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Vaccination practices in pediatric transplantation: A survey among member centers of the European reference network TransplantChild

Daniele Donà[1] | Luz Yadira Bravo-Gallego[2] | Esteban Frauca Remacha[3] | Mara Cananzi[4] | Andrea Gastaldi[1,5] | Juan Torres Canizalez[2] | Xavier Stephenne[6] | Florence Lacaille[7] | Caroline Lindemans[8] | Elisabetta Calore[9] | Nathalie Galea[10] | Elisa Benetti[11] | Edith Nachbaur[12] | Ana Rita Sandes[13] | Ana Teixeira[14] | Sandra Ferreira[15] | Maja Klaudel-Dreszler[16] | Oanez Ackermann[17] | Olivia Boyer[18,19] | Laura Espinosa[20] | Luis García Guereta[21] | Marco Sciveres[22] | Björn Fischler[23,24] | Nicolaus Schwerk[25] | Mette Neland[26] | Emanuele Nicastro[27] | Luca Dello Strologo[28] | Jacek Toporski[29,30] | Inga Vainumae[31] | Jelena Rascon[32] | Vaidotas Urbonas[33] | Teresa del Rosal[34] | Eduardo López-Granados[2,35] | Giorgio Perilongo[36] | Alastair Baker[37] | Paloma Jara Vega[38] | on behalf of ERN TransplantChild Healthcare Working Group

[1]Division of Pediatric Infectious Diseases, Department of Women's and Children's Health, University Hospital of Padua, Padua, Italy

[2]Lymphocyte Pathophysiology in Immunodeficiencies Group, La Paz Institute of Biomedical Research (IdiPAZ), Center for Biomedical Network Research on Rare Diseases (CIBERER U767), Madrid, Spain

[3]Pediatric Hepatology Department, La Paz University Hospital, Molecular Hepatology Group, La Paz Institute of Biomedical Research (IdiPAZ), Madrid, Spain

[4]Unit of Paediatric Gastroenterology, Digestive Endoscopy, Hepatology and Care of the Child with Liver Transplantation, Department of Women's and Children's Health, University Hospital of Padua, Padua, Italy

[5]Department of Pediatrics, Woman and Child Hospital, University of Verona, Verona, Italy

[6]Laboratoire d'Hépatologie Pédiatrique et Thérapie Cellulaire, Unité PEDI, Institut de Recherche Expérimentale et Clinique, Université Catholique de Louvain (UCLouvain), Brussels, Belgium

[7]Service de Gastroentérologie-Hépatologie-Nutrition Pédiatriques, Hôpital Necker-Enfants Malades, AP-HP, Université Paris Descartes, Paris, France

[8]Princess Maxima Center for Pediatric Oncology, Pediatric Blood and Marrow Transplantation Program, University Medical Center Utrecht, Utrecht University, Utrecht, The Netherlands

[9]Pediatric Hematology, Oncology and Stem Cell Transplant Division, Department of Women's and Children's Health, Padua University Hospital, Padua, Italy

[10]Paediatric Department of Mater Dei Hospital, Msida, Malta

[11]Pediatric Nephrology, Dialysis and Transplant Unit, Department of Women's and Children's Health, Azienda Ospedaliera di Padova, Padua, Italy

[12]Division of Pediatric Pulmonology, Allergology and Endocrinology, Department of Pediatrics and Adolescent Medicine, Medical University of Vienna, Vienna, Austria

[13]Unidade de Nefrologia e Transplantação Renal, Serviço de Pediatria Médica, Departamento de Pediatria, Hospital de Santa Maria, Centro Académico de Medicina, Universidade de Lisboa, Lisbon, Portugal

[14]Department of Pediatric Nephrology, Pediatric Service, Centro Materno-Infantil do Norte, Centro Hospitalar do Porto, Porto, Portugal

Abbreviations: BMT, bone marrow transplantation; ERN, European Reference Network; HAV, hepatitis A virus; HBV, hepatitis B virus; HSCT, hemopoietic stem cell transplantation; LAVs, live-attenuated vaccines; MMR, measles, mumps, and rubella; SOT, solid organ transplantation; Tdap, tetanus–diphteria–pertussis; VPIs, vaccine-preventable infections; VZV, varicella–zoster virus.

Daniele Donà and Luz Yadira Bravo-Gallego are co-authors.

[15]Hepatology and Pediatric Liver Transplantation Unit, Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal

[16]Department of Gastroenterology, Hepatology, Feeding Disorders and Pediatrics, The Children's Memorial Health Institute, Warsaw, Poland

[17]Hepatologie et Transplantation Hepatique Pediatriques, Centre de reference de l'atresie des voies biliaires et des cholestases genetiques, FSMR FILFOIE, ERN RARE LIVER, Hôpital Bicêtre, AP-HP, Université Paris-Saclay, Le Kremlin-Bicêtre, France

[18]Service de Néphrologie Pédiatrique, AP-HP, Centre de Référence de maladies rénales rares de l'enfant et de l'adulte (MARHEA), Hôpital Necker—Enfants Malades, Paris, France

[19]Institut Imagine, Laboratoire des maladies rénales héréditaires, INSERM UMR 1163, Université de Paris, Paris, France

[20]Pediatric Nephrology Department, La Paz University Hospital, Diagnosis and Treatment of Diseases Associated with Abnormalities of the Complement System Group, La Paz Institute of Biomedical Research (IdiPAZ), Madrid, Spain

[21]Pediatric Cardiology Department, La Paz University Hospital, Madrid, Spain

[22]Pediatric Hepatology and Liver Transplantation, ISMETT-University of Pittsburgh Medical Center Italy, Palermo, Italy

[23]Department of Pediatric Gastroenterology, Hepatology and Nutrition, Astrid Lindgren Children's Hospital, Karolinska University Hospital, Stockholm, Sweden

[24]Department of Clinical Science, Intervention and Technology, CLINTEC, Karolinska Institutet, Stockholm, Sweden

[25]Paediatric Pneumology, Allergology, and Neonatology, Hannover Medical School, Hannover, Germany

[26]Department of Paediatrics and Adolescence Medicine, Odense University Hospital, Odense, Denmark

[27]Pediatric Hepatology, Gastroenterology and Transplantation, Hospital Papa Giovanni XXIII, Bergamo, Italy

[28]Nephrology Unit, Bambino Gesù Children's Research Hospital, IRCCS, Rome, Italy

[29]Department of Pediatrics, Section of Pediatric Oncology, Hematology, Immunology and Nephrology, Skåne University Hospital, Lund, Sweden

[30]Center of Allogenic Stem Cell Transplantation and Cellular Therapy, Karolinska University Hospital, Stockholm, Sweden

[31]Department of Pediatrics, Tartu University Hospital, Tartu, Estonia

[32]Centre for Paediatric Oncology and Haematology, Vilnius University Hospital Santaros Klinikos, Vilnius, Lithuania

[33]Department of Paediatric Gastroenterology, Vilnius University Hospital Santaros Klinikos, Vilnius, Lithuania

[34]Paediatric Infectious and Tropical Diseases Department, La Paz University Hospital, Translational Research Network in Paediatric Infectious Diseases (RITIP), La Paz Institute of Biomedical Research (IdiPAZ), and Center for Biomedical Network Research on Rare Diseases (CIBERER U767), Madrid, Spain

[35]Clinical Immunology Department, La Paz University Hospital, Madrid, Spain

[36]Department of Women's and Children's Health, University Hospital of Padua, Padua, Italy

[37]Paediatric Liver, Gastrointestinal and Nutrition Centre, King's College London School of Medicine at King's College Hospital, London, UK

[38]Pediatric Hepatology Department, La Paz University Hospital, Molecular Hepatology Group, La Paz Institute of Biomedical Research (IdiPAZ), ERN TransplantChild Coordinator, Madrid, Spain

Correspondence
Daniele Donà, Division of Pediatric Infectious Diseases, Department of Women's and Children's Health, University Hospital of Padua, via Giustiniani 2, Padua 35128, Italy.
Email: daniele.dona@unipd.it

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Abstract

Background: There is considerable variation in vaccination practices between pediatric transplant centers. This study aims to evaluate active immunization attitudes and practices among ERN-TransplantChild centers and identify potential areas of improvement that could be addressed by shared evidence-based protocols.

Methods: A cross-sectional questionnaire of attitudes and practices toward immunization of pediatric SOT and HSCT candidates and recipients was sent to a representative member of multidisciplinary teams from 27 European centers belonging to the ERN-TransplantChild.

Results: A total of 28/62 SOT programs and 6/12 HSCT programs across 21 European centers participated. A quarter of centers did not have an on-site protocol for the immunizations. At the time of transplantation, pediatric candidates were fully immunized (80%–100%) in 57% and 33% of the SOT and HSCT programs. Variations in the time between vaccine administration and admission to the waiting list were reported between the centers, with 2 weeks for inactivated vaccines and variable time (2–4 weeks) for live-attenuated vaccines (LAVs). Almost all sites recommended immunization in the post-transplant period, with a time window of 4–8 months for the inactivated vaccines and 16–24 months for MMR and Varicella vaccines. Only five sites administer LAVs after transplantation, with seroconversion evaluated in 80% of cases.

Conclusions: The immunization coverage of European pediatric transplant recipients is still inconsistent and far from adequate. This survey is a starting point for developing shared evidence-based immunization protocols for safe vaccination among pediatric transplant centers and generating new research studies.

KEYWORDS
children, immunosuppression, transplant, vaccination, vaccine-preventable infections

1 | BACKGROUND

Pediatric solid organ and hematopoietic stem cell transplantation (SOT and HSCT) have been increasing the survival rate and the quality of life of children with organ failure or cancer over the last five decades. However, although many technical and pharmacological advancements have improved the outcome of pediatric transplantation, infectious complications remain a serious cause of morbidity and mortality, with the proportion of transplant recipients developing infectious complications ranging from 7% to 20% in the first 5 years after SOT or HSCT, and this proportion being much higher in the first year.[1–7]

Pediatric transplants constitute approximately 10% of the total number of transplants performed worldwide.[8,9] Children have a higher risk of infections and vaccine-preventable diseases than adult recipients. Indeed, children may lack previous immunity from natural exposure and may not have had time to finish their primary immunization series by the time of transplantation. Vaccine-preventable infections (VPIs) still occur in a high percentage of SOT and HSCT pediatric recipients (15%–20%), negatively affecting patient morbidity and mortality as well as hospitalization rates and health-related costs.[3,6]

International guidelines on the indication, safety, and timing for the immunization of pediatric transplant candidates and recipients have been implemented to control post-transplant VPIs. Nevertheless, there is still a considerable variation between transplant centers in their approach to vaccination schedules,[10–13] and low vaccination coverage has been reported in SOT candidates.[14,15] While the safety of non-live vaccines has been established for patients after pediatric transplantation, safety concerns have generally precluded the use of live-attenuated vaccines (LAVs).[12]

This study aims to evaluate the attitudes and practices with respect to immunization of pediatric transplant recipients among the members of the European Reference Network on Transplantation in Children (ERN-TransplantChild) and to analyze major gaps and differences that the development of evidence-based shared protocols could overcome.

2 | MATERIALS AND METHODS

The Healthcare Working Group of the ERN-TransplantChild agreed on the design of a cross-sectional questionnaire in order to evaluate the attitude toward immunizations of pediatric SOT and HSCT candidates and recipients before and after transplantation and to identify significant discrepancies between centers that could benefit from guidelines adaptation and implementation.

Healthcare professionals from both SOT and HSCT programs, from 27 European center full members and affiliated partners of ERN-TransplantChild were invited to complete the online survey, from June 19th to December 7th, 2020 (https://www.transplantchild.eu/wp-content/uploads/Audit_Vaccines.pdf, see also Supplementary material). A complementary survey was sent in order to collect more data regarding LAVs (varicella—VZV, and measles, mumps, and rubella—MMR-), (https://www.transplantchild.eu/wp-content/uploads/LAV-survey.pdf, see also Supplementary material). Since participation was optional, the decision to participate in the survey was considered as (implicit) consent.

The survey included relevant questions referring to: (1) patients' immunization status at the time of transplant; (2) the protocol of immunization (either standard or accelerated) employed before transplant; (3) the causes of under-vaccination; (4) the immunization schedule employed in the post-transplant period; (5) the practice of monitoring antibody titers against VPIs before and after transplant; (6) influenza vaccination of household contacts and healthcare workers.

Children were considered as fully vaccinated if they had received the recommended doses of a vaccine required for their age and country, by the time of the transplantation.

The results of the survey were summarized by a descriptive analysis using R statistical software, version 3.6.1 (R Foundation for Statistical Computing).

3 | RESULTS

A comprehensive analysis is available online https://datastudio.google.com/reporting/df7becb9-41ef-4b04-973c-28729df1e4df.

Thirty-four of 74 (46%) transplant programs [28/62 (45%) SOT and 6/12 (50%) HSCT] distributed in 21 centers across 14 European countries (Austria, Belgium, Denmark, Estonia, France, Germany, Italy, Lithuania, Malta, The Netherlands, Poland, Portugal, Spain, and Sweden) completed the survey. All SOT programs were represented. Fifty-three percent (18/34) of the respondents were transplant programs with over 100 pediatric transplant recipients in follow-up, and 50% (17/34) had more than 15 years in the field of pediatric transplantation. Detailed information regarding the transplant programs that participated in the study is given in Table 1. Almost a quarter of

TABLE 1 Pediatric SOT and HSCT programs distribution by country, experience, and patients in follow-up.

Tx program (*n*)	Heart (1)	Intestinal (2)	Kidney (9)	Liver (12)	Lung (3)	Pancreas (1)	HSCT (6)	Total (34), *n* (%)
Country, *n* (%)								
Austria					1			1 (3)
Belgium				1				1 (3)
Denmark			1					1 (3)
Estonia			1	1				2 (6)
France		1	1	2				4 (12)
Germany					1			1 (3)
Italy		1	3	3	1	1	1	10 (29)
Lithuania				1			1	2 (6)
Malta							1	1 (3)
Poland				1			1	2 (6)
Portugal			2	1				3 (9)
Spain	1		1	1				3 (9)
Sweden				1			1	2 (9)
The Netherlands							1	1 (3)
Years of experience in PT, *n* (%)								
<5			1					1 (3)
5–10		1		2	2	1		6 (18)
10–15			2	5	1		2	10 (29)
>15	1	1	6	5			4	17 (50)
PT recipients in follow-up, *n* (%)								
<25			1	2	1		3	7 (21)
25–50			1		2	1		4 (12)
50–75	1		1	1			1	4 (12)
75–100				1				1 (3)
>100		2	6	8			2	18 (53)
Official immunization protocol for PT, *n* (%)								
No	1		2	3	1		1	8 (24)

Abbreviations: HSCT, hematopoietic stem cell transplantation; PT, pediatric transplantation; Tx, transplantation.

centers (*n* = 8 of 34) declared they did not have an on-site protocol for the immunization of pediatric transplant recipients, while 48% (*n* = 10), 19% (*n* = 4), and 15% (*n* = 3) stated they had a protocol dedicated to SOT recipients, to HSCT recipients or both SOT and HSCT recipients respectively.

3.1 | Pre-transplant immunization practices

Pre-transplant immunization practices were separately investigated for SOT and HSCT transplantation programs.

3.1.1 | Solid-organ transplantation

At the time of transplant, 15/28 survey participants reported that 80%–100% of their SOT candidates were fully immunized. This proportion decreased to 40%–80% and 0%–40%, in 8/28 (25%) and 5/28 (18%) of SOT programs, respectively (Figure 1). The main reason for under-vaccination attributed by physicians was insufficient time before transplant (24 of 28, 86%), followed by parents' hesitancy (9 of 28, 32%) and specialists' hesitancy (5 of 28, 18%).

As parents' vaccine acceptance can be increased through various interventions, respondents were asked to describe the departmental strategies developed to ameliorate this issue. Thirty-two percent (9/28) of centers had organized meetings with parents to provide accurate vaccine information, and 39% (11/28) of the programs stated that they informed parents about the risks of under-vaccination but still proceeded with transplantation.

Regarding SOT candidates before transplantation, 29% of centers (8/28) directly administer all indicated vaccinations to SOT candidates, and 54% (15/28) stated that they offered some vaccinations (pneumococcal, influenza, and HBV mostly; followed by meningococcal, Tdap, MMR, and VZV). The remaining centers did not provide vaccinations because other healthcare providers were generally responsible for these vaccinations.

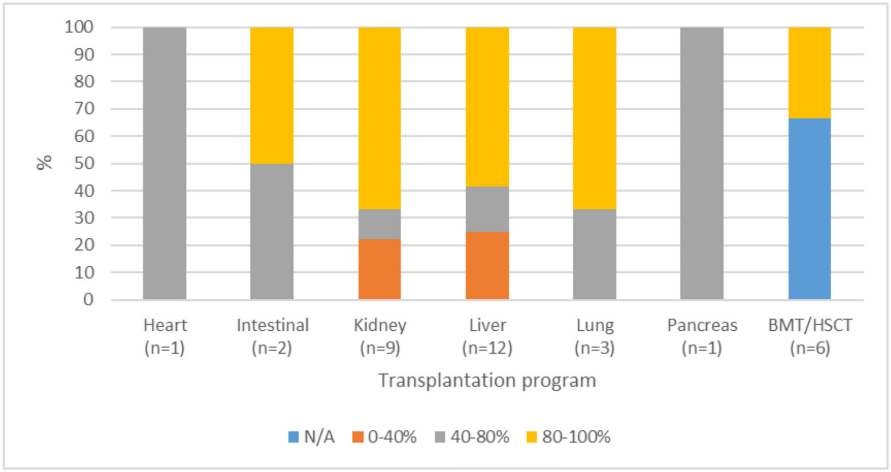

FIGURE 1 Physician-reported proportion of vaccinated recipients at the time of transplantation by transplantation program, according to age and country schedule. BMT/HSCT, bone marrow transplantation/hematopoietic stem cell transplantation; N/A, not available.

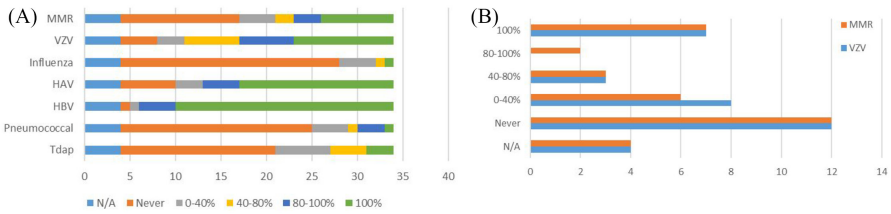

FIGURE 2 Pre-transplant immunization practices: (A) Antibody titer monitored before the admission to the transplant waiting list; (B) LAVs accelerated schedule according to the need for transplant urgency. HAV, hepatitis A; HBV, hepatitis B; MMR, measles, mumps, and rubella; N/A, not available; Tdap, tetanus-diphtheria-pertussis; VZV, varicella.

The most recommended vaccinations consisted of Tdap, pneumococcal, HBV, MMR, and VZV, followed by meningococcal (ACYW and B), HAV, influenza, and human papillomavirus (HPV). Tdap, pneumococcal, and HBV vaccines were given to 100% of candidates by almost all respondents, while other vaccines were less frequently recommended. Respondents reported varied times between vaccine administration and admission to the transplant waiting list. The most frequently adopted time window was 2 weeks for inactivated and subunit/conjugate vaccines (i.e., pneumococcal, meningococcal, HBV, Tdap, and influenza vaccine) and 4 weeks for LAVs (only 29% of respondents reported a shorter time of 2–4 weeks).

The survey also investigated the practice of monitoring IgG antibodies against VPIs before SOT (Figure 2A). Prior to admission to the transplant waiting list, the most frequently tested serologies (in up to 80%–100% of patients) were hepatitis B -HBV (24/28, 86%), hepatitis A -HAV (18/28, 64%), and varicella -VZV (17/28, 61%). Influenza, tetanus-diphtheria-pertussis (Tdap), and pneumococcus antibodies were not tested in most centers (19/28, 68%; 12/28, 43%; 17/28, 61% respectively). Exceptionally, HBV and HAV antibodies were respectively retested in 54% (15/28) and 43% (12/28) of cases on the waiting list; otherwise, antibody titers of the other vaccines were never rechecked before transplantation in 39%–65% of cases. According to the need for transplant urgency, one-quarter of respondents declared their centers always recommend an accelerated schedule for LAVs starting at 6 months of age, whereas 39% of programs did not implement one (Figure 2B).

3.1.2 | Hematopoietic stem cell transplantation

Two of six HSCT programs reported a percentage of 80%–100% of pediatric candidates fully immunized, describing the patient's general condition as the main reason for major risk for patients under vaccination, although four centers did not answer these questions.

No further questions were answered by these centers referring to the pre-transplant period practice.

3.2 | Post-transplant immunization practices

3.2.1 | Solid-organ transplantation

After transplantation, around two-thirds of SOT programs provide all (4/28, 14%) or some vaccinations (13/28, 46%) within the transplant center, which usually consist of pneumococcal, influenza, VZV, and HBV vaccine, followed by meningococcal, HAV and Tdap. More than one-third of transplantation programs do not provide vaccinations, but other services provide them.

Before resuming the vaccination schedule after SOT, 40% of respondents (11/28) check immunoglobulin levels and/or the complete blood cell count with differential, 14% (4/28) check IgG subsets, while 50% (14/28) do not perform any specific blood tests. The serological status against VZV, HBV, and HAV are usually reviewed 7–10 months after transplant, whereas pneumococcus and Tdap are

usually not tested. MMR antibody titers are variably checked 1 year after transplant or when the child is weaned off steroids.

All centers but one administered or recommended inactivated vaccines in the post-transplant period, whereas LAVs were not usually recommended (given by only 4/28, 14%). The most preferred time to resume vaccination is 4–8 months after the transplant (almost 30% of centers), followed by 13–15 months (around 20% of centers). Steroid weaning or single-agent immunosuppression was not usually considered a prerequisite for resuming the vaccination schedule.

Additional investigation from the survey pointed out the following aspects: (1) 68% (19/28) of the SOT programs employed the same schedule for pneumococcal vaccination; (2) only 18% (5/28) of SOT programs administered respiratory syncytial virus -RSV prophylaxis; (3) the influenza vaccine coverage rate among healthcare workers is widely variable, with almost half of the SOT centers having a 40%–60% coverage; (4) finally, 96% (27/28) of SOT programs recommended influenza vaccine also for the SOT recipient's family members, in 82% of cases with no time limits.

3.2.2 | Hematopoietic stem cell transplantation

Before resuming the vaccination schedule after HSCT, 83% of respondents checked complete blood cell count with differential and immunoglobulin levels and 67% also evaluated lymphocyte subsets. Antibody titer monitoring after transplant was not a common practice. Two centers constantly evaluated anti-HBs titer but rarely checked MMR, varicella, and tetanus antibodies. The timing of checking was highly variable.

Almost all HSCT programs recommended immunization with all vaccines during the post-transplant period. For inactivated ones, the administration was usually scheduled after 4–8 months from the transplant, followed by 14–24 months or when the child was on a single-immunosuppressive agent. A longer period was usually required for LAVs (16–24 months after HSCT).

Remarkably, no HSCT program administered RSV prophylaxis. The reported coverage for the influenza vaccine was widely variable, with only one site reporting 80%–100% coverage and two sites between 60% and 80%; all centers suggested the seasonal influenza vaccine also for the HSCT recipient's family members, generally with no time limits.

3.3 | Live-attenuated vaccines

Further questions were posed to the six centers reporting the administration of LAVs after transplantation. Five centers completed the survey (2 SOT and 3 HSCT). The two centers with SOT programs are located in France and Belgium and prescribe LAVs in three SOT programs (2 liver and 1 intestinal). The median year when centers began to vaccinate with LAVs was 2001 (range = 2000–2010). The following criteria were prerequisites for prescribing LAVs: Time after transplantation (4/5 centers), minimal immunosuppressive treatment (4/5 centers, 2 SOT and 2 HSCT), and stable CD4+ T cell count (2/5 centers). Time after transplantation was defined as 12–23 or 24–35 months by two centers, respectively. HSCT centers defined minimal immunosuppressive treatment as the patient is taking a prednisolone dose of less than 0.5 mg/kg and not on calcineurin inhibitors and/or anti-metabolites. SOT centers defined low immunosuppression as the following: tacrolimus level <5 ng/mL; low dose of simple or double immunosuppressive agents. Stable CD4+ T cell count was defined as >200 cells/μL for at least 6 months or >400 cells/μL. No center reported normal lymphoproliferative responses as a criterium to indicate LAVs. According to the respondents, no patients had ever experienced any vaccine-derived infection or adverse events after LAV. Seroconversion was evaluated in 80% of centers.

4 | DISCUSSION

This is the first study evaluating immunization practices and protocols in use across pediatric transplant centers participating in the ERN-TransplantChild.

VPIs are a relevant source of morbidity and mortality after SOT and HSCT, particularly in children.[16,17] A recent North American study reported a 7.1% hospitalization rate for VPIs in a cohort of 9591 pediatric recipients within 5 years after allogeneic or autologous HSCT. VPIs most frequently occurred in the first 6–12 months after transplantation, with an 87% prevalence within the first 2 years. Influenza, varicella, and invasive pneumococcal infections were the most common infections and the ones determining longer hospitalization periods, higher rates of intensive care admission, and mortality.[4] In another review of 6980 pediatric SOT recipients from 45 tertiary care centers across the United States, hospitalization for VPIs occurred in 15.6% of patients within the first 5 years after transplant, at a rate up to 87 times higher than in the general population. The most common VPIs were influenza (40% of cases), followed by rotavirus, varicella, pneumococcus, and respiratory syncytial virus. In a multivariate analysis, age younger than 2 years at the time of transplant and lung, heart, or intestine transplants were associated with an increased risk of hospitalization from a VPI. Transplantations complicated by VPIs also resulted in a considerable increase in healthcare expenditure, with a median cost of $120 498 more than hospitalizations without VPI complications.[3]

Immunization against VPIs of pediatric transplant candidates and recipients is a critical theme, of which the majority of European centers are aware, as positively emerged from this survey. International guidelines advocate a systematic approach to immunization before and after SOT and recommend re-immunizations after HSCT. However, there are still wide variations between immunization practices as supported by the lack of standardized protocols in 25% of the centers from a European Reference Network.

Furthermore, the variable attitude toward vaccinations in transplant recipients could reflect different attitudes and recommendations in immunization practice, as well as routine immunization

coverage and uptake, even within European Countries. However, despite this variety on vaccine schedules, under-vaccination would not be legitimized and should be implemented throughout Europe. In a recent work by Bozzola et al. (2018), it emerged that 11 of 31 EU Countries introduced mandatory vaccinations, while in the remaining States, pediatric vaccinations are still highly recommended (particularly for tetanus, diphtheria, pertussis, Haemophilus influenzae type B, Hepatitis B, poliovirus, mumps, measles, and rubella), almost all within 12 to 18 months of life.[18,19]

In the field of SOT, immunizations must be maximized before transplantation, as the immune response is later impaired by life-long immunosuppressive therapy.[13,20,21] Indeed, most centers recommend immunization before transplantation, with Tdap, pneumococcal, and HBV vaccines in the first place. However, a quarter of the SOT programs seem to report a suboptimal percentage (40%–80%) of fully immunized children at the time of transplantation, which was even lower in 18% of SOT programs. The inclusion of HAV vaccines in such a heterogeneous population of transplant patients resulted in some discrepant responses. Indeed, the indications for the HAV vaccination may vary depending on the type of transplant (i.e., liver) or each country's epidemiology.

Moreover, 39% of the transplant programs never prescribed an accelerated schedule for LAVs to infants, missing the opportunity of an additional valuable strategy to prevent VPIs.

Under-vaccination is an emerging problem in healthy children, which becomes much more serious in transplant recipients since it puts them at higher risk of complications.[15] Since approximately 50% of SOTs do not achieve adequate immunization coverage prior to transplantation, this may also reflect the under-vaccination of the general population, besides lack of time once patients are in transplant list. While a few medical reasons for under-vaccination may be challenging to overcome, strategies are needed to face other causes of under-vaccination, primarily consisting of parental and medical hesitancy and lack of specific protocols. Notably, a significant percentage of physicians are reluctant to recommend vaccination in the transplant setting. Although this issue has not been further investigated, specialists' hesitancy could be related to unexpectedly inadequate training or education on the safety and efficacy of vaccination in pediatric recipients. To this end, pediatric transplant centers should identify the main local barriers to immunization, provide and disseminate consistent and correct information regarding vaccines (i.e., through meetings, discussion, and clinician engagement), guarantee training and constant updating on the most recent evidence to their clinicians and invest resources (i.e., time, expertise, and money) to promote vaccinations. Furthermore, despite many institutions not directly administering their vaccinations because other healthcare providers are responsible outside, transplant centers could improve the under-vaccination issue by offering vaccination programs themselves.

Variable attention to immunization in the post-transplant setting is also evident in the survey. Almost all respondents administer inactivated vaccines, while MMR and varicella are not usually recommended except in rare cases in SOT recipients. After HSCT, revaccination is an established, reliable strategy for infection prevention.[4] During the first months after HSCT, the immunological response to vaccines of transplanted children is usually lower than healthy individuals of the same age, but it improves over time to become close to the standard by 2–3 years after transplant. Thus, even partial immunization is always better than no protection.[10] Much evidence exists regarding the safety of administering inactivated vaccines. Both for SOT and HSCT patients, inactivated vaccines could be administered from 3 months after transplantation, except for the influenza vaccine, which can be given as early as 1 month,[22] due to the absent risk of disease reactivation. However, most centers give inactivated vaccines between 4 and 8 months or even as late as 13 and 15 months after transplantation, exposing children to a higher risk of VPIs.

It is also interesting to notice that the serological status after SOT was declared to be investigated in less the half of cases, while the majority of centers did not performed any antibody search. It could be argued if an improvement toward this attitude would also increase the proportion of adequate immunization after transplant.[12,23]

Currently, LAVs are contraindicated under most immunosuppressive therapies because of the risk of vaccine-transmitted disease.[10,24] However, when no inactivated alternatives exist, the European Conference on Infections in Leukaemia group recommends varicella and MMR LAVs from 24 months after HSCT, only in seronegative patients with no graft-versus-host disease, no immunosuppressants, no relapse, and no recent administration of immunoglobulins.[10] Indeed, differently from SOT, HSCT patients may receive all vaccinations, including live attenuated viruses, after immune reconstitution and immunosuppressive therapy interruption.

SOT is still considered an absolute contraindication to LAVs by most centers and guidelines.[5] Only a few SOT centers report to administer LAVs in the post-transplant period (4 for MMR and 3 for VZV), at least 13–15 months after transplant. A further investigation shows that the main conditions for safe LAVs administration in SOT centers are time after transplantation and minimal immunosuppressive treatment (defined by a low tacrolimus level or a simple/double immunosuppressive agent low dose).

A comprehensive review stated insufficient robust evidence to change currently available recommendations for LAVs in SOT recipients.[5] However, accumulated data from an expert consensus meeting show that LAVs could be safely given to selected solid organ transplanted patients.[25] Remarkably, none in this survey reported adverse effects after LAVs administration over 20 years of experience.

Ideally, SOT patients should always receive LAVs before transplant. However, if it is not possible, selected "low-risk" patients, depending on the time after transplant and low-level immunosuppressive treatment, could receive LAVs later. Thus, until further data are available on LAVs under another immunosuppressive level, they should be administered only after a careful risk–benefit assessment, including the evaluation of the immune system.

Transplant recipients' healthcare workers and close contacts, such as family members, should be fully immunized, receiving the influenza vaccine annually.[12,26] This is also a valuable aspect that seems to be considered by most institutions, as the majority recommend influenza vaccine to family members indefinitely. However, healthcare workers'

influenza coverage still appears suboptimal, as only 6% of responders declare a vaccination coverage >80%. Therefore, any effort must be adopted to limit respiratory virus exposure in transplant recipients.[27]

Finally, it would be of great interest for future research to evaluate the burden of respiratory disease related to both RSV and influenza virus, comparing children receiving prophylaxis to those not receiving it in terms of rate of infections, the severity of symptoms and duration of hospitalization. As these pathogens can cause high morbidity also in previously healthy children, these data could lead to strong implementation of prophylaxis protocols for transplant recipients.

This survey was performed before COVID-19 vaccine license approval for the Pediatric population. It would be interesting further investigate the uptake of this vaccination in transplant recipients and the burden of SARS-CoV-2 infection both in the pre and post-transplant period, with a comparison to other well-known pediatric respiratory infections (such as RSV and influenza).

The value of this survey is considerable. It gives the first broad picture of the current attitude of many of the ERN-TransplantChild members toward immunization of pediatric patients before and after the transplantation throughout Europe. It shows that significant differences exist among centers regarding both the protocols of immunization and the practice of monitoring antibody titers. The detailed analysis of these gaps constitutes a starting point for increasing awareness of patient immunization in the field of pediatric transplantation and also for future planning of specific interventions by adopting and adapting clinical practice guidelines or other decision support tools under the umbrella of the ERN. Efforts are needed to overcome cultural and organizational barriers (such as physicians' hesitancy) that limit the immunizations of likely transplant candidates: increase guidelines uptake, improve the network between transplant centers and other healthcare providers involved in the administration of vaccines at the national level (e.g., primary and secondary care centers or general practitioners), and promote an accelerated immunization schedule to infants.

This study has several limitations, the first of which relies on the methodology of a survey-based study. Unfortunately, many centers did not respond to the survey, and the ones responding still represented a convenience sampling of respondents which can indeed limit the external validity and generalizability. Physicians answered this survey without clarifying whether the estimated proportion came up from personal knowledge or specific internal audit or reviews. Moreover, our results reflect the practices adopted by medical professionals, which, despite being implemented in large transplant centers, may not necessarily reflect the situation at the national level. In addition, since several centers do rely on primary care doctors to immunize, the estimate of unvaccinated children may be slightly different. Furthermore, limited data are available from HSCT programs. Their contemporary adhesion to other haemato-oncological international networks could explain their low rate of responses. Also, in several centers, national protocols state that vaccinations are the responsibility of provider organizations other than the transplant centers. It is unlikely that national programs will fully accommodate the special needs of children approaching or after transplantation.

5 | CONCLUSIONS

Despite the available scientific evidence on vaccine safety and efficacy, the immunization coverage of European pediatric transplant candidates and recipients is still sub-optimal/inadequate. The immunization of pediatric transplant recipients is critical to prevent the common and potentially life-threatening risks related to VPIs. This survey is a starting point for developing shared evidence-based immunization protocols for vaccination among pediatric transplant centers and generating new research studies.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available online at https://datastudio.google.com/reporting/df7becb9-41ef-4b04-973c-28729df1e4df and within the Supplementary material.

ORCID

Daniele Donà https://orcid.org/0000-0001-7105-2105
Luz Yadira Bravo-Gallego https://orcid.org/0000-0002-4919-5166
Olivia Boyer https://orcid.org/0000-0002-3957-1359
Luca Dello Strologo https://orcid.org/0000-0002-8237-852X
Jacek Toporski https://orcid.org/0000-0001-6012-0651
Jelena Rascon https://orcid.org/0000-0003-4420-6943

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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