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2019 update of EULAR recommendations for vaccination in adult patients with autoimmune inflammatory rheumatic diseases

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ABSTRACT

To update the European League Against Rheumatism (EULAR) recommendations for vaccination in adult patients with autoimmune inflammatory rheumatic diseases (AIIRD) published in 2011. Four systematic literature reviews were performed regarding the incidence/prevalence of vaccine-preventable infections among patients with AIIRD; efficacy, immunogenicity and safety of vaccines; effect of anti-rheumatic drugs on the response to vaccines; effect of vaccination of household of AIIRDs patients. Subsequently, recommendations were formulated based on the evidence and expert opinion. The updated recommendations comprise six overarching principles and nine recommendations. The former address the need for an annual vaccination status assessment, shared decision-making and timing of vaccination, favouring vaccination during quiescent disease, preferably prior to the initiation of immunosuppression. Non-live vaccines can be safely provided to AIIRD patients regardless of underlying therapy, whereas live-attenuated vaccines may be considered with caution. Influenza and pneumococcal vaccination should be strongly considered for the majority of patients with AIIRD. Tetanus toxoid and human papilloma virus vaccination should be provided to AIIRD patients as recommended for the general population. Hepatitis A, hepatitis B and herpes zoster vaccination should be administered to AIIRD patients at risk. Immunocompetent household members of patients with AIIRD should receive vaccines according to national guidelines, except for the oral poliomyelitis vaccine. Live-attenuated vaccines should be avoided during the first 6 months of life in newborns of mothers treated with biologics during the second half of pregnancy. These 2019 EULAR recommendations provide an up-to-date guidance on the management of vaccinations in patients with AIIRD.

INTRODUCTION

Patients with autoimmune inflammatory rheumatic diseases (AIIRD) have an increased burden of infections, attributed to the underlying autoimmune disease,^{1–4} comorbidities^{3,5} and immunosuppressive therapy, including glucocorticoids (GCs), disease-modifying antirheumatic drugs (DMARDs): conventional synthetic (csDMARDs), biological

(bDMARDs) and targeted synthetic DMARDs (tsDMARDs).^{3,6,7} As the ‘treat to target’ principle currently guides an intensive immunosuppressive therapy aimed at remission in most rheumatic diseases,^{8–10} these therapies are commonly applied, in particular at early disease stages. Thus, prevention of infections is crucial in the management of patients with AIIRD.

Vaccination prevents infections by inducing and/or enhancing protective immunity. Vaccination is particularly important in AIIRD patients, potentially translating into a lower rate of hospital admissions due to infections, emergency room visits and the rate of invasive infectious diseases.¹¹ Yet, the AIIRD population universally suffers from a suboptimal uptake of vaccinations,^{12–19} in part due to a low rate of referral for vaccination by rheumatologists²⁰ and other treating physicians,²¹ indicating that further interventions are needed to raise the awareness for vaccination among the rheumatology community and involved healthcare professionals. Another important factor for a low vaccination rate relates to concerns about efficacy, immunogenicity and safety of vaccinations,¹⁵ an important issue to be addressed by upcoming evidence.

Our aim was to update the present European League Against Rheumatism (EULAR) recommendations for vaccination in patients with AIIRD published in 2011 and to incorporate the new evidence on the incidence/prevalence of vaccine preventable infections (European League) among AIIRD patients, along with efficacy, immunogenicity and safety of vaccines provided to AIIRD patients under a wide range of immunosuppressive therapies. The update was conducted in line with the standard operating procedures (SOP) of the EULAR,²² combining evidence from clinical studies and expert opinion. Our recommendations target all healthcare professionals involved in the care for patients with AIIRD.

METHODS

Development of recommendations

The present update of the EULAR recommendations for vaccination in patients with AIIRD was a combined project for the adult and paediatric AIIRD populations. Following the 2014 updated

Recommendation

Box 1. Research questions.

- ▶ What is the incidence or prevalence of vaccine-preventable infections in adult patients with autoimmune inflammatory rheumatic diseases (AIIRD)?
- ▶ What is the efficacy, immunogenicity and safety of available vaccines in adult AIIRD patients?
- ▶ Are vaccines efficacious and immunogenic in adult AIIRD patients, treated with immunosuppressive agents and disease-modifying antirheumatic drugs?
- ▶ What is the effect of vaccination of household of AIIRD patients, including newborns, on the prevention of vaccine preventable diseases and safety of the patients?

EULAR SOP,²² the convenor (OE) first formed the task force with a steering committee. The steering committee included the convenor (OE), co-convenor (ULM), methodologists (JvL and RL), three fellows who performed the systematic literature reviews (SLRs) (VF, CR, MH), one expert rheumatologist (MB) and one specialist in infectious diseases (SvA). The steering committee defined the research questions for the SLRs (Box 1) and organised a one-and-a-half-day meeting of the task force. Participants of the adult task force meeting represented seven European countries and Israel, included 10 adult rheumatologists, four clinical immunologists, one infectious disease specialist, one paediatrician/rheumatologist, two delegates of the EULAR young rheumatologists' network Emerging EULAR NETWORK, one health professional in rheumatology (HPR) and two patients. Three fellows (VF, CR, MH) performed four SLRs covering the incidence of VPI, the efficacy, immunogenicity, safety of vaccination in patients with AIIRD, the effect of DMARDs on vaccination response and the effect of vaccination of household of AIIRDs patients, including newborns, on the prevention of VPI and safety of the patients. These SLRs focused on the studies published after the locking date of the SLRs for the previous update, that is, October 2009. MEDLINE (via PubMed), EMBASE and Cochrane were searched from 1 October 2009 to 1 August 2018. As search terms, the medical subject headings (MESH) terms for the defined AIIRD, immunosuppressive medications and vaccines were combined (Box 2). Only articles in English were included. Other papers that were considered relevant in the opinion of the experts could be added.

The first part of the meeting was shared by both adults and paediatric members of the task force, during which the preliminary results of the four SLRs were presented. Following the presentation, the group split in two in order to formulate the separate updated recommendations for vaccination in adults and children with AIIRD. In the adult group, the convenor (OE) proposed the wording of each recommendation. Each recommendation was discussed within the group and formulation was modified until agreement was reached among the members. In the second part of the meeting, the two groups rejoined and reviewed the two sets of recommendations, mainly in order to verify that there was no major discrepancy between them. Minor changes were made following this presentation and approved by all the members of the task force. The second meeting of the task force was then organised and included the presentation of the updated SLRs concerning the adult population with AIIRD. The results of the SLRs are reported in two articles, submitted for publication to RMD Open. Each recommendation was discussed and modified when necessary,

Box 2. Definition of autoimmune inflammatory rheumatic diseases (AIIRD), immunosuppressive agents and vaccines included in the literature search and recommendations

Autoimmune inflammatory rheumatic diseases

- ▶ Rheumatoid arthritis, juvenile idiopathic arthritis
- ▶ Adult Still's disease
- ▶ Systemic lupus erythematosus, Sjogren's syndrome, antiphospholipid syndrome
- ▶ Systemic sclerosis, mixed connective tissue disease
- ▶ Polymyositis, dermatomyositis, antisynthetase syndrome, clinically amyopathic dermatomyositis, inclusion body myositis, eosinophilic myositis, eosinophilic fasciitis
- ▶ Psoriatic arthritis, spondyloarthritis
- ▶ Polymyalgia rheumatica
- ▶ Giant cell arteritis, Takayasu arteritis
- ▶ Antineutrophil cytoplasmic antibody (ANCA)-associated vasculitis: granulomatosis with polyangiitis, microscopic polyangiitis, eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome)
- ▶ Polyarteritis nodosa
- ▶ Cryoglobulinemic syndrome
- ▶ Anti-glomerular basement membrane (GBM) antibody disease (Goodpasture disease)
- ▶ Behcet disease
- ▶ Relapsing polychondritis
- ▶ Periodic fever syndromes
- ▶ Familial Mediterranean fever

Immunosuppressive agents

- ▶ Glucocorticoids
- ▶ Synthetic disease-modifying antirheumatic drugs (DMARDs): methotrexate, leflunomide, sulfasalazine, hydroxychloroquine, azathioprine
- ▶ Mycophenolic acid preparations
- ▶ Calcineurin inhibitors: cyclosporine, tacrolimus
- ▶ Alkylating agent: cyclophosphamide
- ▶ Biologic DMARDs: infliximab, etanercept, adalimumab, certolizumab, golimumab, abatacept, tocilizumab, rituximab, secukinumab, ixekizumab, belimumab, anakinra, canakinumab
- ▶ Targeted synthetic DMARDs: tofacitinib, baricitinib

Vaccines

Inactivated

- ▶ Diphtheria, hepatitis A, hepatitis B, Haemophilus influenzae b, human papillomavirus, influenza, Neisseria meningitidis, pertussis, parenteral poliomyelitis, *streptococcus pneumoniae* (polysaccharide and conjugated), tetanus toxoid, tick-borne encephalitis, parenteral typhoid fever

Live-attenuated

- ▶ Measles, mumps, oral poliomyelitis, oral typhoid fever, varicella zoster, yellow fever

followed by the second round of voting by all the members of the task force.

Six overarching principles and nine recommendations were formulated (tables 1 and 2). For each statement, the available evidence was critically appraised and the strength of the recommendations (SoR) was determined following the standards of the

Table 1 Overarching principles for vaccination in adult patients with AIIRD

| Overarching principles | Level of Agreement (%) |
|---|------------------------|
| 1. The vaccination status and indications for further vaccination in patients with AIIRD should be assessed yearly by the rheumatology team. | 100% |
| 2. The individualised vaccination programme should be explained to the patient by the rheumatology team, providing a basis for shared decision-making, and be jointly implemented by the primary care physician, the rheumatology team and the patient. | 94% |
| 3. Vaccination in patients with AIIRD should preferably be administered during quiescent disease. | 94% |
| 4. Vaccines should preferably be administered prior to planned immunosuppression, in particular B cell depleting therapy. | 100% |
| 5. Non-live vaccines can be administered to patients with AIIRD also while treated with systemic glucocorticoids and DMARDs. | 100% |
| 6. Live-attenuated vaccines may be considered with caution in patients with AIIRD. | 53% |

AIIRD, autoimmune inflammatory rheumatic diseases; DMARDs, disease-modifying antirheumatic drugs.

Table 2 Recommendations for vaccination in adult patients with AIIRD with level of evidence for the incidence/prevalence of VPI, efficacy, immunogenicity and safety of vaccines, strength of recommendations (SoR) and level of agreement for each recommendation

| Recommendation | Infection rate | Efficacy | Immuno-genicity | Safety | SoR* | Level of agreement: average/ range (0–10), %≥8 |
|---|--------------------|----------|-----------------|--------|--------|--|
| 1. Influenza vaccination should be strongly considered for the majority of patients with AIIRD. | 2b | 2b | 2a | 2b | B | 9.4 7–10 93% |
| 2. Pneumococcal vaccination should be strongly considered for the majority of patients with AIIRD. | 2b | 4 | 2a | 4 | C | 8.7 6–10 93% |
| 3. Patients with AIIRD should receive toxoid tetanus vaccination in accordance with recommendations for the general population. Passive immunisation should be considered for patients treated with B cell depleting therapy. | NA | NA | 2b | 4 | B D | 9.5 8–10 100% |
| 4. Hepatitis A and hepatitis B vaccination should be administered to patients with AIIRD at risk. In specific situations booster or passive immunisation is indicated. | HAV – NA HBV 2b | NA | 2b | 4 | B C | 9.6 8–10 100% |
| 5. Herpes zoster vaccination may be considered in high-risk patients with AIIRD. | 2b | 2b | 2b | 4 | B | 9.1 7–10 93% |
| 6. Vaccination against yellow fever should be generally avoided in patients with AIIRD. | NA | NA | 2b | 4 | D | 9.2 6–10 85.7% |
| 7. Patients with AIIRD, in particular patients with SLE, should receive vaccinations against HPV in accordance with recommendations for the general population. | 2b | NA | 2b | 4 | C | 9.5 8–10 100% |
| 8. Immunocompetent household members of patients with AIIRD should be encouraged to receive vaccines according to national guidelines with the exception of the oral polio vaccines. | NA | NA | NA | NA | D | 9.1 7–10 93% |
| 9. Live-attenuated vaccines should be avoided during the first 6 months of life in newborns of mothers treated with biologics during the second half of pregnancy. | NA | NA | NA | NA | D | 9.5 8–10 100% |

*The strength of recommendation was primarily based on the efficacy data. If no efficacy data were available, immunogenicity was used as a major outcome. When immunogenicity outcomes did not directly correlate with protection, the strength of recommendation was downgraded. Few recommendations were primarily based on safety (especially live-attenuated vaccines) and here, the safety outcomes determined the strength of the recommendation.

AIIRD, autoimmune inflammatory rheumatic diseases; HAV, hepatitis A virus; HBV, hepatitis B virus; HPV, human papilloma virus; NA, non-available; SLE, systemic lupus erythematosus.

Oxford Centre for Evidence Based Medicine.²³ (online supplementary file 1)

After the second meeting, the final version of recommendations was disseminated among the members of the task force who electronically voted for agreement for each of the principles and recommendations. Each statement was separately voted on and given a score from 0 (absolutely no agreement with the proposed recommendation) to 10 (maximal possible support for the recommendation). The level of agreement for each recommendation was based on the mean vote score.

The final manuscript was drafted after the second meeting of the task force. The manuscript was structured according to the Appraisal of Guidelines for Research & Evaluation II principles,^{22 24} reviewed, revised and approved by all the task force

members, followed by final review and approval by the EULAR Executive Committee before submission to the journal.

Definitions

In the field of vaccination, several outcome measures are important. First, the capacity of vaccinations to prevent infections, referred to as 'efficacy'. Often, humoral responses to vaccines are considered as surrogate endpoints for efficacy, in particular for rare infections, that otherwise would require infeasible trials needing a very large number of patients to prove the vaccine's efficacy. The capacity of vaccines to induce humoral and/or cellular immune responses is referred to as 'immunogenicity'. These immune responses may correlate with clinical

Recommendation

efficacy for some vaccines, but not necessarily. This should be taken into account when interpreting the available evidence (primarily on immunogenicity) for these recommendations.

The SoR was primarily based on the level of evidence for efficacy of vaccination. In vaccine studies with only immunogenicity outcomes, the SoR was established based on the surrogate outcome (immunogenicity). In case there was no direct correlation between the immunogenicity outcomes and the level of protection, the SoR was downgraded.

Finally, the safety of vaccines is of great importance. Safe vaccination implies that vaccination has no severe adverse effects and does not aggravate the underlying disease. Especially for live-attenuated vaccines, safety is a major concern. For these vaccines, the safety outcomes primarily determined the SoR. The level of available evidence concerning efficacy, immunogenicity and safety provided the data was available, is presented for each recommendation.

RESULTS

Overarching principles

The task force endorsed the presentation of six general principles for vaccination of patients with AIIRD as overarching (table 1). Three new overarching principles were formulated. The other three principles originated from the recommendations #2 to #4 published in the 2011 version and were incorporated in the overarching principles due to their importance and generic nature.²⁵ The level of agreement of each overarching principle is presented in table 1.

The vaccination status and indications for further vaccination in patients with AIIRD should be assessed yearly by the rheumatology team

The force task endorsed an annual assessment of the vaccination status by the treating rheumatology team as a central principle guiding vaccinations in patients with AIIRD, constituting an overarching principle rather than a recommendation. In the 2011 version, the first recommendation referred to the assessment of the vaccination status of patients with AIIRD in the initial workup, without defining the responsible health-care provider. The current version emphasises the need for an *annual assessment*, delegating the responsibility to the treating rheumatologist or rheumatology team. The rheumatology team has an extended knowledge and expertise encompassing all aspects of AIIRD, including related treatment modalities applied to an individual patient. For patients with AIIRD, the treating rheumatology team commonly manages their medical care, communicates with a primary care physician and coordinates a multidisciplinary network when required. As stated in the 2011 version, an inventory of a vaccination history, adverse events and flares of the underlying AIIRD following earlier vaccinations should be included in the assessment and turned into the standard of care of patients with AIIRD.

The individualised vaccination programme should be explained to the patient by the rheumatology team, providing a basis for shared decision-making, and be jointly implemented by the primary care physician, the rheumatology team and the patient

This is a newly formulated principle, strongly endorsed by the patient representatives of the task force and supported by the other members. Shared decision-making and consideration of patient's needs, concerns and preferences have received the most prominent recognition in treatment of chronic diseases, as reflected in the updated EULAR recommendations.^{8–10}

Identifying barriers to immunisation and addressing patients' fears and concerns regarding adverse effects is a crucial step toward adherence with any immunisation programme. Having access to evidence-based information about vaccines and comprehension of risks and benefits of vaccination, enables patients to make a deliberate decision regarding the offered vaccination programme. The rheumatology team should inform patients about the risk of infections and the indications for vaccinations, educate patients about the risk/benefit ratio of vaccines and encourage patients to adhere to the appropriate vaccination schedule. Indeed, surveys among patients with AIIRD demonstrated that better knowledge about vaccination and recommendation for vaccination by a treating specialist were positively associated with improved vaccine uptake.^{15 26} Communication between the rheumatology and primary care teams further supports the implementation of the vaccination programme. A large survey of rheumatoid arthritis (RA) patients in the UK revealed that the majority of vaccination was undertaken in primary care,²⁷ supporting collaboration between primary and secondary care to maximise vaccine uptake.

Vaccination in patients with AIIRD should preferably be administered during quiescent disease

This statement, listed as the second recommendation in the 2011 version, was shifted into the third overarching principle. The rationale for this decision was the shared opinion by the majority of the members that this important message would benefit from being a fundamental general principle. Indeed, most vaccination studies conducted in the AIIRD population included patients with quiescent disease.^{28–33} The number of studies with AIIRD patients immunised at the active disease stage is too low to draw the conclusion that vaccinations during active phases of disease are effective or safe. One study has directly addressed the impact of underlying disease activity on the immunogenicity of vaccination.³⁴ In this study, patients with juvenile systemic lupus erythematosus (SLE) with high SLE activity had reduced seroconversion rates to influenza A H1N1 vaccination. Notably, in a study of 340 RA patients, high disease activity levels did not preclude immune response to influenza A H1N1 vaccination.³⁵ Yet, based on the limited knowledge on safety and immunogenicity of vaccinations in patients with active disease, vaccinations are preferentially administered during quiescent disease, according to expert opinion. In patients with active disease, immunisation should not be precluded and considered on the individual basis.

Vaccines should be preferably administered prior to planned immunosuppression, in particular B cell depleting therapy

This important concept, based on the fourth recommendation in the 2011 version, was further expanded to the initiation of csDMARDs, bDMARDs and tsDMARDs, prompting an early vaccination policy to ensure the optimal response to vaccines. Yet, it is important to emphasise that the intention of this principle is *not* to delay a necessary immunosuppressive treatment in severe cases. In such cases, initiation of the indicated immunosuppressive treatment is the main priority rather than early administration of vaccines.

A clear consensus was reached on the suppressive effect of rituximab (RTX) on humoral response to influenza and pneumococcal vaccination in patients with RA,^{36–47} spondyloarthropathies (SpA)⁴² and SLE,⁴⁸ explaining the rationale to provide vaccination *prior to the administration of rituximab*. Other bDMARD therapies have a variable impact on the response to

immunisation in the AIIRD population, with the majority of patients reaching a satisfactory serological response. The effect of specific DMARDs is broadly discussed in the extended SLR (submitted for publication in RMD Open).

In summary, vaccines should be ideally administered *before* the planned immunosuppression, with the emphasis on B cell-depleting biological therapy. In case of non-immunised patients on B cell-depleting therapy, vaccination should be provided at the following time window: at least *6 months after* the administration and *4 weeks before the next course* of B cell-depleting therapy, based on the state of clinical practice. In cases when this time window for immunisation is not possible, vaccination may be considered under B-cell depleting therapy, taking into consideration a potential suboptimal response to vaccine.

Non-live vaccines can be administered to patients with AIIRD during the use of glucocorticoids and DMARDs

Originally presented as the fourth recommendation in the 2011 version, this statement has been modified and upgraded to an overarching principle, in light of compelling evidence of the overall adequate efficacy and safety of vaccination during the use of GC and/or both csDMARDs, bDMARDs and tsDMARDs in a variety of rheumatic diseases. Accumulating data over the recent years have supported the administration of influenza, pneumococcal, tetanus toxoid, hepatitis B virus (HBV), hepatitis A virus (HAV), and human papilloma virus (HPV) vaccines to patients with AIIRD under immunosuppressive therapy. In the majority of studies adequate immunoprotection was achieved, with no major safety signals, though the follow-up period was short in most studies. The details of the relevant studies are provided in the SLR by Rondaan *submitted for publication in Open RMD*.

Live-attenuated vaccines may be considered with caution in patients with AIIRD

Administration of live-attenuated vaccines in patients with AIIRD warrants special attention. In the 2011 version, the third recommendation stated that live-attenuated vaccines should be *avoided* whenever possible in immunosuppressed patients with AIIRD. In light of the new evidence and experience on administering certain live-attenuated vaccines in patients with AIIRD, the task force has extensively discussed the modification of the original statement to formulate it in a more permissive mode. Agreement was reached to incorporate the new evidence in the updated recommendations with a detailed explanation of the rationale and the new evidence. In general, live-attenuated vaccines should be avoided in patients under immunosuppressive therapy, as these vaccines contain live-attenuated micro-organisms that theoretically might cause infections in the susceptible AIIRD population. Based on expert opinion, the preferable time window for vaccination with live vaccines is *4 weeks prior to treatment initiation*, based on the state of clinical practice. However, vaccinations such as measles, mumps, rubella (MMR) and live-attenuated herpes zoster vaccines may be an exception.

Following the Centers for Disease Control and Prevention (CDC) recommendations, the definition of the 'immunosuppressive therapy' includes GC usage for ≥ 2 weeks in dosages equivalent to prednisone of 20 mg/d or 2 mg/kg body weight are considered immunosuppressive, as is methotrexate (MTX) ≥ 0.4 mg/kg/week, azathioprine ≥ 3.0 mg/kg/day or 6-mercaptopurine ≥ 1.5 mg/kg/day, whereas dosages below these levels may be considered as a 'low grade' immunosuppression. The level of immunosuppression in case of a long-term treatment with low dose GC requires further investigation. In the

field of rheumatology, bDMARDs and tsDMARDs are likewise defined as immunosuppressive therapy.

The evidence on MMR is mainly derived from the observational data in the paediatric population of patients with AIIRD. With regard to immunogenicity, a retrospective study from the Netherlands reported a long-term persistent seroprotection for measles in a large group of patients with juvenile idiopathic arthritis (JIA).⁴⁹ The use of GCs or MTX did not influence the antigen-specific antibody concentration or seroprotection rates. Consistently, a similar outcome was reported in a small retrospective study performed in paediatric SLE patients in Brazil.⁵⁰ A prospective nested case-control study from Germany also reported a protective humoral response following 6 months after measles revaccination in 15 patients with JIA, treated with either low-dose MTX therapy alone or in combination with etanercept.⁵¹ Regarding safety, no increase in disease activity, measles flare or severe serious infections were seen, including JIA patients using etanercept.⁵¹ A randomised, open-label study from the Netherlands confirmed an appropriate immunogenicity and safety of the MMR booster provided to JIA patients, including 60 patients using MTX and a small number of patients using bDMARDs.⁵² Based on these safety data of the MMR booster vaccination, the measles virus booster vaccine (as opposed to neo-immunisation) can be considered in AIIRD patients on low grade of immunosuppression at risk of contracting measles infection (for example, travellers).

Concerning vaccination against herpes zoster (HZ), two studies evaluated the safety of the live-attenuated zoster vaccine in AIIRD patients using immunosuppressive drugs. A large cohort study of Medicare beneficiaries 60 years and older with AIIRD, treated with immunosuppressive therapies, including bDMARDs, did not show any increase in the incidence of herpes zoster during the first 42 days after vaccination.⁵³ Live-attenuated HZ vaccine was safely provided to a small cohort of SLE patients (n=10), followed for 12 weeks.⁵⁴ Based on these studies, the live-attenuated HZ vaccine may be considered in patients at risk. A non-live virus vaccine is now available in some countries. Both vaccines are discussed in the recommendation #5 below.

In summary, live-attenuated vaccines should be avoided during immunosuppression, with a possible exception of a cautious use of MMR booster and HZ vaccine under special circumstances, as discussed above.

Recommendations

A total of nine recommendations have been formulated. For each recommendation, the level of evidence for the incidence/prevalence of VPI in AIIRD, and efficacy/immunogenicity/safety of vaccination were stated, when available, followed by the strength of recommendation and the level of agreement (table 2). Six of these recommendations concerning influenza, pneumococcal, tetanus toxoid, HAV, HBV as well as HPV vaccinations originated from the 2011 recommendations with some modifications. Three recommendations (former #10, #12 in the 2011 version) concerning vaccination in hyposplenic/asplenic patients with AIIRD, BCG vaccination and travelling patients with AIIRD were deleted. The task force decided that the first two topics became irrelevant in a daily rheumatology practice. The recommendation for the travelling patients with AIIRD (former #13) to follow the national guidelines was omitted due to being non-specific. Two new recommendations (#8, #9) were formulated encompassing the vaccination in household members of patients with AIIRD and newborns treated with biologics

Recommendation

during pregnancy. An SLR was performed on these topics which disclosed no relevant papers. Thus, these recommendations were based on expert opinion.

Influenza vaccination should be strongly considered for the majority of patients with AIIRD

This recommendation, listed #5 in the 2011 version, remained essentially unchanged, except for the remark that the vaccine should be considered for the *majority* of patients and not *all* patients. Patients with AIIRD have a higher risk of contracting influenza compared with the general population.^{55–57} The task force panel has extensively discussed the scope of patients for whom the vaccine should be recommended. As there is a substantial variability in national guidelines for influenza vaccination, ranging from the whole population vaccination in the USA to age-based and risk-based vaccination in other countries, the panel has taken into consideration different epidemiological and clinical aspects of influenza vaccination in patients with AIIRD. To date, there is no compelling epidemiological evidence to justify a universal influenza vaccination for the whole population of patients with AIIRD. For example, young patients with ankylosing spondylitis, treated with non-steroidal anti-inflammatory drugs only, are not considered immunosuppressed and thus are not at increased risk of influenza-related morbidity. Yet, the majority of the AIIRD population, in particular patients treated with immunosuppressive therapy, seems to benefit from the vaccine.^{33 38 59}

Regarding efficacy, seasonal trivalent subunit influenza vaccination has been shown to reduce the incidence and bacterial complications of influenza, admissions for and mortality from influenza/pneumonia in AIIRD.^{60–63} Most studies have focused on immunogenicity as surrogate outcome for efficacy. Influenza vaccination has been shown to be immunogenic in patients with RA, SLE, ANCA-associated vasculitis (AAV), SSc, and PsA, treated with all classes of DMARDs,^{33 59 64–98} except for rituximab.^{37 41 43 99 100} Temporary discontinuation of MTX was shown to improve immunogenicity of seasonal influenza vaccination in patients with RA, with the best results when MTX was suspended for 2 weeks before and 2 weeks after vaccination.^{101 102} However, it is currently not recommended to stop MTX before or after vaccinating for influenza. Adverse events of influenza vaccination in patients with AIIRD seem comparable to those in healthy controls, although there are no studies that are sufficiently powered with regard to safety.^{28 33 41 43 64 65 69 73–78 81 83–86 88–90 92 94–96 99 103 104}

Most studies investigating immunogenicity and safety of the pandemic monovalent influenza vaccine found reduced immunogenicity in AIIRD patients (mostly RA and SLE) and on most immunosuppressive medications, although protective antibody levels were reached in the majority of patients,^{34 35 38 40 59 89 105–116} except for those treated with rituximab and abatacept.^{38 42 117} A second booster dose of vaccine was shown to improve immunogenicity, leading to levels of seroprotection comparable to healthy controls.^{40 42 118} This has also been shown in SLE patients who received seasonal influenza vaccine for the first time.²⁹

Following vaccination with both seasonal and pandemic influenza vaccines, the disease activity was stable in the majority of studies and only mild adverse events, comparable with healthy controls, were reported.^{34 35 38 40 59 89 105–109 113–116 119} Based on the data of increased risk and morbidity of influenza infection in AIIRD patients, in combination with studies showing a decrease in influenza infections following vaccination, and a large body of evidence proving good influenza vaccine immunogenicity and safety in AIIRD patients, influenza vaccination should be strongly considered for the majority of patients.

Pneumococcal vaccination should be strongly considered for the majority of patients with AIIRD

This recommendation, listed #6 in the 2011 version, has been modified defining the scope of candidates to pneumococcal vaccine as the ‘majority’ of patients with AIIRD, in order to target patients at risk of pneumococcal disease. The task force panel has extensively discussed the types of pneumococcal vaccine, timing of vaccine administration, the scope of patients who will mostly benefit from vaccination and cost-effectiveness of the vaccine in order to target AIIRD patients at risk of pneumococcal disease.

The risk of pulmonary infection is particularly high for patients with AIIRD. In a study of US veterans with RA, the highest rate of hospitalisation for infection was due to pneumonia (37%).¹²⁰ RA and SLE were identified as additional at-risk conditions for pneumococcal disease.¹²¹ The incidence of invasive pneumococcal infection in SLE patients was 13 times higher compared with the Dutch general population.¹²²

Two pneumococcal vaccines are now available: the 23-valent pneumococcal polysaccharide vaccine (PPSV23) and the 13-valent pneumococcal conjugate vaccine (PCV13). Regarding efficacy, a randomised double-blind trial on the clinical efficacy of PPSV23 in preventing pneumonia in RA patients did not demonstrate an increased efficacy of the vaccine over placebo.¹²³ On the other hand, a retrospective study on the long-term effect of PPSV23 in RA patients treated with MTX showed a relative risk of 9.7 to develop pneumonia in non-vaccinated patients.¹²⁴ The humoral immunogenicity and safety of the PPSV23 has been demonstrated in RA,^{64 87 125–129} SLE,^{130–132} and to a limited extent in SpA and others.¹³³ The long-term immunogenicity of PPSV23 has been evaluated in two studies, in RA patients treated with MTX¹²⁴ and biologics, respectively.¹³⁴ Both have shown a long-term duration of protective antibodies, up to 7 years. The immunogenicity and safety of PCV13 has been evaluated in small groups of patients with RA and found to induce an appropriate humoral response,¹³⁵ although reduced under MTX,¹³⁶ in SLE¹³⁷ and systemic vasculitis patients.¹³⁸ None of the above-mentioned studies raised any safety concerns except for patients with cryopyrin associated periodic syndromes (CAPS), who may develop severe local reactions and systemic reactions to PPSV23.¹³⁹

Stepwise pneumococcal vaccination, a PCV13 prime-PPSV23 boost strategy, with an interval of at least 8 weeks between the two vaccinations, is now recommended based on the CDC and the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) recommendations for young children, adults above 65 years old and patients at risk for pneumococcal disease (table 3). This is mainly based on expert opinion. Evidence from studies conducted in the general population^{140 141} and patients with HIV¹⁴² showed an augmented immunogenic response following the combined vaccination. On the other hand, the evidence for the efficacy of the combination of PCV13 and PPSV23 in patients with AIIRD is insufficient. A randomised controlled study in RA patients evaluated the serological response to PCV13 followed by PPSV23 after 16 to 24 weeks. The study demonstrated an adequate response (87% and 94% in RA patients on bDMARDs and csDMARDs, respectively), with a significantly decreased response in patients treated with RTX. A prime boosting strategy with PCV13 did not improve the response.⁴⁵ However, long-term follow-up studies addressing persistence of the humoral response and immunological memory are not available yet.

In view of the increased risk of non-invasive and invasive pneumococcal disease in patients with AIIRD, along with good

Table 3 Schedule of administration of pneumococcal vaccine in AIIRD patients under immunosuppressive therapy based on the CDC recommendations

| History of prior vaccination | Schedule for administration of PCV13 and PPSV23 |
|--|---|
| None or unknown | Administer PCV13 followed in 8 weeks by PPSV23 #1. Administer PPSV23 #2 at least 5 years after PPSV23 #1. |
| One dose PPSV23; zero or unknown PCV13 | Administer PCV13 at least 1 year after PPSV23 #1. Administer PPSV23 #2 at least 5 years after PPSV23 #1 and at least 8 weeks after PCV13. |
| Zero or unknown PPSV23; one dose PCV13 | Administer PPSV23 #1 at least 8 weeks after PCV13. Administer PPSV23 #2 at least 5 years after PPSV23 #1. |
| One dose PPSV23; one dose PCV13 | Administer PPSV23 #2 at least 5 years after PPSV23 #1 and at least 8 weeks after PCV13. |
| Two doses PPSV23; 0 or unknown PCV13 | Administer PCV13 at least 1 year after PPSV23 #2. |

Reference: <http://www.immunize.org/catg.d/p3075.pdf>

AIIRD, autoimmune inflammatory rheumatic diseases; CDC, Centers for Disease Control and Prevention; PCV13, 13-valent pneumococcal conjugate vaccine; PPSV23, 23-valent pneumococcal polysaccharide vaccine.

efficacy, immunogenicity and favourable safety profile of pneumococcal vaccines in the healthy population, and in line with the present recommendations of the CDC^{143 144} and the ESCMID,¹⁴⁵ pneumococcal vaccination should be strongly considered for the majority of patients with AIIRD. Pneumococcal vaccination should be considered carefully in patients with CAPS given the potential risks of adverse events. The task force does not have a reason to recommend a specific pneumococcal vaccine based policy based on the present data on efficacy, immunogenicity and safety of available pneumococcal vaccines. Costs of vaccines may play a role in the decision of the vaccine choice.

Patients with AIIRD should receive tetanus toxoid vaccination in accordance to recommendations for the general population. Passive immunisation should be considered for patients treated with B cell depleting therapy.

The content of this recommendation remained essentially unchanged (*reference recommendation #7 in the 2011 version*), except of rephrasing of the second statement.

No studies evaluated infection rates of tetanus after vaccination. Humoral response to tetanus vaccination strongly correlates with disease prevention and therefore can be used as a clinical outcome measure. In general, patients with AIIRD are recommended to receive tetanus toxoid vaccination in accordance to recommendations for the general population.

Patients with RA and SLE show a satisfactory immunogenicity for tetanus toxoid vaccination comparable with healthy controls.^{146–148} This also holds true for patients with RA on immunosuppressive drugs,^{128 149} including those treated with rituximab 24 weeks earlier.³⁶ Treatment with belimumab did not affect the ability of patients with SLE to maintain antibody titers to previous tetanus immunisation.¹⁵⁰ Although no data are available regarding the efficacy of tetanus toxoid vaccine under the influence of B cell depleting therapy, the efficacy is assumed to be decreased in this situation, based on the data extrapolation from other vaccines. Therefore, passive immunisation with tetanus immunoglobulins should be considered in case of a high-risk exposure to tetanus in patients treated with B cell therapy, according to the expert opinion.

Hepatitis A and hepatitis B vaccines should be administered to AIIRD patients at risk — in specific situations, booster or passive immunisation is indicated

The original recommendation on HAV and HBV vaccination (#11 in the 2011 version) has been expanded regarding the indication for a booster or passive immunisation in specific cases. No data on the incidence/prevalence of HAV in AIIRD is available. Patients with AIIRD at risk of contracting hepatitis

A are recommended to receive vaccination against hepatitis A. Patients at risk include HAV-seronegative patients travelling to or resident in endemic countries. Data on the vaccine efficacy are lacking, but there is a strong correlation between antibody concentrations and seroprotection against infection. It should be emphasised that, as opposed to strong immunogenicity in healthy individuals, a single dose of HAV vaccine does not seem to afford a sufficient protection in RA¹⁵¹ and patients using immunosuppressive drugs.¹⁵² Therefore, second HAV vaccination after 6 months and determination of post-vaccination antibody titers is recommended. If this is not possible, as in the case of a last-minute traveller, one should be aware that an AIIRD patient may not be protected after a single dose of HAV vaccine, and consider passive immunisation prior to the specific journey.

Studies from the different geographical regions across the world reported a variable serological prevalence of HBV infection among AIIRD patients. Data on the efficacy of hepatitis B vaccination in AIIRD patients are lacking, but antibody concentrations are considered to correlate well with protection. Hepatitis B vaccination was immunogenic in most patients with AIIRD,^{153–156} although two open label small studies reported an insufficient humoral response to HBV vaccine in AIIRD patients treated with bDMARDs.^{157 158} Furthermore, high-dose HBV vaccination did not increase the humoral response rate.¹⁵⁸

In concordance with the previous recommendations, HBV vaccine should be administered only to patients at risk. Patients at risk include HBV-seronegative patients that travel to or are residents in endemic countries, and patients at increased risk of exposure to HBV (eg, medical personnel, household contacts or sexual partners of known persons with chronic HBV infection, intravenous drug users, men who have sex with men). In case of an exposure to HBV (for example percutaneous (needle stick, laceration, bite or permucosal) in an unvaccinated patient or a patient with an insufficient response to HBV vaccine, a booster or passive immunisation with hepatitis B immune globulin is indicated according to the CDC recommendations.¹⁵⁹

Herpes zoster vaccination may be considered in high-risk patients with AIIRD

This recommendation remained identical to the recommendation #8 in the 2011 version. The evidence accumulated over the last decade has further supported this recommendation.

AIIRD patients are at increased risk of HZ compared with the general population, with the highest risk of infection in patients with inflammatory myositis and SLE of all ages.¹⁶⁰ A live-attenuated HZ vaccine reduced the risk of HZ by 51% to 70% among immunocompetent individuals 50 years and older in two randomised blinded trials.^{161 162} In elderly AIIRD patients,

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vaccination with HZ vaccine was associated with a reduced incidence of HZ over a median of 2 years follow-up, as reported in a retrospective large database study including patients with immune-mediated diseases (RA, PsA, AS, psoriasis, inflammatory bowel disease (IBD)). This effect was present regardless of medication use, including bDMARDs. HZ vaccination offered protection for about 5 years among patients with autoimmune diseases.⁵³ Furthermore, the vaccine seemed to be immunogenic and safe in a small sample of SLE⁵⁴ and in GC-treated patients.¹⁶³ Regarding safety, the vaccine was safe within 42 days of follow-up, including for patients on biologics.⁵³ Administration of HZ vaccine to active RA patients ≥ 50 years old treated with MTX, 2 to 3 weeks before starting tofacitinib, was reported to be safe and immunogenic at 14 weeks follow-up.¹⁶⁴ Large prospective trials sufficiently powered for assessing safety of this live-attenuated vaccine are lacking.

Based on the increased infection rates, the efficacy in healthy controls and documented efficacy and safety in one study including 463 541 AIIRD patients, including 633 patients on bDMARDs (predominantly tumour necrosis factor (TNF) blockers), the live-attenuated HZ vaccine may be considered in AIIRD patients. This vaccine is preferably administered 4 weeks prior to initiation of bDMARDs or tsDMARDs,¹⁶⁴ but not during the treatment with bDMARDs or tsDMARDs. In patients with uncertain varicella exposure, evaluation of varicella zoster serostatus may be considered before the administration of live-attenuated HZ vaccine in order to prevent primary varicella infection following the vaccine. There is not enough data on a long-term protection and the need for vaccine booster.

Importantly, a new non-live recombinant subunit adjuvant zoster vaccine called Shingrix was licensed in Europe since March 2018 and available in some countries. The vaccine is recommended for adults 50 years and older, including immunosuppressed patients, and administered in two intramuscular doses provided 2 to 6 months apart. Shingrix has been shown to be safe and more efficacious compared with live-attenuated vaccine in elderly adults.^{165 166} Safety and efficacy of the subunit zoster vaccine have not yet been investigated in AIIRD patients. Based on the fact that Shingrix is a non-live vaccine, it may replace the live-attenuated vaccine in patients with AIIRD.

Vaccination against yellow fever should be generally avoided in patients with AIIRD

This is a newly formulated recommendation. The rationale for specifically addressing the yellow fever vaccine stems from the fact that travelling to the endemic area for yellow fever in the South America and Africa has become popular in the European countries and the question of yellow fever vaccination in patients with AIIRD is commonly raised. A discussion was held regarding keeping the recommendation #12 from the 2011 version that referred to travelling patients with AIIRD. The majority of the panel agreed that the previous recommendation #12 was of a too general character advising to vaccinate travelling AIIRD patients according to general rules, with the exception of avoidance from live-attenuated vaccines. The addition of new, though limited, experience on administration of the vaccine to patients with AIIRD led to a special recommendation for the yellow fever vaccine.

The yellow fever vaccine is a live-attenuated vaccine. A single dose of which is sufficient to confer sustained immunity against yellow fever disease. Primary vaccines typically develop a low-level viraemia, which abates as anti-yellow virus immunoglobulin M (IgM) antibodies develop 4 to 7 days post-vaccination and can persist for several years following vaccination. The vaccine is

recommended for people who are travelling to or living in areas endemic for yellow fever virus in Africa and South America.¹⁶⁷

During the task force meeting, a discussion regarding the safety profile of the primary versus booster vaccination was held. Notably, the booster vaccine was administered without sequelae to 17 Brazilian patients with RA treated with infliximab¹⁶⁸ and 31 Brazilian patients with AIIRD (RA, SLE, SSC, AS), some of them treated with bDMARDs¹⁶⁹ with an adequate immunogenicity in both studies. Yet, these results cannot be extrapolated to immunocompromised individuals receiving yellow fever vaccine for the first time. Notably, 34 French travellers with autoimmune diseases treated with GCs (prednisone or equivalent dosage 7 mg/day) were vaccinated with yellow fever vaccine with an adequate immunogenicity 6 months after immunisation, with a notion of more frequent moderate-to-severe local responses to vaccination, without serious adverse events.¹⁷⁰

The force task also discussed the option to test for yellow fever immunity by measuring the serology (IgM and IgG specific to yellow fever) prior to the planned vaccination.¹⁷¹

In conclusion, patients with AIIRD under immunosuppression should avoid yellow fever vaccination due to the risk of inducing yellow fever infection. For patients with AIIRD travelling to the endemic countries, withholding immunosuppressive therapy to allow a safe vaccination or measuring serology in previously exposed patients may be considered. The duration of withholding of immunosuppressives should be based on the pharmacokinetics of each agent.

Patients with AIIRD, in particular patients with SLE, should receive vaccinations against HPV in accordance with recommendations for the general population

The recommendation concerning HPV vaccination (#9 in the 2011 version) has been modified: instead of considering the HPV vaccine for 'selected' patients with AIIRD, the wording was changed to 'patients with AIIRD, in particular patients with SLE' and the reference to the general population guidance was added. The main reason for this modification was based on the fact that the main bulk of evidence on the epidemiology of HPV in patients with AIIRD is based on studies in female patients with SLE.¹⁷²⁻¹⁷⁶ This population is at a particular high risk to contract genital HPV infection, including high-risk serotypes for cervical dysplasia.^{173 174} Whereas there is still no data on the efficacy of HPV vaccination in patients with AIIRD, new data on the vaccine immunogenicity in patients with SLE was published since 2010. Overall, the immunogenicity of the HPV vaccine was similar in patients with SLE and controls, without significant safety signals in patients with SLE.^{30 177-179} Notably, concerns regarding the safety of HPV vaccine have been raised based by case reports and case series on the onset of autoimmune diseases following HPV vaccination.¹⁸⁰⁻¹⁸⁵ Population based studies have consistently shown that quadrivalent HPV vaccine was not associated with increased incidence of new-onset autoimmune disease in girls and women with pre-existing autoimmune disease.¹⁸⁶⁻¹⁸⁸ Therefore, based on the present data, the task force agreed that HPV vaccination should be encouraged for patients with AIIRD, with a particular focus on patients with SLE, as indicated for the general population.

Immunocompetent household members of patients with AIIRD should be encouraged to receive vaccines according to national guidelines with the exception of the oral polio vaccine

This recommendation, mainly based on expert opinion, is new and follows guidelines of international societies, such as the

Infectious Diseases Society of America.¹⁸⁹ Immunocompetent individuals, who live in a household with immunosuppressed patients, should receive inactivated vaccines as well as live-attenuated vaccines such as MMR, rotavirus, varicella and zoster vaccine, according to national guidelines. Oral polio vaccine should be avoided due to a risk of transmission to household members, with a small risk of vaccine-associated paralytic poliomyelitis in immunosuppressed household members. Highly immunocompromised patients should avoid handling diapers of infants vaccinated against rotavirus for at least 4 weeks following the administration of the vaccine. Contact with persons developing skin lesions after varicella or zoster vaccines should be avoided.¹⁸⁹

Live-attenuated vaccines should be avoided during the first 6 months of life in newborns of mothers treated with biologics during the second half of pregnancy

Since IgG crosses the placenta during the third trimester,¹⁹⁰ anti-TNF biologics, except certolizumab pegol,^{191 192} are detectable in newborns of mothers treated with biologics until 6 months after birth.¹⁹³ Based on this data, live-attenuated vaccines should be avoided during the first 6 months of life in newborns of mothers exposed to anti-TNF biologics during the second half of pregnancy.^{194–199} Despite favourable data regarding the lack of certolizumab transfer to cord blood, it is limited to a small number of patients¹⁹¹ and there is no published data concerning live vaccination of the newborns of mothers treated with certolizumab during pregnancy.

A fatal case of disseminated tuberculosis in a newborn exposed to infliximab and vaccinated with Bacillus Calmette–Guérin (BCG) vaccine, underlines the importance to avoid live-attenuated vaccines for at least first 6 months of life.^{200 201} According to the EULAR points to consider for use of anti-rheumatic drugs before pregnancy, and during pregnancy and lactation, children exposed to biologics only before week 22, can receive vaccinations according to standard protocols including live vaccines. Children exposed to biologics at the late second and during the third trimester, can follow vaccination programme, but should not receive live vaccines in the first 6 months of life.²⁰² When available, measurement of child serum levels of the biologic in question could guide the decision for or against a live vaccine.²⁰²

DISCUSSION

The 2019 update of the EULAR recommendations for vaccination in adult patients with AIIRD was developed by 21 experts including patients, rheumatologists, immunologists, an infectious disease specialist and HPR representing eight countries. The original set of 13 recommendations published in 2011 was expanded and divided into six overarching principles, followed by nine recommendations. The EULAR task force defined the overarching principles as universal ones to guide vaccination in the AIIRD population, with the first two principles focusing on the responsibility for assessment, education and implementation of the individualised vaccination programme by a treating rheumatology team, jointly shared with and consented by patients. In light of the low uptake of vaccination among the AIIRD population worldwide, emphasising the role of the treating rheumatology team in education of patients and other healthcare professionals regarding vaccines benefits should improve the uptake of vaccination. The following overarching principles were based on the new data related to efficacy, immunogenicity and safety of vaccination under immunosuppressive therapies, specifically addressing

the optimal timing of vaccination, the type of vaccine (non-live vs live-attenuated) and the underlying disease activity at the time of vaccination. In line with the 2011 recommendations, vaccination should be ideally administered during quiescent disease, prior to the planned immunosuppressive therapy. Non-live vaccines seem to be safe and sufficiently immunogenic when provided under most immunosuppressive therapies, except for B cell depletion, and probably CTLA4-Ig therapy.

Different from the previous version, current recommendations advocate a more flexible approach to administration of certain live-attenuated vaccines, that is, MMR and HZ. New, but limited, data from the paediatric patients with AIIRD concerning MMR and adult AIIRD patients concerning HZ show efficacy and immunogenicity of both vaccines in patients treated under csDMARDs and bDMARDs.

The core set of recommendations was partially modified compared with the 2011 version, whereas for most recommendations the strength of recommendations remained unchanged, with the exception of HZ. Both influenza and pneumococcal vaccinations are now recommended for the *majority* of patients with AIIRD as opposed to *all* patients, emphasising the importance of an individual infection risk assessment in each case. For example, the risk to contract influenza in a young patient with AS treated with a nonsteroidal anti-inflammatory drug (NSAID) only is not equivalent to a patient with active SLE under immunosuppression. For pneumococcal vaccination, a prime-boost strategy (PCV13 followed by PPSV23 vaccination), a new approach adapted by the CDC for immunosuppressed patients, was presented and discussed. The lack of data on the implementation and efficacy of this regimen in patients with AIIRD was discussed. The choice and sequence of pneumococcal vaccination should be in concordance with local guidelines. The recommendations concerning tetanus, HAV and HBV were expanded to include passive immunisation for selected cases. In the case of HZ vaccination, the sufficient amount of a good-quality new clinical data accumulated over the last decade permitted to upgrade the strength of recommendation to B from C-D in the previous version. Furthermore, new items addressing the vaccination of an AIIRD patient's environment, including household members and newborns of mothers treated with biologics during pregnancy, were added and discussed. The recommendations regarding the BCG vaccine, which is no longer recommended in patients with AIIRD, an approach to hyposplenic/asplenic patients and to travellers with AIIRD were omitted from the present version. Instead, a separate item regarding the yellow fever vaccination in patients travelling to endemic areas was added.

The task force discussed current controversies in the field of vaccinations. In the era of personalised medicine, there is a strong need for a tool to estimate the risk of infection on an individual basis. A tool predicting the probability of contracting serious infections within a specified amount of time will indicate the patients who are most likely to benefit from preventive measures, and accordingly tailor the appropriate vaccination programme and antimicrobial prophylaxis. To date, three scoring systems of serious infection risk were developed in the field of RA, based on the Rochester cohort,²⁰³ large administrative US databases¹⁹ and German Biologics Register RABBIT.²⁰⁴ A patient's age, functional status, disease severity and activity, comorbidities, previous infections and treatments were considered as contributors to the future risk of infections, with each scoring system using a different model of risk assessment. Notably, the Rochester score did not include treatment with bDMARDs or non-biological DMARDs in contrast to the other two scores. Thus, given the differences in the scoring

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systems, no direct comparison between them can be performed. Yet, these scores represent an important step toward personalised medicine in relation to prevention of infectious disease and avoidance of ‘unnecessary’ vaccination in AIIRD patients with low risk of infection. Further research is needed to optimise individual risk stratification, enabling physicians to personalise vaccination recommendations in the near future.

The following topics were in particular discussed during the task force: HZ vaccination in the young SLE population and safety of the HPV vaccine. Currently, the HZ vaccine is approved by the US Food and Drug Administration (FDA) and European Medicines Agency (EMA) only for individuals aged 50 years or older. Given the significantly elevated risk of HZ infection and related comorbidities, including the risk of disseminated disease, in the paediatric/young SLE population,^{160 205–208} clinical studies are required to evaluate the efficacy and safety of the vaccine in this vulnerable population. This topic may be solved in the future with the introduction of a non-live vaccine against HZ.

Concerns have been raised following the publication of several case reports and series on the onset and exacerbation of SLE after HPV vaccination^{185 209 210} and an up to 30% rate of flare in vaccinated patients with SLE in an open study.¹⁷⁷ On the other hand, large scale studies have not shown an increase in the incidence of autoimmune diseases among young females vaccinated against HPV and a case control study on HPV vaccination in SLE patients showed a similar rate of flares in both vaccinated and unvaccinated groups (30). These reports have led the task force to the present recommendation.

In conclusion, the evidence concerning safety, immunogenicity and efficacy of vaccination among patients with AIIRD has markedly grown during the last years allowing to adjust and upgrade the recommendations and guide physicians in the use of vaccinations in AIIRD.

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REFERENCES

- 1 Weaver A, Troum O, Hooper M, *et al.* Rheumatoid arthritis disease activity and disability affect the risk of serious infection events in radius 1. *J Rheumatol* 2013;40:1275–81.
- 2 Danza A, Ruiz-Irastorza G. Infection risk in systemic lupus erythematosus patients: susceptibility factors and preventive strategies. *Lupus* 2013;22:1286–94.
- 3 Listing J, Gerhold K, Zink A. The risk of infections associated with rheumatoid arthritis, with its comorbidity and treatment. *Rheumatology* 2013;52:53–61.
- 4 Au K, Reed G, Curtis JR, *et al.* High disease activity is associated with an increased risk of infection in patients with rheumatoid arthritis. *Ann Rheum Dis* 2011;70:785–91.
- 5 Galicia-Hernández G, Parra-Salcedo F, Ugarte-Martínez P, *et al.* Sustained moderate-to-high disease activity and higher Charlson score are predictors of incidental serious infection events in RA patients treated with conventional disease-modifying anti-rheumatic drugs: a cohort study in the treat-to-target era. *Clin Exp Rheumatol* 2016;34:261–9.
- 6 Ramiro S, Sepriano A, Chatzidionysiou K, *et al.* Safety of synthetic and biological DMARDs: a systematic literature review Informing the 2016 update of the EULAR recommendations for management of rheumatoid arthritis. *Ann Rheum Dis* 2017;76:1101–36.
- 7 Germano V, Cattaruzza MS, Osborn J, *et al.* Infection risk in rheumatoid arthritis and spondyloarthritis patients under treatment with DMARDs, corticosteroids and TNF- α antagonists. *J Transl Med* 2014;12:77.
- 8 Smolen JS, Landewé R, Bijlsma J, *et al.* EULAR recommendations for the management of rheumatoid arthritis with synthetic and biological disease-modifying antirheumatic drugs: 2016 update. *Ann Rheum Dis* 2017;76:960–77.
- 9 Gossec L, Smolen JS, Ramiro S, *et al.* European League against rheumatism (EULAR) recommendations for the management of psoriatic arthritis with pharmacological therapies: 2015 update. *Ann Rheum Dis* 2016;75:499–510.
- 10 van der Heijde D, Ramiro S, Landewé R, *et al.* 2016 update of the ASAS-EULAR management recommendations for axial spondyloarthritis. *Ann Rheum Dis* 2017;76:978–91.
- 11 Fernandez-Martinez S, Cortes X, Borrás-Blasco J, *et al.* Effectiveness of a systematic vaccination program in patients with autoimmune inflammatory disease treated with anti-TNF alpha drugs. *Expert Opin Biol Ther* 2016;16:1317–22.
- 12 Costello R, Winthrop KL, Pye SR, *et al.* Influenza and pneumococcal vaccination uptake in patients with rheumatoid arthritis treated with immunosuppressive therapy in the UK: a retrospective cohort study using data from the clinical practice research Datalink. *PLoS One* 2016;11:e0153848.
- 13 Sandler DS, Ruderman EM, Brown T, *et al.* Understanding vaccination rates and attitudes among patients with rheumatoid arthritis. *Am J Manag Care* 2016;22:161–7.
- 14 McCarthy EM, de Barra E, Bergin C, *et al.* Influenza and pneumococcal vaccination and varicella status in inflammatory arthritis patients. *Ir Med J* 2011;104:208–11.

- 15 Nguyen M, Lindegaard H, Hendricks O, *et al.* Factors associated with influenza and pneumococcal vaccine uptake among rheumatoid arthritis patients in Denmark invited to participate in a pneumococcal vaccine trial (Immunovax_RA). *Scand J Rheumatol* 2017;46:446–53.
- 16 Brocq O, Acquacalda E, Berthier F, *et al.* Influenza and pneumococcal vaccine coverage in 584 patients taking biological therapy for chronic inflammatory joint: a retrospective study. *Joint Bone Spine* 2016;83:155–9.
- 17 Hmamouchi I, Winthrop K, Launay O, *et al.* Low rate of influenza and pneumococcal vaccine coverage in rheumatoid arthritis: data from the International COMORA cohort. *Vaccine* 2015;33:1446–52.
- 18 Morin M-P, Quach C, Fortin E, *et al.* Vaccination coverage in children with juvenile idiopathic arthritis followed at a paediatric tertiary care centre. *Rheumatology* 2012;51:2046–50.
- 19 Curtis JR, Xie F, Chen L, *et al.* Use of a disease risk score to compare serious infections associated with anti-tumor necrosis factor therapy among high- versus lower-risk rheumatoid arthritis patients. *Arthritis Care Res* 2012;64:1480–9. doi:10.1002/acr.21805
- 20 Ng B, McBain L, Grainger R. Rheumatologists fail to advise people with RA to get immunised, which matters if you are under 65: an audit in a new Zealand rheumatology service. *N Z Med J* 2016;129:72–8.
- 21 Lawson EF, Trupin L, Yelin EH, *et al.* Reasons for failure to receive pneumococcal and influenza vaccinations among immunosuppressed patients with systemic lupus erythematosus. *Semin Arthritis Rheum* 2015;44:666–71.
- 22 van der Heijde D, Aletaha D, Carmona L, *et al.* 2014 update of the EULAR standardised operating procedures for EULAR-endorsed recommendations. *Ann Rheum Dis* 2015;74:8–13.
- 23 . Oxford centre for evidence-based medicine – levels of evidence. The Oxford 2009. level of evidence updated in 2012; 2012. <https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/>
- 24 Brouwers MC, Kho ME, Browman GP, *et al.* Agree II: advancing Guideline development, reporting and evaluation in health care. *Can Med Assoc J* 2010;182:E839–E842. doi:10.1503/cmaj.090449
- 25 van Assen S, Agmon-Levin N, Elkayam O, *et al.* EULAR recommendations for vaccination in adult patients with autoimmune inflammatory rheumatic diseases. *Ann Rheum Dis* 2011;70:414–22.
- 26 Loubet P, Kernéis S, Groh M, *et al.* Attitude, knowledge and factors associated with influenza and pneumococcal vaccine uptake in a large cohort of patients with secondary immune deficiency. *Vaccine* 2015;33:3703–8.
- 27 Subesinghe S, Rutherford AL, Ibrahim F, *et al.* A large two-centre study in to rates of influenza and pneumococcal vaccination and infection burden in rheumatoid arthritis in the UK. *BMC Musculoskelet Disord* 2016;17:322.
- 28 Milanovic M, Stojanovich L, Djokovic A, *et al.* Influenza vaccination in autoimmune rheumatic disease patients. *Tohoku J Exp Med* 2013;229:29–34.
- 29 Holvast A, van Assen S, de Haan A, *et al.* Effect of a second, booster, influenza vaccination on antibody responses in quiescent systemic lupus erythematosus: an open, prospective, controlled study. *Rheumatology* 2009;48:1294–9.
- 30 Mok CC, Ho LY, Fong LS, *et al.* Immunogenicity and safety of a quadrivalent human papillomavirus vaccine in patients with systemic lupus erythematosus: a case-control study. *Ann Rheum Dis* 2013;72:659–64.
- 31 Holvast A, de Haan A, van Assen S, *et al.* Cell-Mediated immune responses to influenza vaccination in Wegener's granulomatosis. *Ann Rheum Dis* 2010;69:924–7.
- 32 David Morgan M, Richter A, Al-Ali S, *et al.* Association of low B cell count and IgG levels with infection, and poor vaccine response with all-cause mortality in an immunosuppressed vasculitis population. *Arthritis Care Res* 2016;68:853–60. doi:10.1002/acr.22757
- 33 Liao Z, Tang H, Xu X, *et al.* Immunogenicity and safety of influenza vaccination in systemic lupus erythematosus patients compared with healthy controls: a meta-analysis. *PLoS One* 2016;11:e0147856.
- 34 Campos LMA, Silva CA, Aikawa NE, *et al.* High disease activity: an independent factor for reduced immunogenicity of the pandemic influenza A vaccine in patients with juvenile systemic lupus erythematosus. *Arthritis Care Res* 2013;65:1121–7. doi:10.1002/acr.21948
- 35 Ribeiro ACM, Guedes LKN, Moraes JCB, *et al.* Reduced seroprotection after pandemic H1N1 influenza adjuvant-free vaccination in patients with rheumatoid arthritis: implications for clinical practice. *Ann Rheum Dis* 2011;70:2144–7.
- 36 Bingham CO, Looney RJ, Deodhar A, *et al.* Immunization responses in rheumatoid arthritis patients treated with rituximab: results from a controlled clinical trial. *Arthritis Rheum* 2010;62:64–74.
- 37 Hua C, Barnette T, Combe B, *et al.* Effect of methotrexate, anti-tumor necrosis factor α , and rituximab on the immune response to influenza and pneumococcal vaccines in patients with rheumatoid arthritis: a systematic review and meta-analysis. *Arthritis Care Res* 2014;66:1016–26. doi:10.1002/acr.22246
- 38 Adler S, Krivine A, Weix J, *et al.* Protective effect of A/H1N1 vaccination in immune-mediated disease—a prospectively controlled vaccination study. *Rheumatology* 2012;51:695–700. doi:10.1093/rheumatology/ker389
- 39 Eisenberg RA, Jawad AF, Boyer J, *et al.* Rituximab-treated patients have a poor response to influenza vaccination. *J Clin Immunol* 2013;33:388–96.
- 40 Gabay C, Bel M, Combesure C, *et al.* Impact of synthetic and biologic disease-modifying antirheumatic drugs on antibody responses to the A503-adjuvanted pandemic influenza vaccine: a prospective, open-label, parallel-cohort, single-center study. *Arthritis Rheum* 2011;63:1486–96.
- 41 van Assen S, Holvast A, Benne CA, *et al.* Humoral responses after influenza vaccination are severely reduced in patients with rheumatoid arthritis treated with rituximab. *Arthritis Rheum* 2010;62:75–81.
- 42 Kapetanovic MC, Kristensen L-E, Saxne T, *et al.* Impact of anti-rheumatic treatment on immunogenicity of pandemic H1N1 influenza vaccine in patients with arthritis. *Arthritis Res Ther* 2014;16.
- 43 Arad U, Tzadok S, Amir S, *et al.* The cellular immune response to influenza vaccination is preserved in rheumatoid arthritis patients treated with rituximab. *Vaccine* 2011;29:1643–8.
- 44 Westra J, van Assen S, Wilting KR, *et al.* Rituximab impairs immunoglobulin (Ig) M and IgG (subclass) responses after influenza vaccination in rheumatoid arthritis patients. *Clin Exp Immunol* 2014;178:40–7.
- 45 Nguyen MTT, Lindegaard H, Hendricks O, *et al.* Initial serological response after prime-boost pneumococcal vaccination in rheumatoid arthritis patients: results of a randomized controlled trial. *J Rheumatol* 2017;44:1794–803.
- 46 Rehnberg M, Brissler M, Amu S, *et al.* Vaccination response to protein and carbohydrate antigens in patients with rheumatoid arthritis after rituximab treatment. *Arthritis Res Ther* 2010;12.
- 47 Crnkic Kapetanovic M, Saxne T, Jónsson G, *et al.* Rituximab and abatacept but not tocilizumab impair antibody response to pneumococcal conjugate vaccine in patients with rheumatoid arthritis. *Arthritis Res Ther* 2013;15. doi:10.1186/ar4358
- 48 Albert D, Dunham J, Khan S, *et al.* Variability in the biological response to anti-CD20 B cell depletion in systemic lupus erythematosus. *Ann Rheum Dis* 2008;67:1724–31.
- 49 Heijstek MW, van Gageldonk PGM, Berbers GAM, *et al.* Differences in persistence of measles, mumps, rubella, diphtheria and tetanus antibodies between children with rheumatic disease and healthy controls: a retrospective cross-sectional study. *Ann Rheum Dis* 2012;71:948–54.
- 50 Miyamoto M, Ono E, Barbosa C, *et al.* Vaccine antibodies and T- and B-cell interaction in juvenile systemic lupus erythematosus. *Lupus* 2011;20:736–44.
- 51 Borte S, Liebert UG, Borte M, *et al.* Efficacy of measles, mumps and rubella revaccination in children with juvenile idiopathic arthritis treated with methotrexate and etanercept. *Rheumatology* 2009;48:144–8.
- 52 Heijstek MW, Kamphuis S, Armbrust W, *et al.* Effects of the live attenuated measles-mumps-rubella booster vaccination on disease activity in patients with juvenile idiopathic arthritis: a randomized trial. *JAMA* 2013;309:2449–56.
- 53 Zhang J, Xie F, Delzell E, *et al.* Association between vaccination for herpes zoster and risk of herpes zoster infection among older patients with selected immune-mediated diseases. *JAMA* 2012;308:43–9.
- 54 Guthridge JM, Cogman A, Merrill JT, *et al.* Herpes zoster vaccination in SLE: a pilot study of immunogenicity. *J Rheumatol* 2013;40:1875–80.
- 55 Dirven L, Huizinga TWJ, Allaart CF. Risk factors for reported influenza and influenza-like symptoms in patients with rheumatoid arthritis. *Scand J Rheumatol* 2012;41:359–65.
- 56 Blumentals WA, Arreglado A, Napalkov P, *et al.* Rheumatoid arthritis and the incidence of influenza and influenza-related complications: a retrospective cohort study. *BMC Musculoskelet Disord* 2012;13:158.
- 57 Carvalho LM, de Paula FE, Silvestre RVD, *et al.* Prospective surveillance study of acute respiratory infections, influenza-like illness and seasonal influenza vaccine in a cohort of juvenile idiopathic arthritis patients. *Pediatr Rheumatol Online J* 2013;11.
- 58 Chen C-M, Chen H-J, Chen W-S, *et al.* Clinical effectiveness of influenza vaccination in patients with rheumatoid arthritis. *Int J Rheum Dis* 2018;21:1246–53.
- 59 Kostianovsky A, Charles P, Alves J-F, *et al.* Immunogenicity and safety of seasonal and 2009 pandemic A/H1N1 influenza vaccines for patients with autoimmune diseases: a prospective, monocentre trial on 199 patients. *Clin Exp Rheumatol* 2012;30(1 Suppl 70):S83–9.
- 60 Nichol KL, Wuorenma J, von Sternberg T. Benefits of influenza vaccination for low-, intermediate-, and high-risk senior citizens. *Arch Intern Med* 1998;158:1769–76.
- 61 Hak E, Nordin J, Wei F, *et al.* Influence of high-risk medical conditions on the effectiveness of influenza vaccination among elderly members of 3 large managed-care organizations. *Clin Infect Dis* 2002;35:370–7.
- 62 Chang C-C, Chang Y-S, Chen W-S, *et al.* Effects of annual influenza vaccination on morbidity and mortality in patients with systemic lupus erythematosus: a nationwide cohort study. *Sci Rep* 2016;6:37817.
- 63 Kobashigawa T, Nakajima A, Taniguchi A, *et al.* Vaccination against seasonal influenza is effective in Japanese patients with rheumatoid arthritis enrolled in a large observational cohort. *Scand J Rheumatol* 2013;42:445–50.
- 64 Kivitz AJ, Schechtman J, Texter M, *et al.* Vaccine responses in patients with rheumatoid arthritis treated with certolizumab pegol: results from a single-blind randomized phase IV trial. *J Rheumatol* 2014;41:648–57.
- 65 Kaine JL, Kivitz AJ, Birbara C, *et al.* Immune responses following administration of influenza and pneumococcal vaccines to patients with rheumatoid arthritis receiving adalimumab. *J Rheumatol* 2007;34:272–9.

- 66 Denman EJ, Denman AM, Greenwood BM, *et al.* Failure of cytotoxic drugs to suppress immune responses of patients with rheumatoid arthritis. *Ann Rheum Dis* 1970;29:220–31.
- 67 Kapetanovic MC, Saxne T, Nilsson J-A, *et al.* Influenza vaccination as model for testing immune modulation induced by anti-TNF and methotrexate therapy in rheumatoid arthritis patients. *Rheumatology* 2007;46:608–11.
- 68 Kubota T, Nii T, Nanki T, *et al.* Anti-Tumor necrosis factor therapy does not diminish the immune response to influenza vaccine in Japanese patients with rheumatoid arthritis. *Mod Rheumatol* 2007;17:531–3.
- 69 Fomin I, Caspi D, Levy V, *et al.* Vaccination against influenza in rheumatoid arthritis: the effect of disease modifying drugs, including TNF alpha blockers. *Ann Rheum Dis* 2006;65:191–4.
- 70 Gelinck LBS, van der Bijl AE, Beyer WEP, *et al.* The effect of anti-tumour necrosis factor alpha treatment on the antibody response to influenza vaccination. *Ann Rheum Dis* 2008;67:713–6.
- 71 Herron A, Dettliff G, Hixon B, *et al.* Influenza vaccination in patients with rheumatic diseases. safety and efficacy. *JAMA* 1979;242:53–6.
- 72 Turner-Stokes L, Cambridge G, Corcoran T, *et al.* In vitro response to influenza immunisation by peripheral blood mononuclear cells from patients with systemic lupus erythematosus and other autoimmune diseases. *Ann Rheum Dis* 1988;47:532–5.
- 73 Del Porto F, Laganà B, Biselli R, *et al.* Influenza vaccine administration in patients with systemic lupus erythematosus and rheumatoid arthritis. safety and immunogenicity. *Vaccine* 2006;24:3217–23.
- 74 Elkayam O, Bashkin A, Mandelboim M, *et al.* The effect of infliximab and timing of vaccination on the humoral response to influenza vaccination in patients with rheumatoid arthritis and ankylosing spondylitis. *Semin Arthritis Rheum* 2010;39:442–7.
- 75 Williams GW, Steinberg AD, Reinertsen JL, *et al.* Influenza immunization in systemic lupus erythematosus. A double-blind trial. *Ann Intern Med* 1978;88:729–34.
- 76 Ristow SC, Douglas RG, Condemni JJ. Influenza vaccination of patients with systemic lupus erythematosus. *Ann Intern Med* 1978;88:786–9.
- 77 Brodman R, Gillfillan R, Glass D, *et al.* Influenza vaccine response in systemic lupus erythematosus. *Ann Intern Med* 1978;88:735–40.
- 78 Louie JS, Nies KM, Shoji KT, *et al.* Clinical and antibody responses after influenza immunization in systemic lupus erythematosus. *Ann Intern Med* 1978;88:790–2.
- 79 Winthrop KL, Silverfield J, Racewicz A, *et al.* The effect of tofacitinib on pneumococcal and influenza vaccine responses in rheumatoid arthritis. *Ann Rheum Dis* 2016;75:687–95.
- 80 Pons VG, Reinertsen JL, Steinberg AD, *et al.* Decreased cell-mediated cytotoxicity against virus-infected cells in systemic lupus erythematosus. *J Med Virol* 1979;4:15–23.
- 81 Abu-Shakra M, Press J, Varsano N, *et al.* Specific antibody response after influenza immunization in systemic lupus erythematosus. *J Rheumatol* 2002;29:2555–7.
- 82 Mercado U, Acosta H, Avendaño L. Influenza vaccination of patients with systemic lupus erythematosus. *Rev Invest Clin* 2004;56:16–20.
- 83 Holvast A, Huckriede A, Wilschut J, *et al.* Safety and efficacy of influenza vaccination in systemic lupus erythematosus patients with quiescent disease. *Ann Rheum Dis* 2006;65:913–8.
- 84 Holvast A, Stegeman CA, Benne CA, *et al.* Wegener's granulomatosis patients show an adequate antibody response to influenza vaccination. *Ann Rheum Dis* 2009;68:873–8.
- 85 Chalmers A, Scheifele D, Patterson C, *et al.* Immunization of patients with rheumatoid arthritis against influenza: a study of vaccine safety and immunogenicity. *J Rheumatol* 1994;21:1203–6.
- 86 Zycinska K, Romanowska M, Nowak I, *et al.* Antibody response to inactivated subunit influenza vaccine in patients with Wegener's granulomatosis. *J Physiol Pharmacol* 2007;58 Suppl 5:819–28.
- 87 Tsuru T, Terao K, Murakami M, *et al.* Immune response to influenza vaccine and pneumococcal polysaccharide vaccine under IL-6 signal inhibition therapy with tocilizumab. *Mod Rheumatol* 2014;24:511–6.
- 88 Stojanovich L. Influenza vaccination of patients with systemic lupus erythematosus (SLE) and rheumatoid arthritis (RA). *Clin Dev Immunol* 2006;13:373–5.
- 89 Milanetti F, Germano V, Nisini R, *et al.* Safety and immunogenicity of co-administered MF59-adjuvanted 2009 pandemic and plain 2009-10 seasonal influenza vaccines in rheumatoid arthritis patients on biologicals. *Clin Exp Immunol* 2014;177:287–94. 10.1111/cei.12292
- 90 Wallin L, Quintilio W, Locatelli F, *et al.* Safety and efficiency of influenza vaccination in systemic lupus erythematosus patients. *Acta Reumatol Port* 2009;34:498–502.
- 91 Więsik-Szewczyk E, Romanowska M, Mielnik P, *et al.* Anti-Influenza vaccination in systemic lupus erythematosus patients: an analysis of specific humoral response and vaccination safety. *Clin Rheumatol* 2010;29:605–13.
- 92 Crowe SR, Merrill JT, Vista ES, *et al.* Influenza vaccination responses in human systemic lupus erythematosus: impact of clinical and demographic features. *Arthritis Rheum* 2011;63:2396–406.
- 93 Launay O, Paul S, Servettaz A, *et al.* Control of humoral immunity and auto-immunity by the CXCR4/CXCL12 axis in lupus patients following influenza vaccine. *Vaccine* 2013;31:3492–501.
- 94 Litinsky I, Balbir A, Zisman D, *et al.* Vaccination against influenza in patients with systemic sclerosis. *Clin Exp Rheumatol* 2012;30(2 Suppl 71):S7–11.
- 95 Polachek A, Korobko U, Mader-Balakirski N, *et al.* Immunogenicity and safety of vaccination against seasonal 2012 influenza virus among patients with psoriatic arthritis and psoriasis. *Clin Exp Rheumatol* 2015;33:181–6.
- 96 Caso F, Ramonda R, Del Puente A, *et al.* Influenza vaccine with adjuvant on disease activity in psoriatic arthritis patients under anti-TNF- α therapy. *Clin Exp Rheumatol* 2016;34:507–12.
- 97 Nii T, Kubota T, Nanki T, *et al.* Reevaluation of antibody titers 1 year after influenza vaccination in patients with rheumatoid arthritis receiving TNF blockers. *Mod Rheumatol* 2009;19:216–8.
- 98 Salemi S, Picchianti-Diamanti A, Germano V, *et al.* Influenza vaccine administration in rheumatoid arthritis patients under treatment with TNFalpha blockers: safety and immunogenicity. *Clin Immunol* 2010;134:113–20.
- 99 Oren S, Mandelboim M, Braun-Moscovici Y, *et al.* Vaccination against influenza in patients with rheumatoid arthritis: the effect of rituximab on the humoral response. *Ann Rheum Dis* 2008;67:937–41.
- 100 Gelinck LBS, Teng YKO, Rimmelzwaan GF, *et al.* Poor serological responses upon influenza vaccination in patients with rheumatoid arthritis treated with rituximab. *Ann Rheum Dis* 2007;66:1402–3.
- 101 Park JK, Lee MA, Lee EY, *et al.* Effect of methotrexate discontinuation on efficacy of seasonal influenza vaccination in patients with rheumatoid arthritis: a randomised clinical trial. *Ann Rheum Dis* 2017;76:1559–65.
- 102 Park JK, Lee YJ, Shin K, *et al.* Impact of temporary methotrexate discontinuation for 2 weeks on immunogenicity of seasonal influenza vaccination in patients with rheumatoid arthritis: a randomised clinical trial. *Ann Rheum Dis* 2018;388:annrheumdis-2018-213222–904. 10.1136/annrheumdis-2018-213222
- 103 Vista ES, Crowe SR, Thompson LF, *et al.* Influenza vaccination can induce new-onset anticardiolipins but not β 2-glycoprotein-I antibodies among patients with systemic lupus erythematosus. *Lupus* 2012;21:168–74.
- 104 Setti M, Fenoglio D, Ansaldo F, *et al.* Flu vaccination with a virosomal vaccine does not affect clinical course and immunological parameters in scleroderma patients. *Vaccine* 2009;27:3367–72.
- 105 Saad CGS, Borba EF, Aikawa NE, *et al.* Immunogenicity and safety of the 2009 non-adjuvanted influenza A/H1N1 vaccine in a large cohort of autoimmune rheumatic diseases. *Ann Rheum Dis* 2011;70:1068–73.
- 106 Elkayam O, Amir S, Mendelson E, *et al.* Efficacy and safety of vaccination against pandemic 2009 influenza A (H1N1) virus among patients with rheumatic diseases. *Arthritis Care Res* 2011;63:1062–7. 10.1002/acr.20465
- 107 França ILA, Ribeiro ACM, Aikawa NE, *et al.* Tnf blockers show distinct patterns of immune response to the pandemic influenza A H1N1 vaccine in inflammatory arthritis patients. *Rheumatology* 2012;51:2091–8.
- 108 Iwamoto M, Homma S, Onishi S, *et al.* Low level of seroconversion after a novel influenza A/H1N1/2009 vaccination in Japanese patients with rheumatoid arthritis in the 2009 season. *Rheumatol Int* 2012;32:3691–4.
- 109 Miraglia JL, Abdala E, Hoff PM, *et al.* Immunogenicity and reactivity of 2009 influenza A (H1N1) inactivated monovalent non-adjuvanted vaccine in elderly and immunocompromised patients. *PLoS One* 2011;6:e27214. 10.1371/journal.pone.0027214
- 110 Kapetanovic MC. Further evidence for influenza and pneumococcal vaccination in patients treated with disease modifying antirheumatic drugs and anti-tumor necrosis factor agents. *J Rheumatol* 2014;41:626–8.
- 111 Lu C-C, Wang Y-C, Lai J-H, *et al.* A/H1N1 influenza vaccination in patients with systemic lupus erythematosus: safety and immunity. *Vaccine* 2011;29:444–50.
- 112 Aikawa NE, Campos LMA, Silva CA, *et al.* Glucocorticoid: major factor for reduced immunogenicity of 2009 influenza A (H1N1) vaccine in patients with juvenile autoimmune rheumatic disease. *J Rheumatol* 2012;39:167–73.
- 113 Borba EF, Saad CGS, Pasoto SG, *et al.* Influenza A/H1N1 vaccination of patients with SLE: can antimalarial drugs restore diminished response under immunosuppressive therapy? *Rheumatology* 2012;51:1061–9.
- 114 Shinjo SK, de Moraes JCB, Levy-Neto M, *et al.* Pandemic unadjuvanted influenza A (H1N1) vaccine in dermatomyositis and polymyositis: immunogenicity independent of therapy and NO harmful effect in disease. *Vaccine* 2012;31:202–6.
- 115 Miossi R, Fuller R, Moraes JCB, *et al.* Immunogenicity of influenza H1N1 vaccination in mixed connective tissue disease: effect of disease and therapy. *Clinics* 2013;68:129–33.
- 116 Pasoto SG, Ribeiro AC, Viana VST, *et al.* Short and long-term effects of pandemic unadjuvanted influenza A(H1N1)pdm09 vaccine on clinical manifestations and autoantibody profile in primary Sjögren's syndrome. *Vaccine* 2013;31:1793–8.
- 117 Ribeiro AC, Laurindo IM, Guedes LK, *et al.* Abatacept and reduced immune response to pandemic 2009 influenza A/H1N1 vaccination in patients with rheumatoid arthritis. *Arthritis Care Res* 2013;65:476–80. 10.1002/acr.21838
- 118 Mathian A, Devilliers H, Krivine A, *et al.* Factors influencing the efficacy of two injections of a pandemic 2009 influenza A (H1N1) nonadjuvanted vaccine in systemic lupus erythematosus. *Arthritis Rheum* 2011;63:3502–11.
- 119 Aikawa NE, Campos LMA, Goldenstein-Schainberg C, *et al.* Effective seroconversion and safety following the pandemic influenza vaccination

- (anti-H1N1) in patients with juvenile idiopathic arthritis. *Scand J Rheumatol* 2013;42:34–40. 10.3109/03009742.2012.709272
- 120 Curtis JR, Yang S, Patkar NM, *et al.* Risk of hospitalized bacterial infections associated with biologic treatment among US veterans with rheumatoid arthritis. *Arthritis Care Res* 2014;66:990–7. 10.1002/acr.22281
- 121 Shea KM, Edelsberg J, Weycker D, *et al.* Rates of pneumococcal disease in adults with chronic medical conditions. *Open Forum Infect Dis* 2014;1.
- 122 Luijten RKM, Cuppen BVJ, Bijlsma JWJ, *et al.* Serious infections in systemic lupus erythematosus with a focus on pneumococcal infections. *Lupus* 2014;23:1512–6.
- 123 Izumi Y, Akazawa M, Akeda Y, *et al.* The 23-valent pneumococcal polysaccharide vaccine in patients with rheumatoid arthritis: a double-blinded, randomized, placebo-controlled trial. *Arthritis Res Ther* 2017;19. 10.1186/s13075-016-1207-7
- 124 Coulson E, Saravanan V, Hamilton J, *et al.* Pneumococcal antibody levels after pneumovax in patients with rheumatoid arthritis on methotrexate. *Ann Rheum Dis* 2011;70:1289–91.
- 125 Migita K, Akeda Y, Akazawa M, *et al.* Pneumococcal polysaccharide vaccination in rheumatoid arthritis patients receiving tacrolimus. *Arthritis Res Ther* 2015;17. 10.1186/s13075-015-0662-x
- 126 Migita K, Akeda Y, Akazawa M, *et al.* Oponic and antibody responses to pneumococcal polysaccharide in rheumatoid arthritis patients receiving golimumab plus methotrexate. *Medicine* 2015;94:e2184.
- 127 Mori S, Ueki Y, Akeda Y, *et al.* Pneumococcal polysaccharide vaccination in rheumatoid arthritis patients receiving tocilizumab therapy. *Ann Rheum Dis* 2013;72:1362–6.
- 128 Bingham CO, Rizzo W, Kivitz A, *et al.* Humoral immune response to vaccines in patients with rheumatoid arthritis treated with tocilizumab: results of a randomised controlled trial (VISARA). *Ann Rheum Dis* 2015;74:818–22.
- 129 Migita K, Akeda Y, Akazawa M, *et al.* Effect of abatacept on the immunogenicity of 23-valent pneumococcal polysaccharide vaccination (PPSV23) in rheumatoid arthritis patients. *Arthritis Res Ther* 2015;17. 10.1186/s13075-015-0863-3
- 130 Rezende RPV, Ribeiro FM, Albuquerque EMN, *et al.* Immunogenicity of pneumococcal polysaccharide vaccine in adult systemic lupus erythematosus patients undergoing immunosuppressive treatment. *Lupus* 2016;25:1254–9.
- 131 Alyasin S, Adab M, Hosseinpour A, *et al.* Immunogenicity of 23-valent pneumococcal vaccine in children with systemic lupus erythematosus. *Iran J Immunol* 2016;13:204–19.
- 132 Chatham W, Chadha A, Fettiplace J, *et al.* A randomized, open-label study to investigate the effect of belimumab on pneumococcal vaccination in patients with active, autoantibody-positive systemic lupus erythematosus. *Lupus* 2017;26:1483–90.
- 133 Fischer L, Gerstel PF, Poncet A, *et al.* Pneumococcal polysaccharide vaccination in adults undergoing immunosuppressive treatment for inflammatory diseases – a longitudinal study. *Arthritis Res Ther* 2015;17. 10.1186/s13075-015-0663-9
- 134 Broyde A, Arad U, Madar-Balakirski N, *et al.* Longterm efficacy of an antipneumococcal polysaccharide vaccine among patients with autoimmune inflammatory rheumatic diseases. *J Rheumatol* 2016;43:267–72. 10.3899/jrheum.150397
- 135 Rákóczi Éva, Perge B, Végh E, *et al.* Evaluation of the immunogenicity of the 13-valent conjugated pneumococcal vaccine in rheumatoid arthritis patients treated with etanercept. *Joint Bone Spine* 2016;83:675–9.
- 136 Kapetanovic MC, Nagel J, Nordström I, *et al.* Methotrexate reduces vaccine-specific immunoglobulin levels but not numbers of circulating antibody-producing B cells in rheumatoid arthritis after vaccination with a conjugate pneumococcal vaccine. *Vaccine* 2017;35:903–8.
- 137 Nagel J, Saxne T, Geborek P, *et al.* Treatment with belimumab in systemic lupus erythematosus does not impair antibody response to 13-valent pneumococcal conjugate vaccine. *Lupus* 2017;26:1072–81. 10.1177/0961203317695465
- 138 Nived P, Nagel J, Saxne T, *et al.* Immune response to pneumococcal conjugate vaccine in patients with systemic vasculitis receiving standard of care therapy. *Vaccine* 2017;35:3639–46.
- 139 Walker UA, Hoffman HM, Williams R, *et al.* Brief Report: Severe Inflammation Following Vaccination Against *Streptococcus pneumoniae* in Patients With Cryopyrin-Associated Periodic Syndromes. *Arthritis Rheumatol* 2016;68:516–20.
- 140 Greenberg RN, Gurtman A, Frenck RW, *et al.* Sequential administration of 13-valent pneumococcal conjugate vaccine and 23-valent pneumococcal polysaccharide vaccine in pneumococcal vaccine-naïve adults 60–64 years of age. *Vaccine* 2014;32:2364–74.
- 141 Jackson LA, Gurtman A, van Cleeff M, *et al.* Influence of initial vaccination with 13-valent pneumococcal conjugate vaccine or 23-valent pneumococcal polysaccharide vaccine on anti-pneumococcal responses following subsequent pneumococcal vaccination in adults 50 years and older. *Vaccine* 2013;31:3594–602.
- 142 Lesprit P, Pédrone G, Molina J-M, *et al.* Immunological efficacy of a prime-boost pneumococcal vaccination in HIV-infected adults. *AIDS* 2007;21:2425–34.
- 143 Centers for Disease Control and Prevention (CDC). Licensure of 13-valent pneumococcal conjugate vaccine for adults aged 50 years and older. *MMWR Morb Mortal Wkly Rep* 2012;61:394–5.
- 144 Kobayashi M, Bennett NM, Gierke R, *et al.* Intervals between PCV13 and PPSV23 vaccines: recommendations of the Advisory Committee on immunization practices (ACIP). *MMWR Morb Mortal Wkly Rep* 2015;64:944–7.
- 145 Esposito S, Bonanni P, Maggi S, *et al.* Recommended immunization schedules for adults: clinical practice guidelines by the ESCMID vaccine Study Group (EVASG), European geriatric medicine Society (EUGMS) and the world association for infectious diseases and immunological disorders (WAaidid). *Hum Vaccin Immunother* 2016;12:1–18.
- 146 Devey ME, Bleasdale K, Isenberg DA. Antibody affinity and IgG subclass of responses to tetanus toxoid in patients with rheumatoid arthritis and systemic lupus erythematosus. *Clin Exp Immunol* 1987;68:562–9.
- 147 Battafarano DF, Battafarano NJ, Larsen L, *et al.* Antigen-Specific antibody responses in lupus patients following immunization. *Arthritis Rheum* 1998;41:1828–34.
- 148 Kashef S, Ghazizadeh F, Derakhshan A, *et al.* Antigen-Specific antibody response in juvenile-onset SLE patients following routine immunization with tetanus toxoid. *Iran J Immunol* 2008;5:181–4.
- 149 Bingham CO, Winthrop KL, Yang L, *et al.* Baff inhibition does not significantly impair immunization responses in patients with rheumatoid arthritis. *Arthritis Res Ther* 2015;17. 10.1186/s13075-015-0867-z
- 150 Chatham WW, Wallace DJ, Stohl W, *et al.* Effect of belimumab on vaccine antigen antibodies to influenza, pneumococcal, and tetanus vaccines in patients with systemic lupus erythematosus in the BLISS-76 trial. *J Rheumatol* 2012;39:1632–40.
- 151 Asklings HH, Rombo L, van Vollenhoven R, *et al.* Hepatitis A vaccine for immunosuppressed patients with rheumatoid arthritis: a prospective, open-label, multi-centre study. *Travel Med Infect Dis* 2014;12:134–42. 10.1016/j.tmaid.2014.01.005
- 152 van den Bijllaardt W, Siers HM, Timmerman-Kok C, *et al.* Seroprotection after hepatitis A vaccination in patients with Drug-Induced immunosuppression. *J Travel Med* 2013;20:278–82. 10.1111/jtm.12050
- 153 Elkayam O, Yaron M, Caspi D. Safety and efficacy of vaccination against hepatitis B in patients with rheumatoid arthritis. *Ann Rheum Dis* 2002;61:623–5.
- 154 Erkek E, Ayaslioglu E, Erkek AB, *et al.* Response to vaccination against hepatitis B in patients with Behçet's disease. *J Gastroenterol Hepatol* 2005;20:1508–11.
- 155 Kuruma KAM, Borba EF, Lopes MH, *et al.* Safety and efficacy of hepatitis B vaccine in systemic lupus erythematosus. *Lupus* 2007;16:350–4.
- 156 Aytac MB, Kasapcopur O, Aslan M, *et al.* Hepatitis B vaccination in juvenile systemic lupus erythematosus. *Clin Exp Rheumatol* 2011;29:882–6.
- 157 Intongkam S, Samakarnthai P, Pakhotanon R, *et al.* Efficacy and safety of hepatitis B vaccination in rheumatoid arthritis patients receiving disease-modifying antirheumatic drugs and/or biologics therapy. *J Clin Rheumatol* 2018. doi:10.1097/RHU.0000000000000877. [Epub ahead of print: 27 Jul 2018].
- 158 Haykir Solay A, Eser F. High dose hepatitis B vaccine is not effective in patients using immunomodulatory drugs: a pilot study. *Hum Vaccin Immunother* 2019;15:1177–82. Available: <https://www.cdc.gov/vaccines/pubs/pinkbook/downloads/hepb.pdf>
- 159 Yun H, Yang S, Chen L, *et al.* Risk of herpes zoster in autoimmune and inflammatory diseases: implications for vaccination. *Arthritis Rheumatol* 2016;68:2328–37.
- 160 Oxman MN, Levin MJ, Johnson GR, *et al.* A vaccine to prevent herpes zoster and postherpetic neuralgia in older adults. *N Engl J Med* 2005;352:2271–84.
- 161 Schmadher KE, Levin MJ, Gnann JW, *et al.* Efficacy, safety, and tolerability of herpes zoster vaccine in persons aged 50–59 years. *Clin Infect Dis* 2012;54:922–8.
- 162 Levin MJ, Smith JG, Kaufhold RM, *et al.* Decline in varicella-zoster virus (VZV)-specific cell-mediated immunity with increasing age and boosting with a high-dose VZV vaccine. *J Infect Dis* 2003;188:1336–44.
- 163 Winthrop KL, Wouters AG, Choy EH, *et al.* The safety and immunogenicity of live zoster vaccination in patients with rheumatoid arthritis before starting tofacitinib: a randomized phase II trial. *Arthritis Rheumatol* 2017;69:1969–77.
- 164 Lal H, Cunningham AL, Godeaux O, *et al.* Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. *N Engl J Med* 2015;372:2087–96.
- 165 Cunningham AL, Lal H, Kovac M, *et al.* Efficacy of the herpes zoster subunit vaccine in adults 70 years of age or older. *N Engl J Med* 2016;375:1019–32.
- 166 WHO. WHO position paper on vaccines and vaccination against yellow fever; 2013.
- 167 Scheinberg M, Guedes-Barbosa L, Manguiera C, *et al.* Yellow fever revaccination during infliximab therapy. *Arthritis Care Res* 2010;62:896–8. 10.1002/acr.20045
- 168 Oliveira ACV, Mota LMH, Santos-Neto LL, *et al.* Seroconversion in patients with rheumatic diseases treated with immunomodulators or immunosuppressants, who were inadvertently revaccinated against yellow fever. *Arthritis Rheumatol* 2015;67:582–3.
- 169 Kernéis S, Launay O, Ancelle T, *et al.* Safety and immunogenicity of yellow fever 17D vaccine in adults receiving systemic corticosteroid therapy: an observational cohort study. *Arthritis Care Res* 2013;65:1522–8. 10.1002/acr.22021
- 170 Staples JE, Gershman M, Fischer M, *et al.* Yellow fever vaccine: recommendations of the Advisory Committee on immunization practices (ACIP). *MMWR Recomm Rep* 2010;59:1–27.
- 171 Klumb EM, Pinto AC, Jesus GR, *et al.* Are women with lupus at higher risk of HPV infection? *Lupus* 2010;19:1485–91. 10.1177/0961203310372952
- 172 Lee Y-H, Choe J-Y, Park S-H, *et al.* Prevalence of human papilloma virus infections and cervical cytological abnormalities among Korean women with systemic lupus erythematosus. *J Korean Med Sci* 2010;25:1431–7.

- 174 Lyrio LDC, Grassi MFR, Santana IU, *et al.* Prevalence of cervical human papillomavirus infection in women with systemic lupus erythematosus. *Rheumatol Int* 2013;33:335–40.
- 175 Mendoza-Pinto C, García-Carrasco M, Vallejo-Ruiz V, *et al.* Incidence of cervical human papillomavirus infection in systemic lupus erythematosus women. *Lupus* 2017;26:944–51.
- 176 Méndez-Martínez S, García-Carrasco M, Jiménez-Herrera EA, *et al.* Factors of the epidemiological triad that influence the persistence of human papilloma virus infection in women with systemic lupus erythematosus. *Lupus* 2018;27:1542–6.
- 177 Soybilgic A, Onel KB, Utset T, *et al.* Safety and immunogenicity of the quadrivalent HPV vaccine in female Systemic Lupus Erythematosus patients aged 12 to 26 years. *Pediatr Rheumatol Online J* 2013;11.
- 178 Dhar JP, Essenmacher L, Dhar R, *et al.* The safety and immunogenicity of quadrivalent HPV (qHPV) vaccine in systemic lupus erythematosus. *Vaccine* 2017;35:2642–6. 10.1016/j.vaccine.2017.04.001
- 179 Mok CC, Ho LY, To CH. Long-Term immunogenicity of a quadrivalent human papillomavirus vaccine in systemic lupus erythematosus. *Vaccine* 2018;36:3301–7.
- 180 Akioka S. Bivalent HPV vaccine safety depending on subtypes of juvenile idiopathic arthritis. *Ann Rheum Dis* 2014;73:e75.
- 181 Geier DA, Geier MR. A case-control study of quadrivalent human papillomavirus vaccine-associated autoimmune adverse events. *Clin Rheumatol* 2015;34:1225–31.
- 182 Holt HD, Hinkle DM, Falk NS, *et al.* Human papilloma virus vaccine associated uveitis. *Curr Drug Saf* 2014;9:65–8.
- 183 Hotta O, Tanaka A, Torigoe A, *et al.* Involvement of chronic epipharyngitis in autoimmune (auto-inflammatory) syndrome induced by adjuvants (Asia). *Immunol Res* 2017;65:66–71.
- 184 Ito H, Noda K, Hirai K, *et al.* A case of systemic lupus erythematosus (SLE) following human papillomavirus (HPV) vaccination. *Jpn.J.clin.Immun* 2016;39:145–9.
- 185 Soldevilla HF, Briones SFR, Navarra SV. Systemic lupus erythematosus following HPV immunization or infection? *Lupus* 2012;21:158–61.
- 186 Grönlund O, Herweijer E, Sundström K, *et al.* Incidence of new-onset autoimmune disease in girls and women with pre-existing autoimmune disease after quadrivalent human papillomavirus vaccination: a cohort study. *J Intern Med* 2016;280:618–26.
- 187 Arnheim-Dahlström L, Pasternak B, Svanström H, *et al.* Autoimmune, neurological, and venous thromboembolic adverse events after immunisation of adolescent girls with quadrivalent human papillomavirus vaccine in Denmark and Sweden: cohort study. *BMJ* 2013;347:f5906.
- 188 Chao C, Klein NP, Velicer CM, *et al.* Surveillance of autoimmune conditions following routine use of quadrivalent human papillomavirus vaccine. *J Intern Med* 2012;271:193–203.
- 189 Rubin LG, Levin MJ, Ljungman P, *et al.* 2013 IDSA clinical practice guideline for vaccination of the immunocompromised host. *Clin Infect Dis* 2014;58:309–18.
- 190 Ling J, Koren G. Challenges in vaccinating infants born to mothers taking immunoglobulin biologicals during pregnancy. *Expert Rev Vaccines* 2016;15:239–56.
- 191 Mariette X, Förger F, Abraham B, *et al.* Lack of placental transfer of certolizumab pegol during pregnancy: results from CRIB, a prospective, postmarketing, pharmacokinetic study. *Ann Rheum Dis* 2018;77:228–33.
- 192 Förger F, Zbinden A, Villiger PM. Certolizumab treatment during late pregnancy in patients with rheumatic diseases: low drug levels in cord blood but possible risk for maternal infections. A case series of 13 patients. *Joint Bone Spine* 2016;83:341–3.
- 193 Julsgaard M, Christensen LA, Gibson PR, *et al.* Concentrations of Adalimumab and Infliximab in Mothers and Newborns, and Effects on Infection. *Gastroenterology* 2016;151:110–9.
- 194 Mahadevan U, Wolf DC, Dubinsky M, *et al.* Placental transfer of anti-tumor necrosis factor agents in pregnant patients with inflammatory bowel disease. *Clin Gastroenterol Hepatol* 2013;11:286–92. quiz e24.
- 195 Zelinkova Z, de Haar C, de Ridder L, *et al.* High intra-uterine exposure to infliximab following maternal anti-TNF treatment during pregnancy. *Aliment Pharmacol Ther* 2011;33:1053–8.
- 196 Murashima A, Watanabe N, Ozawa N, *et al.* Etanercept during pregnancy and lactation in a patient with rheumatoid arthritis: drug levels in maternal serum, cord blood, breast milk and the infant's serum. *Ann Rheum Dis* 2009;68:1793–4.
- 197 Berthelsen BG, Fjeldsøe-Nielsen H, Nielsen CT, *et al.* Etanercept concentrations in maternal serum, umbilical cord serum, breast milk and child serum during breastfeeding. *Rheumatology* 2010;49:2225–7.
- 198 Friedrichs B, Tiemann M, Salwender H, *et al.* The effects of rituximab treatment during pregnancy on a neonate. *Haematologica* 2006;91:1426–7.
- 199 Mahadevan U, Cucchiara S, Hyams JS, *et al.* The London position statement of the world Congress of gastroenterology on biological therapy for IBD with the European Crohn's and colitis organisation: pregnancy and pediatrics. *Am J Gastroenterol* 2011;106:214–23. quiz 24.
- 200 Cheent K, Nolan J, Shariq S, *et al.* Case report: fatal case of disseminated BCG infection in an infant born to a mother taking infliximab for Crohn's disease. *J Crohns Colitis* 2010;4:603–5.
- 201 Gisbert JP, Chaparro M. Safety of anti-TNF agents during pregnancy and breastfeeding in women with inflammatory bowel disease. *Am J Gastroenterol* 2013;108:1426–38.
- 202 Götestam Skorpen C, Hoeltzenbein M, Tincani A, *et al.* The EULAR points to consider for use of antirheumatic drugs before pregnancy, and during pregnancy and lactation. *Ann Rheum Dis* 2016;75:795–810.
- 203 Crowson CS, Hoganson DD, Fitz-Gibbon PD, *et al.* Development and validation of a risk score for serious infection in patients with rheumatoid arthritis. *Arthritis Rheum* 2012;64:2847–55.
- 204 Zink A, Manger B, Kaufmann J, *et al.* Evaluation of the rabbit risk score for serious infections. *Ann Rheum Dis* 2014;73:1673–6.
- 205 Chen H-H, Chen Y-M, Chen T-J, *et al.* Risk of herpes zoster in patients with systemic lupus erythematosus: a three-year follow-up study using a nationwide population-based cohort. *Clinics* 2011;66:1177–82.
- 206 Gormezano NWS, Silva CA, Otsuzi CI, *et al.* Higher prevalence and distinct features of herpes zoster infection in children than adults with systemic lupus erythematosus. *Pediatr Infect Dis J* 2015;34:905–7.
- 207 Wu S-A, Yeh K-W, Yao T-C, *et al.* Association of herpes zoster infection with clinical characteristics and MBL2 gene polymorphisms in Chinese children with systemic lupus erythematosus. *Pediatr Infect Dis J* 2011;30:656–60.
- 208 Ferreira JCOA, Marques HH, Ferriani MPL, *et al.* Herpes zoster infection in childhood-onset systemic lupus erythematosus patients: a large multicenter study. *Lupus* 2016;25:754–9.
- 209 Baker B, Eça Guimarães L, Tomljenovic L, *et al.* The safety of human papilloma virus-blockers and the risk of triggering autoimmune diseases. *Expert Opin Drug Saf* 2015;14:1387–94.
- 210 Segal Y, Calabrò M, Kanduc D, *et al.* Human papilloma virus and lupus: the virus, the vaccine and the disease. *Curr Opin Rheumatol* 2017;29:331–42.