



## Measles Guidance Document for the Transplant Community

### Executive Summary

- Measles is a highly contagious human pathogen, with an attack rate of 90% in measles-nonimmune people.
- The transplant community must educate patients and their families on defining measles exposure.
- Solid organ transplant recipients are expected to have a higher risk of severe measles, and a higher risk of complications and mortality are expected. In addition, since the development of rash is associated with the onset of immunity, solid organ transplant recipients may present without a rash or with an atypical one.
- Testing patients most likely to have measles is essential to maximize diagnostic performance. The decision to test should be based on risk factors and a compatible clinical presentation. Testing for all suspected measles cases includes serologic (IgM & IgG) testing and RT-PCR to optimize sensitivity and specificity. The diagnostic performance of both assays is higher after the onset of the rash. Transplant specialists should be mindful of the potential risks of false negative and false positive results in solid organ transplant recipients.
- The Centers for Disease Control and Prevention has a definition for presumptive evidence of immunity. Solid organ transplant candidates not meeting the above criteria are considered nonimmune and should be vaccinated with MMR unless contraindicated. There is no data to support measles vaccination in adult solid organ transplant recipients. Pediatric solid organ transplant recipients can be vaccinated in selected scenarios.
- The CDC recommends post-exposure prophylaxis for severely immunocompromised hosts with immunoglobulin. It is unclear which sub-groups would benefit the most from this intervention.
- The treatment of measles is supportive; there is no specific antiviral therapy approved for treatment of measles.
- Vitamin A deficiency contributes to delayed recovery and to risk of complications. There is a role for Vitamin A only in selected scenarios. It is recommended for children with severe measles, and children with measles in resource-limited settings.

As with any other outbreaks, the information outlined in this guidance document is dynamic. We encourage transplant specialists to discuss any evolving information with their local experts.

### 1. Overview

Since the first known description of measles in the 10<sup>th</sup> century, we have acquired knowledge regarding the pathogenesis and epidemiology of measles, including individuals at risk, the role of protective immunity, the incubation period, and the mode of transmission(1, 2). This body of evidence can guide strategies to minimize the risk of measles in the solid organ transplant population.

The United States faced several measles outbreaks in 2024 and 2025. In developed countries, measles outbreaks have often been associated with vaccine hesitancy(3). In 2019, the World Health Organization (WHO) recognized vaccine hesitancy as among the top 10 current threats to global health(4). To prevent the spread of measles, at least 95% of the population must be vaccinated(5).

Measles outbreaks pose a threat to pre- and post-organ transplant recipients. Here, we provide interim recommendations to minimize the risk of measles in this population.

### 2. Transmission

Measles is a highly contagious human pathogen, with an attack rate of 90% in measles-nonimmune people(6). Transmission occurs via airborne routes when an infected person releases infectious droplets and aerosols by coughing, sneezing, or breathing.

### 3. Definition of Measles Immunity

The Centers for Disease Control and Prevention defines presumptive evidence of immunity, to measles, in any of the following ways:

- Birth before 1957
- Laboratory confirmation of disease
- Written documentation of adequate vaccination with MMR. For high-risk adults, two doses at least 4 weeks apart are required to meet this definition during a measles outbreak.
- Laboratory evidence of immunity (positive measles IgG)

Persons not meeting the above criteria are considered nonimmune and should be vaccinated unless contraindicated (see below).

For reference, measles was widespread before the vaccine became available in 1963. Nearly everyone was exposed to the virus during childhood at that point(7). Measles vaccination usually leads to long-term immunity(8). In the United States, measles antibodies develop in 93 %of individuals vaccinated after 12 months of age. For the small percentage of nonresponders to the first vaccine, a second dose provides close to 97% (9) immunity among individuals who have received two doses of measles vaccine. In addition, a study assessing the performance of a third dose of MMR vaccine amongst young adults showed minimal improvements in several markers of immune response(10). Thus, no compelling data support a routine third dose of MMR vaccine. Although measles antibody titers have been shown to decrease over time, most people

with waning antibody titers after vaccination have an anamnestic response to revaccination, suggesting continued cellular immunity. Furthermore, a study from Israel during a measles outbreak in a highly vaccinated population (2-dose vaccination coverage) described a low vaccination failure rate (8 cases) amongst 1,392 exposed and no tertiary cases. In summary, these studies provide robust data to support their use as presumptive evidence of immunity; however, it is unclear how these criteria will apply to solid organ transplant recipients.

#### 4. Definition of Exposure

The transplant community must educate their patients on defining a measles exposure. Exposure to measles is defined by sharing the same airspace with a person with measles during the period when they are known to be contagious (4 days before until 4 days after rash onset). The measles virus can live up to 2 hours in an airspace where an infected person has coughed or sneezed. Thus, those in the same space as the contagious patient for up to 2 hours after the patient with measles was present should also be regarded as measles exposed.

#### 5. Infection Control

In regions experiencing significant community measles outbreaks, appropriate precautions should be implemented at healthcare entry points to identify individuals who may have been exposed to or are showing symptoms of measles. For outpatient visits, pre-appointment phone screenings may help identify such patients in advance. Likewise, individuals seeking care in emergency departments, ambulatory settings, or hospital admissions should undergo screening upon arrival.

Transplant recipients should be advised to promptly report any known exposure to measles or symptoms suggestive of infection. If an exposed patient requires medical care—whether related to measles or another condition—they should consult with their healthcare team to determine the safest approach that minimizes exposure risks to other vulnerable patients.

Patients with suspected measles who require medical evaluation should notify their transplant team before visiting a healthcare facility. Whenever possible, an initial assessment should be conducted via telehealth. If an in-person evaluation is necessary, the transplant team should coordinate with the emergency department, outpatient clinic, or hospital admission team to ensure appropriate precautions are in place before the patient's arrival. Efforts should be made to conduct the evaluation in a designated area that limits contact with other patients.

Upon arrival, the patient should be met in a designated area, immediately provided with a surgical mask, and placed in a private negative-pressure isolation room, if available. If a negative-pressure room is not accessible, alternative options include isolating the patient in a single room with the door closed, with or without a portable negative-pressure system. Only healthcare personnel with documented immunity should enter the room, and those providing care should wear an N95 mask or a powered respirator in addition to standard infection control measures such as hand hygiene and glove use.

Patients with confirmed measles exposure should remain in quarantine for at least 21 days following exposure, or 28 days if they have received immunoglobulin (IG) for post-exposure prophylaxis. Immunocompetent individuals diagnosed with measles should be isolated for four days following rash onset. Immunocompromised patients with measles should remain in isolation for the full duration of illness due to their potential for prolonged viral shedding.

## 6. Clinical Presentation

- Classic Measles: Occurs in immunocompetent patients without prior immunity who did not receive immunoglobulin for postexposure prophylaxis. It can be subdivided into the following stages(2, 11, 12):
  - a. Incubation Period: The incubation period for measles is 6 to 21 days. The period in which the patient is contagious is from four days before the onset of rash to four days after. After inoculation, the virus present in the respiratory tract is captured by mononuclear cells, mediating the measles virus's dissemination (primary viremia) to the thymus, spleen, lymph nodes, liver, skin, conjunctiva, intestine, bladder, and lung.
  - b. Prodrome: Typical symptoms during this stage include fever (typically present), malaise, anorexia, conjunctivitis, coryza (runny nose, sneezing), and cough. The symptoms during this stage result from mucosal inflammation from viral infection of the respiratory epithelium. A secondary viremia also occurs during this phase.
  - c. Exanthem: Koplik spots are pathognomonic of measles. They appear approximately 48 hours before the onset of the exanthem. They are 1-3 mm whitish, grayish, or bluish elevations with an erythematous base. They are usually located in the buccal mucosa of the molar teeth, although in severe cases, the entire buccal mucosa can be involved. They are present for 12 to 72 hours and start to slough as the exanthem appears. Furthermore, they are not present in all infected patients.
  - d. Exanthem: The maculopapular rash usually begins on the head and face and proceeds cephalocaudally and centrifugally to involve the neck, upper trunk, lower trunk, and extremities. The onset of the rash coincides with the development of immunity and is present in almost all immunocompetent patients.
  - e. Recovery and immunity: The entire uncomplicated illness from prodrome to resolution of fever and rash last 7-10 days; cough is usually the last symptom to resolve. Measles, unfortunately, is associated with the development of immune defects that increase the risk of secondary infections (see below).
- Complications  
Measles complications are most frequently observed in children younger than 5 years of age, adults older than 20 years, pregnant women, and individuals who are malnourished or immunocompromised(2, 13). The complications of measles involve the gastrointestinal (diarrhea), respiratory, and central nervous systems. Measles-

induced immunosuppression with a risk of secondary infection is also a significant complication.

- a. Respiratory: Pulmonary complications from measles virus include bronchopneumonia, laryngotracheobronchitis, and bronchiolitis. Measles has also been associated with the development of bronchiectasis (14). Pneumonia is the most common cause of measles-associated death in children.
  - b. Central nervous system:
    1. Acute disseminated encephalomyelitis (ADEM): This complication occurs most commonly in children and is thought to be a postinfectious autoimmune response. ADEM occurs 2-4 weeks after the exanthem. It is characterized by the abrupt onset of fever, headache, neck stiffness, changes in cognition, seizures, and focal neurological symptoms.
    2. Subacute sclerosing panencephalitis (SSPE): Is most likely to develop in children whose primary infection occurred before two years of age. The average time to onset of SSPE after measles is 6-10 years, but ranges from 1 to 24. The typical presentation is with mental deterioration accompanied by alterations in personality. Subsequently, there is myoclonus, and often seizures, followed by progressive neurological deterioration and coma.
  - c. Immunosuppressive state: Several profound immune alterations have been associated with measles virus infection, including T-cell lymphopenia with depletion of T-dependent areas of lymph nodes and spleen, diminished T-cell proliferation and reduced antibody production (15). These derangements and the injury to the respiratory mucosa may explain the risk of secondary infections like bacteremia, bacterial and viral pneumonia, and otitis media. Additionally, tuberculosis reactivation in the setting of recent measles infection has also been described. Furthermore, measles associated immune defects may account for increased mortality up to three years following infection in children (16).
- Measles in immunocompromised hosts  
Solid organ transplant recipients are at risk for severe measles, and a higher risk of complications and mortality may be expected(13). In addition, since the development of rash is associated with the onset of immunity, solid organ transplant recipients may present without a rash or with an atypical one. The immunocompromised host may also present with giant cell interstitial pneumonia without evidence of rash. Pathological examination in those cases showed interstitial pneumonitis with multinuclear giant cells that contained numerous intranuclear and intracytoplasmic inclusions. PCR confirmed the diagnosis in the lung tissue(17). In addition, measles inclusion body encephalitis has been described in immunocompromised hosts (18). The onset between measles and the onset of neurological symptoms ranges from five weeks to six months, which is much shorter than SSPE and longer than the usually observed acute encephalitis and ADEM. The

clinical presentation includes disturbances of consciousness, seizures, and neurological defects. Seizures are common and often the first symptom, and the CSF formula is usually normal. Pathologically, eosinophilic inclusions in the nuclei of neurons and glial cells are characteristic. These atypical pulmonary and CNS presentations should be considered in SOT recipients with compatible presentations.

## 7. Diagnosis

Testing patients most likely to have measles is essential to maximize diagnostic performance. The decision to test should be based on risk factors and a compatible clinical presentation. Testing for all suspected measles cases includes serologic (IgM & IgG) testing and RT-PCR to optimize sensitivity and specificity.

Serological testing includes IgM and IgG. The results should be interpreted with caution in those who recently received IVIg. IgM appears within 1-4 days of rash onset and peak within the first week after rash onset; it is most sensitive  $\geq 3$  days after rash onset. IgM can be detected for 6-8 weeks following acute measles infection. In settings of low pre-test probability, false positive results are expected. Conversely, due to the net state of immunosuppression, false negative results are anticipated in immunocompromised hosts. Assessing for evidence of measles immunity is done by testing for measles-specific IgG. Testing for evidence of immunity should not include IgM given the risk of false positives. Detection of IgG at the time of rash onset, or after exposure and prior to rash onset represents prior immunity.

Clinical specimens for RT-PCR testing should be collected alongside serologic samples to improve measles diagnosis. The test is most sensitive within the first three days of rash onset but can detect measles virus for up to ten days after rash appearance. Throat (OP) or nasopharyngeal (NP) swabs should be obtained at first contact, and urine samples may also help confirm infection. Detection of measles RNA via RT-PCR confirms measles unless the patient was recently vaccinated. However, a negative RT-PCR test does not rule out measles, as timing, specimen quality, and handling can impact results. Clinical and epidemiologic context should guide the final diagnosis.

## 8. Prevention of Measles

- Vaccination of SOT candidates and timing of transplantation: Best practice before immune suppression would be to screen transplant candidates for either a history of receiving two doses of MMR or having positive measles serology. Many people born between 1957 and the late 1970s may have only received a single dose of the measles vaccine and may be at higher risk for poor measles protection. Those without a history of two doses of MMR and who are measles IgG negative should receive two doses of MMR during a measles outbreak. Clinical teams could consider suspending immunosuppression before and after vaccination for those on immunosuppression pre-transplant. The optimal strategy in this scenario is unknown and will likely vary from patient to patient depending on the underlying conditions. (19) Live viral vaccines should not be given to patients who would likely undergo organ transplantation within the next month (e.g., critically ill, high on a waiting list). Live viral vaccines such as measles and

varicella should not be given for 3 months after red blood cell transfusions or 8 to 11 months after administration of intravenous immunoglobulin products due to decreased immunogenicity(20).

- The CDC and IDSA recommend delaying immunosuppression for four weeks after administration of MMR vaccination. This recommendation was based on the 2-week duration of viremia seen in humans and after inoculation of macaques with wild-type measles. The optimal timing of transplantation after MMR vaccination is unknown. In certain circumstances (e.g. unexpected organ offer), transplant teams could consider a shorter waiting period (>2 weeks) before transplant after MMR vaccination, especially with a second dose, healthier patients, etc. Such decisions would need to be made on a case-by-case basis, weighing risks and benefits. Additionally, the administration of immunoglobulin could be considered in these scenarios. Recent data suggests a shorter period of detectable measles virus viremia (21), although clinical trials have not verified the safety of earlier immunosuppression administration. Fevers, febrile seizures, and rashes can occur for up to two weeks after vaccine administration, suggesting possible ongoing measles virus viremia.
- Accidental vaccination of an adult SOT recipient: In the absence of data describing the safety of measles vaccination in adult SOT recipients, we would recommend administering immunoglobulin following the recommendations for measles post-exposure prophylaxis (see below). Reporting to the [VAERS](#) database is recommended and mandated if there is a significant adverse reaction to the vaccine.
- Vaccination of SOT recipients in selected scenarios: Vaccination with MMR is an option for some SOT recipients(18). For several years, pediatric, adolescent and young adult SOT recipients have received MMR as part of clinical studies or carefully monitored clinical care(22). Initially, MMR was only recommended in pediatric liver transplant recipients on minimal single-agent immunosuppression either as part of a clinical trial or under carefully controlled settings(22, 23). Additional data since that time indicate that MMR is immunogenic and can be safely administered to carefully selected pediatric, adolescent, and young adult liver and kidney recipients on one or two immunosuppressive medications(24, 25). Some parameters to consider are the level of immunosuppression, recent augmented immunosuppression, absolute lymphocyte count, and perceived “net state of immunosuppression”. Data are lacking as to whether heart or lung recipients, older adults, those with recent augmented immunosuppression, or those with other significant immunosuppressing co-morbid conditions can safely receive MMR after SOT.
- Post-exposure prophylaxis (PEP) for SOT recipients: non-immune (unvaccinated or IgG negative pre-transplant) solid organ transplant recipients may benefit from the administration of immunoglobulins delivered within six days of measles exposure. Those under 30 kg could receive intramuscular gamma globulin at a dose of 0.5 mL/kg up to a maximum dose of 15 mL. Those over 30 kg should receive an infusion of intravenous immunoglobulin (IVIG) at a dose of 400 mg/kg.(7) It is unknown which SOT recipients will benefit the most from PEP with immunoglobulins. The CDC (2013) guidelines (7) do not state whether organ transplant recipients with immunity should be given PEP. The Canadian guidelines (2025) state that within the first year after transplant, they should

be given PEP regardless of their serologic status, and that more than a year after transplant, they should get PEP if seronegative or if other factors suggest they are at higher risk. Our challenge is the lack of data to predict who will proceed to symptomatic disease without PEP.

For those already receiving IVIG therapy, administration of at least 400 mg/kg body weight within 3 weeks before measles exposure should be sufficient to prevent measles infection, and for those receiving subcutaneous immune globulin therapy, administration of at least 200 mg/kg body weight for two consecutive weeks before measles exposure should be sufficient.(7) PEP administration is likely to introduce numerous challenges, including the need for strict infection control given measles exposure, the need for prolonged infusions (for IVIG) necessitating the use of infusion suite or hospital resources, high cost, lack of availability or significant supplies of gammaglobulin or intravenous immunoglobulin, and possible reactions to immunoglobulins. The duration of protection is not well studied, but it is probably measured in weeks, so protection during an ongoing measles outbreak may be suboptimal.

Given the increased rates of measles worldwide, consideration for evaluation of measles immunity status may be indicated in transplant recipients traveling to higher-risk destinations or who might be exposed to measles during travel. For higher-risk travel in nonimmune transplant recipients, when possible, administration of pre-exposure gamma globulin or IVIG as dosed above may provide protection; risks and benefits of pre-exposure prophylaxis should be carefully discussed.

- PEP for SOT candidates: For those who lack evidence of presumptive immunity who are eligible for vaccination, MMR vaccination should be considered if the exposure is within 72 hours of the exposure. PEP with IG should be considered for those who lack presumptive evidence of immunity and are either not eligible for vaccination (e.g. if receiving pre-transplant immunosuppression) or within 4-6 days post-exposure. PEP could be deferred for those immunocompetent transplant candidates who have evidence of immunity and are not critically ill.
- Household vaccination: vaccination of people close to the transplant candidate/recipient is a key step in prevention. Although it is a live vaccine, MMR transmission between people has not been documented and having an immunocompromised person in the home is not a contraindication to vaccination. CDC guidance suggests that all family and other close contacts of people with compromised immune systems who are 12 months of age and older should have been documented to have received, or should receive two doses of MMR vaccine separated by 28 days, unless they have other presumptive evidence of measles immunity (serology documented to be positive) (7).
- Medical staff should be immune to measles, either by receiving two doses of vaccine, or having documented disease or positive measles IgG. Most occupational health programs have protocols to ensure that healthcare workers are immune.

## 9. Treatment

The treatment of measles is supportive; there is no specific antiviral therapy approved for the treatment of measles.

Vitamin A deficiency contributes to delayed recovery and to risk of complications. There is a role for Vitamin A administration only in selected scenarios. It is recommended for children with severe measles, and children with measles in resource-limited settings(26, 27).

There is insufficient evidence to recommend the use of intravenous ribavirin for treating measles; this could be accessed through the FDA and CDC.

#### 10. Preventing Donor-Derived Measles and Measles Vaccine virus

To minimize the risk of donor-derived measles and measles vaccine virus, organ procurement organizations (OPO) should consider evaluating deceased donors for a history of measles, measles vaccination, measles exposure, and symptoms compatible with measles. The following scenarios may arise:

- Donor with a recent history of measles vaccination: A donor who recently received a dose of MMR vaccine does not shed the virus in a manner that poses a risk of transmission to the OPO or recovery teams(19). Such a donor only poses a theoretical risk of donor-derived measles vaccine virus. The potential risk is related to the duration of viremia, which is currently unknown. Studies in humans with measles and studies in macaques inoculated with wild-type measles virus describe 10-14 days of viremia(11, 12, 28, 29). A small study of unvaccinated pediatric patients (<12 months old) with liver disease awaiting transplantation also described less than 14 days of viremia (21). The duration of viremia is hypothesized to be modified by prior immunity, with a theoretically shorter duration after a second dose. OPOs and transplant teams could use this preliminary information to evaluate the risks and benefits of donation and transplantation in such a scenario.
- Donor with a measles exposure: A non-immune donor with a history of measles exposure may pose a risk of donor-derived measles and a risk of disease transmission to the OPO and recovery teams. Based on the duration of the incubation period, donation should be deferred for at least 21 days, although the optimal timing remains unknown(30). The risk of disease transmission is expected to be modified by the intensity of the exposure and prior immunity. Patients at risk for measles include children too young to be vaccinated and those who lack presumptive evidence of measles immunity. Conversely, natural infection confers lifelong immunity, and reinfections are rare(31). Although rare, individuals with vaccine-induced immunity can develop infection(32).
- The donor with suspected or confirmed measles poses a threat of donor-derived measles and risk of disease transmission to the OPO and recovery teams. Ruckle studied patients pre- and post-mortem using culture techniques (11, 12). Based on these studies, the infectious period has been determined to start four days before and last until four days after the onset of the rash. Although the optimal timing of organ donation in this scenario is unknown, these studies suggest that it should be deferred for at least four days after the onset of the rash.

## Emerging Infections American Society of Transplantation Taskforce

In the above scenarios, the recipient or next of kin should provide consent; this process and the decision to accept or decline the organ offer from a donor with a recent measles vaccination, a donor exposed to measles, or with a history of suspected or confirmed measles should also factor in what is known about the biology and pathogenesis of measles, the intended recipient's pre-transplant mortality rate and organ quality(33).

### Contributors

Emily Blumberg

Lara Danziger-Isakov

Camille Kotton

Ricardo La Hoz – Chair

Marian Michaels

Stephanie Pouch

Raymund Razonable

Fernanda Silveira

Cameron Wolfe

### References

1. Berche P. History of measles. *Presse Med.* 2022;51(3):104149.
2. Hubschen JM, Gouandjika-Vasilache I, Dina J. Measles. *Lancet.* 2022;399(10325):678-90.
3. Phadke VK, Bednarczyk RA, Omer SB. Vaccine Refusal and Measles Outbreaks in the US. *JAMA.* 2020;324(13):1344-5.
4. Zipprich J, Winter K, Hacker J, Xia D, Watt J, Harriman K, et al. Measles outbreak--California, December 2014-February 2015. *MMWR Morb Mortal Wkly Rep.* 2015;64(6):153-4.
5. Holzmann H, Hengel H, Tenbusch M, Doerr HW. Eradication of measles: remaining challenges. *Med Microbiol Immunol.* 2016;205(3):201-8.
6. Simpson RE. Infectiousness of communicable diseases in the household (measles, chickenpox, and mumps). *Lancet.* 1952;2(6734):549-54.
7. McLean HQ, Fiebelkorn AP, Temte JL, Wallace GS, Centers for Disease C, Prevention. Prevention of measles, rubella, congenital rubella syndrome, and mumps, 2013: summary recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep.* 2013;62(RR-04):1-34.
8. Watson JC, Hadler SC, Dykewicz CA, Reef S, Phillips L. Measles, mumps, and rubella--vaccine use and strategies for elimination of measles, rubella, and congenital rubella syndrome and control of mumps: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep.* 1998;47(RR-8):1-57.
9. Watson JC, Pearson JA, Markowitz LE, Baughman AL, Erdman DD, Bellini WJ, et al. An evaluation of measles revaccination among school-entry-aged children. *Pediatrics.* 1996;97(5):613-8.
10. Fiebelkorn AP, Coleman LA, Belongia EA, Freeman SK, York D, Bi D, et al. Measles Virus Neutralizing Antibody Response, Cell-Mediated Immunity, and Immunoglobulin G Antibody Avidity Before and After Receipt of a Third Dose of Measles, Mumps, and Rubella Vaccine in Young Adults. *J Infect Dis.* 2016;213(7):1115-23.
11. Ruckle G. Studies with measles virus. III. Attempts at isolation from post-mortem human tissue. *J Immunol.* 1957;79(5):361-9.

12. Ruckle G, Rogers KD. Studies with measles virus. II. Isolation of virus and immunologic studies in persons who have had the natural disease. *J Immunol.* 1957;78(5):341-55.
13. Kaplan LJ, Daum RS, Smaron M, McCarthy CA. Severe measles in immunocompromised patients. *JAMA.* 1992;267(9):1237-41.
14. Beckford AP, Kaschula RO, Stephen C. Factors associated with fatal cases of measles. A retrospective autopsy study. *S Afr Med J.* 1985;68(12):858-63.
15. Griffin DE. Measles virus-induced suppression of immune responses. *Immunol Rev.* 2010;236:176-89.
16. Mina MJ, Metcalf CJ, de Swart RL, Osterhaus AD, Grenfell BT. Long-term measles-induced immunomodulation increases overall childhood infectious disease mortality. *Science.* 2015;348(6235):694-9.
17. Okamura A, Itakura O, Yoshioka M, Kubota M, Kikuta H, Kobayashi K. Unusual presentation of measles giant cell pneumonia in a patient with acquired immunodeficiency syndrome. *Clin Infect Dis.* 2001;32(3):E57-8.
18. Aicardi J, Goutieres F, Arsenio-Nunes ML, Lebon P. Acute measles encephalitis in children with immunosuppression. *Pediatrics.* 1977;59(2):232-9.
19. Rubin LG, Levin MJ, Ljungman P, Davies EG, Avery R, Tomblyn M, et al. 2013 IDSA Clinical Practice Guideline for Vaccination of the Immunocompromised Host. *Clin Infect Dis.* 2014;58(3):e44-e100.
20. Kroger A, L. B, S. L, P. S. General Best Practice Guidelines for Immunization Atlanta GA: United States Centers for Disease Control and Prevention; 2014 [Available from: <https://www.cdc.gov/vaccines/hcp/acip-recs/general-recs/downloads/general-recs.pdf>.
21. Kemme S, Canniff JD, Garth KM, Li S, Mysore K, Weinberg A, et al. Detection of viral RNA and DNA and immune response following administration of live attenuated measles and varicella vaccines in children with chronic liver disease. *Am J Transplant.* 2025;25(1):181-8.
22. Pittet LF, Verolet CM, McLin VA, Wildhaber BE, Rodriguez M, Cherpillod P, et al. Multimodal safety assessment of measles-mumps-rubella vaccination after pediatric liver transplantation. *Am J Transplant.* 2019;19(3):844-54.
23. Suresh S, Upton J, Green M, Pham-Huy A, Posfay-Barbe KM, Michaels MG, et al. Live vaccines after pediatric solid organ transplant: Proceedings of a consensus meeting, 2018. *Pediatr Transplant.* 2019;23(7):e13571.
24. Feldman AG, Beaty BL, Ferrolino JA, Maron G, Ali SA, Bitterfeld L, et al. Postvaccination Immunogenicity Among Pediatric Solid Organ Transplant Recipients. *JAMA Pediatr.* 2025.
25. Feldman AG, Beaty BL, Ferrolino JA, Maron G, Weidner HK, Ali SA, et al. Safety and Immunogenicity of Live Viral Vaccines in a Multicenter Cohort of Pediatric Transplant Recipients. *JAMA Netw Open.* 2023;6(10):e2337602.
26. Huiming Y, Chaomin W, Meng M. Vitamin A for treating measles in children. *Cochrane Database Syst Rev.* 2005;2005(4):CD001479.
27. Hussey GD, Klein M. A randomized, controlled trial of vitamin A in children with severe measles. *N Engl J Med.* 1990;323(3):160-4.

28. de Vries RD, McQuaid S, van Amerongen G, Yuksel S, Verburgh RJ, Osterhaus AD, et al. Measles immune suppression: lessons from the macaque model. *PLoS Pathog.* 2012;8(8):e1002885.
29. Nelson AN, Lin WW, Shivakoti R, Putnam NE, Mangus L, Adams RJ, et al. Association of persistent wild-type measles virus RNA with long-term humoral immunity in rhesus macaques. *JCI Insight.* 2020;5(3).
30. Richardson M, Elliman D, Maguire H, Simpson J, Nicoll A. Evidence base of incubation periods, periods of infectiousness and exclusion policies for the control of communicable diseases in schools and preschools. *Pediatr Infect Dis J.* 2001;20(4):380-91.
31. Schaffner W, Schluederberg AE, Byrne EB. Clinical epidemiology of sporadic measles in a highly immunized population. *N Engl J Med.* 1968;279(15):783-9.
32. Avramovich E, Indenbaum V, Haber M, Amitai Z, Tsifanski E, Farjun S, et al. Measles Outbreak in a Highly Vaccinated Population - Israel, July-August 2017. *MMWR Morb Mortal Wkly Rep.* 2018;67(42):1186-8.
33. La Hoz RM. Minimizing the Risk of Donor-Derived Events and Maximizing Organ Utilization Through Education and Policy Development. *Infect Dis Clin North Am.* 2023;37(3):443-58.