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SUPPLEMENT ARTICLE

Pre-Transplantation Strategies for Infectious Disease Mitigation and Prevention

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Pediatric Infectious Disease (ID) clinicians play a critical role in helping prevent and mitigate infectious risks in children peri- and post-transplantation. Prevention starts during the pre-transplant evaluation and persists throughout the solid organ transplant and hematopoietic cell transplant continuum. The pre-transplant evaluation is an opportunity to screen for latent infections, plan preventative strategies, optimize immunizations, and discuss risk mitigation practices. An ideal pre-transplant evaluation establishes a relationship with the family that further promotes post-transplant infectious risk reduction. This manuscript builds on shared pediatric ID prevention strategies, introduces updated ID testing recommendations for transplant donors/candidates, highlights emerging data, and identifies ongoing knowledge gaps that are potential areas of research.

Key words. hematopoietic cell transplantation; pediatric; pre-transplant evaluation; prevention; safe living; screening; solid organ transplantation; vaccination.

PRE-TRANSPLANT SCREENING FOR INFECTIONS

Infections continue to be a frequent cause of morbidity and mortality after solid organ transplant (SOT), arising from the candidate's own flora, the donor organ/accompanying cells, or acquired from the environment [1]. With broader indications for hematopoietic cell transplant (HCT), increasing use of cellular immunotherapies, and more immunosuppressive chemotherapies, infections remain one of the most frequent causes of non-relapse-related death after pediatric HCT [2, 3]. In both SOT and HCT, the risk for and type of infection is variable and influenced by host, transplant, and pathogen-specific factors, environmental exposures, and the magnitude of immunosuppression. Risk assessment involves a detailed history, including prior infections, known colonization, and pre-transplant Pediatric Infectious Disease (ID) screening to evaluate for infections that may increase the risk of post-transplant complications. This assessment guides the implementation of appropriate mitigation and both peri and post-transplant prophylaxis strategies. Recommended ID laboratory screening tests in SOT and HCT candidates and donors are summarized in Table 1; additional testing may be necessary based on a candidate's age and epidemiologic exposures.

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Donor-Derived Infections (DDI)

Infections from a donor can either be anticipated, such as cytomegalovirus (CMV) in seropositive donors, or unexpected, occurring more frequently after deceased organ transplantation [4]. Along with prescribed ID laboratory screening of donors, standardized questions are asked of family members of potential deceased donors to assess risk for other infections [5–7]. In the United States, policies for the type and timing of tests for organs and tissues are mandated by the Organ Procurement and Transplantation Network (OPTN) for SOT and U.S. Department of Health and Human Services and Food and Drug Administration (FDA) for HCT [1, 5]. Unexpected SOT transmissions are reported to the OPTN for review by the ad hoc Disease Transmission Advisory Committee (DTAC). A contemporary 10-year review found that while unanticipated DDI were rare (0.18% of all recipients), infections were the most frequently reported transmission event after SOT (67% of all reports), resulting in disease in 46% of recipients within 30–45 days post-SOT [1]. Pediatric organ donors and recipients were less frequently involved in unanticipated disease transmissions [8].

Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV), and Hepatitis C Virus (HCV) DDI

The opioid epidemic and associated increases in overdose-related deaths uncovered a bittersweet benefit by decreasing some of the gaps in the availability of organs for SOT. Individuals who died from drug overdoses were more likely to be younger adults without medical comorbidities precluding organ donation; however, the mean organ yield was lower because of concerns for possible HIV, HBV, and HCV DDI [9–11].

Table 1. Recommended Routine Infectious Diseases Screening in Pediatric Solid Organ (SOT) and Hematopoietic Cell Transplantation (HCT) Donors and Candidates [2, 7, 86, 87]

Required Testing For	Recommended Test	SOT [2]			HCT [7, 88]		Pediatric Considerations([a])
		Deceased Donor	Living Donor	Candidate	Donor	Candidate	
CMV	CMV IgG	x	x	x	x	x	In infants <12 months of age, CMV urine PCR (or saliva CMV PCR, if + confirmed by urine CMV PCR) is recommended
EBV	EBV antibody test	x	x	x		x	
HIV([b])	HIV Ab *or* HIV Ag/Ab combination and HIV NAT	x x	x x	x x	x x (HIV 1&2)	x x	
Hepatitis B virus (HBV)*	HBV surface Ag, HBV core Ab (total), and HBV NAT	x x	x x	x x	x x	x x	
	HBV surface Ab			x			
Hepatitis C virus (HCV)*	HCV antibody and HCV NAT	x x	x x	x x	x x	x x	
HSV	HSV 1 and 2 IgG	x	x	x	x	x	
SARS-CoV-2	SARS-CoV-2 NAT upper respiratory tract([c])	x	x	x		x	SARS-CoV-2 NAT from lower respiratory specimens is required for all lung grafts
Syphilis	Syphilis diagnostic test([d])	x	x	x	x	x	
Toxoplasmosis	*T. gondii* IgG	x	x	x	*If risk*	x	
Additional infectious disease screening that *may* be performed based on risk assessment, epidemiologic exposures, and graft-dependent factors, or transplant center-specific requirements							
Coccidioides	Coccidioides serology	+	+	+		+	Screen in living D or R with risk factors ([e])
Human T-lymphotropic virus (HTLV)	HTLV, types I and II	+			+	+	
HHV-8	HHV-8 serology in at risk persons([f])	+	+	+			No clear data to guide testing in children
Malaria	Malaria NAT if risk factors	+	+	+	+	+	Risk factors include birth or long-term residence in a malaria-endemic area, history of prior malaria, or travel to endemic area in the past 2–3 years.
Schistosomiasis	Schistosoma IgM/IgG; if symptomatic or positive serologic screening, ova examination of urine and stool		+	+			Screen D or R with risk factors, including residence, travel, and exposure to fresh water in endemic areas in the past 5 years.
Strongyloides	*Strongyloides* IgG	+	+	+	+	+	
Trypanosoma cruzii (Chagas)	*T. cruzii* serology	+	+	+	+	+	Screen D or R with risk factors. Screen infants born to mothers from an endemic area or family history of Chagas
Tuberculosis	Tuberculin skin test *or* Interferon Gamma Release Assay (IGRA)		+	+		+	IGRA can be used for tuberculosis screening in candidates ≥2 years of age; a tuberculin skin test (TST) can be considered in children <2 years old

Table 1. Continued

Required Testing For	Recommended Test	SOT [2]			HCT [7, 88]		Pediatric Considerations([a])
		Deceased Donor	Living Donor	Candidate	Donor	Candidate	
West Nile virus (WNV)	WNV serology *or* WNV NAT (seasonal)		+ (Seasonal)	+	+ (Living donor)	+	
Zika virus	Zika NAT				+		

Ab, antibody; Ag, antigen; Ag/Ab, antigen/antibody combination test; IGRA, interferon gamma release assay (includes Quantiferon-TB or TSPOT-TB assays in the United States); IgG, immunoglobulin G; NAT, nucleic acid test; RNA, ribonucleic acid.

[a] As with all serologic testing in children, caution is recommended in the interpretation of serology results, including false positive serologies (eg, in infants ≤12–15 months of age from passive transplacental maternal antibody, children who have received multiple blood products or immunoglobulin supplementation) and false negative serologies (eg, in patients who are severely immunocompromised, have hypogammaglobulinemia, or have received CD20 monoclonal antibodies in the preceding 6–9 months). It is prudent to defer assignment of highest risk categories and management when testing is inconclusive, in discussion with families and transplant teams.

[b] HIV, HCV, and HBV testing pre-SOT should be obtained at least: 28 days before organ procurement in living donors, 96 hours before organ procurement in deceased donors, once listed in all children of any age and again in children ≥12 years of age at the time of hospital admission for SOT, before implantation, and within 30 days of planned HCT. In addition, HIV, HBV, and HCV NAT are recommended at 4–6 weeks after SOT and at any time if signs and symptoms of viral hepatitis develop, even if previous tests were negative.

[c] Deceased SOT donors: SARS-CoV-2 PCR performed on nasopharyngeal sample within 72 hours and as close as possible to organ procurement. If lungs are recovered, SARS-CoV-2 PCR from both the upper and lower respiratory tract compartments should be obtained. SARS-CoV-2 testing should be performed on symptomatic SOT candidates and living donors; pre-transplant screening recommendations for asymptomatic SOT living donors and candidates are suggested and may vary by local transplant center policy and epidemiology. HCT candidates should undergo screening with SARS-CoV-2 PCR in respiratory specimens ≤48–72 hours before the start of HCT conditioning/lymphodepletion [6].

[d] Syphilis testing should be an FDA-cleared screening test, including: fluorescent treponema antibody absorption (FTA-ABS), *T. pallidum* particle agglutination (TPPA), *T. pallidum* enzyme immunoassay (TP-EIA), rapid plasma regain (RPR), venereal disease research laboratory (VDRL) in SOT; for HCT, additional anti-*T. pallidum* assays are acceptable (refer to: https://www.fda.gov/vaccines-blood-biologics/complete-list-donor-screening-assays-infectious-agents-and-hiv-diagnostic-assays).

[e] *Coccidioides* species are endemic in the southwestern United States (UNOS region 5) and south central Washington, areas of Mexico adjacent to the U.S. border, and regions of Central and South America. Consider screening transplant candidates and living donors who reside or travel to endemic areas.

[f] HHV-8 seroprevalence is higher in individuals from certain geographic areas (eg, sub-Saharan Africa, Middle East, and Mediterranean countries).

However, with a better understanding of risk factors for undetected DDI, improved testing strategies in both donors and recipients and availability of highly effective direct-acting antiviral treatments, the risk of dying while on the organ waitlist exceeds the very low risk of infection transmission. In 2020, the U.S. Public Health Service (PHS) updated its previous 2013 guideline recommendations, revised risk criteria, removed associated risk labels, and recommended universal nucleic acid testing (NAT) in all donors. These changes narrowed the window period for detecting new HIV, HBV, and HCV infections pre- and post-SOT, regardless of donor risk criteria or age [12]. United Network for Organ Sharing (UNOS), OPTN, and DTAC continue to monitor outcomes with the aim of balancing the safety of SOT while simultaneously optimizing the donor pool. The American Society of Transplantation (AST) ID-Community of Practice (IDCOP) guidelines are available to guide antiviral prophylaxis, treatment, and viral monitoring recommendations [13].

Herpes Viruses: Cytomegalovirus (CMV), Epstein Barr Virus (EBV), Herpes Simplex Virus (HSV), and Varicella (VZV)

CMV infection is a frequent cause of complications after transplantation, from both direct viral and indirect effects of infection or treatment; guidelines for CMV management in both SOT and HCT recipients are available [14–16]. Pretransplant CMV donor (D) seropositive, recipient (R) seronegative (D+/R) status in SOT, and recipient CMV seropositive (R+) in HCT remain the most important predictors of post-transplant CMV infection. A prophylaxis strategy involving either antiviral prophylaxis prescribed to high-risk D/R or a pre-emptive strategy that requires viral surveillance and starting antivirals upon CMV detection can be chosen during the pre-transplant evaluation. Ganciclovir or valganciclovir prescribed as prophylaxis or pre-emptive therapy have reduced the burden of CMV disease in high-risk SOT recipients [14]. However, several knowledge gaps remain in children, including defining the optimal prophylaxis strategy and how to effectively and safely dose valganciclovir [17]. A pre-emptive strategy had been the mainstay of CMV prophylaxis among HCT recipients but recently letermovir, a CMV terminase inhibitor with a more favorable side effect profile, was approved as primary prophylaxis in CMV seropositive allogeneic HCT recipients ≥18 years of age [16, 18, 19]. An open-label, pharmacokinetic and pharmacodynamic study of letermovir in children 12–18 years of age, with planned age de-escalation to infants, is currently enrolling subjects (ClinicalTrials.gov identifier: NCT03940586).

Application of CMV-specific T-cell immunity panels to quantify both CD4+ and CD8+ T-cell responses to CMV antigens have been investigated as potential surrogates of protection against CMV, informing the need for and duration of antiviral prophylaxis in adult SOT and HCT recipients [20–22]. However, the performance characteristics and utility of these assays across all pediatric age groups require further study [23]. A prospective, observational trial evaluating CMV-specific T-cell responses among pediatric heart, liver, and kidney recipients in the first year post-SOT is underway (ClinicalTrials.gov identifier: NCH03924219). Adoptive CMV-specific T-cell immunotherapies are being used for prophylaxis in adult HCT recipients [24–26]. Though promising, viral adoptive immunotherapies require additional controlled studies to evaluate the

safety and efficacy of prophylaxis or pre-emptive therapies in pediatric transplant recipients.

Epstein Barr virus (EBV) disease. including post-transplant lymphoproliferative disorder (PTLD), is more frequently a problem after pediatric than adult SOT. The risk is highest after SOT if EBV D+/R− and after HCT if unrelated donor, cord, or T-cell depleted grafts are used [27]. It is critical that families understand that EBV-PTLD can range from a self-limited mononucleosis-like syndrome to a fulminant disease process, including lymphoma. EBV consensus guidelines for SOT have recently been published [28–31].

Both SOT and HCT candidates are screened for HSV and VZV, and if seropositive for either, many transplant centers will employ antiviral prophylaxis to prevent reactivation early after transplantation and with augmented immunosuppression for the treatment of rejection or graft-vs-host disease (GVHD).

Parasitic Infections

The Centers for Disease Control and Prevention (CDC) has estimated that 11% of the U.S. population ≥ 6 years old have been infected with the parasite *Toxoplasma gondii* [32]. Given the proclivity of *T. gondii* to affect cardiac muscle, D+/R− heart transplants are at the highest risk for transmission. However, DDI with toxoplasmosis have also occurred from non-heart grafts and donors not previously identified as high risk [33]. In 2017, OPTN policy 2.9 required that all donors undergo universal *Toxoplasma* IgG screening [34]. The AST IDCOP guidelines recommend risk stratification to identify recipients in whom prophylaxis with trimethoprim/sulfamethoxazole (TMP/S) is recommended (heart, D+/R−) or considered (non-heart, D+/R−) [35]. In contrast to SOT where reactivation in R+ is infrequent, most cases of toxoplasmosis after HCT occur as a result of reactivation of latent *T. gondii* infection in R+ allogeneic HCT recipients [36–38]. Although there is significant variability among type and duration of prophylaxis across adult and pediatric SOT and HCT centers, TMP/S prophylaxis remains the cornerstone for toxoplasmosis prevention [35, 39].

Given the prevalence of parasitic infections globally, coupled with increasing population movement and broader organ distribution, practitioners must be aware of parasitic DDI and implement appropriate treatment strategies. Infections caused by the *Strongyloides stercoralis* and *Trypanosoma cruzi,* causing Chagas disease, are the 2 most frequent causes of unanticipated proven or probable parasitic DDI reviewed by DTAC. Immunocompetent donors are frequently asymptomatic, but the infection becomes pathogenic when transplanted into an immunosuppressed recipient.

Strongyloides is an underestimated global public health problem, known to be most prevalent in the tropics and subtropics of Africa, Asia, and Latin America, but also endemic in the United States in the Appalachian region, southeastern, and mid-Atlantic states [40]. In 2023, OPTN DTAC proposed universal screening of deceased donors with a *Strongyloides* antibody test which is anticipated to be implemented as policy by 2024 [41]. If the donor screens positive, there is no need for SOT deferral as *Strongyloides* in the recipient can be prevented with ivermectin prophylaxis [42]. SOT living donors and candidates with risk factors who are screened and test positive, should also be treated with ivermectin before transplant.

Recipients of organs from a *T. cruzi*-infected donor are at risk of infection, with risk highest in heart grafts. OPTN policy updates based on the 2023 DTAC proposal for *T. cruzi* antibody screening in deceased donors who were born or spent ≥6 months living in countries endemic for Chagas (eg, Mexico, Central and South America, see: CDC Chagas Disease: What US Clinicians Need to Know) are also anticipated to be in place by 2024 [41]. For pediatric donors and recipients, a maternal history of birth or residence in an endemic region should also prompt screening. Importantly, results should be available pre-SOT, particularly for heart transplantation where deferral is recommended given high mortality rates [35]. If the donor screens positive for Chagas antibody, then confirmatory testing is required within 72 hours, either through the CDC or as a combination of 2 distinct, FDA licensed, approved, or cleared antibody tests [43]. Additionally, modifications in SOT immunosuppressive regimens, including avoidance of anti-thymocyte globulin or mycophenolate mofetil and when possible, employing PCR surveillance to trigger pre-emptive anti-trypanosomal therapy, should be considered [35]. Individuals with Chagas disease (active or past history) should not serve as HCT donors.

Community Respiratory Viral Infections

Community respiratory viral infections (CRVI) may disproportionally affect children both before and after transplant, leading to CRVI-associated hospitalizations, particularly in lung recipients and the very young [44, 45]. CRVI detection pre-transplantation poses a clinical challenge [46]. CRVI detection in pediatric HCT candidates has been shown to negatively impact post-transplant outcomes, such that delaying HCT may be recommended [47, 48]. Management in SOT is varied [48, 49]. Given the high sensitivity of molecular diagnostic assays and that children have higher rates of asymptomatic viral shedding, viral detection in an otherwise asymptomatic child may lead to unnecessary delays in transplantation. In addition, the risk of underlying disease progression and mortality while awaiting transplantation must be considered. A prospective, multicenter study is underway in pediatric SOT and HCT recipients to better understand the host response to CRVI that predicts disease severity and progression to LRTI, which may better inform peri-transplant management (VIPER, ClinicalTrials NCT05550298).

During the coronavirus disease 2019 (COVID-19) pandemic, proven and probable severe acute respiratory syndrome

coronavirus 2 (SARS-CoV-2) transmission occurred in lung transplant recipients due to discordant screening results in donors with negative SARS-CoV-2 NAT testing from the upper respiratory tract (URT) relative to later testing from lower respiratory tract (LRT) compartments [50, 51]. Understanding of SARS-CoV-2 transmission has evolved and informed OPTN policy, which requires SARS-CoV-2 NAT testing from a URT source in all donors and additional testing from the LRT in potential lung donors [52]. In addition, there are increasing reports of safe and successful transplantation of non-lung organs from SARS-CoV-2 positive donors in adults, with good short-term clinical and graft outcomes [53, 54]. There remains a paucity of published clinical experience regarding outcomes in pediatric recipients receiving grafts from SARS-CoV-2 positive donors [55]. HCT candidates should undergo SARS-CoV-2 NAT on a respiratory specimen ≤72 hours before HCT conditioning [56].

Infection control practices pre- and peri-transplant are fundamental in preventing acute infections, including CRVI in transplant candidates, recipients, and living donors. Given the burden of RSV-associated hospitalizations among young transplant recipients [57, 58], SOT and HCT candidates ≤2 years of age who are profoundly immunocompromised may be candidates for palivizumab [49]. Nirsevimab, a monoclonal antibody with an extended half-life and improved neutralization activity is safe and effective in preventing medically attended RSV-associated LRTI in premature and otherwise healthy young infants [59–61]. Nirsevimab may be an option for pediatric transplant candidates at the highest risk for RSV-associated disease. The MUSIC clinical trial is a phase 2, open-label, single-dose study evaluating the safety, pharmacokinetics, and efficacy of nirsevimab in immunocompromised children ≤24 months of age, including SOT and HCT recipients (ClinicalTrials.gov identifier: NCH04484935).

Pre-Transplant Screening for Multidrug-Resistant Organisms

Surgical site infections (SSI) remain one of the most frequent healthcare-associated infections, occurring in 3–53% of SOT recipients and varying by graft type [62]. In general, using the narrowest and most efficacious agents for the shortest duration should be applied to prophylaxis. However, in certain situations, the choice and duration of antibiotics may warrant individual, patient-specific modifications. Colonization with certain bacteria may confer an increased risk for surgical site infection (SSI) and early post-transplant infections. For example, testing for *Staphylococcus aureus* nasal colonization is frequently performed in transplant candidates to help guide possible pre-operative decolonization strategies and peri-operative antibiotic prophylaxis choices to prevent post-SOT SSI. There are no conclusive data regarding the utility of pre-transplant recipient screening for other Gram-negative multi-drug resistant organisms (MDRO) since it is not known whether perioperative antibiotics targeted at the MDRO result in a benefit to the patient [63]. However, knowledge of known MDRO colonization and past infections may inform empirical antibiotic management should fever occur after transplantation.

In pediatrics, *Candida auris* disproportionally affects neonates and immunocompromised children with an indwelling central venous catheter, carrying higher mortality than other invasive candidemias [64, 65]. In addition, *C. auris* co-colonization with Gram-negative carbapenemase-producing bacteria is reported to occur. Testing for *C. auris* colonization is available through the CDC (https://www.cdc.gov/drugresistance/laboratories.html) and should be coordinated with local public health authorities. There are no proven effective decolonization strategies. Importantly, patients with confirmed MDRO colonization or infection should be placed on appropriate transmission-based precautions [3].

VACCINATION STRATEGIES

Immunizing candidates before SOT remains one of the most important, yet underutilized preventive strategies in our armamentarium [66, 67]. Immunization strategies to protect SOT and HCT recipients also include advocating for improved community vaccination rates. Introducing the cocooning strategy and counseling families during pre- and post-transplant visits underscores the importance of immunizing household and close contacts to protect the transplant recipient. Additional studies are needed to evaluate the benefits of HCT donor vaccination and current guidelines do not recommend vaccinating the donor solely to benefit the recipient [7, 68]. However, donor immunization also protects against vaccine-preventable infections that may delay transplant, as was highlighted during the COVID-19 pandemic [69]. Every effort to prevent infections in donors and candidates should be advocated.

For SOT candidates, immunizations should be up to date at the time of transplantation [67, 70, 71]. The pre-SOT evaluation may allow sufficient time to complete age-appropriate vaccines or apply an expedited immunization schedule. Patients with certain medical conditions or risk factors may require additional immunizations. Table 2 highlights the minimum ages and dosing intervals for expedited vaccination. Live vaccines should be provided to SOT candidates on an accelerated schedule as soon as SOT is planned; live vaccination is generally avoided 2–4 weeks before SOT. There are emerging data and published consensus guidance regarding the safety and immunogenicity of live vaccines in certain pediatric liver and kidney recipients post-transplantation [72–75]. While it is recommended that recipients are up to date on immunizations prior to HCT conditioning as able given co-morbidities, it is important to advise all autologous and allogeneic HCT recipients that they will require all vaccines after transplant; non-live vaccines are generally recommended beginning 3–12 months post-HCT [68, 76]. Stable HCT recipients without active GHVD may be candidates for

Table 2. Expedited Vaccination Schedule Pre-Solid Organ Transplantation

Pathogen	Vaccine	Type	**Minimum Age**%	**Minimum Doses**$	**Minimum Interval Between Doses**$	Comments
Recommended for all patients (as appropriate for age)						
Diphtheria, tetanus, pertussis*	DTaP	Toxoid/subunit	6 weeks	4–5	4 weeks–6 months	Dosing interval, type, and minimum doses highly dependent on age, and type of prior immunizations
Haemophilus influenzae type b*	Hib	Conjugate	6 weeks	1–4	4–8 weeks	
Hepatitis A	HepA**	Inactivated	6 months	1–3	6 months	
Hepatitis B	HepB**	Subunit	Birth	2–3	4–8 weeks	
	Heplisav-B	Adjuvanted subunit	18 years	2	4 weeks	
	PreHevbrio	Adjuvanted subunit	18 years	3	6 months	
Human papillomavirus	HPV	Virus-like particle	9 years	2–3	4 weeks–5 months	
Influenza	IIV4	Inactivated	6 months	n/a	Yearly	
	LAIV4	Live attenuated	2 years	n/a	Yearly	Contraindicated in immunocompromised individuals
Measles, mumps, rubella*#	MMR	Live attenuated	6 months	2–3	4 weeks–3 years	Generally, not recommended within 2–4 weeks pretransplant; contraindicated in severe immunocompromise
Meningococcus serogroups ACWY	MenACWY-CRM	Conjugate	2 months	2–4	8 weeks–6 months	MenACWY-D should not be given concurrently with PCV
	MenACWY-D	Conjugate	9 months	2	8–12 weeks	
	MenACWY-TT	Conjugate	2 years	2	8 weeks	
Pneumococcus	PCV15 or PCV20	Conjugate	6 weeks	1–4	4 weeks-6 months	
	PPSV23	Polysaccharide	2 years	1	8 weeks after PCV	Booster dose 5 years later (max 2); not required after PCV20
Poliovirus*	IPV	Inactivated	6 weeks	3–4	4 weeks-6 months	
Rotavirus	RV1	Live attenuated	6 weeks	2	4 weeks	Contraindicated in immunocompromise
	RV5	Live attenuated	6 weeks	3	4 weeks	
SARS-CoV-2	2vCOV-mRNA	mRNA	6 months	See CDC.gov	See CDC.gov	
	1vCOV-aPS	Subunit	12 years	2	8 weeks	Booster with mRNA vaccine recommended
Tetanus, diphtheria, pertussis	Tdap	Toxoid/subunit	7 years	1–4	4 weeks- 6 months	Dosing interval, type, and minimum doses dependent on age, number and type of prior immunizations
Varicella*#	VAR	live attenuated	6 months	2–3	4 weeks; 3 months in children ≤12 years of age, 3 months is recommended, though 4 weeks is allowable	Generally, not recommended within 2–4 weeks pretransplant; contraindicated in severe immunocompromise
	Shingrix	subunit	19 years	2	4 weeks	
Recommended for select patients with certain exposure risks (see cdc.gov/vaccines for additional guidance)						
Anthrax	AVA	Toxoid	18 years	5	4 weeks–6 months	Three dose prime followed by 2 dose booster, timing depends on risk
Dengue virus	DEN4CYD	Live attenuated	9 years	3	6 months	Only for seropositive patients in endemic areas; contraindicated in severe immunocompromise
Japanese encephalitis	IXIARO	Inactivated	2 months	2	4 weeks	
Meningococcus serogroup B	MenB-4C	Subunit	Years	2	4 weeks	*Routinely recommended pretransplant by some transplant providers*
	MenB-FHbp	Subunit	10 years	2-3	6 months	

Table 2. Continued

Pathogen	Vaccine	Type	Minimum Age%	Minimum Doses$	Minimum Interval Between Doses$	Comments
Mpox	JYNNEOS	Live attenuated/replication deficient	6 months	2	4 weeks	Approved in ages ≥18 years but authorized for children
Rabies	HDCV or PCECV	Inactivated	None	2	7 days	
Salmonella typhi	Typhim Vi	Polysaccharide	2 years	1	n/a	
	Vivotif	Live attenuated	6 years	4	2 days	Contraindicated in immunocompromise
Yellow fever	YF-VAX	Live attenuated	9 months	1	n/a	Contraindicated in severe immunocompromise

*Available as a combination vaccine for children.

**Available as a combination vaccine for adults.

%Some vaccines require additional doses if given at the youngest age; such as MMR and Varicella require 3rd dose if first given prior to twelve months of age.

$Varies by dose number and age at prior doses.

#Consider delaying dose after blood product or immunoglobulin administration (www.cdc.gov/vaccines/hcp/acip-recs/general-recs/timing.html).

live vaccines if ≥2 years post-HCT, ≥1 year since stopping systemic immunosuppression, and ≥8 months since the last immunoglobulin supplementation [68, 76]. The optimal timing of vaccines for both SOT and HCT will also depend on the receipt of other therapies, including anti-CD20 monoclonals, and the extent of immune reconstitution.

Emerging developments in immunization practices may modify current vaccine recommendations for transplant recipients. In June 2023, the Advisory Committee on Immunization Practices (ACIP) voted to approve the use of the 20-valent protein-conjugated pneumococcal vaccine (PCV20) in children ≥2–71 months of age with specified risk conditions, according to currently recommended PCV dosing and schedules [77]. In addition, for children aged 2–18 years with specified risk conditions who have received all recommended pneumococcal doses before age 6 years, ≥1 dose of PCV20 may be provided, with no additional doses indicated. Distinct vaccine formulations may also be an option for certain patients. Vaccines that have recently been approved include recombinant VZV (age ≥19 years) and adjuvanted Hepatitis B vaccine (age ≥18 years). Lastly, 2 doses of high-dose inactivated influenza vaccine (IIV) were found to be more immunogenic than the standard dose IIV formulation in pediatric HCT recipients [78]. Based on preliminary data, a clinical trial will soon evaluate the immunogenicity and safety of high-dose vs standard-dose IIV in pediatric SOT recipients (ClinicalTrials.gov identifier: NCT05947071) [79].

Ultimately, vaccines are useful only if administered. Providers should rectify vaccine misinformation and address vaccine hesitancy. Vaccine mandates have long been proposed in transplantation; the COVID-19 pandemic brought the topic further into public light. There are many ethical and legal considerations with no current consensus regarding vaccine mandates in pediatric transplantation [80, 81].

STRATEGIES FOR SAFE LIVING AFTER TRANSPLANTATIONS

The pre-transplant evaluation also allows practitioners to review individual patient and family lifestyles and help to minimize infectious risks. Although activities will change with a patient's age and the amount of immunosuppression/extent of immune reconstitution, the pre-transplant evaluation starts the education for lifelong consideration of ID risk management.

While the COVID-19 pandemic familiarized the public with minimizing infectious risks in their daily lives through frequent handwashing, physical distancing, and wearing masks, transplant patients had been taught these strategies for decades. Surveyed families of pediatric SOT recipients reported that normalization of these risk reduction strategies decreased the stigma their children felt from practicing them even in the pre-pandemic world [82]. Good hand hygiene should always be emphasized, while physical distancing and masking in public can be used early after transplant and during periods of increased immunosuppression for treatment of rejection or GVHD. Many aspects of life have distinct infectious risks, making it difficult to cover all possibilities during a short clinic visit [83, 84]. Table 3 covers some of the more frequent infectious risks and mitigation strategies.

One way to structure and tailor the safe living conversation is to discuss the 5 F's: Foods, Furry Friends, Flights, Family, and Fooling around. Food covers not just what transplant recipients may eat, but anything that could be ingested, including unpasteurized dairy products, raw or undercooked meat or seafood, and safe water sources, for drinking and recreational water activities. Furry friends encompass animal exposure through pets or other activities such as being on a farm or at a petting zoo. Flights refer to all travel (domestic and international) and local environmental exposures that may occur with outdoor activities, such as endemic infections and insect

Table 3. Examples of Risk and Mitigation When Discussing Safe Living Strategies for Children Undergoing Transplantation

Category	Risks (example of pathogens)*	Mitigation
Food	Bacteria (*E. coli 0157-H7, Campylobacter*, *Salmonella, Yersinia, Staphylococcus aureus, Bacillus cereus, Listeria, Brucella, Vibrio*) Parasites (*Toxoplasma gondii*, tapeworms, *Cryptosporidium, Giardia, Trichinella, Cyclospora*) Viruses (norovirus, Hepatitis A virus, Hepatitis E virus)	• Thoroughly cook meats and fish, seafood, or eggs • Wash cutting boards and knives after use on raw meats and fish • Do not cross contaminate foods • Wash fresh vegetables and fruit including skins of melons and bananas; canned fruits and dried fruits are safe • Avoid raw, rare, or medium rare meat and fish • Avoid sauces or dressing made with raw egg • HCT recipients should avoid raw nuts and vegetable sprouts during periods of augmented immunosuppression • Discard any food with mold or rotting immediately
Water and drinks	Bacteria (*Campylobacter, E. coli, Shigella, Salmonella*) Parasites (*Giardia, Cryptosporidium*) Viruses (Hepatitis A Virus)	• Use treated tap water, bottled water, canned, or bottled drinks • Well water should be tested for microbial contamination at least annually ◦ Boil well water ◦ Use NSF-certified filters • Avoid raw or unpasteurized milk, milk products, cider, and juices • Heed water safety community advisories
Recreational water	Bacteria (*E. coli, Shigella,* or other enteric pathogens, *Legionella*) Parasites (*Cryptosporidium* [chlorine tolerant], *Naegleria fowleri* [warm, fresh water], avian schistosomes [ocean], *Giardia*) Viruses (norovirus, adenovirus)	• All bodies of water can harbor pathogens but in general treated swimming pools are safer than untreated recreational waters • People with diarrhea should not swim for at least 2 weeks • Water parks have risks of aerosolization of infections • Avoid discolored, smelly, foamy, or scummy water or water likely contaminated with human or animal waste • Avoid swimming when there are open sores or when increased immunosuppression • Avoid swallowing water or having water entering nose, particularly in warm freshwater • Clean wounds that occur while bathing in fresh or ocean water with a clean water source • Heed posted advisories by local monitoring agencies
Pets and animal contact	Bacteria (*Campylobacter* [kittens, puppies, chickens], *Salmonella* [reptiles, amphibians, chickens, ducks], *Bartonella henselae* [cat bite], *Chlamydophila psittaci* [birds], *Coxiella burnetii* [parturient goats, sheep], *Streptobacillus moniliformis* [rat bite fever from rodents], *Francisella tularensis* [handling infected carcasses]) Parasites (*Toxoplasma gondii*) Fungi (dermatophytes) Viruses (Rabies, lymphocytic choriomeningitis virus [LCMV])	• Older animals are generally less of a risk than young animals; traditional pets are preferred • Animals should be seen by a vet and receive all of their immunizations and flea and tick prevention • Ideally the transplant recipient should avoid contacts with animal excrement, such as with litter cleaning for cats, cage cleaning for small animals or birds, or barn muck raking; if not able to avoid, then gloves should be worn and hand washing performed afterward, consider masking if aerosolization possible • Animal bites should be attended to quickly and consideration for prophylaxis discussed with the transplant team • Avoid reptiles and amphibians due to the elevated risk of *Salmonella* • Avoid feral animals due to elevated risk of rabies and rodents due to risk of LCMV • Avoid parturient farm animals due to risk of *Coxiella burnetii* and *Brucella* • Transplant patients should not skin or be in contact with animal carcasses, if this cannot be avoided then gloves should be worn and handwashing performed afterward
Travel and environmental exposures	Variable depending on geography and epidemiology	• Individualized counseling by family's home geography • Directed counseling based on the type of travel, geography, and season, and on the specific type of activity with which they will engage (camping, spelunking) • Special considerations for being up to date on immunizations, hand hygiene, food and water safety issues, fungal, or viral exposures different from home • Optimal mosquito and tick prevention (insect repellants, netting, and cover skin) • The potential for fungal exposure should be reviewed for risks during home renovation projects or with gardening or mulching • Bring your own travel health kit, including transplant-related medications, and basic first aid supplies and sunscreen with SPF ≥15.
Family, close contacts and community contacts	Variable depending on circulating microbes and transmissible infections in household contacts Bacteria (*Staphylococcus aureus*, *Bordetella pertussis*, *Mycobacterium tuberculosis*) Viruses (community respiratory viruses, measles, mumps, varicella, hepatitis, and herpes simplex viruses)	• Promote appropriate handwashing and avoid sharing • Household members and close contacts should have their immunizations up to date • Ideally the school system should enforce school entry immunizations • Families should be queried about tuberculosis exposures • Families should be queried about methicillin-resistant *Staphylococcus aureus* infections in household contacts • Visitors should be healthy and without recent infectious exposures

Table 3. Continued

Category	Risks (example of pathogens)*	Mitigation
Sexual activity, tattoos, piercings, recreational drugs	Bacteria (*Gonorrhea, Chlamydia*, syphilis, soft tissue skin infection) Viruses (Epstein Barr virus, Cytomegalovirus, Human Immunodeficiency Virus [HIV], hepatitis A virus [HAV], Hepatitis B virus [HBV], Hepatitis C virus [HCV], human papilloma virus [HPV]) Fungal (*Aspergillus* spp, other molds)	• Adolescents and teenagers need private discussions about risks of unprotected intercourse, including risks of pregnancy and infection and extragenital infections • Immunization against HPV, HBV, and HAV should be up to date • Saliva transmission of cytomegalovirus and Epstein Barr virus can be significant even from community acquisition and should be discussed during the pretransplant evaluation • Candidates should be cautioned against self-piercing and tattoos; use reputable licensed sites when immunosuppression is minimized • Inhalational marijuana can be contaminated with fungal elements

*This list provides examples of common organisms and disease states from specific exposures but is not inclusive of all microbes that could be transmitted to cause infection.

avoidance including the use of repellants with DEET with outdoor activities during mosquito and tick season. Family includes household members and frequent contacts, including at school. While the mental health benefits of animal ownership have been demonstrated, the type and age of the pet along with the age of the child impacts infectious risk [83]. Finally, "fooling around" reminds providers to have discussions around safe sex and to discuss other sensitive topics that may not be immediately relevant, but require counseling even for young patients. Safe sexual encounters are important to prevent infections, cancers, and unintentional pregnancies [85]. Recreational drug use carries a risk of infection, for example from contaminated marijuana leaves, but also potential direct toxicity from vaping or drug-drug interactions. A non-judgmental conversation allows families and their children to have honest discussions and share risk mitigation plans.

CONCLUSIONS

The pre-transplant evaluation provides an opportunity to screen for infections and plan actionable preventative measures, including optimal prophylaxis, vaccination, and safe living strategies. Knowledge and improved laboratory screening of potential DDIs, allow for a more balanced risk assessment, reduce unanticipated DDI, and improve surveillance and management efforts. Additional robust studies are needed to answer ongoing knowledge gaps after pediatric transplantation. Combined, these approaches aim to reduce post-transplant infectious complications and improve overall outcomes in pediatric SOT and HCT recipients.

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References

1. Kaul DR, Vece G, Blumberg E, et al. Ten years of donor-derived disease: a report of the disease transmission advisory committee. *Am J Transplant* **2021**; 21:689–702.
2. Lindsay J, Kerridge I, Wilcox L, et al. Infection-related mortality in adults and children undergoing allogeneic hematopoietic cell transplantation: an Australian Registry Report. *Transplant Cell Ther* **2021**; 27:798 e1–e10.
3. Auletta JJ, Kou J, Chen M, Shaw BE. Current use and outcome of hematopoietic stem cell transplantation: CIBMTR US summary slides, **2021**. Accessed January 1, 23, https://cibmtr.org/CIBMTR/Resources/Summary-Slides-Reports
4. Wolfe CR, Ison MG, Practice ASTIDCo. Donor-derived infections: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13547.
5. US FDA. Testing Donors of Human Cells, Tissues, and Cellular and Tissue-Based Products: Specific Requirements. Updated 5/3/19. Accessed May 1, 2023, at https://www.fda.gov/vaccines-blood-biologics/safety-availability-biologics/testing-donors-human-cells-tissues-and-cellular-and-tissue-based-products-hctp-specific-requirements
6. Malinis M, Boucher HW, Practice ASTIDCo. Screening of donor and candidate prior to solid organ transplantation-Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13548.
7. Tomblyn M, Chiller T, Einsele H, et al; Center for International Blood and Marrow Research. Guidelines for preventing infectious complications among hematopoietic cell transplantation recipients: a global perspective. *Biol Blood Marrow Transplant* **2009**; 15:1143–238.
8. Green M, Covington S, Taranto S, Michaels MG, Wolfe C, Kaul DR. Pediatrics and donor-derived disease transmission: The US OPTN experience. *Pediatr Transplant* **2018**; 22.
9. Goldberg DS, Blumberg E, McCauley M, Abt P, Levine M. Improving organ utilization to help overcome the tragedies of the opioid epidemic. *Am J Transplant* **2016**; 16:2836–41.
10. Kaul DR, Tlusty SM, Michaels MG, Limaye AP, Wolfe CR. Donor-derived hepatitis C in the era of increasing intravenous drug use: a report of the Disease Transmission Advisory Committee. *Clin Transplant* **2018**; 32:e13370.
11. Bixler D, Annambhotla P, Montgomery MP, et al. Unexpected hepatitis B virus infection after liver transplantation—United States, 2014-2019. *MMWR Morb Mortal Wkly Rep* **2021**;70:961–6.
12. Jones JM, Kracalik I, Levi ME, et al. Assessing solid organ donors and monitoring transplant recipients for human immunodeficiency virus, hepatitis B virus, and hepatitis C virus infection—U.S. Public Health Service Guideline, 2020. *MMWR Recomm Rep* **2020**; 69:1–16.
13. Te H, Doucette K. Viral hepatitis: Guidelines by the American Society of Transplantation Infectious Disease Community of Practice. *Clin Transplant* **2019**; 33:e13514.
14. Razonable RR, Humar A. Cytomegalovirus in solid organ transplant recipients-Guidelines of the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13512.
15. Kotton CN, Kumar D, Caliendo AM, et al; The Transplantation Society International CMV Consensus Group. The Third International Consensus Guidelines on the management of cytomegalovirus in solid-organ transplantation. *Transplantation* **2018**; 102:900–31.
16. Hakki M, Aitken SL, Danziger-Isakov L, et al. American Society for Transplantation and Cellular Therapy Series: #3-prevention of cytomegalovirus

infection and disease after hematopoietic cell transplantation. *Transplant Cell Ther* **2021**; 27:707–19.
17. Dulek DE, Ardura MI. "Weighting" for an answer on optimal valganciclovir prophylaxis dosing in pediatric solid organ transplantation recipients. *Pediatr Transplant* **2023**; 27:e14494.
18. Marty FM, Ljungman P, Chemaly RF, et al. Letermovir prophylaxis for cytomegalovirus in hematopoietic-cell transplantation. *N Engl J Med* **2017**; 377:2433–44.
19. US FDA Approves New Indication for Merck's PREVYMIS (letermovir) for Prevention of Cytomegalovirus (CMV) Disease in High-Risk Adult Kidney Transplant Recipients. June 6, **2023**. Accessed June 12, 2023, https://www.merck.com/news/u-s-fda-approves-new-indication-for-mercks-prevymis-letermovir-for-prevention-of-cytomegalovirus-cmv-disease-in-high-risk-adult-kidney-transplant-recipients/.
20. Kumar D, Chin-Hong P, Kayler L, et al. A prospective multicenter observational study of cell-mediated immunity as a predictor for cytomegalovirus infection in kidney transplant recipients. *Am J Transplant* **2019**;19: 2505–16.
21. Chemaly RF, El Haddad L, Winston DJ, et al. Cytomegalovirus (CMV) cell-mediated immunity and CMV infection after allogeneic hematopoietic cell transplantation: the REACT study. *Clin Infect Dis* **2020**; 71:2365–74.
22. Azar MM, Turbett S, Gaston D, et al; Transplant ID Diagnostics Consensus Conference Working Group. A consensus conference to define the utility of advanced infectious disease diagnostics in solid organ transplant recipients. *Am J Transplant* **2022**; 22:3150–69.
23. *PLACEHOLDER FOR ARTICLE IN THIS SUPPLEMENT: JPIDS-2023-271—Cytomegalovirus Cell-Mediated Immunity Assays in Pediatric Transplantation*.
24. Ouellette CP. Adoptive immunotherapy for prophylaxis and treatment of cytomegalovirus infection. *Viruses* **2022**; 14:2370.
25. Peggs KS, Verfuerth S, Pizzey A, et al. Adoptive cellular therapy for early cytomegalovirus infection after allogeneic stem-cell transplantation with virus-specific T-cell lines. *Lancet* **2003**; 362:1375–7.
26. Micklethwaite KP, Clancy L, Sandher U, et al. Prophylactic infusion of cytomegalovirus-specific cytotoxic T lymphocytes stimulated with Ad5f35pp65 gene-modified dendritic cells after allogeneic hemopoietic stem cell transplantation. *Blood* **2008**; 112:3974–81.
27. Heslop HE. How I treat EBV lymphoproliferation. *Blood* **2009**; 114:4002–8.
28. Wilkinson JD, Allen U, Green M, et al; IPTA Pediatric PTLD Consensus Guidelines Conference. The IPTA Nashville consensus conference on post-transplant lymphoproliferative disorders after solid organ transplantation in children: I-Methodology for the development of consensus practice guidelines. *Pediatr Transplant* **2022**:e14333.
29. Green M, Squires JE, Chinnock RE, et al. The IPTA Nashville consensus conference on post-transplant lymphoproliferative disorders after solid organ transplantation in children: II-consensus guidelines for prevention. *Pediatr Transplant* **2022**:e14350.
30. Preiksaitis J, Allen U, Bollard CM, et al. The IPTA Nashville Consensus Conference on post-transplant lymphoproliferative disorders after solid organ transplantation in children: III—Consensus guidelines for Epstein-Barr virus load and other biomarker monitoring. *Pediatr Transplant* **2023**:e14471.
31. *PLACEHOLDER FOR ARTICLE IN THIS SUPPLEMENT: JPIDS-2023-259—A Focused Review of Epstein Barr Virus Infections and PTLD in Pediatric Transplant Recipients: Guidance from the IPTA and ECIL Guidelines*.
32. CDC. Parasites: Toxoplasmosis (Toxoplasma Infection). Accessed May 1, 2023, https://www.cdc.gov/parasites/toxoplasmosis/
33. Dhakal R, Gajurel K, Montoya JG. Toxoplasmosis in the non-orthotopic heart transplant recipient population, how common is it? Any indication for prophylaxis? *Curr Opin Organ Transplant* **2018**; 23:407–16.
34. OPTN Policy 2.9. Required Deceased Donor Infectious Disease Testing. Accessed January 5, 2023, https://optn.transplant.hrsa.gov/media/eavh5bf3/optn_policies.pdf
35. La Hoz RM, Morris MI; Infectious Diseases Community of Practice of the American Society of Transplantation. Tissue and blood protozoa including toxoplasmosis, Chagas disease, leishmaniasis, Babesia, Acanthamoeba, Balamuthia, and Naegleria in solid organ transplant recipients- Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13546.
36. Contopoulos-Ioannidis DG, Cho SM, Bertaina A, et al. Toxoplasmosis among 38 751 hematopoietic stem-cell transplant recipients: a systematic review of disease prevalence and a compilation of imaging and autopsy findings. *Transplantation* **2021**; 105:e375–86.
37. Gajurel K, Dhakal R, Montoya JG. Toxoplasma prophylaxis in haematopoietic cell transplant recipients: a review of the literature and recommendations. *Curr Opin Infect Dis* **2015**; 28:283–92.
38. Schwenk HT, Khan A, Kohlman K, et al. Toxoplasmosis in pediatric hematopoietic stem cell transplantation patients. *Transplant Cell Ther* **2021**; 27:292–300.
39. Hanisch B, Sprott K, Ardura MI. *Pneumocystis jirovecii* and toxoplasmosis prophylaxis strategies among pediatric organ transplantation recipients: A US National Survey. *Transpl Infect Dis* **2020**; 22:e13290.
40. Inagaki K, Bradbury RS, Hobbs CV. Hospitalizations associated with strongyloidiasis in the United States, 2003–2018. *Clin Infect Dis* **2022**; 75: 1548–55.
41. OPTN Ad Hoc Disease Transmission Advisory Committe. Public Comment Proposal: Improve Deceased Donor Evaluation for Endemic Diseases. Accessed October 5, 2023, https://optn.transplant.hrsa.gov/media/uwepwvkn/improve-deceased-donor-evaluation-for-endemic-diseases_dtac_pc-winter-2023.pdf.
42. La Hoz RM, Morris MI, Practice ASTIDCo. Intestinal parasites including cryptosporidium, cyclospora, giardia, and microsporidia, entamoeba histolytica, strongyloides, schistosomiasis, and echinococcus: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13618.
43. Forsyth CJ, Manne-Goehler J, Bern C, et al. Recommendations for screening and diagnosis of Chagas disease in the United States. *J Infect Dis* **2022**; 225:1601–10.
44. Fisher BT, Danziger-Isakov L, Sweet LR, et al. A multicenter consortium to define the epidemiology and outcomes of inpatient respiratory viral infections in pediatric hematopoietic stem cell transplant recipients. *J Pediatric Infect Dis Soc* **2018**; 7:275–82.
45. Danziger-Isakov L, Steinbach WJ, Paulsen G, et al. A multicenter consortium to define the epidemiology and outcomes of pediatric solid organ transplant recipients with inpatient respiratory virus infection. *J Pediatric Infect Dis Soc* **2019**; 8:197–204.
46. *PLACEHOLDER FOR ARTICLE IN THIS SUPPLEMENT: JPIDS-2023-243—Impact of Respiratory Viral Infections In Transplant Recipients*
47. Campbell AP, Guthrie KA, Englund JA, et al. Clinical outcomes associated with respiratory virus detection before allogeneic hematopoietic stem cell transplant. *Clin Infect Dis* **2015**; 61:192–202.
48. L'Huillier AG, Green M, Danziger-Isakov L, et al. Infections among pediatric transplant candidates: an approach to decision-making. *Pediatr Transplant* **2019**; 23:e13375.
49. Manuel O, Estabrook M; American Society of Transplantation Infectious Diseases Community of Practice. RNA respiratory viral infections in solid organ transplant recipients: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13511.
50. Kaul DR, Valesano AL, Petrie JG, et al. Donor to recipient transmission of SARS-CoV-2 by lung transplantation despite negative donor upper respiratory tract testing. *Am J Transplant* **2021**; 21:2885–9.
51. Kumar D, Humar A, Keshavjee S, Cypel M. A call to routinely test lower respiratory tract samples for SARS-CoV-2 in lung donors. *Am J Transplant* **2021**;21:2623–4.
52. American Society of Transplantation. Recommendations and Guidance for Donor Testing. Accessed December 6, 2023, https://www.myast.org/recommendations-and-guidance-organ-donor-testing.
53. Goldman JD, Pouch SM, Woolley AE, et al. Transplant of organs from donors with positive SARS-CoV-2 nucleic acid testing: A report from the organ procurement and transplantation network ad hoc disease transmission advisory committee. *Transpl Infect Dis* **2023**; 25:e14013.
54. Schold JD, Koval CE, Wee A, Eltemamy M, Poggio ED. Utilization and outcomes of deceased donor SARS-CoV-2-positive organs for solid organ transplantation in the United States. *Am J Transplant* **2022**; 22:2217–27.
55. Goss MB, Leung DHB, Pouch SM, et al. A new chapter in an evolving pandemic: successful pediatric liver transplantation with SARS-CoV-2+ donors. *Pediatr Transplant* **2022**; 26:e14407.
56. Waghmare A, Abidi MZ, Boeckh M, et al. Guidelines for COVID-19 management in hematopoietic cell transplantation and cellular therapy recipients. *Biol Blood Marrow Transplant* **2020**; 26:1983–94.
57. Feldman AG, Sundaram SS, Beaty BL, Kempe A. Hospitalizations for respiratory syncytial virus and vaccine-preventable infections in the first 2 years after pediatric liver transplant. *J Pediatr* **2017**; 182:232–238.e1.
58. Hayes EA, Hart SA, Gowda C, Nandi D. Hospitalizations for respiratory syncytial virus and vaccine preventable infections following pediatric heart transplantation. *J Pediatr* **2021**; 236:101–107.e3.
59. Hammitt LL, Dagan R, Yuan Y, et al; MELODY Study Group. Nirsevimab for prevention of RSV in healthy late-preterm and term infants. *N Engl J Med* **2022**; 386:837–46.
60. Simoes EAF, Madhi SA, Muller WJ, et al. Efficacy of nirsevimab against respiratory syncytial virus lower respiratory tract infections in preterm and term infants, and pharmacokinetic extrapolation to infants with congenital heart disease and chronic lung disease: a pooled analysis of randomised controlled trials. *Lancet Child Adolesc Health* **2023**; 7:180–9.

61. Wilkins D, Yuan Y, Chang Y, et al. Durability of neutralizing RSV antibodies following nirsevimab administration and elicitation of the natural immune response to RSV infection in infants. *Nat Med* **2023**; 29:1172–9.
62. Abbo LM, Grossi PA, Practice AIC. Surgical site infections: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13589.
63. Anesi JA, Blumberg EA, Abbo LM. Perioperative antibiotic prophylaxis to prevent surgical site infections in solid organ transplantation. *Transplantation* **2018**; 102:21–34.
64. Ashkenazi-Hoffnung L, Rosenberg Danziger C. Navigating the new reality: a review of the epidemiological, clinical, and microbiological characteristics of *Candida auris*, with a focus on children. *J Fungi (Basel)* **2023**; 9:176.
65. Berrio I, Caceres DH, Coronell RW, et al. Bloodstream infections with *Candida auris* among children in Colombia: clinical characteristics and outcomes of 34 cases. *J Pediatric Infect Dis Soc* **2021**; 10:151–4.
66. Feldman AG, Beaty BL, Curtis D, Juarez-Colunga E, Kempe A. Incidence of hospitalization for vaccine-preventable infections in children following solid organ transplant and associated morbidity, mortality, and costs. *JAMA Pediatr* **2019**; 173:260–8.
67. Feldman AG, Curtis DJ, Moore SL, Kempe A. Under-immunization of pediatric transplant recipients: a call to action for the pediatric community. *Pediatr Res* **2020**; 87:277–81.
68. Rubin LG, Levin MJ, Ljungman P, et al; Infectious Diseases Society of America. 2013 IDSA clinical practice guideline for vaccination of the immunocompromised host. *Clin Infect Dis* **2014**; 58:309–18.
69. Salvalaggio PR, Ferreira GF, Caliskan Y, et al. An International survey on living kidney donation and transplant practices during the COVID-19 pandemic. *Transpl Infect Dis* **2021**; 23:e13526.
70. Feldman AG, Marsh R, Kempe A, Morris MA. Barriers to pretransplant immunization: a Qualitative Interview Study of pediatric solid organ transplant stakeholders. *J Pediatr* **2020**; 227:60–8.
71. Danziger-Isakov L, Kumar D, Practice AIC. Vaccination of solid organ transplant candidates and recipients: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13563.
72. Suresh S, Upton J, Green M, et al. Live vaccines after pediatric solid organ transplant: proceedings of a consensus meeting, 2018. *Pediatr Transplant* **2019**; 23:e13571.
73. Pittet LF, Verolet CM, McLin VA, et al. Multimodal safety assessment of measles–mumps–rubella vaccination after pediatric liver transplantation. *Am J Transplant* **2019**; 19:844–54.
74. Posfay-Barbe KM, Pittet LF, Sottas C, et al. Varicella-zoster immunization in pediatric liver transplant recipients: safe and immunogenic. *Am J Transplant* **2012**; 12:2974–85.
75. Dipchand AI, Seifert-Hansen M. Early experience with varicella vaccination in pediatric heart transplant recipients. *J Heart Lung Transplant* **2022**; 41:1023–6.
76. Cordonnier C, Einarsdottir S, Cesaro S, et al; European Conference on Infections in Leukaemia group. Vaccination of haemopoietic stem cell transplant recipients: guidelines of the 2017 European Conference on Infections in Leukaemia (ECIL 7). *Lancet Infect Dis* **2019**; 19:e200–12.
77. Advisory Committee on Immunization Practices (ACIP) Presentation Slides: July 21-23, 2023 Meeting: Pneumococcal Vaccines. Accessed July 3, 2023, https://www.cdc.gov/vaccines/acip/meetings/slides-2023-06-21-23.html
78. Schuster JE, Hamdan L, Dulek DE, et al; Pediatric HCT Flu Study Group. Influenza vaccine in pediatric recipients of hematopoietic-cell transplants. *N Engl J Med* **2023**; 388:374–6.
79. GiaQuinta S, Michaels MG, McCullers JA, et al. Randomized, double-blind comparison of standard-dose vs. high-dose trivalent inactivated influenza vaccine in pediatric solid organ transplant patients. *Pediatr Transplant* **2015**; 19:219–28.
80. Lara Carrion L, Bramstedt KA. Exploring the ethical complexity of pediatric organ transplant candidates and COVID-19 vaccination: tensions between autonomy and beneficence, children and parents. *Pediatr Transplant* **2023**; 27:e14408.
81. Kates OS, Stohs EJ, Pergam SA, et al. The limits of refusal: an ethical review of solid organ transplantation and vaccine hesitancy. *Am J Transplant* **2021**; 21:2637–45.
82. Forner-Puntonet M, Castell-Panisello E, Quintero J, et al. Impact of COVID-19 on families of pediatric solid organ transplant recipients. *J Pediatr Psychol* **2021**; 46:927–38.
83. Avery RK, Michaels MG, Practice ASTIDCo. Strategies for safe living following solid organ transplantation—Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* **2019**; 33:e13519.
84. Yokoe D, Casper C, Dubberke E, et al; Center for International Blood and Marrow Transplant Research. Safe living after hematopoietic cell transplantation. *Bone Marrow Transplant* **2009**; 44:509–19.
85. Ardura MI, Coscia LA, Meyers MR. Promoting safe sexual practices and sexual health maintenance in pediatric and young adult solid organ transplant recipients. *Pediatr Transplant* **2021**; 25:e13949.
86. OPTN policies. Effective 3/16/23. Accessed January 5, 2023, https://optn.transplant.hrsa.gov/media/eavh5bf3/optn_policies.pdf.
87. US FDA: Testing Human Cells, Tissues, and Cellular and Tissue Based Product (HCT/P) Donors for Relevant Communicable Disease Agents and Diseases. Content as of 11/4/22. Accessed January 5, 23, https://www.fda.gov/vaccines-blood-biologics/safety-availability-biologics/testing-human-cells-tissues-and-cellular-and-tissue-based-product-hctp-donors-relevant-communicable.
88. US FDA. Testing Donors of Human Cells, Tissues, and Cellular and Tissue-Based Products: Specific Requirements. Updated 5/3/19. Accessed May 1, 2023, https://www.fda.gov/vaccines-blood-biologics/safety-availability-biologics/testing-donors-human-cells-tissues-and-cellular-and-tissue-based-products-hctp-specific-requirements.