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Solid organ transplantation in pediatric patients treated for cancer: a survey of European reference network centers

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Solid organ transplantation (SOT) may be considered for selected children with a previous or current malignancy. However, information on clinical practice in this setting is limited. This questionnaire-based study aimed to characterize current attitudes and clinical practices regarding pediatric SOT in cancer patients across European centers. Forty healthcare providers (HCP) from 21 European countries participating in the European Reference Network (ERN) TransplantChild were invited to complete a cross-sectional online survey. Participation was voluntary, and no patient-level data was collected. Twenty-six responses were received from 22 (55%) HCPs. Nearly all respondents (96%) reported that they would consider SOT for a child with a previous or current malignancy, although only 50% considered candidates with high estimated risk of recurrence eligible for SOT. Considerable variation was observed in approaches to transplant timing, donor selection, and immunosuppressive management. National guidelines were available in 45% of centers, and 45% reported institution-specific protocols. As a secondary descriptive component of the survey, participating centers reported 309 SOT procedures in pediatric patients with previous or current malignancy. European pediatric transplant centers broadly accept SOT in this population, but substantial variability in clinical practice highlights the need for multidisciplinary, evidence-based, organ-specific recommendations.

KEYWORDS

childhood cancer survivors, children, malignancy, outcome, pediatric transplantation

Introduction

Survival among children with cancer has significantly improved over recent decades [1–7]. Consequently, an increasing number of patients with current or previous malignancies are being considered for solid organ transplantation (SOT) [6–8]. These patients represent a heterogeneous population encompassing at least three clinically distinct scenarios: SOT performed as part of oncological treatment, SOT for end-stage organ failure secondary to previous cancer therapy, and SOT for organ failure unrelated to either the malignancy or its treatment [7, 9, 10]. Each of these scenarios presents distinct challenges regarding transplant indications, timing, assessment of recurrence risk, and post-transplant management. In selected cases, SOT may be incorporated into the oncological treatment plan itself, for example, liver transplantation in patients with primary liver malignancies such as hepatoblastoma or hepatocellular carcinoma or kidney transplantation following bilateral nephrectomy in patients with bilateral Wilms tumor, for which disease-specific treatment approaches have been established [11, 12].

Despite increasing clinical experience, contemporary practices regarding SOT in children with current or previous malignancy remain poorly characterized. The overall utilization of SOT in this population is difficult to assess because registry data often classify the underlying cause of organ failure using broad or non-specific categories. Furthermore, there is limited evidence to guide clinical decision-making regarding candidate selection, donor choice, timing of transplantation, and immunosuppressive management.

Active malignancy is generally considered as a contraindication to SOT, whereas the management of patients following successful cancer treatment remains less clearly defined. Currently, there are no formal guidelines for transplantation after cancer treatment in pediatric patients. A recent European Society for Pediatric Nephrology/European Renal Association (ESPN/ERA) Registry-based study indicates that access to kidney transplantation among childhood cancer survivors is lower compared with other candidates, and available data on patient and graft survival outcomes are still inconsistent [7, 8, 12–14]. Consequently, clinical practice is likely to vary considerably between centers.

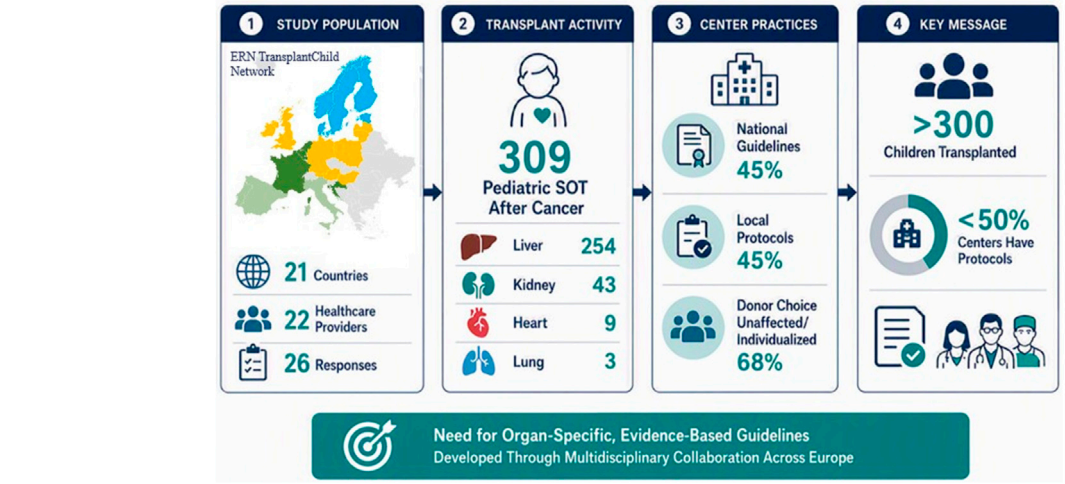
The primary aim of this study was to assess current attitudes and practices regarding SOT in children with a history of cancer among members of the European Reference Network (ERN) on Transplantation in Children (TransplantChild), and to identify areas of consensus, inter-center variability, and unmet needs that could be addressed through the development of standardized, evidence-based protocols. A secondary aim was to descriptively report transplant activity and center reported oncological outcomes in this patient population.

Materials and methods

This questionnaire-based survey did not involve the collection of patient-level data and patients were not contacted. In accordance with current regulations, ethical approval was not required.

The ERN TransplantChild is a network comprising healthcare providers (HCP) involved in SOT and hematopoietic stem cell transplantation (HSCT) across Europe. The network includes 40 healthcare providers (HCP) across 21 European countries, of

Abbreviations: AST, American Society of Transplantation; ERA, European Renal Association; ERN, European Reference Network; ESPN, European Society for Pediatric Nephrology; HCP, Healthcare providers; HSCT, Hematopoietic stem cell transplantation; ISHLT, International Society for Heart and Lung Transplantation; KDIGO, Kidney Disease: Improving Global Outcomes; OA, Operational area; SOT, Solid organ transplantation.



GRAPHICAL ABSTRACT

which 33 are Full Members (fully validated and integrated into the ERN) and seven are Affiliated Partners (collaboration with the ERN with a more limited role). The HCPs represented between one and five transplant programs each, including solid organ transplantation (SOT) and hematopoietic stem cell transplantation (HSCT) programs. TransplantChild is organized into four Operational Areas (OAs), each grouping member HCPs by geographic region: OA1 (Northern Europe) includes Denmark, Estonia, Finland, Norway, and Sweden; OA2 (Central and Eastern Europe) Austria, Germany, Hungary, Ireland, Latvia, Lithuania, and Poland; OA3 (Western Europe) Belgium, Croatia, France, Luxembourg, and the Netherlands; OA4 (Southern Europe) Italy, Malta, Portugal, and Spain. Network activities are carried out through six Working Groups, each dedicated to a specific strategic domain.

The present study was carried out by the Clinical Audits Working Group which developed and approved a cross-sectional questionnaire (https://transplantchild.eu/wp-content/uploads/Survey-SOTafterPaediatricCancer.pdf). All 40 full member and affiliated partner HCPs of the ERN offering SOT and/or HSCT programs were invited to participate in an online survey conducted between July 3 and November 30, 2024. The study did not involve any patient data, and no patients were contacted during its conduct.

The survey consisted of questions grouped into five sections:

1. Characteristics of each HCP and transplant program and the existence of national guidelines concerning SOT with previous or current malignancy;
2. Individual criteria on the eligibility of children with previous or current malignancy as potential SOT recipients;
3. Principles guiding donor selection for recipients with previous or current malignancy;
4. Number of transplanted patients, by organ (kidney, liver, heart, lung, intestine), with a history of cancer;
5. Time frame and clinical details of transplants performed after the year 2000.

The questionnaire was developed by a multidisciplinary group with expertise in pediatric oncology and transplantation to map contemporary clinical practice across participating centers. The questionnaire did not undergo formal validation, including pilot testing or assessment of face validity and inter-rater reliability. The questionnaire was designed primarily to characterize current clinical practices, attitudes, and decision-making processes regarding SOT in children with a history of cancer and to identify areas of consensus and inter-center variability. Collection of transplant activity data and reported oncological outcomes was intended as a secondary descriptive component and was not based on patient-level data.

Results

Background information on respondent

A total of 26 survey responses were received from 22 of the 40 affiliated healthcare providers (HCPs), corresponding to an overall response rate of 55%. These responses represented 44 solid organ transplantation (SOT) programmes out of the 96 SOT programmes available across the network, corresponding to programme coverage of 45.8%. The completion rate varied across survey items, with response rates ranging from 30% to 100%. (Supplementary Table S1). Several items were conditional and therefore applicable only to a subset of participating centres, which explains the lower response rates observed for some questions related to clinical experience and post-transplant

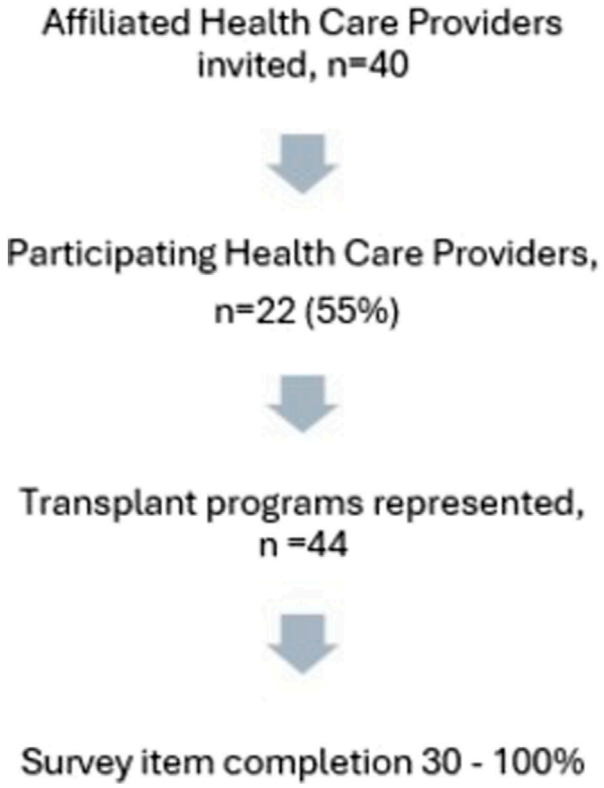


FIGURE 1
Flowchart of survey participation. Of 40 affiliated healthcare providers (HCPs), 22 participated in the survey (response rate 55%), providing 26 survey responses representing 44 solid organ transplantation (SOT) programs. Completion rates for individual survey items ranged from 30% to 100%.

outcomes. Response rates differed across geographic regions: OA1 had a response rate of 50% (4/8); OA2 13% (1/8); OA3 78% (7/9); and OA4 73% (11/15) (Figure 1).

The HCPs that responded to the survey reported the following active transplant programs: kidney in 16/22 (73%), liver in 12/22 (55%), heart in 8/22 (36%), lung in 4/22 (18%), and intestinal in 4/22 (18%) of the HCPs (Table 1). One of the HCPs performed HSCTs in addition to SOT programs. Twenty-one of the 26 (81%) of the respondents were pediatricians, 4 (15%) were transplant surgeons, and one (4%) was a transplant coordinator.

Attitudes toward SOT in children with a history of cancer

Eighteen of the 22 HCPs (81.8%) had performed SOT in pediatric patients either following a previous cancer diagnosis or as part of an oncological treatment. Nine HCPs (41%) had transplanted only patients with solid tumors, while an additional 10 HCPs (45%) had performed transplants in patients with both solid tumors and hematological malignancies, including those who had undergone HSCT. Overall, 21/22 (96%) transplant HCPs stated that they would consider SOT for a child with a prior cancer diagnosis, whereas only 11/22 (50%) considered patients with a high estimated risk of cancer recurrence to be eligible candidates for SOT. Three HCPs (14%) had not had transplant candidates in this patient group. Among HCPs that had not performed SOT in pediatric cancer patients, this was attributed to the absence of suitable candidates rather than to other reasons.

Donor selection, recipient assessment, and immunosuppressive strategies

Donor selection practices varied across centers (Table 2). Fifteen of the 22 HCPs (68%) reported that a cancer diagnosis did not routinely influence donor selection, although decisions were individualized considering the patient's cancer history. Two HCPs (9%) accepted only deceased donors in this setting, whereas two (9%) preferentially selected donors with lower HLA mismatch to potentially limit immunosuppressive exposure. The questionnaire did not specifically distinguish donor selection practices between recipients with a previous malignancy and those with a current malignancy. Therefore, responses regarding donor selection represent general center-level approaches to transplantation in pediatric patients with previous or current malignancy.

Approaches to transplant timing differed substantially. Half of the responding centers (11/22, 50%) based transplantation on an estimated

TABLE 1 Summary of solid organ transplants in children with cancer.

Category	Kidney	Liver	Heart	Lung	Intestine
Number of centers performing SOT, n (%)	12 (55)	10 (45)	8 (36)	4 (18)	4 (18)
Total number of SOTs performed, n	43	254	9	3	0
Indication of SOT, n (%)					
Cancer treatment–related	7 (16)	218 (86)	0	0	0
Organ failure from cancer treatment	12 (28)	12 (5)	7 (78)	2 (67)	0
Unrelated to cancer or treatment	24 (56)	24 (9)	2 (22)	1 (33)	0
Cancer recurrence (primary malignancy), n (%)	1 (2)	42 (17)	0	—	—
Secondary malignancy after SOT, n (%)	4 (9)	2 (0.8)	0	—	—
Retransplantation due to secondary malignancy, n (%)	3 (7)	2 (0.8)	0	0	0

SOT, solid organ transplantation.

TABLE 2 Summary of clinical practices and guideline awareness for solid organ transplantation after childhood cancer.

Category, n (%)	Findings
HCPs with specific SOT guidelines after childhood cancer	4 (18)
Effect of prior cancer on donor selection	
No effect, or individualized to clinical needs	15 (68)
Only deceased donors accepted	2 (9)
Low HLA-mismatch donors prioritized	2 (9)
Timing of SOT after cancer diagnosis	
Based on recurrence risk	11 (50)
Decision case-by-case	11 (50)
Use of modified/individualized immunosuppression	22 (100)
HCPs aware of national guidelines	10 (45)
HCPs with institutional protocols including cancer-related SOT guidance	6 (27)
HCPs with center-specific guidelines in absence of national ones	4 (18)
Professionals willing to consider SOT for a child with prior cancer	21 (96)

HLA; Human leukocyte antigen, HCP; Health care provider, SOT; Solid organ transplantation.

cancer specific relapse-free time, whereas the remaining 50% of the HCPs adopted a case-by-case approach based on individual patient factors without a predefined minimum waiting period.

All participating HCPs reported using modified or individualized immunosuppressive strategies for recipients with a history of cancer, although detailed protocol information was not collected.

Guideline awareness and institutional protocols

Overall, guideline availability was limited and heterogeneous across HCPs. Ten of the 22 respondents (45%) reported being aware of national guidelines concerning SOT in pediatric patients with a history of cancer. Of these, six HCPs indicated that their institution-specific SOT protocols included guidance on transplantation in this population. Four HCPs reported having center-specific guidelines in the absence of national recommendations.

Transplant activity and reported oncological outcomes

As a secondary descriptive component of the survey, participating centers reported aggregated data on transplant activity and post-transplant oncological events in children with a previous or current malignancy. These data were collected at the center level and were not supported by patient-level follow-up information.

The responding centers reported a total of 309 SOTs performed in children with a previous or current malignancy, including 43 kidney, 254 liver, 9 heart, and 3 lung transplants (Table 1). No intestinal transplants were reported in this patient population.

The indication for transplantation varied according to organ type. Transplantation directly related to cancer treatment was reported 7 (16%) kidney and 218 (86%) liver transplant recipients, while none of the heart or lung transplants were performed for this indication. Organ failure secondary to cancer treatment was reported in 28% kidney, 5% of liver, 78% of heart, and 67% lung transplant recipients. In the remaining cases, organ failure was unrelated to either malignancy or its treatment.

Data on post-transplant oncological events were available from 11 of the 12 kidney-transplanting HCPs, 9 of the 10 liver-transplanting HCPs, and all 4 heart-transplanting HCPs. Based on center-reported aggregate data, recurrence of primary malignancy was reported in one kidney transplant recipient (2% of the reported kidney transplants) and 42 liver transplant recipients (17% of the reported liver transplants), while no recurrences were reported following heart transplantation.

Data regarding secondary malignancies were provided by all kidney-, liver-, and heart-transplanting HCPs, and by three of the four lung transplantation performing HCPs. Centers reported secondary malignancies in 4/43 kidney transplant recipients (9%) and 2 of 254 liver transplant recipients (0.8%). Retransplantation due to secondary malignancy was reported in 3/43 kidney recipients (7%) and 2/254 liver transplant recipients (0.8%).

Because these findings were derived from center-level reports without access to patient-level data, follow-up duration, or outcome adjudication, they should be interpreted as descriptive observations rather than estimates of oncological risk following transplantation.

Discussion

This study provides a multinational overview of clinical practice regarding SOT in children with a previous or current malignancy among participating TransplantChild centers. The principal findings are that most responding HCPs consider transplantation

a feasible treatment option for selected patients with a cancer history, but substantial variation exists regarding transplant eligibility, timing, donor selection, and post-transplant management. Furthermore, national and center-specific guidance remains limited, suggesting that many decisions continue to rely on individual center experience and multidisciplinary case-by-case assessment.

The expanding population of childhood cancer survivors has brought increasing attention to the long-term health consequences of oncological diseases and therapies. These patients carry an elevated lifelong risk of chronic and sometimes progressive organ dysfunction due to the combined effects of their disease and its treatment [9]. Although many late effects can be managed conservatively, a subset of patients eventually develop end-stage organ failure, for which SOT may become a necessary therapeutic option. Deciding whether to transplant individuals with a previous or current malignancy is challenging, as it requires balancing the risk of death without transplantation, the risk of cancer recurrence or new malignancy after transplant, and the need to ensure appropriate use of donor organs in contexts of organ shortage. Mechanical organ support may be required as a bridge to organ transplantation; consequently, when transplantation is not feasible in a cancer patient, initiation of dialysis or other mechanical support may not be clinically warranted.

A key finding of this survey was that despite the broad acceptance of SOT as a therapeutic option in children with a previous or current malignancy, considerable variability exists in clinical decision-making across centers. Half of the responding centers reported using estimated relapse-free survival when determining transplant timing, whereas the remaining centers relied primarily on individualized assessments without predefined waiting periods. Similarly, although most centers reported that a history of malignancy did not influence donor selection, a minority applied additional restrictions or preferences regarding donor type or HLA matching. These findings suggest that substantial differences in practice persist despite broad agreement that transplantation can be offered to selected patients.

The observed variability is likely explained, at least in part, by the paucity of pediatric-specific recommendations. Consistent with this knowledge gap, fewer than half of participating centers reported awareness of national guidance, and only a minority reported center-specific protocols. In adult patients, several guidelines and consensus documents are available, including the 2021 American Society of Transplantation (AST) Consensus Statement, the 2024 International Society for Heart and Lung Transplantation (ISHLT) Heart Transplant Candidate Guidelines, and the 2020 Kidney Disease: Improving Global Outcomes (KDIGO) Kidney Transplant Candidate Guidelines [15–17]. In the pediatric setting, disease-specific consensus recommendations and authoritative reviews support liver transplantation as an integral part of curative oncologic therapy for selective hepatic malignancies, particularly unresectable hepatoblastoma and some cases of pediatric hepatocellular carcinoma, even in the absence of liver dysfunction [18, 19].

Conversely, no formal pediatric guidelines specifically address children who develop end-stage organ failure following cancer treatment, and decisions remain largely institution-dependent and based on expert opinion. These gaps underscore the need for dedicated pediatric guidelines, which would help to harmonize clinical practice across transplant programs (an aim that is also consistent with the objectives of the ERNs), while ensuring more uniform and evidence-based care for this complex patient population.

A notable finding of this survey was the heterogeneity of the clinical scenarios in which transplantation was considered. Reported SOT procedures included transplantation performed as part of curative oncologic treatment, transplantation for organ failure resulting from cancer therapy, and transplantation for organ failure unrelated to either the malignancy or its treatment. These clinical scenarios differ substantially with respect to transplant indications, recurrence risk, timing considerations, and assessment of transplant candidacy, and should therefore not be regarded as a single clinical entity. Some of the observed inter-center variation may be attributable to differences in the underlying patient populations treated at participating centers rather than to differences in clinical practice alone. This heterogeneity should be taken into consideration when interpreting the survey findings.

Among centers that had performed SOT in pediatric patients with a previous or current malignancy, solid tumors were the most common indication, followed by hematological malignancies, including cases previously treated with HSCT. Except for cases of liver transplantation performed as part of curative therapy for hepatic malignancies, in which transplantation was undertaken in the absence of organ dysfunction, the contribution of cancer treatment to organ failure varied markedly across organs. Cancer treatment-related organ failure was common among heart and lung transplant recipients, less frequent among kidney, and relatively uncommon among liver recipients. In the remaining cases, organ failure occurred independently of the malignancy or its treatment. Comparing our findings with previously published data, the Canadian study reported a similar distribution of solid and hematological tumors, but it did not examine the etiological pathways to organ failure nor provide information on how transplant candidacy or timing were determined [14]. The ESPN/ERA study described only broad categories leading to kidney failure, without distinguishing treatment-related from unrelated causes, and did not report underlying cancer types or offer insight into how centers determine the timing of SOT after cancer, underscoring the absence of standardized decision-making frameworks in the pediatric setting [7].

As a secondary descriptive component of the survey, participating centers reported more than 300 transplant procedures in children with previous or current malignancy. Although these aggregate data cannot be used to estimate incidence rates, they illustrate that transplantation in this patient population is encountered across multiple pediatric SOT programs. Similar observations have been reported in registry-based studies from Europe and North America, which indicate that, although only a small proportion of childhood cancer survivors ultimately require SOT, these procedures are not merely anecdotal and are relevant to pediatric transplant practice [7, 8, 14].

The variability observed in SOT timing likely reflects the absence of pediatric guidance. Across existing guidelines, the AST Consensus Statement provides the most detailed, tumor-specific

recommendations, including recurrence-risk categorizations and suggested waiting times before transplantation [15]. The ISHLT guidelines provide broader transplant criteria with a dedicated section outlining when different malignancies constitute absolute or relative contraindications and the advisable interval after remission, although their scope is limited to heart transplantation [16]. A recent recommendation of the International Society of Liver Transplantation and the Spanish Society of Liver Transplantation consensus conference states that if the 5-year oncological survival rate is at least 50%, no predetermined waiting time recommendation can be given to children with pre-transplant malignancy [20]. KDIGO provides general principles for evaluating transplant candidates with a history of cancer, focusing on multidisciplinary assessment and appropriate cancer-free periods, but without tumor-specific timing, and its recommendations apply only to kidney transplantation [17]. The European best practice recommendation suggests a 2-year waiting period between cancer treatment and kidney transplantation [21]. As a result, clinicians are often required to make difficult decisions regarding whether and when to proceed with transplantation in cancer survivors without structured guidance, relying largely on individual judgment or local experience. Moreover, no cross-cutting recommendations applicable to all solid organs exist, particularly for pediatric patients, leaving a substantial gap in standardized practice.

Regarding donor selection, most respondent centers reported that a recipient's prior cancer diagnosis did not alter their standard approach, with only a few centers restricting such cases to deceased donors or preferentially selecting low–HLA-mismatch donors to minimize immunosuppressive burden. This approach is consistent with the existing guidelines, which provide no recommendations on donor selection for recipients with a prior malignancy and do not suggest that donor choice should be modified based on the recipient's cancer history [15, 16]. However, all participating centers reported adapting or individualizing immunosuppressive regimens for pediatric recipients with a history of cancer, a practice that mirrors the limited guidance provided by existing guidelines, which offer high-level principles, without detailed indications or specific protocols, particularly for children [15, 16]. Indeed, even in the absence of explicit recommendations from guidelines, reducing immunosuppression in transplanted patients with a history of cancer appears to be a broadly accepted, common-sense practice, given that the development of malignancies is a well-recognized long-term consequence of immunosuppressive therapy [22, 23].

The survey also collected center-level information on post-transplant oncological events. Because no patient-level data, follow-up information, or standardized outcome definitions were available, these findings should be interpreted as descriptive observations only and not as estimates of recurrence risk or long-term oncological outcomes. Nevertheless, these survey-derived observations are broadly consistent with and complement existing pediatric registry studies, which generally suggest favorable oncological outcomes following transplantation in carefully selected patients [7, 14]. Further registry-based and disease-specific studies are needed to better define long-term risks.

This study has some limitations. First, the overall response rate was moderate (55%), with substantial variation across operational areas (13%–78%), which may have affected the representativeness of the findings. Furthermore, because this was a questionnaire-based survey rather than a registry-based study, recall bias and errors resulting from incomplete records or inaccurate reporting cannot be excluded. Nevertheless, responses were obtained from centers performing transplants across all SOT categories. Responses were received from 11 European countries, providing a multinational overview of current clinical practices and perspectives among transplant centers across Europe. Second, the questionnaire was sent to representatives of each center, and it is not known whether responses reflected formal institutional policies or personal views of the respondent. Furthermore, some key terms were not predefined, and differences in their interpretation may have contributed to the observed inter-center variability. Third, the survey did not distinguish between transplantations performed as part of cancer treatment, transplantations for treatment-related organ failure, and transplantations for organ failure unrelated to either malignancy or its treatment. Because these clinical scenarios differ substantially with respect to indication, recurrence risk, timing considerations, and transplant candidacy, the findings should be interpreted within the context of this heterogeneity. Finally, the primary objective of this study was to characterize practices, attitudes, and decision-making processes regarding SOT in children with previous or current malignancy and to identify areas of consensus and variability across centers. The descriptive data concerning transplant activity and reported oncological outcomes were secondary components of the survey and should be interpreted cautiously.

In conclusion, this survey demonstrates broad acceptance of SOT as a treatment option for selected pediatric patients with previous or current malignancy across European transplant centers. However, there appears to be considerable variability in clinical practice. Our results suggest that there is a need for organ-specific guidelines for SOTs among pediatric cancer patients, developed collaboratively by transplant surgeons, pediatricians involved in SOT, and pediatric oncologists to support clinical decision-making and harmonize practice across centers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This questionnaire-based survey did not involve the collection of patient-level data and patients were not contacted. In accordance with current regulations, ethical approval and written informed consent were not required.

Author contributions

TJ and EB are first co-authors who equally contributed to the manuscript. All authors participated in the survey and reviewed the manuscript. LB-G provided the data analysis. The paper was written on behalf of ERN TransplantChild. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/ti.2026.16920/full#supplementary-material

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