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Recommendations for *herpes zoster* prevention in solid organ transplant recipients in Poland

Abstract

Herpes zoster (i.e. shingles) is a widespread infectious disease caused by reactivation of the varicella-zoster virus. Although the cutaneous manifestation of the disease is the most common, shingles is also associated with numerous complications, e.g. neurological, including postherpetic neuralgia. It is estimated that one-third of the general population will develop herpes zoster during their lifetime, and the incidence in solid organ recipients is even higher. What is more transplant recipients are more likely to suffer from severe complications of the disease. The most effective method of preventing herpes zoster is vaccination. The only vaccine recommended and available in Poland is recombinant adjuvanted zoster vaccine. Its safety and effectiveness were demonstrated in both the general adult population and solid organ recipients.

In this article, we present the position of experts in transplantation and infectious diseases on herpes zoster prevention in the solid organ transplant recipient population. The group includes kidney, liver, lung, and heart recipients.

Key words: herpes zoster prevention, solid organ transplant recipients, vaccination

INTRODUCTION

ETIOLOGY AND PATHOGENESIS

Herpes zoster (HZ, i.e. shingles) is an infectious disease caused by reactivation of the varicella-zoster virus (VZV, currently described as Human Herpesvirus-3 — HHV-3). The primary VZV infection, usually in the form of chickenpox, most commonly affects children. The primary disease occasionally occurs as an intrauterine infection or as a result of live zoster vaccination [1]. In the further course of the infection, when the immunity to VZV is established, the virus spreads along sensory neurons to the dorsal root ganglia. The infection then progresses to a latent form [2]. In immunocompromised or elderly patients, due to immune response disabilities, latent VZV infection reactivation may occur. The 10-year recurrence rate reaches up to 10% [3]. The virus travels antegradely to the skin nerve terminals and accesses epithelial cells causing clinically active *herpes zoster* [1, 4–5].

RISK FACTORS

The additional risk factors for developing *herpes zoster* are age ≥ 50 years, immunodeficiency (immunosuppression, human immunodeficiency virus [HIV] infection, malignancies, solid organ or hematopoietic stem cell trans-

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plantation), and additional comorbidities (e.g. cardiovascular disease, chronic liver disease, chronic kidney disease, chronic obstructive pulmonary disease, autoimmune diseases: systemic lupus erythematosus or rheumatoid arthritis, diabetes mellitus, inflammatory bowel disease, depression, bronchial asthma, physical trauma [e.g. surgery], COVID-19). The highest incidence rates apply to patients with hematological malignancies and patients with solid organ tumors (e.g. lung cancer). What is more, elderly patients with cancer have a 1.2–2.4-fold higher risk of developing HZ than those without malignancy [6–8].

EPIDEMIOLOGY

There is no obligation to report *herpes zoster* incidents in Poland; therefore, the exact number of cases is not known. Worldwide, the incidence of *herpes zoster* ranges from 1.2 to 3.4 cases per 1000 people per year. What is more, the incidence increases to 3.9–11.8 per 1000 people for people over 65 years of age. Most (95–97%) of the adult population is VZV-IgG-positive. Thus, it is estimated that one-third of the worldwide general population will develop *herpes zoster* during their lifetime [9].

CLINICAL MANIFESTATIONS AND COMPLICATIONS OF *HERPES ZOSTER*

Herpes zoster usually begins with prodromal non-specific symptoms such as hypersensitivity, itching, burning, or pain of the skin. It is followed by a vesicular rash along corresponding dermatomes (one or two unilateral dermatomes innervated by the same sensory nerve). The vesicles filled with serous content containing VZV particles transform into scabs within 2–4 weeks [10–11]. The rash most often develops on the trunk (in one-third it is located on the upper part of the trunk) [12]. In rare cases, the lesions may affect ≥ 3 dermatomes (disseminated form). Other manifestations are less common and are associated with severe course and complications. It is estimated that 8–20% of patients suffer from zoster ophthalmicus caused by reactivation of latent VZV in the trigeminal ganglion. The viruses spread through the ocular nerve causing lesions on the skin of the upper eyelid, the conjunctiva, and on the cornea itself. A possible complication of this form of the disease is painful ulceration that can lead to loss of eyesight [13].

Another form of *herpes zoster* is herpes zoster oticus involving the auricle (painful lesions on the earlobe), external auditory canal, or tympanic membrane. The possible complication of this form of the disease is hearing loss or persistent tinnitus. In rare cases, it manifests as Ramsay-Hunt syndrome which is defined by a triad of symptoms including unilateral ear pain, vesicles in the external auditory canal, and facial nerve palsy [14]. HZ is not always associated with visible skin lesions, e. g. the visceral zoster (presenting as abdominal pain, elevated liver enzymes, and hyponatremia often without visible skin lesions) may present with delayed or absent rash.

The most common symptom of *herpes zoster* is pain, which can be of inflammatory or neuropathic origin. The acute phase of pain lasts up to 30 days and the subacute phase 30–90 days. However, the most common long-term complication is chronic pain — post-herpetic neuralgia (PHN) defined as pain lasting for longer than 3 months. It is estimated that even up to 40% of patients may experience pain six months after the disease and 20% after 1 year. The incidence of PHN increases in the elderly patients to 60–70% [15]. This pain is most likely related to post-herpetic tissue damage and significantly affects patients' quality of life [16–18].

A recent publication identified also an increased incidence of myocardial infarction within the 30 days following *herpes zoster*. The additional risk factors described were previous history of myocardial infarction, male sex, age ≥ 50 years, history of heart failure, peripheral vascular disease, HIV infection, previous cerebrovascular incident, and renal disease [19].

THE COURSE OF *HERPES ZOSTER* AFTER SOLID ORGAN TRANSPLANTATION

The incidence rates of herpes zoster in immunocompromised or immunosuppressed patients are significantly higher in comparison to the age-adjusted healthy population [20]. That higher incidence is associated with reduced cellular immunity; thus, the viral replication is not inhibited properly, which causes susceptibility to VZV replication [21].

Several studies including patients after solid organ transplantation (SOT) demonstrate that the organ recipient population is at exceptional risk of developing HZ, including the severe, complicated, recurrent, and disseminated form. It is estimated that the *herpes zoster* incidence in adult SOT recipients is approximately 8–11% during the first

4 years post-transplantation [37]. In a cohort study, in 1077 eligible SOT recipients, the cohort-specific HZ incidence rate was 22.2 per 1000 patient-years (0.95 CI, 18.1–27.4). The highest HZ incidence was observed in heart transplant recipients (40.0 per 1000 patient-years [PY][95% CI, 23.2–68.9]) [22]. What is more, another study by Klo MML et al. including 1033 SOT recipients, indicated that, in addition to heart recipients, lung recipients are also at significant risk of HZ and its complications (38.8 per 1000 PY). In the case of older recipients, the lack of CMV (cytomegalovirus) prophylaxis and inductive therapy with anti-thymocyte globulin (ATG) were also shown as additional risk factors for HZ incidence after SOT [23]. The incidence of HZ in orthotopic liver transplantaion (OLTx) recipients is comparable between countries, ranging from about 16.3 to 22.7 per 1000 PY [24]. As with the above, the incidence of HZ in kidney recipients does not differ substantially between developed countries and ranges from 24.4 to 28.0 per 1000 PY [25].

The disseminated, ophthalmic, and facial form of HZ with the involvement of multiple dermatomes is more frequent in SOT recipients. Such complications as PHN, ocular complications (keratopathy, episcleritis, iritis, monocular blindness), cranial nerve involvement, or encephalitis occur on average in 31% [39% of heart transplantation (HTx), 47% of lung transplantation (LuTx), 20% of OLTx, 20% of kidney transplantation (KTx)] [23, 26].

VACCINATION AGAINST *HERPES ZOSTER* — SAFETY AND EFFECTIVENESS

The most effective method of preventing *herpes zoster* and its complications is vaccination; however, it is not intended for post-exposure prophylaxis or HZ treatment. Currently, two vaccines against *herpes zoster* are registered in the European Union (EU):

- live, attenuated herpes zoster vaccine (*Zostavax, ZVL*): registered in the USA and EU in 2006, currently unavailable in Poland. It is given subcutaneously in one dose. It can only be administered to immunocompetent individuals (healthy adults 50 years or older) as it contains replication-competent viruses. The efficacy in HZ prevention is 51%, and PHN prevention is 67% in an average 3-year post-vaccination follow-up [27]
- recombinant, adjuvanted zoster vaccine (*Shingrix, RZV*): subunit vaccine containing recombinant glycoprotein E in combination with adjuvant ($AS01_B$) to boost the immune response. Currently, it is the only recombinant vaccine available in Poland (registered in the EU in 2018, in Poland in 03.2023) for the prevention of *herpes zoster* and post-herpetic neuralgia in patients ≥ 50 years of age and those aged ≥ 18 years with increased risk of developing HZ. It is also preferred over the Zostavax vaccine. The vaccination schedule includes the intramuscular administration of 2 doses within 2–6 months.

The efficacy of the RZV vaccine is very high. It has been shown to reduce the risk of developing *herpes zoster* by 97.2% in adults ≥ 50 years of age and by 89.8% in adults over 70 years of age in 3-year follow-up. Moreover, vaccination with RZV decreased significantly the risk of PHN by 91.2% in people aged ≥ 50 years and by 88.8% in people aged ≥ 70 years [28, 29]. Vaccination also substantially reduced the duration of HZ-associated pain, its intensity, and the amount of used analgesic medications [30]. Recently published data have also shown a reduction in the likelihood of myocardial infarction in patients aged ≥ 50 years after vaccination against *herpes zoster* [19].

Most adverse reactions (AEs) after RZV vaccination were described as mild to moderate in intensity (such as fatigue or myalgia) with a median duration of 3 days. The incidence rate of severe AEs or death was similar to the placebo group [28, 29]. Immunization was associated with long-term protection, as demonstrated in 6-year follow-up. Specific antibody titer was shown to be 7.3-fold higher at month 72 post-vaccination, and the gE-specific cell-mediated immune response was 3.8-fold higher than the pre-vaccination value [31].

It is not necessary to confirm serological VZV-IgG status before vaccination against *herpes zoster*. The vaccine can be given to patients vaccinated against VZV in the past. In case of acute HZ, vaccination should be postponed for 12 months. There are no data on the requirement for booster doses.

VACCINATION AGAINST *HERPES ZOSTER* IN SOLID ORGAN TRANSPLANT RECIPIENTS

In SOT recipients, the immunosuppressive treatment causes a reduced B and/or T lymphocyte reaction; therefore, the humoral and cellular response to vaccination is suboptimal implying the insufficiency of specific immuni-

ty. The ultimate response to vaccination after transplantation depends also on many factors, such as the type and dosage of immunosuppression, the age of the recipient, or additional comorbidities. What is more, the antibodies produced after vaccination tend to disappear more rapidly in this group of patients; however, antibody titers before transplantation are a predictor of antibody titers after the procedure. The timing of vaccination appears to determine the crucial role of the immunization process, and it should ideally be carried out during the pre-transplantation waiting period (ZVL or RZV). Most vaccines appear to be safe in SOT recipients; however, live attenuated vaccines are contraindicated after transplantation due to the risk of developing vaccine-induced disease, and they should be given at least 4 weeks before transplantation. On the other hand, the safety, immunogenicity, and efficacy of the recombinant, adjuvanted vaccine have been demonstrated in groups at increased risk of developing HZ: autologous hematopoietic stem cell transplantation (HSCT) recipients (vaccine efficacy [VE] of 68.2%), patients with solid or hematopoietic malignancies (VE of 87.2%), those infected with HIV or after solid organ transplantation. The serious AEs ratio is comparable between placebo and RZV recipients (risk ratios ranged from 0.79 to 1.99) [25, 32–38].

Moreover, long-term HZ prevention in autologous HSCT has been shown, as immunogenicity was sustained up to 10 years after vaccination [39].

KIDNEY TRANSPLANT RECIPIENTS (KTRS)

Research into the efficacy and safety of recombinant adjuvanted vaccines against HZ in renal recipient populations is emerging in the literature. A phase III study investigating the safety and immunogenicity of two doses of RZV in KTRs (aged ≥ 18 years) showed humoral responses at month 2 (anti-glycoprotein E antibody geometric mean concentrations of 19163.8 mIU/mL) that persisted until month 13 (8545 mIU/mL). The antibody titers were significantly higher than pre-vaccination baseline levels and significantly higher than in the placebo group. What is more, cellular-mediated immunogenicity was measured, and the study objectives were met (vaccine response rate [VRR] in the RZV group was 80.2% at month 2). No clinically relevant safety concerns were identified as the vaccinated KTR group reported mild to moderate AEs, such as myalgia, shivering, and fever with a median duration of ≤ 4 days [34]. Another study carried out by Lindemann et. Al. showed that RZV is associated with the strongest vaccination-induced cellular immunity against the VZV gE peptide. The responses measured with interferon-gamma ELISpot after stimulation with a gE peptide after the second dose of vaccine were 8-fold and 4.8-fold higher than the response before vaccination and after the first dose, respectively [40]. Similar results regarding increased cellular and humoral responses after RZV were shown in a cross-sectional study by Roch et. Al. on 39 immunosuppressed KTRs [41].

A matter of great concern Is the potential vaccine-induced allograft rejection. In the mentioned study, no difference was observed in terms of rejection between the placebo and RZV. No biopsy-proven rejection was observed in first 30 day post-vaccination. A total of 11 rejection processes were recorded (4 in RZV, 7 in the placebo group), of which 1 was in the RZV group and 4 in the placebo group in KTRs with low rejection risk based on PRA/cPRA (PRA/cPRA, 0–19%). Allograft function was similar in both groups in long-term follow-up [34].

RZV was also shown to be safe and effective in VZV-seronegative SOT patients and may be considered as prevention against primary VZV infection [42].

There are several ongoing clinical studies investigating ZVL administered before renal transplantation.

LIVER TRANSPLANT RECIPIENTS

Herpes zoster remains a risk factor for chronic liver disease (CLD) decompensation. Although the probability of HZ occurrence in CLD patients is similar to the general population, it significantly increases after liver transplantation and as a result of the associated immunosuppression. Therefore, the Advisory Committee on Immunization Practices (ACIP) recommends vaccination against HZ in the pre-transplantation period in patients aged ≥ 50 years (RZV is preferred). As CLD severity progresses, vaccine efficacy declines, thus for optimal immune response, vaccines should be ideally administered early in the disease course. The overall incidence of HZ in liver recipients in the first year after transplantation is around 6%, increases up to 12% in 10-year follow-up, and is lower than in other SOT recipients. No HZ risk factors, attributed specifically to liver transplantation, were identified in multivariate analysis [Ref?] . Serious

complications such as visceral dissemination, cranial nerve involvement, or death are uncommon after OLT, but patients may suffer from long-lasting PHN with a significant decrease in the quality of life [43]. Vaccinations against HZ in liver recipients turned out to be safe and effective. In the post-transplantation period, ZVL vaccines are contraindicated, and RZV is the vaccine of choice [44, 45].

LUNG AND HEART TRANSPLANT RECIPIENTS

The lung and heart transplant recipient are at very high risk of *herpes zoster* and its complications. The data describing the safety and efficacy of the HZ vaccines are, however, limited. In a recently published study, the immunogenicity and safe profile of RZV in LuTx recipients (aged ≥ 50 years, > 90 days after LuTx, VZV-IgG-seropositive) was presented. There was an increase in the percentage of VZV gE-specific CD4+T cells from a median of 85 $CD4^{2+}$ T cells per 10^6 CD4 T cells (IQR: 46–180) before vaccination to a median of 361 $CD4^{2+}$ T cells per 10^6 CD4 T cells (IQR: 146–848; $p < 0.0001$) after the second dose of vaccine. During the follow-up, mostly local AEs were reported (tenderness at the injection site, redness and swelling; all were self-limiting). Several severe AEs (respiratory failures, death, and graft rejection) were observed; however, due to a long interval between AEs and RZV immunization, these episodes were classified as unrelated to vaccination [46].

The data concerning heart transplant recipients are limited. Several single-center studies have been performed; however, efficacy was not evaluated. Vaccination with RZV in HTx recipients was well tolerated. Reported AEs were mostly mild and local (arm soreness, swelling). There was no evidence of an increased allograft rejection ratio [47]. The efficacy of vaccination against HZ before transplantation was, however, suggested as a decrease in the clinical development of HZ was observed [48] [Unclear sentence].

RECOMMENDATIONS FOR THE USE OF *HERPES ZOSTER* VACCINES IN SOLID ORGAN TRANSPLANT RECIPIENTS IN POLAND

1. All adult (≥18 years of age) solid organ transplant recipients should be vaccinated against herpes zoster.
2. All adult (≥ 18 years of age) candidates qualified for organ transplantation should be vaccinated against herpes zoster before transplantation. If possible, the vaccine should be administered when the primary disease is stable. The recombinant adjuvanted vaccine is recommended.
3. The recombinant adjuvanted vaccine is recommended in the post-transplantation period. The live, attenuated VZV vaccine is contraindicated after organ transplantation.
4. Two RZV doses are necessary, regardless of previous history of herpes zoster, VZV vaccination, and VZV-IgG status.
5. In patients not vaccinated before transplantation, the first dose of RZV is recommended at least 3–6 months after transplantation. The second RZV dose should be administered 2–6 months after the first. No booster doses are recommended.
6. Currently, it is not recommended to perform serological or cellular response tests to assess response to vaccination against herpes zoster.
7. Vaccination may be administered during antiviral treatment or prophylaxis.
8. RZV can be administered concomitantly with other vaccines; however, at different anatomic sites. If possible, administration of the second vaccine should be postponed due to post-vaccination adverse events overlaps.
9. Before vaccination, providers should counsel patients about expected local and systemic adverse events. It is not recommended to take antipyretic or analgesic medications prophylactically before vaccination.
10. The only permanent contraindication to herpes zoster vaccination is hypersensitivity to any component of the vaccine or serious AEs following the previous dose.
11. Short-term prophylaxis with acyclovir or valacyclovir is recommended for organ recipients who are HSV and VZV seropositive and not receiving CMV prophylaxis.
12. If herpes zoster occurs after organ transplantation, the RZV dose should be administered at least 1 year after the incident.
13. Herpes zoster vaccines should be widely available to all patients qualified for solid organ transplantation as well as to organ recipients.

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Not required

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Conceptualization — ADŚ.; Writing — all authors. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST:

All authors participated in GlaxoSmithKline's expert panel: EXPERT ROUND TABLE DISCUSSION ON REDUCING THE RISK OF DEVELOPING HERPES ZOSTER INFECTION IN PATIENTS AFTER ORGAN TRANSPLANTATION AND IN POTENTIAL RECIPIENTS ON THE WAITING LIST FOR TRANSPLANTATION.

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References

1. Weller TH. Varicella and herpes zoster. Changing concepts of the natural history, control, and importance of a not-so-benign virus. N Engl J Med. 1983; 309(23): 1434–1440, doi: 10.1056/NEJM198312083092306, indexed in Pubmed: 6195526.
2. Zerboni L, Sen N, Oliver SL, et al. Molecular mechanisms of varicella zoster virus pathogenesis. Nat Rev Microbiol. 2014; 12(3): 197–210, doi: 10.1038/nrmicro3215, indexed in Pubmed: 24509782.
3. Tseng HFu, Bruxvoort K, Ackerson B, et al. The Epidemiology of Herpes Zoster in Immunocompetent, Unvaccinated Adults ≥50 Years Old: Incidence, Complications, Hospitalization, Mortality, and Recurrence. J Infect Dis. 2020; 222(5): 798–806, doi: 10.1093/infdis/jiz652, indexed in Pubmed: 31830250.
4. Schmader K. Herpes Zoster. Clin Geriatr Med. 2016; 32(3): 539–553, doi: 10.1016/j.cger.2016.02.011, indexed in Pubmed: 27394022.
5. John AR, Canaday DH. Herpes Zoster in the Older Adult. Infect Dis Clin North Am. 2017; 31(4): 811–826, doi: 10.1016/j.idc.2017.07.016, indexed in Pubmed: 29079160.
6. Marra F, Parhar K, Huang B, et al. Risk Factors for Herpes Zoster Infection: A Meta-Analysis. Open Forum Infect Dis. 2020; 7(1): ofaa005, doi: 10.1093/ofid/ofaa005, indexed in Pubmed: 32010734.
7. Bhavsar A, Lonnet G, Wang C, et al. Increased Risk of Herpes Zoster in Adults ≥50 Years Old Diagnosed With COVID-19 in the United States. Open Forum Infect Dis. 2022; 9(5): ofac118, doi: 10.1093/ofid/ofac118, indexed in Pubmed: 35392454.
8. Yenikomshian MA, Guignard AP, Haguinet F, et al. The epidemiology of herpes zoster and its complications in Medicare cancer patients. BMC Infect Dis. 2015; 15: 106, doi: 10.1186/s12879-015-0810-6, indexed in Pubmed: 25888128.
9. Varicella and herpes zoster vaccines: WHO position paper, June 2014--Recommendations. Vaccine. 2016; 34(2): 198–199, doi: 10.1016/j.vaccine.2014.07.068, indexed in Pubmed: 26723191.
10. Johnson RW, Alvarez-Pasquin MJ, Bijl M, et al. Herpes zoster epidemiology, management, and disease and economic burden in Europe: a multidisciplinary perspective. Ther Adv Vaccines. 2015; 3(4): 109–120, doi: 10.1177/2051013615599151, indexed in Pubmed: 26478818.
11. Patil A, Goldust M, Wollina U. Herpes zoster: A Review of Clinical Manifestations and Management. Viruses. 2022; 14(2), doi: 10.3390/v14020192, indexed in Pubmed: 35215786.
12. Curran D, Matthews S, Boutry C, et al. Natural History of Herpes Zoster in the Placebo Groups of Three Randomized Phase III Clinical Trials. Infect Dis Ther. 2022; 11(6): 2265–2277, doi: 10.1007/s40121-022-00689-7, indexed in Pubmed: 36322332.
13. Shaikh S, Ta CN. Evaluation and management of herpes zoster ophthalmicus. Am Fam Physician. 2002; 66(9): 1723–1730, indexed in Pubmed: 12449270.
14. Bienkowski C, Kowalczyk M, Talarek E, et al. Meningitis and Ramsay-Hunt syndrome in a 17-year old girl. Neuroendocrinol Lett. 2019; 40: 149–151.
15. Albrecht P, Patrzałek M, Goryński P. Zagrożenie półpaścem i jego powikłaniami w Polsce i na świecie w zależności od wieku. Przegl Epidemiol. 2015; 69: 841–843.
16. Dworkin RH, Gnann JW, Oaklander AL, et al. Diagnosis and assessment of pain associated with herpes zoster and postherpetic neuralgia. J Pain. 2008; 9(1 Suppl 1): S37–S44, doi: 10.1016/j.jpain.2007.10.008, indexed in Pubmed: 18166464.
17. Jung BF, Johnson RW, Griffin DRJ, et al. Risk factors for postherpetic neuralgia in patients with herpes zoster. Neurology. 2004; 62(9): 1545–1551, doi: 10.1212/01.wnl.0000123261.00004.29, indexed in Pubmed: 15136679.
18. Gross GE, Eisert L, Doerr HW, et al. S2k guidelines for the diagnosis and treatment of herpes zoster and postherpetic neuralgia. J Dtsch Dermatol Ges. 2020; 18(1): 55–78, doi: 10.1111/ddg.14013, indexed in Pubmed: 31951098.
19. Parameswaran GI, Drye AF, Wattengel BA, et al. Increased Myocardial Infarction Risk Following Herpes Zoster Infection. Open Forum Infect Dis. 2023; 10(4): ofad137, doi: 10.1093/ofid/ofad137, indexed in Pubmed: 37035490.
20. Forbes HJ, Bhaskaran K, Thomas SL, et al. Quantification of risk factors for herpes zoster: population based case-control study. BMJ. 2014; 348: g2911, doi: 10.1136/bmj.g2911, indexed in Pubmed: 25134101.
21. Arvin A. Aging, immunity, and the varicella-zoster virus. N Engl J Med. 2005; 352(22): 2266–2267, doi: 10.1056/NEJMp058091, indexed in Pubmed: 15930416.
22. Pergam SA, Forsberg CW, Boeckh MJ, et al. Herpes zoster incidence in a multicenter cohort of solid organ transplant recipients. Transpl Infect Dis. 2011; 13(1): 15–23, doi: 10.1111/j.1399-3062.2010.00547.x, indexed in Pubmed: 20636480.
23. Kho MML, Roest S, Bovée DM, et al. Herpes Zoster in Solid Organ Transplantation: Incidence and Risk Factors. Front Immunol. 2021; 12: 645718, doi: 10.3389/fimmu.2021.645718, indexed in Pubmed: 33815403.
24. Kim W, Kim S, Oh J, et al. Incidence and risk factors for herpes zoster after adult liver transplantation. Ann Surg Treat Res. 2019; 96(2): 95–99, doi: 10.4174/astr.2019.96.2.95, indexed in Pubmed: 30746357.
25. Sullivan KM, Farraye FA, Winthrop KL, et al. Safety and efficacy of recombinant and live herpes zoster vaccines

for prevention in at-risk adults with chronic diseases and immunocompromising conditions. Vaccine. 2023; 41(1): 36–48, doi: 10.1016/j.vaccine.2022.10.063, indexed in Pubmed: 36460534.
26. Davis AR, Sheppard J. Herpes Zoster Ophthalmicus Review and Prevention. Eye Contact Lens. 2019; 45(5): 286–291, doi: 10.1097/ICL.0000000000000591, indexed in Pubmed: 30844951.
27. Gabutti G, Valente N, Sulcaj N, et al. Italian Universities and Epidemiology. [Herpes Zoster and its prevention in Italy. Scientific consensus statement]. Ig Sanita Pubbl. 2014; 70(1): 111–127, indexed in Pubmed: 24770367.
28. Lal H, Cunningham AL, Godeaux O, et al. ZOE-50 Study Group. Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. N Engl J Med. 2015; 372(22): 2087–2096, doi: 10.1056/NEJMoa1501184, indexed in Pubmed: 25916341.
29. Cunningham AL, Heineman TC, Lal H, et al. ZOE-50/70 Study Group, ZOE-50/70 Study Group, ZOE-70 Study Group, ZOE-50 Study Group. Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. N Engl J Med. 2015; 372(22): 2087–2096, doi: 10.1056/NEJMoa1501184, indexed in Pubmed: 25916341.
30. Kim JH, Johnson R, Kovac M, et al. Adjuvanted recombinant zoster vaccine decreases herpes zoster-associated pain and the use of pain medication across 3 randomized, placebo-controlled trials. Pain. 2023; 164(4): 741–748, doi: 10.1097/j.pain.0000000000002760, indexed in Pubmed: 36066965.
31. Chlibek R, Pauksens K, Rombo L, et al. Long-term immunogenicity and safety of an investigational herpes zoster subunit vaccine in older adults. Vaccine. 2016; 34(6): 863–868, doi: 10.1016/j.vaccine.2015.09.073, indexed in Pubmed: 26432913.
32. Duchini A, Goss JA, Karpen S, et al. Vaccinations for adult solid-organ transplant recipients: current recommendations and protocols. Clin Microbiol Rev. 2003; 16(3): 357–364, doi: 10.1128/CMR.16.3.357-364.2003, indexed in Pubmed: 12857772.
33. Kumar D. Immunizations following solid-organ transplantation. Curr Opin Infect Dis. 2014; 27(4): 329–335, doi: 10.1097/QCO.0000000000000078, indexed in Pubmed: 24945614.
34. Vink P, Ramon Torrell JM, Sanchez Fructuoso A, et al. Z-041 Study Group. Immunogenicity and Safety of the Adjuvanted Recombinant Zoster Vaccine in Chronically Immunosuppressed Adults Following Renal Transplant: A Phase 3, Randomized Clinical Trial. Clin Infect Dis. 2020; 70(2): 181–190, doi: 10.1093/cid/ciz177, indexed in Pubmed: 30843046.
35. Bastidas A, de la Serna J, El Idrissi M, et al. ZOE-HSCT Study Group Collaborators. Effect of Recombinant Zoster Vaccine on Incidence of Herpes Zoster After Autologous Stem Cell Transplantation: A Randomized Clinical Trial. JAMA. 2019; 322(2): 123–133, doi: 10.1001/jama.2019.9053, indexed in Pubmed: 31287523.
36. Dagnew AF, Ilhan O, Lee WS, et al. Zoster-039 study group. Immunogenicity and safety of the adjuvanted recombinant zoster vaccine in adults with haematological malignancies: a phase 3, randomised, clinical trial and post-hoc efficacy analysis. Lancet Infect Dis. 2019; 19(9): 988–1000, doi: 10.1016/S1473-3099(19)30163-X, indexed in Pubmed: 31399377.
37. Pergam SA, Limaye AP. AST Infectious Diseases Community of Practice. Varicella zoster virus in solid organ transplantation: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. Clin Transplant. 2019; 33(9): e13622, doi: 10.1111/ctr.13622, indexed in Pubmed: 31162727.
38. Anderson TC, Masters NB, Guo A, et al. Use of Recombinant Zoster Vaccine in Immunocompromised Adults Aged ≥19 Years: Recommendations of the Advisory Committee on Immunization Practices - United States, 2022. MMWR Morb Mortal Wkly Rep. 2022; 71(3): 80–84, doi: 10.15585/mmwr.mm7103a2, indexed in Pubmed: 35051134.
39. Strezova A, Diez-Domingo J, Al Shawafi K, et al. Zoster-049 Study Group. Long-term Protection Against Herpes Zoster by the Adjuvanted Recombinant Zoster Vaccine: Interim Efficacy, Immunogenicity, and Safety Results up to 10 Years After Initial Vaccination. Open Forum Infect Dis. 2022; 9(10): ofac485, doi: 10.1093/ofid/ofac485, indexed in Pubmed: 36299530.
40. Lindemann M, Baumann C, Wilde B, et al. Prospective, Longitudinal Study on Specific Cellular Immune Responses after Vaccination with an Adjuvanted, Recombinant Zoster Vaccine in Kidney Transplant Recipients. Vaccines (Basel). 2022; 10(6), doi: 10.3390/vaccines10060844, indexed in Pubmed: 35746452.
41. Roch T, Wehler P, Blazquez-Navarro A, et al. Kidney Transplant Patients Generate Varicella Zoster-Reactive T-cell and Humoral Immunity Following Protein-based Varicella Zoster Vaccination. Transplantation. 2023; 107(2): e58–e59, doi: 10.1097/TP.0000000000004406, indexed in Pubmed: 36696521.
42. L'Huillier AG, Hirzel C, Ferreira VH, et al. Evaluation of Recombinant Herpes Zoster Vaccine for Primary Immunization of Varicella-seronegative Transplant Recipients. Transplantation. 2021; 105(10): 2316–2323, doi: 10.1097/TP.0000000000003621, indexed in Pubmed: 33528118.
43. Levitsky J, Kalil A, Meza JL, et al. Herpes zoster infection after liver transplantation: a case-control study. Liver Transpl. 2005; 11(3): 320–325, doi: 10.1002/lt.20356, indexed in Pubmed: 15719387.
44. Alukal JJ, Naqvi HA, Thuluvath PJ. Vaccination in Chronic Liver Disease: An Update. J Clin Exp Hepatol. 2022; 12(3): 937–947, doi: 10.1016/j.jceh.2021.12.003, indexed in Pubmed: 34975241.
45. Dooling KL, Guo A, Patel M, et al. Recommendations of the Advisory Committee on Immunization Practices for Use of Herpes Zoster Vaccines. MMWR Morb Mortal Wkly Rep. 2018; 67(3): 103–108, doi: 10.15585/mmwr.mm6703a5, indexed in Pubmed: 29370152.
46. Hirzel C, L'Huillier AG, Ferreira VH, et al. Safety and immunogenicity of adjuvanted recombinant subunit herpes zoster vaccine in lung transplant recipients. Am J Transplant. 2021; 21(6): 2246–2253, doi: 10.1111/ajt.16534, indexed in Pubmed: 33565711.
47. Barghash MH, Taimur S, Rana M, et al. Recombinant herpes zoster vaccine after heart transplantation: A single-center experience. J Heart Lung Transplant. 2020; 39(12): 1501–1503, doi: 10.1016/j.healun.2020.09.001, indexed in Pubmed: 33067105.
48. Kittleson M, Patel J, Chang D, et al. Effect of the Shingles Vaccine in Altering Clinical Shingles after Heart Transplantation. The Journal of Heart and Lung Transplantation. 2020; 39(4): S479, doi: 10.1016/j.healun.2020.01.032.