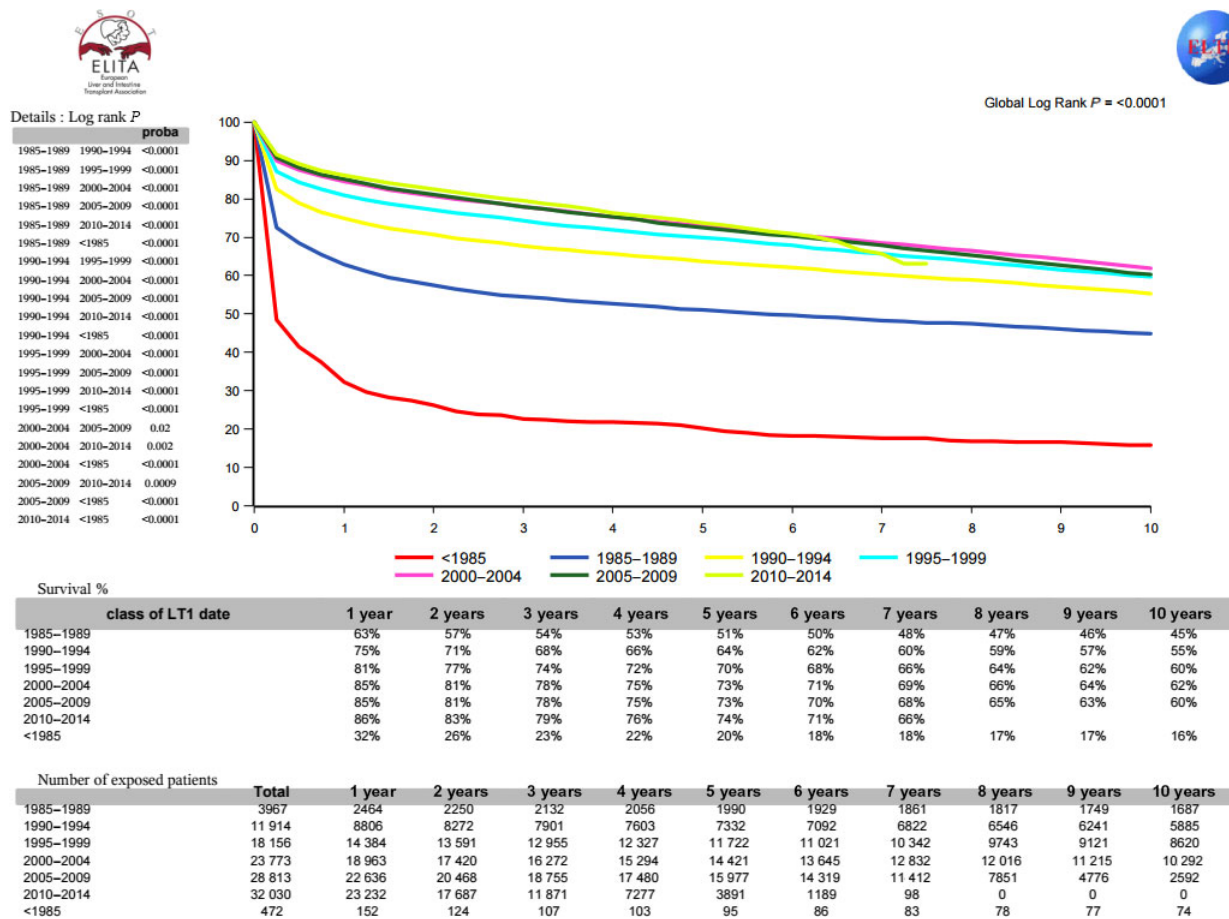
The proportions of the main indications for LT are differently distributed according to the age of recipients. While biliary atresia and metabolic diseases were the major indications in pediatric patients (≤18 years), cirrhosis with end stage liver disease, and cancer were the major indications in adults. An exponential increase in the proportion of cancer cases was noted with recipient age. Acute liver failure (ALF) mostly of unknown cause was frequent in young patients, with the highest incidence at 18–24 years.

**Evolution of indications**

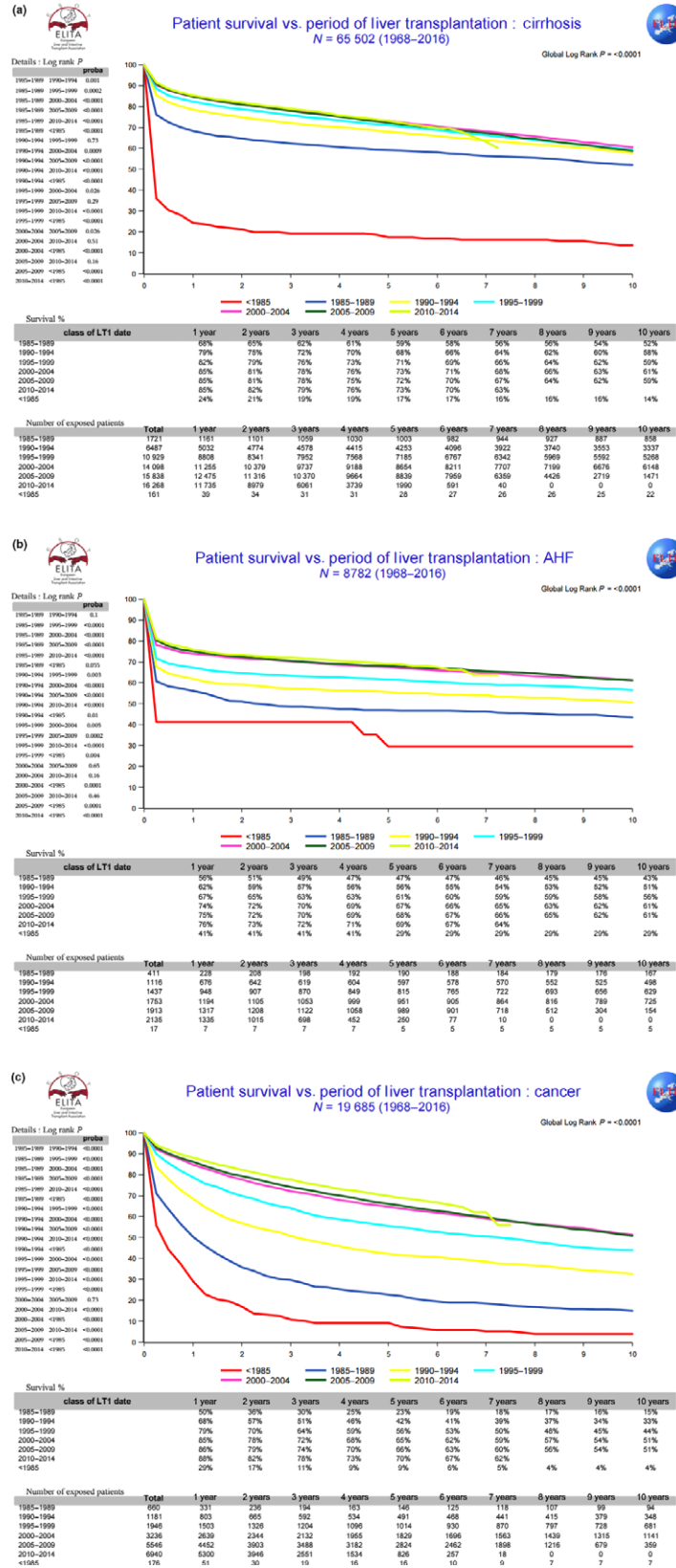
The percentage of main indications has significantly changed with time (Fig. 3). Whereas cancers represented 12% of indications before 1997, their incidence has doubled in the last decade to represent currently more than 24%. Metabolic diseases and primary sclerosing cholangitis have slightly increased during the last decade. Conversely, while comparing the last decade with the previous one, we found that the proportion of cirrhosis alone, ALF and primary biliary cholangitis decreased. The decrease in cirrhosis is mainly because of the decrease in HCV cirrhosis, and the reduction in ALF cases is mainly because of the decline of ALF of unknown origin.

**Survival according to the indication for LT**

When all indications were considered, during the entire study period, patient survival rates were 83% at 1 year, 71% at 5 years, 61% at 10 years, 51% at 15 years, and



**Figure 4** Patient survival versus period of liver transplantation, n = 119 125 (1968–2016).



**Figure 5** Patient survival versus period of liver transplantation: (a) Cirrhosis,  $n = 65\,502$  (1968–2016), (b) AHF,  $n = 8782$  (1968–2016). (c) Cancer,  $n = 19\,685$  (1968–2016).

41% at 20 years. After an improvement between 1985 and 2000, the survival of patients appears to be relatively steady since 2000 (Fig. 4).

The improvement in survival was seen in patients transplanted for all the three main indications; cirrhosis (Fig. 5a), fulminant hepatitis (Fig. 5c) but was particularly regular in LT for cancers (Fig. 5c). The 5-year patient survival rate was significantly better for cirrhosis (71%) than for primary liver tumors (64%,  $P < 0.001$ ) and acute hepatic failure (65%,  $P < 0.001$ ). HBV and HCV co-infection had a better 5-year survival (80%) compared with mono-infection with HCV (64%) or HBV (74%). The better 5-year survival rates obtained in metabolic diseases (79%), cholestatic disease (79%), and congenital biliary disease (85%), are partly explained by the high percentage of children in these groups. The survival rates in adults and children were, respectively, 76% and 85% for metabolic diseases, 79% and 86% for cholestatic disease, and 82% and 85% for congenital biliary disease. The details of survival rates at 1, 5 and 10, 15 and 20 years according to the primary indication are listed in Table 1.

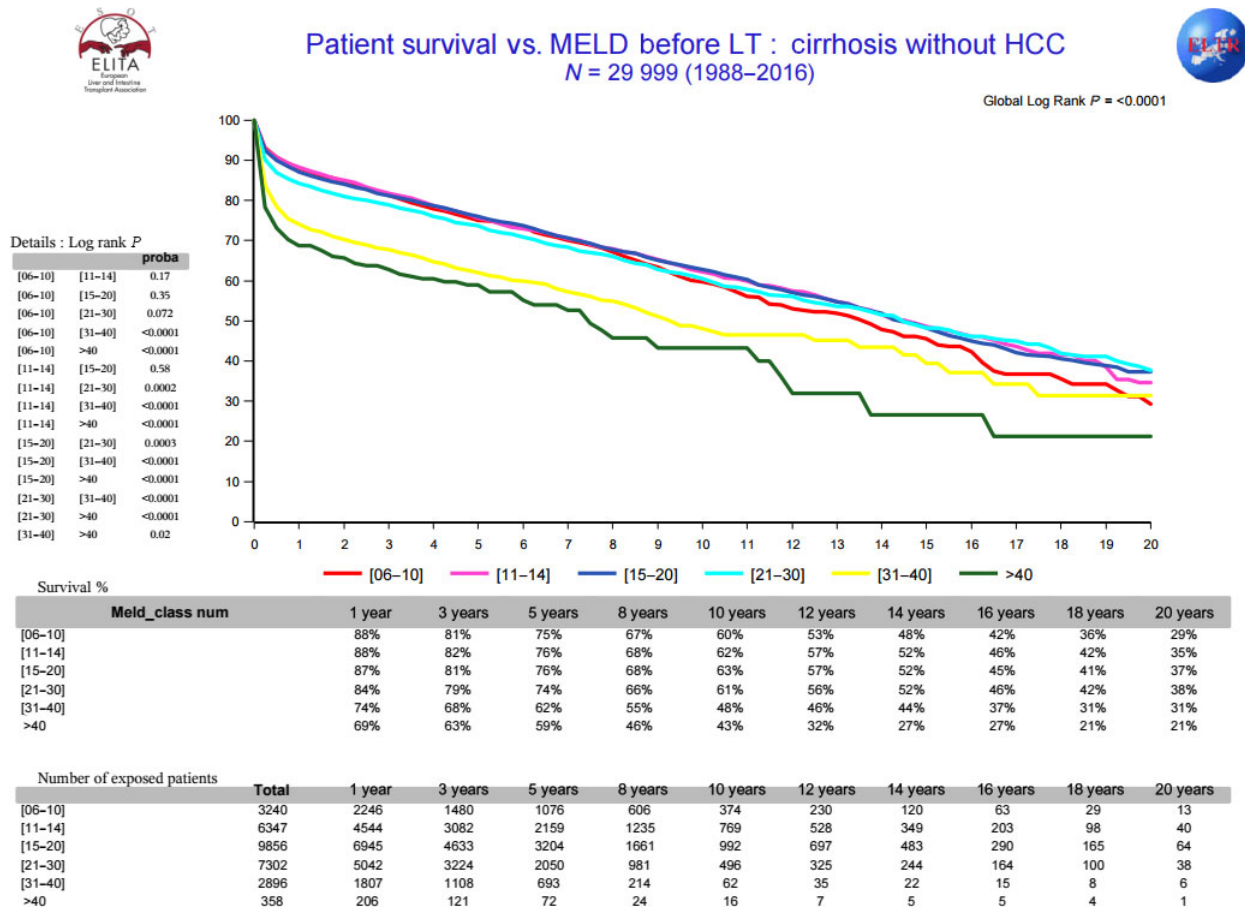
Although the 5-year survival improved in the 15 recent years for all the indications, the most important gain in survival was observed in LT for primary liver tumors (67%), liver metastases (61%), and acute liver failure (69%).

Since the adoption of the transplantation Model for End-stage Liver Disease (MELD) score in the majority of European countries in 2006–2007, the proportion of patients with a high MELD score (>30) at transplant has almost doubled. However, the survival of these patients is less optimal, especially for those with a MELD score at transplant higher than 40 (Fig. 6).

### Survival according to donor and recipient characteristics

#### Donor characteristics

The majority of donors were male (57%). Fifty-eight percent were younger than 50 years, whereas 23% were older than 60 years. A gradual increase in the percentage of livers coming from septuagenarian donors was

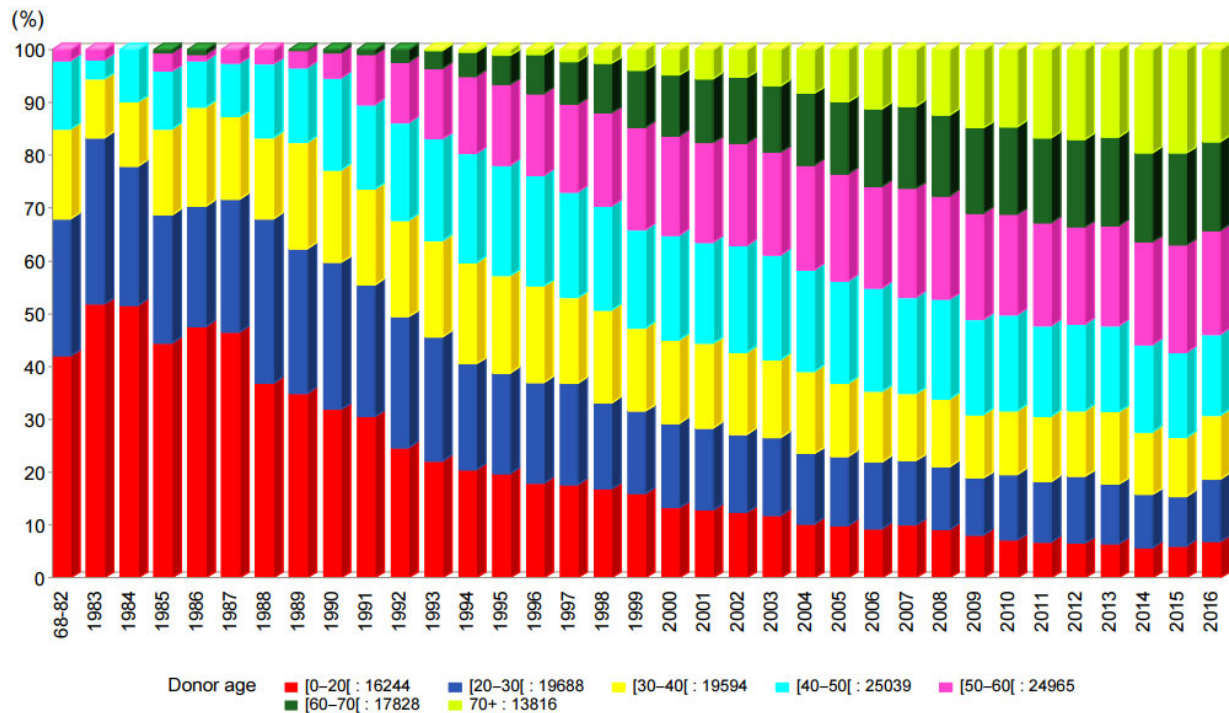


**Figure 6** Patient survival versus MELD before LT: cirrhosis without HCC,  $N = 29\,999$  (1988–2016).



## Evolution of donor age

N = 137 174



**Figure 7** Evolution of donor age, N = 137 174.

observed (1% in 1993, 10% in 2005 and 20% in 2015) in relation to the increasing gap between a growing waiting list and a relatively stable donor pool (Fig. 7). Graft survival when organs were procured from donors younger than 55 years was significantly better than that with organs from donors older than 65 years (67% vs. 60% at 5 years,  $P < 0.0001$ ) (Fig. 8). However, attention should be paid to the donor to recipient matching to interpret these results, older donor livers being more frequently transplanted to older recipients.

### Recipient age

In addition to the better 5-year survival of pediatric versus adult LT recipients (90% vs. 81%,  $P < 0.0001$ ), an influence of age was noted for adult recipients. Survival rates were 75% for adults aged 18–45 years, 71% for 46–60 years, 65% for 60–70 years, and 60% for septuagenarians. However, average age of transplanted recipients has increased steadily during the last decade, and patients older than 60 years, who represented <5% in

the 1980s, currently represent more than 30% of transplant recipients (Fig. 9). Older grafts are more frequently transplanted to older recipients. Septuagenarian recipients received 43% grafts older than 60-years and only 12% of grafts younger than 30-years, explaining at least in part, the difference in survival between recipient age groups (Fig. 10). Importantly, LT offered a 10-year survival up to 40% in septuagenarians.

### Blood group compatible and incompatible transplants

In elective conditions, 93% of LTs were isogroup, and 6.5% were compatible, whereas in emergency, 3% of LT were incompatible. In both elective and emergency conditions, isogroup LTs had a better 5-year survival compared with compatible or incompatible LTs (66% vs. 62% vs. 57%,  $P < 0.0001$ ) and (56% vs. 53% vs. 28%,  $P = 0.001$ ) respectively. However, the use of these incompatible grafts in emergency indications allows a 38% survival rate at 1 year in patients otherwise expected to have a fatal outcome.

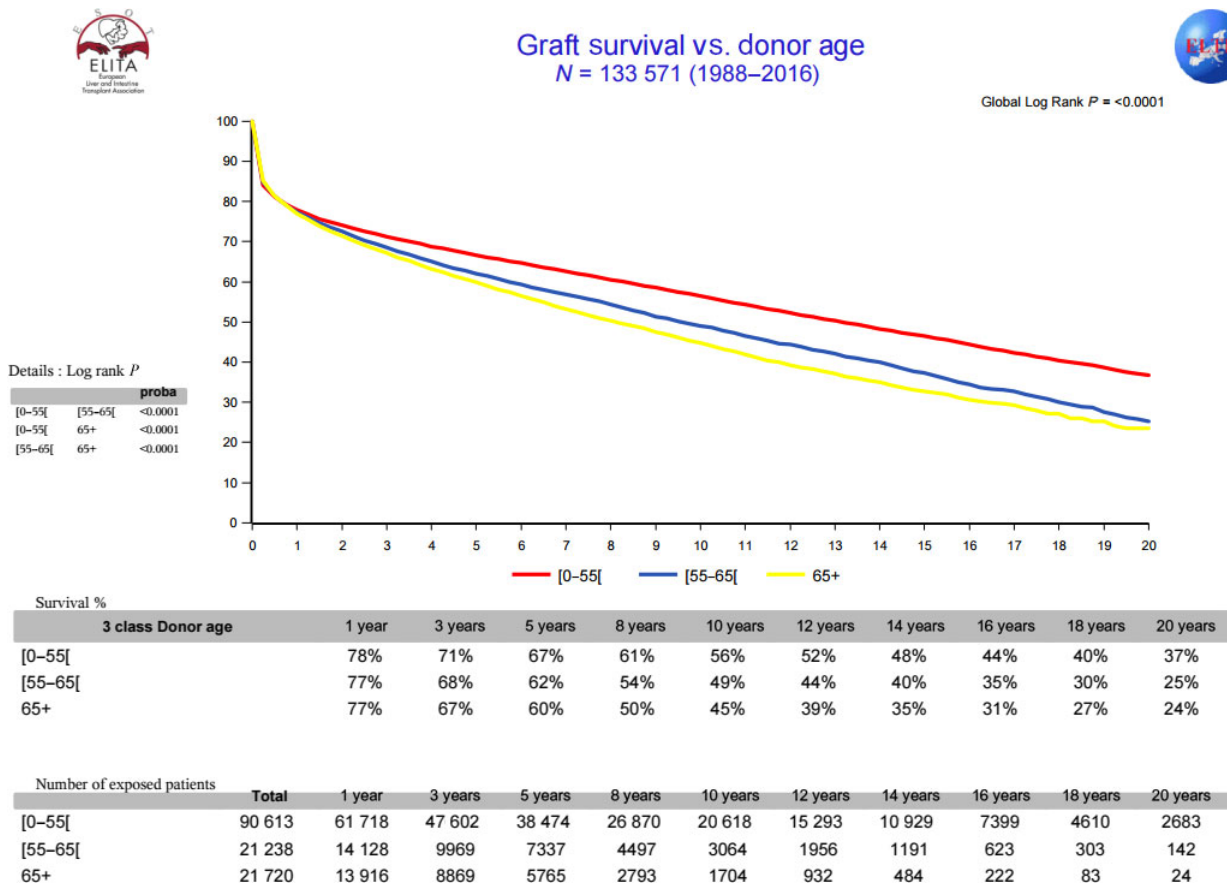


Figure 8 Graft survival versus donor age,  $n = 133\,571$  (1988–2016).

### Survival according to surgical technique

Auxiliary grafts represented 0.5% of overall LTs with a similar graft survival as compared with nonauxiliary grafts in urgent (5-year survival rates: 57% vs. 56%), and elective (66% vs. 69%) indications. The shorter the ischemia time; the better was the graft survival. Five-year survival was 70% for ischemia time  $<6$  h, 67% for 6–12 h, 63% for 12–15 h, and 58% for  $>15$  h. The use of static graft preservation solutions evolved during three distinct periods: period 1 before 1990 with the main use of Collins solution; period 2 between 1990 and 2000 with the almost exclusive use of UW (University of Wisconsin); period 3 after 2000 with an increasing use of new solutions with different characteristics such as HTK, Celsior, IGL 1 or SCOT (Fig. 11). Overall graft survival at 5 years for the main solutions was 74% for Celsior and IGL 1, 72% for UW and 69% for HTK (Fig. 12). If only partial livers were considered, survival was 83% for IGL 1, 79% for Celsior, 77% for UW, and 71% for HTK.

Alternative procedures to LT using full size livers from donors after brain death (DBD) have been increasingly used in recent years. While representing  $<10\%$  before

2000 they concerned more than 20% of overall LT procedures after 2000 and 75% in pediatrics. A differentiation between adult and pediatric patients is necessary; because alternative techniques are used differently in each population and the patient's outcome may differ.

#### Adult population

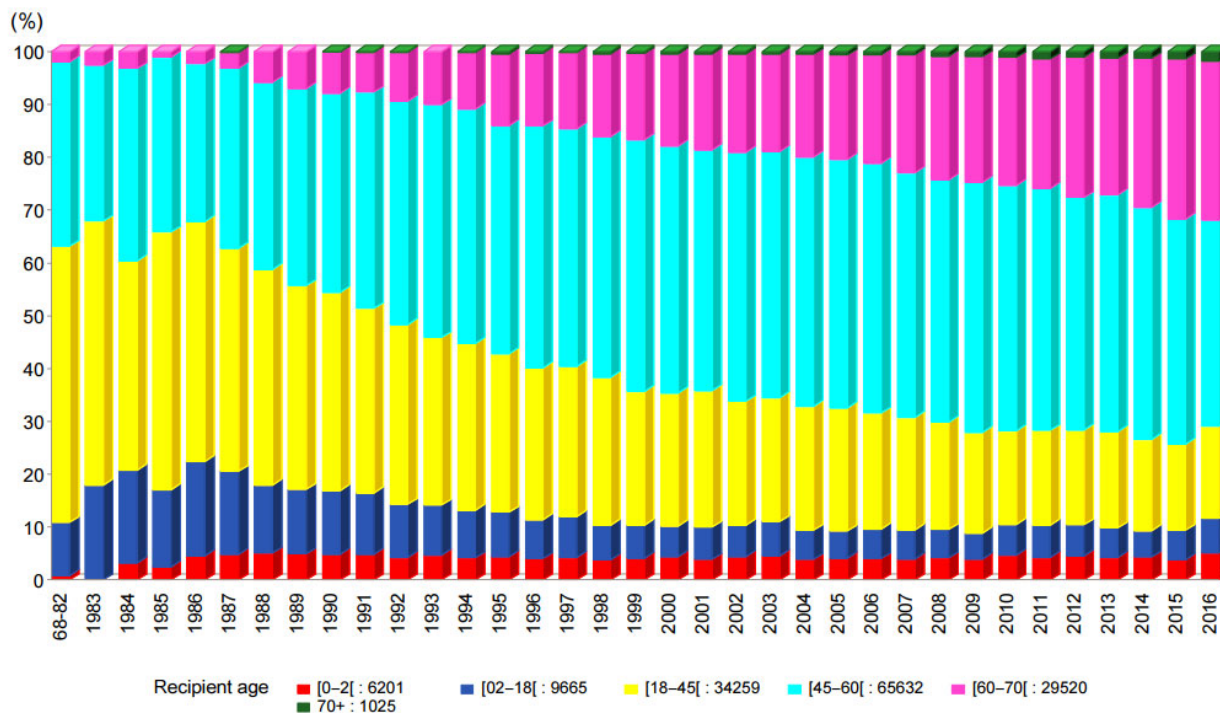
Before 1994, alternative procedures concerned mainly reduced and split livers. Domino grafts were introduced in 1994 and living donation in 1996. Donation after cardiac death (DCD) was introduced in 2001 and since then, has gradually increased to represent currently almost 40% of the alternative procedures in adults. Consequently, the proportion of split, living, reduced, and domino grafts has decreased. The latter two modalities are really associated with the more significant decrease (Fig. 13a). Ten-year graft survivals for each type of graft are summarized in Fig. 13b. Survival at 5 years was similar between DBD full size grafts, split liver, domino, and DCD (66% to 67%), but higher than that of reduced grafts and living donors (63% in both).





## Evolution of recipient age

N = 146 302



**Figure 9** Evolution of recipient age, N = 146 302.

### Pediatric population

Before 1988, alternative procedures concerned mainly reduced livers. Split livers were introduced in 1988 and living donation in 1991 and since their introduction both have gradually increased to represent currently more than 90% of the alternative procedures in children (Fig. 14a). Ten-year graft survivals for each type of graft are summarized in Fig. 14b. Survival at 5 years was similar between DCD and living donors (80% and 78%, respectively), but higher than that of DBD full size grafts, split liver, and reduced grafts (74%, 71%, and 65% respectively). Domino transplant is rarely used in pediatric patients.

### Mortality after LT

While 1 year patient survival was 81% between 1995 and 1999, it has dramatically improved to reach 86%

after 2010 (Fig. 4). The critical period for post-LT outcome is represented by the first year: 46% of deaths and 67% of re-LT occur within the first year after LT (Fig. 15). In 44% of cases, re-LT is indicated in the month after primary LT, and more than a half (59%) of patients who die, do so within the 6 months after LT.

Data represented in Fig. 16 correspond to the distribution of main causes of death according to the time of their incidence. Main causes of death in the 28 637 patients who died after primary LT or Re-LT were differently distributed. Whereas death from primary graft nonfunction or dysfunction, infections, and technical (biliary or vascular) complications were more frequent within the first 6 months post-LT, tumor or nontumor recurrence and tumor *de novo* were more frequent after the first month. Interestingly, the proportion of tumor and nontumor recurrences as a cause of death is decreasing during the last years.



Patient survival vs. recipient age : adults  
N = 114 487 (1988–2016)



Global Log Rank P = <0.0001

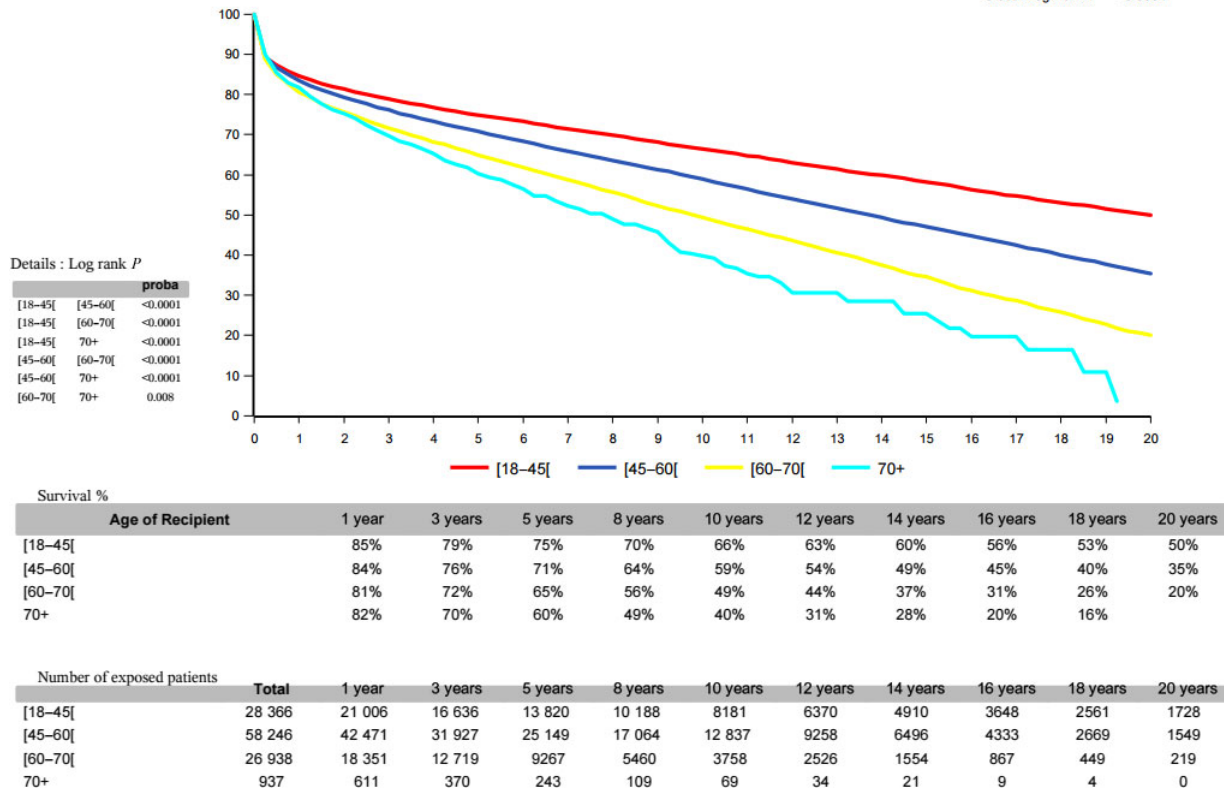


Figure 10 Patient survival versus recipient age: adults N = 114 487 (1988–2016).

Re-transplantation

Five-year graft survival rates following a second and a third LTs were 48% and 42%, respectively, significantly lower than those for primary LT (66% – P < 0.0001) (Fig. 17).

Re-LT was indicated in 8482 cases mainly for primary nonfunction, technical complications (biliary or vascular), and rejection within the first month post-LT. Tumor or nontumor recurrences and *de novo* tumor were more frequent after the first month (Fig. 18). Late re-LT, more than 1 month after the first LT, has a significantly better graft survival than early re-LT performed within the month after the first LT (50% vs. 45% at 5 years, P < 0.0001) (Fig. 19). Re-LT which is mostly used in young patients (Fig. 3a) has declined during the last decade (Fig. 3b). Interestingly, tumor causes and nontumor recurrence are decreasing during the last years, whereas technical complications, primary graft nonfunction or dysfunction and infection are increasing.

Waiting time

When more than 90% of candidates waited <3 months in the 1980s, they represented 70% in the 1990s and slightly more than a half since 2000. This evolution is likely because of three main reasons: the increase in the number of candidates for transplantation following the advent of more and more effective immunosuppressive treatments, the scarcity of grafts and the use of the MELD which gives priority to the sickest candidates. The 5-year survival of patients who have spent <3 months on the waiting list, certainly because they were more severe, was 70%, 5% lower than that of all the other groups of waiting times in the list (P < 0.0001).

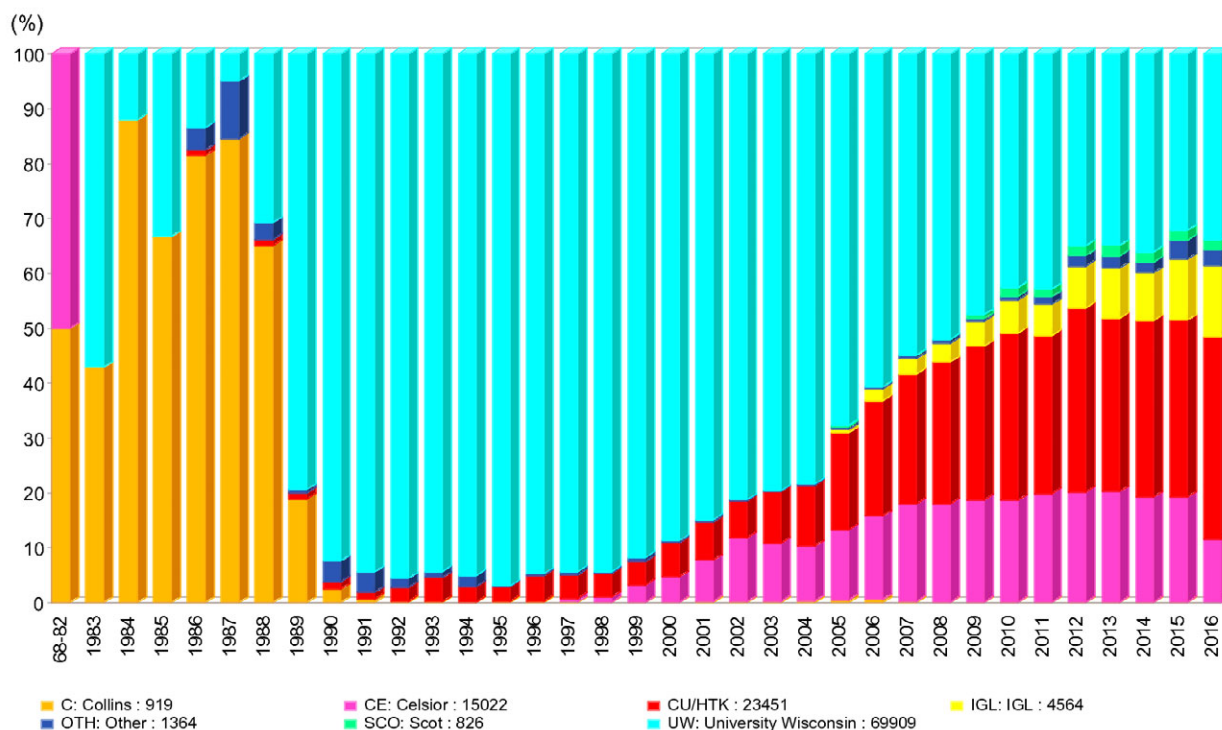
Discussion

The ELTR data provide a descriptive overview of the overall situation of LT in Europe. There is of course heterogeneity in the policies in the 29 contributing countries. This manuscript summarizes the results as



## Evolution of preservation liquid used in liver transplantation in Europe

$N = 116\ 055$  overall population



**Figure 11** Evolution of preservation liquid used in liver transplantation in Europe,  $n = 116\ 055$  overall population.

a whole, and represents a kind of freeze-frame rather than a generalized statement for Europe. At the same time, the ELTR remains the unique entity capable of providing such statistics, capable of giving a global snapshot of the European experience, and helping to identify important trends that may guide further practice.

Liver transplantation has become the best, if not the only effective treatment for severe irreversible liver disease. More than 7000 LTs are performed annually in Europe, and the results look satisfactory at 5 years (71% survival) with still a room for improvement at long-term (61% at 10 years and 41% at 20 years). The demand far exceeds the availability of organs for transplantation. It is therefore essential to continue to promote organ donation in Europe in order to avoid mortality on the waiting list, and a “drastic” selection of candidates. By allowing the transplant of the sickest candidates first, the MELD score has dramatically decreased the risk of death on the waiting list. However, the post-LT survival of high MELD

score patients is less optimal, mostly for those with MELD score at transplant higher than 40. It also appears essential to continue to improve the perioperative management of LT at all levels, along with a better prevention of long-term complications. The data provided by the ELTR are a basis to target the timing, and fields to improve the results.

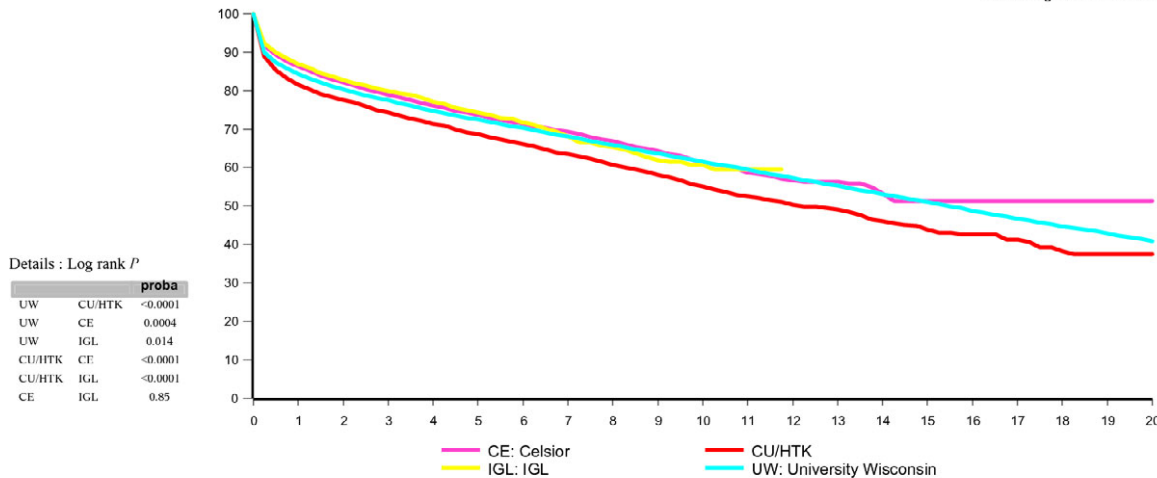
The main indication for LT is cirrhosis with end stage liver disease. However, its proportion is decreasing continuously as compared with HCC. Fulminant hepatitis of unknown cause is also declining. Such relative diminution of cirrhosis is mainly related to the accelerated decline in HCV indications as a result of effective direct-acting antiviral drugs [17]. Thus, hundreds of liver grafts every year are becoming available for indications other than HCV. Even though NASH related cirrhosis is still less frequent in Europe compared with the US, it is anticipated to become the leading indication for LT within the next decade.



Patient survival vs. MAIN preservation liquid  
N = 100 005 Overall population (1988–2016)



Global Log Rank P = <0.0001



Details : Log rank P

		proba
UW	CU/HTK	<0.0001
UW	CE	0.0004
UW	IGL	0.014
CU/HTK	CE	<0.0001
CU/HTK	IGL	<0.0001
CE	IGL	0.85

Survival %	preserv_liq_c	1 year	3 years	5 years	8 years	10 years	12 years	14 years	16 years	18 years	20 years
UW: University Wisconsin		84%	77%	72%	66%	62%	57%	53%	49%	45%	41%
CU/HTK		82%	74%	69%	61%	55%	50%	46%	43%	38%	37%
CE: Celsior		86%	79%	74%	67%	61%	57%	53%	51%	51%	51%
IGL: IGL		87%	80%	74%	65%	61%					

Number of exposed patients	Total	1 year	3 years	5 years	8 years	10 years	12 years	14 years	16 years	18 years	20 years
UW: University Wisconsin	61 288	46 592	37 560	30 864	21 906	16 781	12 273	8669	5775	3493	1878
CU/HTK	21 027	12 826	7287	4613	1897	912	425	223	108	42	31
CE: Celsior	13 544	9339	5797	3718	1548	703	275	85	4	3	1
IGL: IGL	4146	2722	1587	853	261	63	0	0	0	0	0

Figure 12 Patient survival versus main preservation liquid, n = 100 005 overall population (1988–2016).

In terms of results, all the indications have shown an improvement of survival especially HCC, mainly because of a better selection of patients, and the increasing effectiveness of down-staging techniques [18]. The ELTR cohort of patients has also established that some rare malignant tumors like hepatic hemangiosarcoma should be considered absolute contraindications for LT [19], while others like hereditary hemorrhagic telangiectasia [8] or hepatic epithelioid hemangio-endothelioma represent a good indication even in the presence of limited extrahepatic disease [12,24].

The average age of transplanted recipients has increased steadily during the last decade and a third of patients transplanted nowadays are >60 years. Noteworthy, LT can offer a 10 additional year benefit to 40% of septuagenarians. Also, an increasing number of transplanted liver grafts are coming from older donors with in most cases, the application of the old-to-old rule concerning the donor to recipient matching.

Alternatives to the conventional DBD full size graft are increasingly used in Europe. Split liver and living

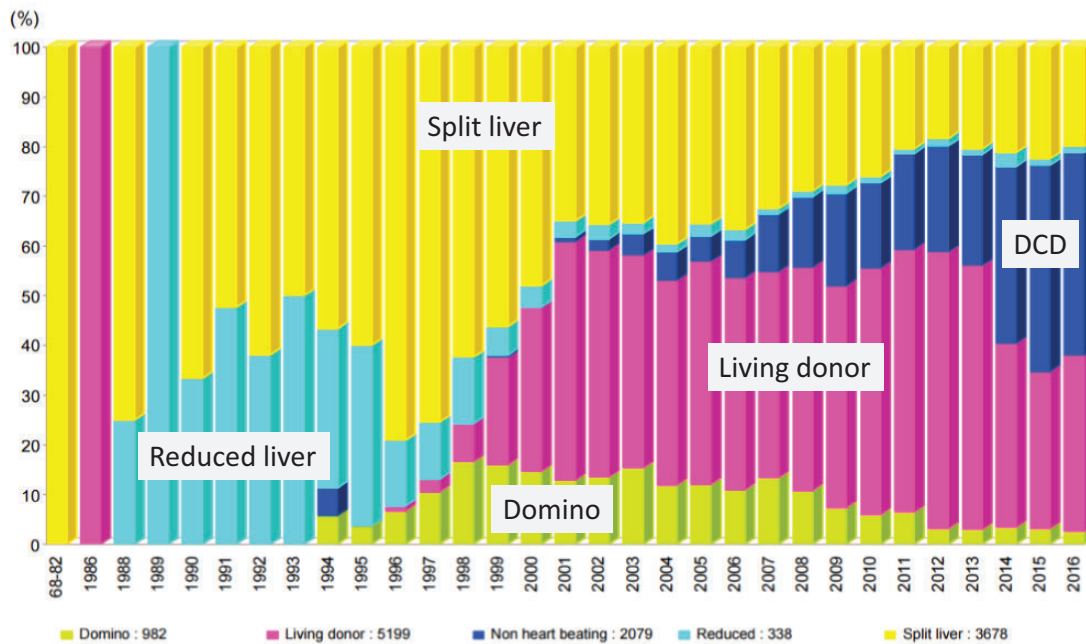
donation are increasingly used both in adult and pediatric LT, and DCD grafts are mostly used in adults with quite good survival results. Domino and reduced livers seem to be gradually disappearing. Optimization of donor management and organ preservation, offers the most realistic way to improve both the quality and pool of current organs. While only UW solution was used before 2000, an increasing number of new solutions are available today; the choice in preservation solution may have an independent impact on graft survival [25].

Also, while the introduction of cyclosporine and more recently Tacrolimus optimized immunosuppressive protocols, there is still room for improvement as recently shown by the use of prolonged release tacrolimus [26].

As a cause of graft loss, technical complications, primary graft nonfunction or dysfunction and infection are increasing, relatively. This could be related to the increasing use of marginal grafts coming from expanded donor criteria. Conversely, *de novo* tumor and nontumor recurrence as cause of graft loss or mortality are decreasing during the last years.



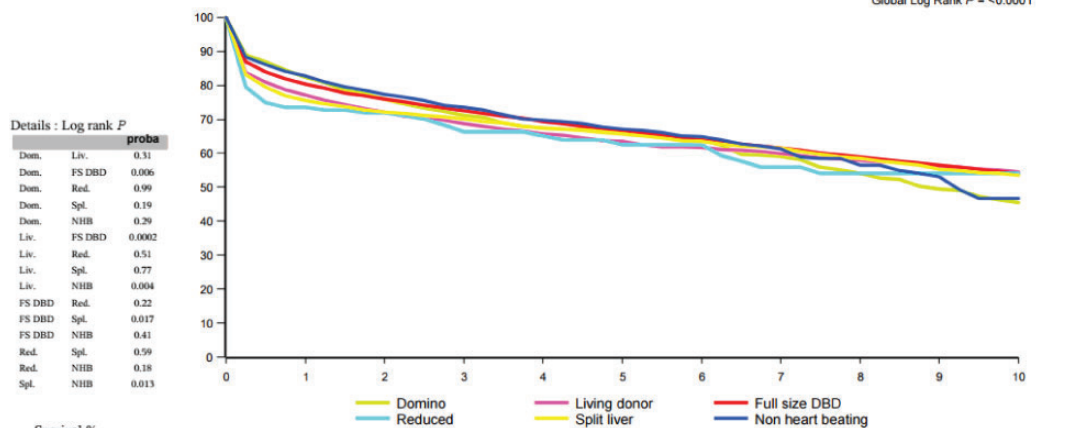
### Evolution of Alternatives to the use of full size DBD liver grafts in Europe N = 12 276 Adults



### Graft survival vs. type of graft : Adults N = 87 127 (2001–2016)



Global Log Rank  $P = <0.0001$



Details : Log rank  $P$

		proba
Dom.	Liv.	0.31
Dom.	FS DBD	0.006
Dom.	Red.	0.99
Dom.	Spl.	0.19
Dom.	NHB	0.29
Liv.	FS DBD	0.0002
Liv.	Red.	0.51
Liv.	Spl.	0.77
Liv.	NHB	0.004
FS DBD	Red.	0.22
FS DBD	Spl.	0.017
FS DBD	NHB	0.41
Red.	Spl.	0.59
Red.	NHB	0.18
Spl.	NHB	0.013

Survival %	Type_of_liver_graft	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Domino		82%	76%	71%	67%	66%	64%	59%	54%	49%	45%
Living donor		77%	72%	69%	66%	63%	62%	60%	58%	56%	54%
Full size DBD		80%	76%	72%	69%	67%	64%	61%	59%	56%	54%
Reduced		74%	72%	66%	65%	63%	63%	56%	54%	54%	54%
Split liver		75%	72%	70%	67%	66%	63%	61%	58%	55%	53%
Non heart beating		83%	77%	74%	70%	67%	65%	61%	57%	53%	47%

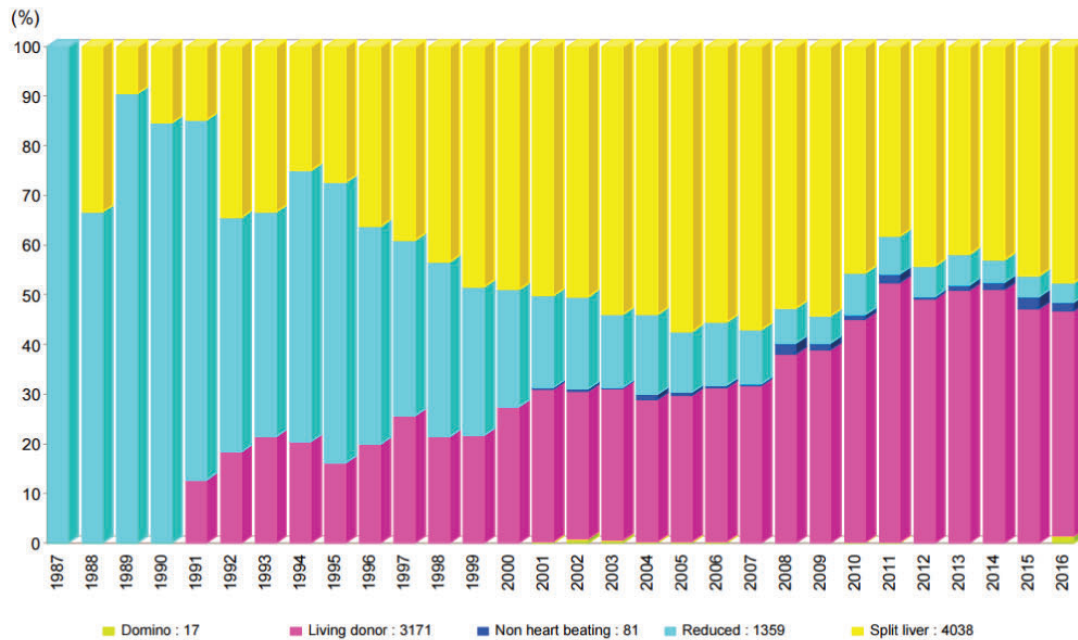
Number of exposed patients	Total	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Domino	810	586	500	431	367	332	277	218	158	120	92
Living donor	4894	2450	1681	1325	1088	866	719	559	446	351	282
Full size DBD	76 415	51 605	42 566	35 463	30 034	25 490	21 379	17 596	14 170	11 141	8706
Reduced	171	99	82	66	56	44	39	31	28	24	19
Split liver	2878	1792	1521	1282	1089	960	813	656	502	378	279
Non heart beating	1959	1188	822	617	457	328	235	159	80	45	21

**Figure 13** (a) Evolution of alternatives to the use of full size donors after brain death (DBD) liver grafts in Europe,  $n = 12\,276$  adults. (b) Graft survival versus type of graft: Adults,  $N = 87\,127$  (2001–2016).





### Evolution of Alternatives to the use of full size DBD liver grafts in Europe N = 8666 Children

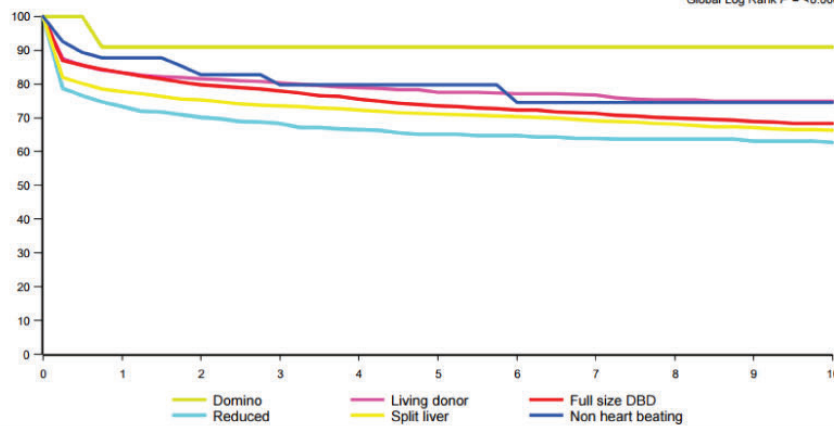


### Graft survival vs. type of graft : Children N = 9440 (2001–2016)

Global Log Rank P = <0.0001

Details : Log rank P

		proba
Dom.	Liv.	0.25
Dom.	FS DBD	0.2
Dom.	Red.	0.069
Dom.	Spl.	0.11
Dom.	NHB	0.43
Liv.	FS DBD	0.002
Liv.	Red.	<0.0001
Liv.	Spl.	<0.0001
Liv.	NHB	0.66
FS DBD	Red.	0.0002
FS DBD	Spl.	0.001
FS DBD	NHB	0.33
Red.	Spl.	0.044
Red.	NHB	0.023
Spl.	NHB	0.096



Survival %	Type_of_liver_graft	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Domino		91%	91%	91%	91%	91%	91%	91%	91%	91%	91%
Living donor		83%	82%	80%	79%	78%	77%	75%	75%	75%	75%
Full size DBD		83%	80%	78%	75%	74%	72%	71%	70%	69%	68%
Reduced		73%	70%	68%	66%	65%	65%	64%	64%	63%	63%
Split liver		78%	75%	74%	72%	71%	70%	69%	68%	67%	66%
Non heart beating		88%	83%	80%	80%	80%	75%	75%	75%	75%	75%

Number of exposed patients	Total	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Domino	17	9	3	3	3	3	2	2	2	1	1
Living donor	2710	1518	1178	942	783	640	527	438	311	240	185
Full size DBD	2808	1936	1591	1332	1125	966	836	702	570	468	375
Reduced	594	391	348	309	272	239	206	186	166	139	115
Split liver	3241	2100	1759	1484	1277	1101	954	797	625	469	367
Non heart beating	70	45	31	26	20	19	14	11	7	5	4

**Figure 14** (a) Evolution of alternatives to the use of full size donors after brain death (DBD) liver grafts in Europe, N = 8666 children. (b) Graft survival versus type of graft: children, N = 9440 (2001–2016).



### Mortality and retransplantation post LT in Europe (1988–2016)

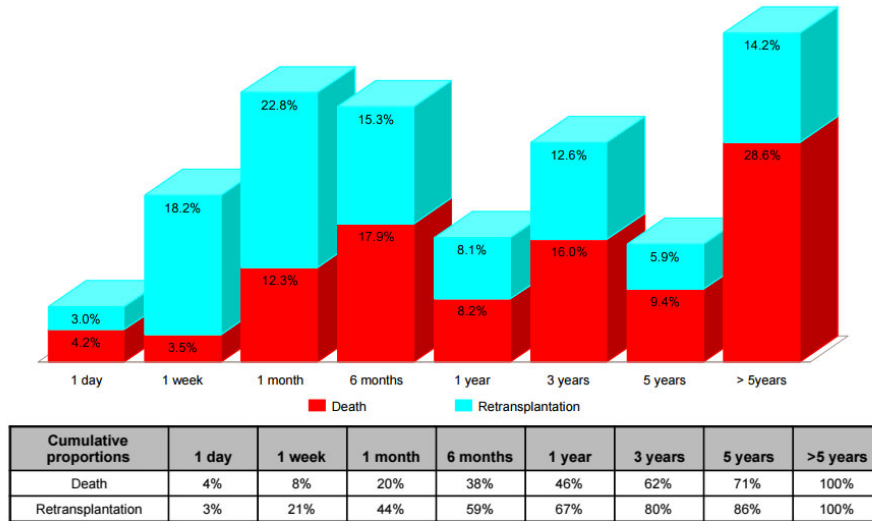


Figure 15 Mortality and retransplantation post LT in Europe (1988–2016).



### Mortality following first liver transplantation in Europe N = 28 637 (1988–December 2016)

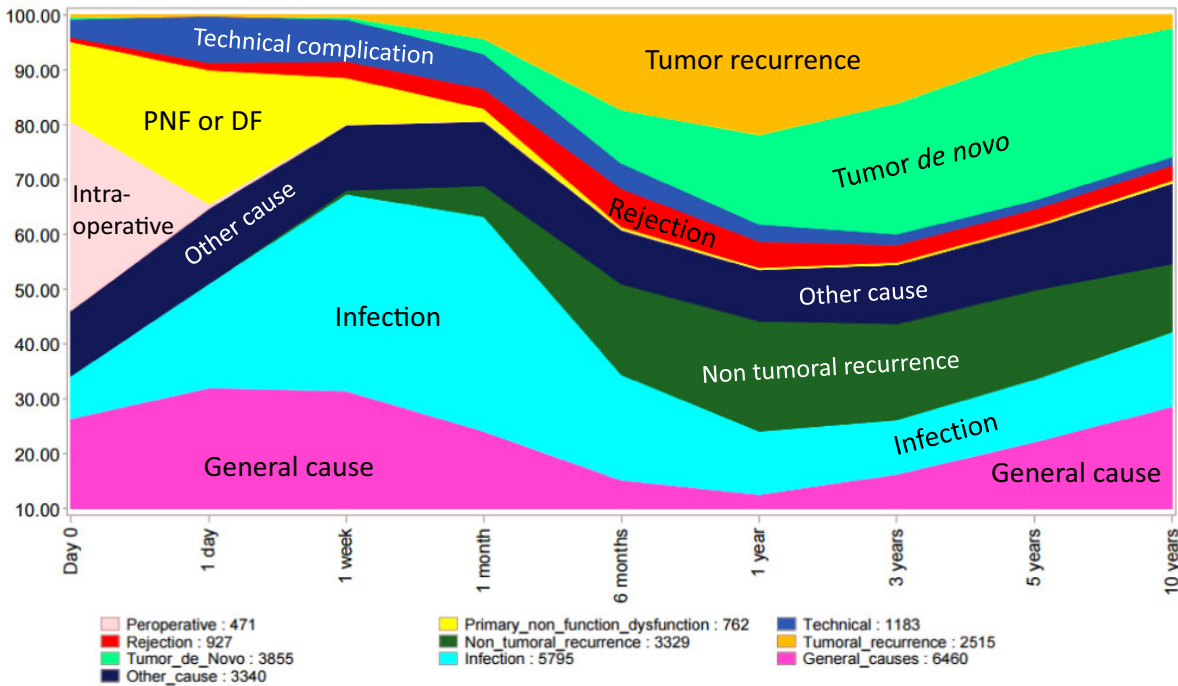


Figure 16 Mortality following first liver transplantation in Europe, N = 28 637 (1988–December 2016).

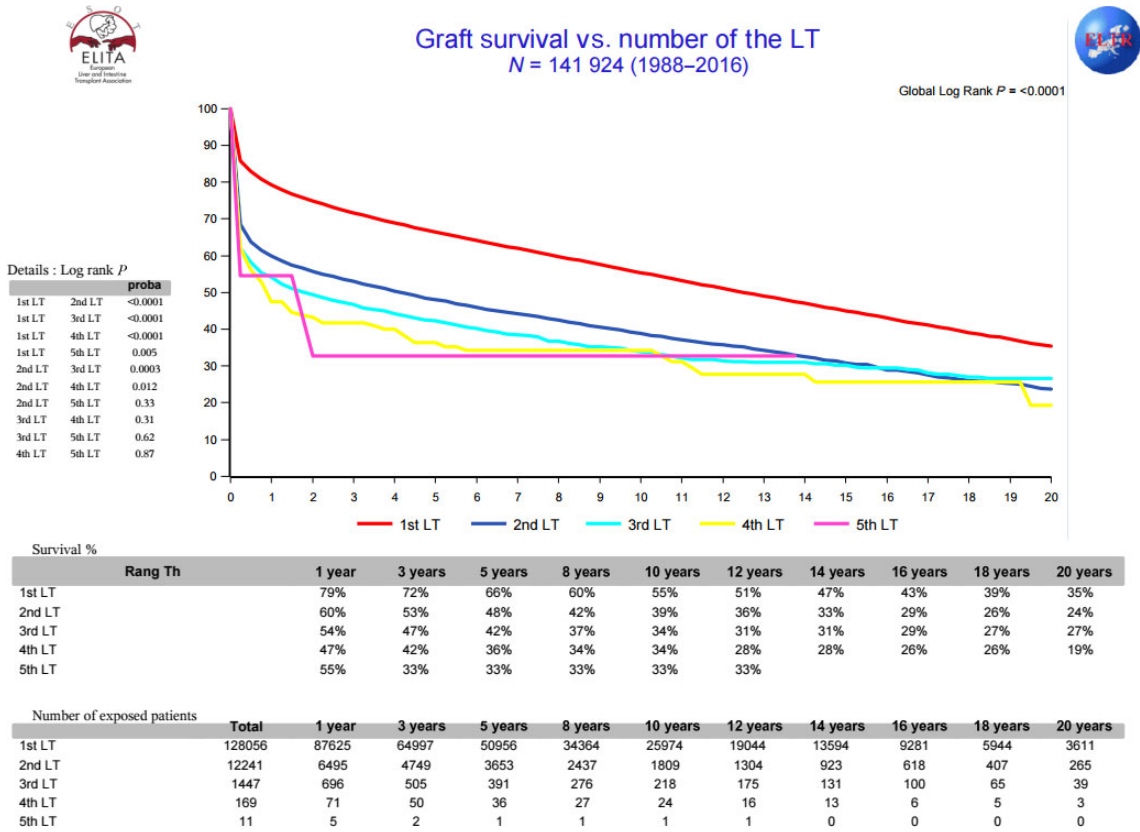


Figure 17 Graft survival versus number of the LT, N = 141 924 (1988–2016).

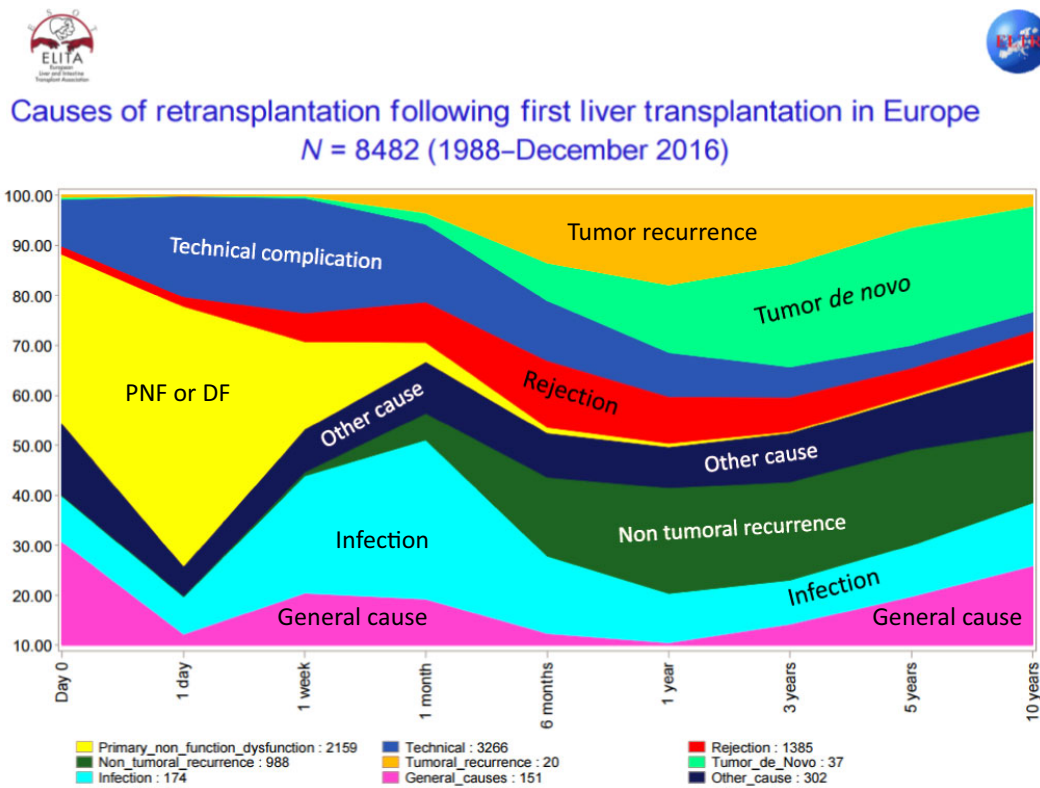
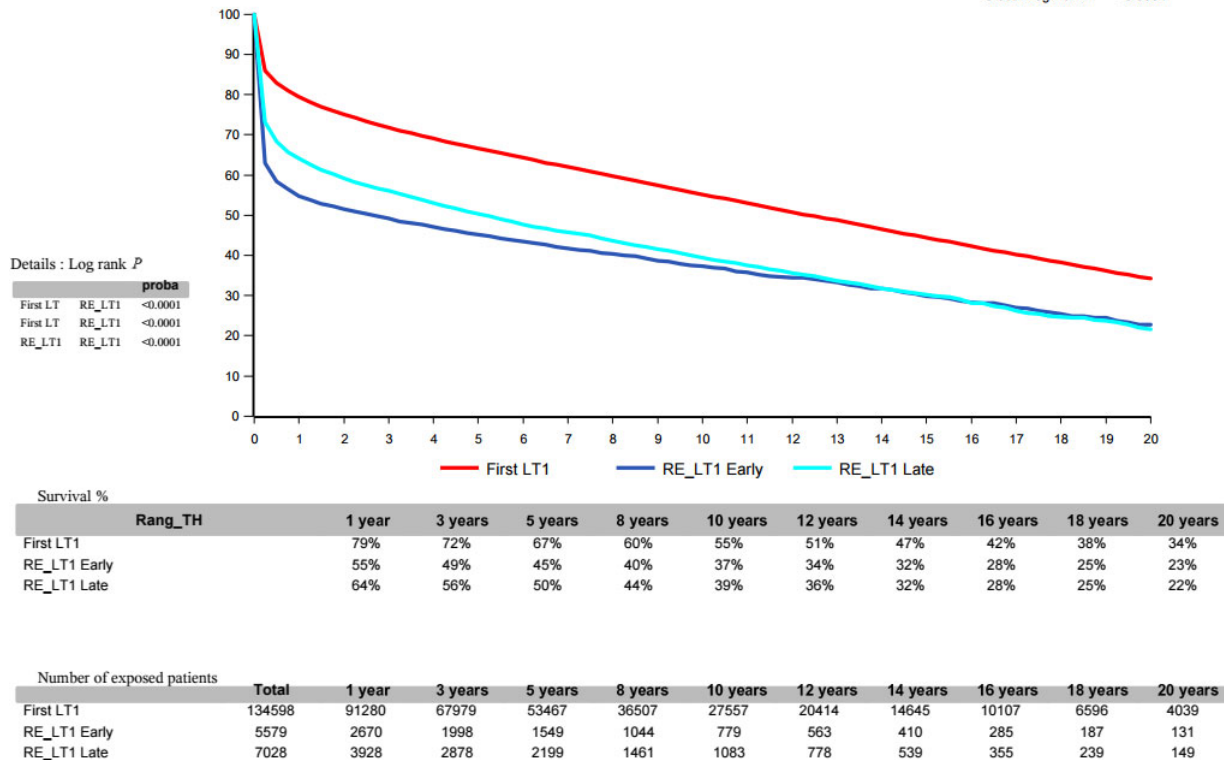


Figure 18 Causes of retransplantation following first liver transplantation in Europe, N = 8482 (1988–December 2016).





## Graft survival vs. early or late ReLT1 N = 147 205 (1988–2017)

Global Log Rank  $P = <0.0001$ 

**Figure 19** Graft survival versus early or late ReLT1,  $N = 147\,205$  (1988–2017).

There are some limitations to our study. Data quality, reliability, and representativeness is an everyday concern for the ELTR since its creation in 1986. With this constantly in mind, the ELTR has implemented several procedures and adapted them all along the years to control the quality of data, from collection, to statistical analysis. However, biases may persist as for all observational studies; therefore, the interpretation of these descriptive data must be done with caution. Lost-to-follow-up (LTFU) patients are a real problem in the reported outcome. It is mainly related to the increasing number of transplanted patients who move to another place within a country or outside the country. More than 72% of ELTR data are shared with official OSOs who have setup a drastic tracking procedure to minimize the rate of LTFU. The remaining 28% who enter the data directly in our platform are regularly invited to consult the dynamically updated list of queries to solve all discrepancies and to report a recent patient follow-up.

By the prospective evaluation of almost all patients transplanted in Europe since the last fifty years, the ELTR provides valuable data concerning the evolution of LT, the dynamic changes in indications, in donor

and recipients profile, as well as in preservation, technical aspects and post-transplant management. These data can help refine the indications for transplant in rare diseases, and establish new guidelines, while targeting the real fields which need improvement in order to optimize the results of LT.

### Authorship

RA, VK and VC: conception and design, acquisition of data, data analysis and interpretation of results, writing the first draft, critical revision, final approval. All the rest of co-authors: acquisition of data, critical revision, final approval.

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### Conflicts of interest

The authors have declared no conflicts of interest.

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