

EAACI Guidelines on Allergen Immunotherapy: Hymenoptera venom allergy

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Short title: EAACI guideline: AIT for venom immunotherapy

Key words: anaphylaxis, allergen immunotherapy, effectiveness, honeybee venom, hymenoptera venom allergy, safety, systemic sting reaction, venom immunotherapy, vespid venom.

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Abbreviations:

AAI, adrenaline autoinjector; AIT, allergen immunotherapy; ACEI, angiotensin-converting enzyme inhibitors; AGREE II, Appraisal of Guidelines for Research & Evaluation; BAT, basophil activation test; CBA, controlled before-and-after studies; CCT non-randomized controlled clinical trial; EAACI, European Academy of Allergy and Clinical Immunology; ELIFAB, enzyme-linked immunosorbent facilitated antigen binding; ENT, ear nose and throat; HVA, hymenoptera venom allergy; LLR, large local reaction; MAOI, monoamine oxidase inhibitors; QoL, quality of life; RCT, randomized controlled trial; SCIT, subcutaneous immunotherapy; SLIT, sublingual immunotherapy; SR, systematic review; SSR, systemic sting reaction; VIT, venom immunotherapy (subcutaneous, unless otherwise stated).

Abstract

Hymenoptera venom allergy is a potentially life-threatening allergic reaction following a honeybee, vespid or ant sting. Systemic allergic sting reactions have been reported in up to 7.5% of adults and up to 3.4% of children. They can be mild and restricted to the skin or moderate-to-severe with a risk of life-threatening anaphylaxis. Patients should carry an emergency kit containing an adrenaline autoinjector, H₁-antihistamines, and corticosteroids depending on the severity of their previous sting reaction(s). The only treatment to prevent further systemic sting reactions is venom immunotherapy. This guideline has been prepared by the European Academy of Allergy and Clinical Immunology's (EAACI) Taskforce on Venom Immunotherapy as part of the EAACI Guidelines on Allergen Immunotherapy initiative. The guideline aims to provide evidence-based recommendations for the use of venom immunotherapy, has been informed by a formal systematic review and meta-analysis and produced using the Appraisal of Guidelines for Research and Evaluation (AGREE II) approach. The process included representation from a range of stakeholders. Venom immunotherapy is indicated in venom allergic children and adults to prevent further moderate to severe systemic sting reactions. Venom immunotherapy is also recommended in adults with only generalized skin reactions as it results in significant improvements in quality of life compared to carrying an adrenaline auto-injector. This guideline aims to give practical advice on performing venom immunotherapy. Key sections cover general considerations before initiating venom immunotherapy, evidence-based clinical recommendations, risk factors for adverse events and for relapse of systemic sting reaction, and a summary of gaps in the evidence.

Introduction

This guideline has been prepared by the European Academy of Allergy and Clinical Immunology's (EAACI) Taskforce on Venom Immunotherapy (VIT) and are part of the EAACI Guidelines on Allergen Immunotherapy (AIT). This guideline aims to provide evidence-based recommendations for the use of VIT in children and adults. The primary audience is clinical allergists although these are also likely to be of relevance to all other healthcare professionals (e.g. primary care practitioners, emergency departments and other specialist doctors, nurses and pharmacists working across a range of clinical settings) who may be dealing with insect venom allergic patients. Development of this guideline has been informed by a formal systematic review and meta-analysis of AIT for Hymenoptera venom allergy (HVA) with systematic review principles being used to identify additional evidence where necessary¹.

Insect stings by Hymenoptera species are very common with data indicating that 56.6-94.5% of the general population has been stung at least once in their lifetime². The most frequent clinical presentations of HVA are large local reactions (LLR) at the sting site and systemic sting reactions (SSR). A large local reaction has been defined as a swelling exceeding a diameter of 10 cm that lasts for longer than 24 hours³. In SSR, mild symptoms usually manifest as generalized skin symptoms including flushing, urticaria and angioedema. Typically, dizziness, dyspnea and nausea are examples of moderate reactions, while shock and loss of consciousness, or even cardiac or respiratory arrest all define a SSR. The rate of self-reported SSR in European epidemiological studies ranges from 0.3 to 7.5% in adults⁴ and up to 3.4% in children^{4,5}. LLRs occur in 2.4% to 26.4%⁶ of the general population. Severe reactions are life-threatening and have been attributed to fatalities. Although only 0.03 to 0.48 fatalities/1 000 000 inhabitants/year are reported², Hymenoptera sting mortality may

have been underestimated due to unrecognized stings in unexplained causes of death. Patients with HVA are advised to carry an emergency kit comprising of an adrenaline autoinjector (AAI), H₁-antihistamines, and corticosteroids depending on the severity of their previous sting reaction(s). The only treatment that can potentially prevent further systemic sting reactions is venom immunotherapy (VIT), which is reported to be effective in 77-84% of patients treated with honeybee venom^{7,8}, in 91-96% of patients receiving vespid venom^{7,8}, and in 97-98% of patients treated with ant venom^{9,10}.

The systematic review suggested that VIT is effective in reducing subsequent SSRs reactions in both children and adults and that this treatment modality can have a significant beneficial impact on disease specific quality of life (QoL)¹. VIT proved to be safe and no fatalities were recorded in the studies included in this review. The cost-effectiveness of VIT needs to be established. Modelling cost-effectiveness suggested that VIT was likely to be cost-effective in those at high risk of repeated systemic sting reactions and/or impaired quality of life. However, primary studies assessing the cost-effectiveness of VIT could not be identified.

Methodology

This guideline was produced using the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach^{11, 12}, an internationally recognized and accepted structured approach to guideline production. This is designed to ensure appropriate representation of the full range of stakeholders, a careful search for and critical appraisal of the relevant literature, a systematic approach to the formulation and presentation of recommendations and steps to ensure that the risk of bias is minimized at each step of the process. The process started in April 2015 beginning with detailed face-to-face discussions agreeing the process and the key clinical areas to address, followed by face-to-face meetings and regular web-conferences in which professional and lay representatives participated. The present guideline is based on the systematic review and they follow the methods and criteria applied¹.

Clarifying the scope and purpose of the guideline

The scope of this EAACI guideline is multifaceted, providing statements that assist clinicians in the optimal use of use of VIT in the management of patients with Hymenoptera venom allergy and identifying gaps for further research.

Ensuring appropriate stakeholder involvement

Participants in the EAACI Taskforce on VIT represented a range of 14 European countries and disciplinary and clinical backgrounds, including allergists, pediatricians, primary care practitioners, ophthalmologists, ear nose and throat (ENT) specialists, pharmacists, immunologists, nurses and patient representatives. Representatives of immunotherapy product manufactures were given the opportunity to review and comment on the draft guideline as part of the peer review and public comment process. These comments were considered by the taskforce and, where appropriate, revisions were made.

Systematic reviews of the evidence

The initial full range of clinical questions that were considered important were rationalized

through several rounds of iteration to agree on one key question: what is the effectiveness, cost-effectiveness and safety of VIT in patients. This was then pursued through a formal systematic review and meta-analysis of the evidence¹. We continued to track evidence published after our systematic review and meta-analysis with a cut-off date of July 1, 2017 and, where relevant, studies were considered by the taskforce chairs. This evidence will formally be considered in the systematic review update that will precede the update of this guideline, which is scheduled for publication in 2022.

Formulating recommendations

We graded the strength and consistency of key findings from these systematic reviews¹ to formulate evidence-based recommendations for clinical care by applying the GRADE process¹³ (Box 2). This involved formulating clear recommendations with the strength of evidence underpinning each recommendation. Where the systematic review did not cover the clinical area, we took a hierarchical approach reviewing other evidence until we could formulate a recommendation, i.e.: (i) other systematic reviews on the subject to see if these provided any clarity on the topic; (ii) randomized controlled trials (RCTs) within these systematic reviews; (iii) other RCTs known to Taskforce members; and (iv) a consensus-based approach using an expert panel. Recommendations apply to all ages unless otherwise indicated in the tables. Experts identified the resource implications of implementing the recommendations, barriers, and facilitators to the implementation of each recommendation, advice on approaches to implementing the recommendations and suggested audit criteria that can help with assessing organizational compliance with each recommendation.

Peer review and public comment

A draft of this guideline was externally peer-reviewed by invited experts from a range of organizations, countries and professional backgrounds. Additionally, the draft guideline was made available on the EAACI website for a 3-week period in May 2017 to allow a broader array

of stakeholders to comment. All feedback was considered by the taskforce and, where appropriate, final revisions were made in the light of the feedback received. We will be pleased to continue to receive feedback on this guideline, which should be addressed to the corresponding author.

Identification of evidence gaps

The process of developing this guideline has identified a number of evidence gaps which are prioritized.

Editorial independence and managing conflict of interests

The production of this guideline was funded and supported by EAACI. The funder did not have any influence on the guideline production process, on its contents or on the decision to publish. Taskforce members' conflict of interests were declared at the start of the process and taken into account by the taskforce chairs as recommendations were formulated. Final decisions about the strength of evidence for recommendations were checked by the methodologists who had no conflict of interests in this area.

Updating the guideline

EAACI plans to update this guideline in 2022 unless there are important advances before then.

General considerations before initiating venom immunotherapy

General indications

VIT is indicated in children and adults following a systemic allergic reaction exceeding generalized skin symptoms with a documented sensitization to the venom of the culprit insect with either skin prick tests and/or specific serum IgE tests and/or the basophil activation test (BAT). VIT should also be considered for adults with skin symptoms only but at high risk of re-exposure and/or impairment in QoL. VIT is not indicated if no sensitization to insect venom can be verified. Also, an incidental finding of sensitization to insect venom (e.g. using a multiplex system) in patients who have not had a SSR is not an indication for VIT. Furthermore it is not indicated in patients with unusual reactions that cannot be attributed to Type I immediate reactions such as thrombocytopenic purpura and vasculitis, rhabdomyolysis or renal failure after multiple stings. The risk for future systemic reactions is low in patients with LLR, in whom only 0.8-7% are expected to develop SSR in the future¹⁴⁻¹⁶. As patients with repeated LLRs have been reported to have a minimal risk for SSR^{17, 18}, VIT is generally not recommended in these patients. However, subcutaneous VIT has been shown to reduce the size and duration of LLR¹⁹. Therefore, VIT could be considered a treatment option in patients with recurrent, troublesome LLRs. Additional precautions should be taken to avoid insect stings during the build-up phase of VIT by following preventive measures such as not going barefoot, not eating outdoors and avoiding gardening. Beekeepers should stop beekeeping until the maintenance dose is reached because of the increased risk of stings and consecutive SSR (Table 1).

Absolute and relative contraindications and VIT in patients with special conditions

An European position paper on clinical contraindications has been in 2015 published tackling all relevant contraindications in detail²⁰. In a recently published survey among 520 mainly European allergists, up to 47% had experience with administration of AIT in patients with risk conditions such as cardiovascular disease, taking ACEI or beta-blockers, malignant disease in

remission, and autoimmune disease which previously had been considered as contraindications²¹. Problems were uncommon and mostly minor so we have reconsidered contraindications in VIT. Below contraindications are briefly described, and recommendations are given in Table 2.

Cardiovascular disease

Fatality studies have shown that particularly elderly patients with HVA and pre-existing cardiovascular disease have an increased risk of dying from a sting²². Therefore, in contrast to respiratory allergies, VIT is commonly performed in elderly patients. Based on the risk / benefit profile, cardiovascular diseases *per se* are not a contraindication for VIT²⁰.

Beta-blockers

There is good evidence that anaphylaxis does not occur more frequently in patients receiving beta-blockers, as recently summarized in an EAACI position paper²⁰. However, these patients may theoretically be at increased risk of more SSRs, and emergency treatment with adrenaline may be less effective. Elderly patients with HVA and cardiovascular disease treated with beta-blockers are considered to be particularly at high risk of severe SSR in the case of an insect sting²³. Based on the risk/benefit profile, there is no contraindication for VIT in patients treated with beta-blockers²⁰.

Angiotensin-converting enzyme inhibitors (ACEI)

Studies with large number of patient participants conclude that treatment with ACEI does not affect the safety of VIT^{24, 25}. One study reported a higher risk for more severe SSR²⁶, however there is a growing base of evidence that indicates that ACEI do not increase the risk for severe SSR in untreated patients²⁷⁻²⁹. In univariate analyses, results are often confounded by patient's older age which has been shown to be a strong risk factor for more severe SSR^{27, 29, 30}. One multicenter study reported that all patients on ACEI tolerated a sting challenge or field sting during VIT³¹, whereas in another study patients taking ACEI had a higher risk for relapse³².

However, the risk of ACEI may have been overestimated in certain studies due to the very small patients' group and highly selected patients with suggested cardiovascular comorbidity³³.

Therefore, ACE inhibitor therapy may be continued during VIT, but the patient should be informed about possible risks

Malignant neoplasia

AIT was safely administered in patients suffering concomitantly from vespid venom allergy and less advanced stage cancer in one small case series of four patients³⁴. No controlled studies are available relating to the risk or effectiveness of AIT are available in malignant neoplasias²⁰.

Therefore, acute malignant neoplasias are considered a relative contraindication, even if there is no evidence on any unfavourable effects of VIT on tumor growth or the efficacy of chemotherapy. The benefits of VIT should be weighed against the possible burdens of the treatment and the activity of the tumour disease. To conclude, VIT can be recommended in high risk venom allergic patients when malignant disease is stable or in remission.

Autoimmune disorders

Caution should be exercised when prescribing VIT to patients with multi-organ autoimmune disorders. Due to a lack of available data, there is a relative contraindication in autoimmune disorders in remission and an absolute contraindication in active forms²⁰. Organ-specific autoimmune disorders, such as e.g. diabetes mellitus, Hashimoto's thyroiditis, Crohn's disease, ulcerative colitis, and rheumatoid arthritis are not considered a contraindication when the disease is stabilized, but concerns were raised that immune-suppressive medication could theoretically negatively influence the effectiveness of VIT³⁵. Therefore, VIT can be recommended in patients with organ-specific autoimmune disorders when the underlying disease is stabilized

Monoamine oxidase inhibitors (MAOI)

The prescribing of MAOIs is now extremely limited, due to their wide range of dangerous drug-drug interactions³⁶. The major concern with their use in the context of AIT is that they prevent

the breakdown of sympathomimetic drugs; therefore, in the event of adverse events emergency treatment with adrenaline could result in severe hypertension and/or tachycardia^{20, 36}. To conclude, treatment with MAOIs is not a contraindication for VIT but caution is recommended with the use of adrenaline

Children below five years of age

Generally, severe SSR are less frequent in children, and appear to be rare in children of preschool age (<5 years)³⁷. In the rare event of a SSR, decisions should be made on an individual basis considering the risk of future severe systemic reactions. Successful VIT in children under four years have been reported³⁸; as the age limit of five years is arbitrary, there are no specific concerns regarding children younger than five years and the same recommendations as in adults apply.

Pregnancy

The incidence of prematurity, toxemia, abortion, neonatal death and congenital malformation appears to be similar in patients on AIT during pregnancy compared to the general population³⁹. During VIT only two mild adverse events were observed in 43 pregnancies⁴⁰. VIT appears to be safe in pregnant women, but data are scarce. Therefore, initiation of VIT is not recommended. Due to the high risk of relapse after early termination of VIT^{41, 42} and the low risk of adverse events^{24, 43}, a well-tolerated ongoing VIT regime during pregnancy should be continued, using the tolerated VIT maintenance dose administered before pregnancy.

Mastocytosis

Mastocytosis is a risk factor for both the development of HVA and for more severe SSR⁴⁴. VIT is usually well tolerated by the majority of patients with underlying systemic mastocytosis⁴⁵, although adverse events can occur more frequently⁴⁶. In a recent large study on patients with confirmed systemic mastocytosis and severe initial sting reactions (63% suffered from loss of consciousness), it could be shown that VIT was safe and effective⁴⁷. Whether elevated serum

tryptase levels alone increase the risk for adverse events is still a debated issue and robust data are scarce. One study showed a slightly elevated risk for adverse events²⁴, whereas others did not identify a higher risk²⁵ which may be related to a very low overall rate in objective side effects in all patients. Generally, there is no evidence from the literature that VIT should be performed indefinitely in patients with mastocytosis⁴⁸. However, VIT may be less protective in patients with severe initial SSR and mastocytosis and/or elevated serum tryptase ($>11.4 \mu\text{g/L}$).

Therefore, for safety reasons, it should be prolonged in those patients; it remains unclear whether it should be given life-long or after which duration of treatment it should be stopped.

Quality of life

For most patients, and their families, any allergic reaction (regardless of severity) is a frightening experience. Given the effort required to avoid accidental exposures and the inherent uncertainty of success, living with HVA negatively influences QoL. This is particularly due to emotional distress of being alert during activities of daily living⁴⁹. VIT improves QoL in vespid venom allergic patients even when they do not experience a re-sting⁵⁰. In a study where patients were offered a sting challenge after VIT, 80% of patients reported a significantly increased QoL after tolerating a sting challenge⁵¹. In contrast, therapy with the AAI alone was shown to negatively impact on health related QoL^{50, 52}, a significantly increased burden for patients⁵³ and a higher level of anxiety and depression⁵⁴. In contrast, more than 90% of patients perceived VIT as (extremely) positive⁵³, with health and allergy-related QoL improving significantly during treatment^{50, 52, 55}, dysfunctional beliefs decreasing⁵⁵ and anxiety and depression levels were the lowest among VIT treated subjects⁵⁴. In a randomized study evaluating dermal reactors, QoL was also impaired in these systemic reactors and VIT was also able to improve their QoL in contrast to the AAIs⁵².

Venom immunotherapy: evidence based clinical recommendations

Available venoms

Venom of *Apis mellifera* and *Vespula* species is available throughout Europe, whereas venom of *Polistes* is accessible in those countries where allergy to *Polistes species* (e.g. *Polistes dominula* in Spain and Italy) is most often occurs. The use of bumblebee venom would be preferable if the primary sensitization was induced by bumblebee stings^{56, 57}. Bumblebee venom for VIT is currently only available in some countries, e.g. in Italy. Worldwide, also ant venoms are available, such as venom of *Myrmecia pilosula* (Jack Jumper Ant) in Australia.

Preparation of venom

Throughout Europe, non-purified aqueous, purified aqueous preparations and purified aluminium hydroxide adsorbed preparations (so-called “depot” preparations) are used to perform subcutaneous VIT⁵⁸. The efficacy is supported by studies using both sting challenge and ‘in-field’ stings⁵⁸. The aqueous preparations can be used for build-up protocols including ultra-rush, rush, clustered and conventional, as well as for maintenance phase. Purified aluminium hydroxide adsorbed preparations are typically used for the conventional or clustered build-up and maintenance schedule. Treatment can be switched from aqueous to depot preparations following the rapid up-dosing phase⁵⁹. Depot preparations seem to be associated with fewer local side effects than aqueous preparations, but results may have been biased by the slower build-up phase with depot preparations⁶⁰. Purified aqueous preparations cause smaller local reactions compared with non-purified aqueous preparations⁶¹. A systematic literature review has documented a similar rate of systemic adverse events when depot and aqueous venom allergen preparations were used, but the difference between purified and non-purified aqueous preparations was not taken into account⁶². A comparative study in honeybee venom allergic patients indicates the superiority of the purified aqueous preparations over the corresponding

non-purified aqueous preparation under the same rush protocol in terms of systemic reactions during the build-up phase⁶³ (Table 3).

Treatment with more than one venom

Selection of the correct venom preparation(s) is important to ensure optimal efficacy of VIT. Sensitization to venom of more than one Hymenoptera species is common in insect venom allergic patients⁶⁴ and it can be difficult to determine whether this reflects double sensitization due to cross-reactivity of shared allergenic determinants or genuine multiple sensitization to more than one venom. However, in most of these cases treatment with only one venom appears to be sufficient⁶⁴. A major diagnostic problem is that currently available tests, such as skin testing, IgE determination including component-resolved diagnosis or the BAT are not able to distinguish between asymptomatic sensitization and clinically relevant allergy with LLR and SSR¹⁸. However, if the initial sting reaction was severe and all allergy tests are almost equally positive to vespid and to honeybee venom, VIT with both venoms should be considered. As there is only limited cross-reactivity between honeybee and vespid venom and *Vespula* and *Polistes* venom, simultaneous injections with both venoms should be safe. This approach is common in the United States (US) and partly in Europe, however, no studies have examined this question (Table 3).

Preventive pre-treatment

In several double-blind, placebo-controlled trials, it has been shown that pretreatment with H₁ antihistamines improves the tolerability of VIT⁶⁵⁻⁶⁸. In detail, it was reported that levocetirizine decreased the rate of SSR⁶⁸ and fexofenadine decreased the rate of LLR and cutaneous SSR⁶⁷ (Table 3). Importantly, effectiveness of VIT was not negatively influenced^{68, 69}. Antihistamines were usually administered 1-2 hours before the injections or sometimes twice daily. In case of repeated adverse events during up-dosing, pre-treatment with Omalizumab may be recommended⁷⁰⁻⁷².

Treatment protocols

VIT is performed by subcutaneous injections. VIT consists of an up-dosing phase and a maintenance phase, which is necessary to ensure a sustained effect of VIT. Conventional protocols, where the maintenance dose is reached in several weeks to months, can be administered in outpatient clinics⁷³. In an effort to reach the maintenance dose faster, rush⁷³⁻⁷⁷ and ultra-rush protocols⁷⁸⁻⁸¹ with several injections per day on consecutive days are performed in hospitals. Maintenance dose is reached either within a few hours or within a few days, respectively. Cluster protocols, with several injections per day usually 1-2 weeks apart, are also a quick alternative to conventional protocols^{82, 83}. Importantly, the risk of adverse events is not associated with the severity of initial reactions^{24, 25, 84}, high venom-specific IgE levels, or skin test reactivity at low venom concentrations^{84, 85}. Conventional regimes appear to be best tolerated while rush and ultra-rush protocols are more frequently associated with adverse events²⁴.

Up-dosing

The recommended starting dose in up-dosing protocols lies between 0.001 and 0.1 μ g, but it has also been shown that a starting dose of 1 μ g is usually safe and not associated with a higher rate of side effects in adults or in children⁸⁶. A maximum dose of 100 μ g venom allergen dose usually offers adequate protection against systemic allergic sting reactions in the majority of venom allergic individuals⁸⁷⁻⁸⁹.

Maintenance dosing

A maintenance dose of 100 μ g venom is significantly more effective than 50 μ g⁸⁸. This dose is equivalent to the dry weight of approximately two honeybee stings or five wasp stings⁹⁰ and has been adhered to as the recommended maintenance dose since the first controlled trial⁸⁷. A further increased dose gives a better protection when needed⁹¹. A dose of 200 μ g is recommended in patients who develop systemic allergic reactions following a field sting or sting challenge while

on 100 μ g maintenance VIT⁹¹. An increased maintenance dose should also be considered in allergic populations at high risk of multiple stings, such as beekeepers⁹² and in exceptional cases where patients have accumulated risk factors for treatment failure.

Although the European Medicines Agency (EMA) had no safety concerns regarding aluminium toxicity from their pharmacovigilance review of aluminium hydroxide in standard AIT, high dose VIT and life-long therapy has not been specifically evaluated. As a precaution, where life-long therapy is planned it can be undertaken with aqueous preparations. If a 200 μ g dose is required for maintenance, half can be given as an aqueous preparation.

The interval for maintenance VIT with 100 μ g venom recommended by the manufacturers has been 4-6 weeks for aqueous preparations and 6-8 weeks for purified aluminium hydroxide adsorbed preparations (depot preparations). According to expert consensus, injections are usually given every four weeks in the first year of treatment, every six weeks in the second year, and in case of a five year treatment every eight weeks from year 3-5⁹³. Extending the maintenance interval to three months does not seem to reduce effectiveness or increase adverse events⁹⁴⁻⁹⁶, which could be relevant in terms of convenience and economic savings if life-long treatment is necessary. As there is no specific study available for mastocytosis patients with severe initial SSR, caution should be used in extending the intervals to three months in those patients. A dose interval of six months did not provide suitable protection in honeybee venom allergic patients⁹⁷ and is therefore not recommended for standard practice (Table 3).

Duration of VIT

Termination after approximately one or two years leads to a relapse rate of 22-27%^{41,42}. Some studies have concluded that VIT for three years may be sufficient⁹⁸, particularly in patients with only mild to moderate initial sting reactions⁹⁸. Nevertheless, most of the studies concluded that a minimum of a five-year treatment is superior for long-term effectiveness⁹⁹⁻¹⁰². Life-long therapy should be considered in patients with severe initial SSR, systemic adverse events during VIT,

and honeybee venom allergic patients with high risk of future honeybee stings (Table 3, 4).

Adherence

Adherence to VIT is high, possibly because of patients' perception of an unpredictable risk of life threatening sting reactions. In a recent study 95% and 84% of patients still continued VIT after three and five years, respectively¹⁰³.

Effectiveness

Treatment with ant venom is very effective as 97 to 98% are protected after VIT^{9, 10}. The effectiveness of honeybee and vespid VIT is different and ranges from 77 to 84% for honeybee venom compared to 91 to 96% for vespid venom^{7, 8}. The underlying reasons are still unclear. It has been speculated that the amount of venom delivered by a honeybee sting is much larger and more consistent⁹⁰. This may also explain the difference in the reaction rate to sting challenges, which has also been observed in untreated patients¹⁰⁴⁻¹⁰⁶. It also appears that the broad sensitization pattern in honeybee venom allergic patients may play a role in the lower effectiveness of honeybee VIT¹⁰⁷. For example, some patients are predominantly sensitized to Api m 10, which may be underrepresented in certain available honeybee venom preparations^{108, 109}. However, none of these studies included a patient analysis of molecular sIgE binding patterns to honeybee venom allergens before the start of VIT. Without such a specific IgE stratification aligned with the clinical outcome, the conclusions are of limited value. The specific preparation does not seem to have an impact on the effectiveness. The effectiveness of aqueous and purified aluminium hydroxide adsorbed preparations has been shown to be similar^{60, 110}.

Effectiveness of VIT after up-dosing phase

Only one recent study has looked at how rapidly protection occurs. In honeybee VIT, 89%

tolerated the sting challenge one week after reaching the maintenance dose in a 3-5 day rush protocol or a 3-4 month conventional protocol. Those patients who were not protected with 100µg venom, tolerated the sting challenge immediately after reaching the dose of 200µg⁸⁹.

Effectiveness during/after maintenance VIT

Most effectiveness data are obtained during VIT. Re-sting reaction rates of 0-10% 1-5 years after discontinuation of vespid VIT have been reported^{100, 101, 111}. Relapses after honeybee VIT are more frequent as 17% are reported to relapse one year after stopping VIT¹¹². There are only few reports on the outcome following VIT withdrawal for more than five years, and there are no data for more than 10 years after discontinuing VIT. In two studies 7-7.5% of patients treated with vespid venom relapsed after 7 to 10 years^{98, 99}, while 15.8% after stopping honeybee VIT had re-sting reactions⁹⁹. Another study compared relapse rates after four and approximately 10 years and reported relapse rates of 10.2% and 16.2%, respectively¹¹³. In children, the long term outcome is superior compared to adults as only 5% with moderate-to-severe reactions relapsed after up to 20 years after stopping VIT¹⁵.

Carriage of adrenaline auto-injectors during and after VIT

It is still a debated issue whether AAI should be carried during and after VIT, and it has also been difficult to reach a consensus on this topic. Most patients are protected after reaching the maintenance dose⁸⁹. Therefore, patients usually do not need to carry AAIs at this point, particularly if their sting reaction had been mild or they had tolerated a sting challenge or field sting during VIT. It should also be considered that carrying an AAI can negatively impact on health-related QoL^{50, 52} (Table 3). According to the EAACI position paper “Self-medication of anaphylactic reactions due to Hymenoptera stings”, 13% of experts/authors would still prescribe an AAI to patients who initially only had generalized skin symptoms after discontinuation of VIT; and 100% considered recommending carrying an AAI in patients who initially suffered

from moderate-to-severe reactions after terminating VIT if risk factors for treatment failure were present¹¹⁴.

Risk factors for systemic adverse events with VIT and relapse of SSR

Risk factors for systemic adverse events with VIT

The frequency of systemic adverse events with VIT in large multi-center studies ranges from 8-20%^{24, 43, 84}. Several risk factors for the occurrence of systemic adverse events have been described. Most of the studies include only small numbers of patients and provide conflicting data. The most important risk factor is treatment with honeybee venom. It has been consistently reported that there is a 3.1 to 6.0-fold higher risk for systemic adverse events due to treatment with honeybee venom^{24, 77, 86}. Rapid dose increase during the build-up phase is a weaker, but nonetheless established risk factor^{24, 43}. Mastocytosis and/or elevated serum tryptase was initially considered as risk factor for adverse events. An EAACI multicenter study found a slightly elevated risk when tryptase was elevated in vespid venom allergic patients (OR 1.56; CI 1.15-2.10)²⁴, whereas another study performed in honeybee venom allergic patients did not⁸⁵. A study performed in patients with mastocytosis concluded that VIT is safe and efficacious⁴⁷, confirming previous data⁴⁵. Although still a debated issue, ACE inhibitors and beta-blockers are not considered to be independent risk factors for adverse events²³⁻²⁵. Importantly, severe initial sting reactions^{24, 25, 84}, positive skin tests at low test concentrations and high specific-IgE levels^{25, 84, 85} are not regarded as risk factors for adverse events (Table 4).

Management of adverse events during build-up phase of VIT

Adverse events are generally mild and adequately respond to standard anti-allergic treatment^{20, 36}. In the case of systemic adverse events, a common procedure during build-up phase is reducing the allergen dose (going one to two steps back in the protocol) and then continuing with the second last well tolerated dose of VIT. If not yet considered, premedication with H₁ antihistamines should be established. When systemic adverse events prevent reaching the maintenance dose, premedication with Omalizumab may be an option. Currently, case reports

and a case series have documented the usefulness of Omalizumab^{70-72, 115} but there is also one negative report¹¹⁶ (Table 4).

Risk factors for relapse of SSR (Table 4)

Age and type of venom

As already mentioned above, children generally have a more favorable prognosis than adults¹⁵, and patients who were treated with honeybee venom had a higher risk for relapse compared to those who were treated with vespid venom^{98, 99, 113}.

Severity of reaction prior to VIT

Two studies reported a higher relapse rate in patients who have had a severe SSR before VIT^{98, 100}. In the larger study, relapses were observed in 4% with mild but 14% with severe pretreatment reactions⁹⁸. Other studies concluded that the grade of the SSR prior to VIT was not relevant to the probability of a relapse^{112, 117}. Although it is still controversial whether severe initial SSR are a risk factor for relapse, it has been agreed that those patients are at greater risk for severe SSR when they relapse¹¹⁸.

Systemic adverse events during VIT

Patients who developed systemic allergic adverse events during VIT showed a relapse risk of 38%, while those who did not, only had a 7% risk¹¹². Two more studies reported similar results (46% vs. 8% and 16.4 vs. 5.4%, respectively)^{32, 102}.

Mastocytosis/elevated serum tryptase levels

A large multicenter study could not detect an association between higher baseline tryptase and therapy failure³¹, and 86% of 50 mastocytosis patients were protected after initiation of VIT⁴⁷. However, one study indicated that patients with tryptase >20 µg/L and/or mastocytosis in the skin had a 2.7-fold higher risk for therapy failure³². Available data are scarce and heterogeneous

but it appears that mastocytosis is not a strong general risk factor for relapse but should be considered as risk factor in individuals with severe initial SSR.

ACEI

While in one multi-center study all patients on ACEI tolerated a sting challenge or field sting during VIT³¹, another study reported a higher risk for relapse in patients taking ACEI³².

However, the risk of ACEI might have been overestimated due to the very small patients' group and highly selected patients with suggested cardiovascular comorbidity³³.

Procedures to monitor VIT

Many attempts have been made to identify biomarkers to monitor AIT. In peripheral venous blood samples of treated patients, there are significant changes of venom-specific T cell populations, secreted cytokine patterns and immunoglobulin levels but these are not appropriate to estimate the individual risk for relapse of SSR. The sting challenge remains the gold standard in identifying unprotected patients (Table 5).

Sting challenges / field stings

Performing sting challenges is still the most reliable method and gold standard to monitor the effectiveness of VIT. VIT is effective immediately after reaching the first maintenance dose⁸⁹. Therefore, if feasible, sting challenges should be performed as early as possible to identify those who are not protected with the maintenance dose of 100µg. If sting challenges cannot be performed, information about field stings may be helpful. However, the risk of misidentification of the stinging insect and the non-standardized sting procedure reduce reliability¹¹².

The reproducibility of sting challenges, at least for diagnostic purposes, is a debated issue. A study on 129 patients revealed that in 95% of patients a diagnostic sting challenge provided a good prediction of tolerance for subsequent field stings¹¹⁹. On the other hand, it has been shown that 21% of patients not treated with VIT, who initially tolerated a sting challenge, had systemic symptoms after a second challenge¹²⁰. The reliability of early sting challenges to monitor effectiveness of VIT appears to be high¹²¹, although repeated sting challenges during three to five years after treatment identified 8-10% of patients who relapsed^{101, 117}. Importantly, tolerated sting challenges can improve health related QoL, especially in patients reporting high impairment of health related QoL before the sting challenge⁵¹. Thus, sting challenges should not only be seen in the context of evaluating effectiveness but also in terms of fostering individual belief in disease-specific safety.

Specific-IgE and IgG4 levels

It has been repeatedly shown that specific-IgE levels to the respective venom decrease during VIT after an initial rise during the first months of treatment^{60, 121}; they usually remain low even after stopping VIT¹¹⁷. VIT is associated with a significant increase in specific IgG antibodies that has initially been suggested as a marker of effectiveness¹²²; these immunological changes induced by VIT were also reported in honeybee venom allergic children¹²³. The sub-class of IgG antibodies is usually restricted to IgG1 and IgG4¹²¹. However, after stopping VIT, specific IgG starts to decrease^{99, 124, 125} and patients appear to be protected by a mechanism independent from venom-specific IgG¹²². Taken together, available data do not support the use of specific IgE, specific IgG or specific IgG subclasses or even ratios can be used as predictors for protection during and after VIT in the individual patient.

Intradermal testing

Similar to the decline of specific IgE levels during VIT, intradermal test endpoint concentrations usually decrease from before to after VIT^{99, 101}. No study has been able to identify a relevant difference in skin test reactivity between tolerant subjects and patients with relapses^{99, 100, 112}. Moreover, patients with negative intradermal tests have been reported to have significant relapse, a few with near fatal reactions^{102, 113}.

Basophil activation test (BAT)

Allergen-specific basophil response remains positive¹²⁶ or even unchanged¹²⁵ during VIT. However, basophil responses at submaximal allergen concentrations are markedly decreased after VIT in tolerant subjects and this decline seemed to be associated with the induction of tolerance^{125, 127}. Also the measurement of basophil threshold sensitivity to anti-FcεRI stimulation has been proposed to monitor an early protective effect of VIT¹²⁸. BAT inhibition with sera of treated subjects correlated well with effectiveness of AIT in grass pollen allergic patients¹²⁹ but this has not yet been shown in patients with HVA.

Enzyme-linked immunosorbent facilitated antigen binding (ELIFAB)

The ELIFAB is a cell-free assay which is used to demonstrate inhibition of allergen-specific IgE binding by blocking antibodies¹³⁰. One study measured the serum inhibitory activity of VIT-treated vespid-venom patients¹²⁴. During VIT, patients displayed an increased ability to inhibit Ves v 5 binding by IgE antibodies. This allergen-blocking capacity correlated with serum concentrations of Ves v 5-specific IgG4. However, both the inhibitory activity and specific IgG4 levels were again reduced in patients who stopped VIT several years ago¹²⁴.

Despite of the availability of new methods such as the BAT and the ELIFAB, most of the parameters cannot precisely distinguish between patients who are protected from future SSR and those who are at risk. Currently, it is not possible to estimate the individual risk for relapse of SSR with any of the currently available parameters (Table 6).

Summary, gaps in the evidence and future perspectives

The EAACI Taskforce on VIT has developed this guideline as part of the EAACI AIT Guidelines initiative. The guideline have been informed by a formal systematic review and meta-analysis of VIT¹. The guideline provides evidence-based recommendations for the use of VIT for patients with LLR and SSR. A summary of the guideline is provided in Box 3 and key messages for primary care practitioners are given in Box 4. The recommendations should be of value to all healthcare professionals involved in the management of patients with HVA.

There are a number of areas in this guideline where high-quality evidence is not available. The primary gaps are highlighted here and in Table 6. There is a major gap in the evidence for the clinical effectiveness of VIT in children and adolescents with recommendations at least one grade lower than for adults in most areas. Contrary to anecdotal findings, an important number of children do not outgrow allergic reactions to insect stings¹⁵. Additionally, the effect of VIT in children and their parents on health-related QoL should be investigated further. In adults, there is need for studies with sufficient power to evaluate risk factors for adverse effects during VIT or for treatment failure. There is also minimal data in the elderly population particularly for patients with cardiovascular disease. Additionally, we need cost-effectiveness and cost utility studies to use in discussions with healthcare funders. Biomarkers to predict effectiveness of VIT and to identify treatment failure are also urgently needed.

Despite all these gaps, we have clear evidence for the clinical effectiveness of VIT for patients with SSR. Potential barriers and facilitators for the implementation of these recommendations are described in Table 7. There is now a need to ensure that primary care healthcare professionals know which patients might benefit from VIT, that national healthcare providers understand that VIT is highly effective and is likely to be cost-effective, and that patients and patient support groups are aware of this approach.

Acknowledgements:

The EAACI Guideline VIT Taskforce would like to thank Stefan Vieths and Andreas Bonertz for their advice; Patrizia Bonadonna and Axel Trautmann for their expert review of the draft guideline; all the EAACI members who commented about the draft guideline on the public website; and EAACI and the EU for the BM4SIT project (grant number 601763) in the European Union's Seventh Framework Programme FP7 for funding this guideline.

Contributorship:

GJ Sturm and EM Varga jointly chaired the EAACI Guideline on VIT and initially drafted the manuscript. H Mosbech, MB Bilò, CA Akdis, D Antolín-Amérigo, E Cichočka-Jarosz, R Gawlik, T Jakob, M Kosnik, J Lange, E Mingomataj, DI Mitsias, M Ollert, JNG Oude Elberink, O Pfaar, C Pitsios, V Pravettoni, F Ruëff, BA Sin, I Agache, E Angier, S Arasi, MA Calderón, M Fernandez-Rivas, S Halcken, M Jutel, S Lau, A Muraro, GB Pajno, R van Ree, G Roberts, D Ryan, R Gerth van Wijk were members of the taskforce who were involved in conceptualizing the guidelines and critically reviewed guideline drafts. S Dhami, H Zaman and A Sheikh provided methodological support to the taskforce. O Spranger was the patient group representative. All the authors satisfied the international authorship criteria with further details in table 1 of the online repository. This Guideline is part of the EAACI Guidelines on Allergen Immunotherapy, chaired by Antonella Muraro and coordinated by Graham Roberts.

References

1. Dhimi S, Zaman H, Varga EM, Sturm GJ, Muraro A, Akdis CA, et al. Allergen immunotherapy for insect venom allergy: a systematic review and meta-analysis. *Allergy* 2017; 72:342-65.
2. Antonicelli L, Bilo MB, Bonifazi F. Epidemiology of Hymenoptera allergy. *Curr Opin Allergy Clin Immunol* 2002; 2:341-6.
3. Bilo BM, Rueff F, Mosbech H, Bonifazi F, Oude-Elberink JN. Diagnosis of Hymenoptera venom allergy. *Allergy* 2005; 60:1339-49.
4. Bilo BM, Bonifazi F. Epidemiology of insect-venom anaphylaxis. *Curr Opin Allergy Clin Immunol* 2008; 8:330-7.
5. Jennings A, Duggan E, Perry IJ, Hourihane JO. Epidemiology of allergic reactions to hymenoptera stings in Irish school children. *Pediatr Allergy Immunol* 2010; 21:1166-70.
6. Bilo MB, Bonifazi F. The natural history and epidemiology of insect venom allergy: clinical implications. *Clin Exp Allergy* 2009; 39:1467-76.
7. Muller U, Helbling A, Berchtold E. Immunotherapy with honeybee venom and yellow jacket venom is different regarding efficacy and safety. *J Allergy Clin Immunol* 1992; 89:529-35.
8. Rueff F, Vos B, Elberink JO, Bender A, Chatelain R, Dugas-Breit S, et al. Predictors of clinical effectiveness of Hymenoptera venom immunotherapy. *Clin Exp Allergy* 2014.
9. Brown SG, Wiese MD, Blackman KE, Heddle RJ. Ant venom immunotherapy: a double-blind, placebo-controlled, crossover trial. *Lancet* 2003; 361:1001-6.
10. Tankersley MS, Walker RL, Butler WK, Hagan LL, Napoli DC, Freeman TM. Safety and efficacy of an imported fire ant rush immunotherapy protocol with and without prophylactic treatment. *J Allergy Clin Immunol* 2002; 109:556-62.
11. Collaboration A. Development and validation of an international appraisal instrument for assessing the quality of clinical practice guidelines: the AGREE project. *Qual Saf Health Care* 2003; 12:18-23.
12. Brouwers MC, Kho ME, Browman GP, Burgers JS, Cluzeau F, Feder G, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. *CMAJ* 2010; 182:E839-42.
13. Oxford Centre for Evidence-based Medicine. Levels of Evidence and Grades of Recommendation. 2013. <http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/>, last accessed 15th July 2017. .
14. Graft DF, Schuberth KC, Kagey-Sobotka A, Kwiterovich KA, Niv Y, Lichtenstein LM, et al. A prospective study of the natural history of large local reactions after Hymenoptera stings in children. *J Pediatr* 1984; 104:664-8.
15. Golden DB, Kagey-Sobotka A, Norman PS, Hamilton RG, Lichtenstein LM. Outcomes of allergy to insect stings in children, with and without venom immunotherapy. *N Engl J Med* 2004; 351:668-74.
16. Mauriello PM, Barde SH, Georgitis JW, Reisman RE. Natural history of large local reactions from stinging insects. *J Allergy Clin Immunol* 1984; 74:494-8.
17. Pucci S, D'Alo S, De Pasquale T, Illuminati I, Makri E, Incorvaia C. Risk of anaphylaxis in patients with large local reactions to hymenoptera stings: a retrospective and prospective study. *Clin Mol Allergy* 2015; 13:21.
18. Sturm GJ, Kranzelbinder B, Schuster C, Sturm EM, Bokanovic D, Vollmann J, et al. Sensitization to Hymenoptera venoms is common, but systemic sting reactions are rare. *J Allergy Clin Immunol* 2014; 133:1635-43 e1.

19. Golden DB, Kelly D, Hamilton RG, Craig TJ. Venom immunotherapy reduces large local reactions to insect stings. *J Allergy Clin Immunol* 2009; 123:1371-5.
20. Pitsios C, Demoly P, Bilo MB, Gerth van Wijk R, Pfaar O, Sturm GJ, et al. Clinical contraindications to allergen immunotherapy: an EAACI position paper. *Allergy* 2015; 70:897-909.
21. Rodriguez Del Rio P, Pitsios C, Tsoumani M, Pfaar O, Paraskevopoulos G, Gawlik R, et al. Physicians' experience and opinion on contraindications to allergen immunotherapy: The CONSIT survey. *Ann Allergy Asthma Immunol* 2017; 118:621-8.e1.
22. Sasvary T, Muller U. [Fatalities from insect stings in Switzerland 1978 to 1987]. *Schweiz Med Wochenschr* 1994; 124:1887-94.
23. Muller UR, Haeberli G. Use of beta-blockers during immunotherapy for Hymenoptera venom allergy. *J Allergy Clin Immunol* 2005; 115:606-10.
24. Rueff F, Przybilla B, Bilo MB, Muller U, Scheipl F, Aberer W, et al. Predictors of side effects during the buildup phase of venom immunotherapy for Hymenoptera venom allergy: the importance of baseline serum tryptase. *J Allergy Clin Immunol* 2010; 126:105-11 e5.
25. Stoevesandt J, Hain J, Stolze I, Kerstan A, Trautmann A. Angiotensin-converting enzyme inhibitors do not impair the safety of Hymenoptera venom immunotherapy build-up phase. *Clin Exp Allergy* 2014; 44:747-55.
26. Rueff F, Przybilla B, Bilo MB, Muller U, Scheipl F, Aberer W, et al. Predictors of severe systemic anaphylactic reactions in patients with Hymenoptera venom allergy: importance of baseline serum tryptase—a study of the European Academy of Allergology and Clinical Immunology Interest Group on Insect Venom Hypersensitivity. *J Allergy Clin Immunol* 2009; 124:1047-54.
27. Brown SG. Clinical features and severity grading of anaphylaxis. *J Allergy Clin Immunol* 2004; 114:371-6.
28. Stoevesandt J, Hain J, Kerstan A, Trautmann A. Over- and underestimated parameters in severe Hymenoptera venom-induced anaphylaxis: cardiovascular medication and absence of urticaria/angioedema. *J Allergy Clin Immunol* 2012; 130:698-704 e1.
29. Arzt L, Bokanovic D, Schwarz I, Schrautzer C, Massone C, Horn M, et al. Hymenoptera stings in the head region induce impressive, but not severe sting reactions. *Allergy* 2016; 71:1632-4.
30. Nassiri M, Babina M, Dolle S, Edenharter G, Rueff F, Worm M. Ramipril and metoprolol intake aggravate human and murine anaphylaxis: evidence for direct mast cell priming. *J Allergy Clin Immunol* 2015; 135:491-9.
31. Rueff F, Przybilla B, Bilo MB, Muller U, Scheipl F, Seitz MJ, et al. Clinical effectiveness of hymenoptera venom immunotherapy: a prospective observational multicenter study of the European academy of allergology and clinical immunology interest group on insect venom hypersensitivity. *PLoS One* 2013; 8:e63233.
32. Rueff F, Vos B, Oude Elberink J, Bender A, Chatelain R, Dugas-Breit S, et al. Predictors of clinical effectiveness of Hymenoptera venom immunotherapy. *Clin Exp Allergy* 2014; 44:736-46.
33. Slade CA, Douglass JA. Changing practice: no need to stop ACE inhibition for venom immunotherapy. *Clin Exp Allergy* 2014; 44:617-9.
34. Wohrl S, Kinaciyani T, Jalili A, Stingl G, Moritz KB. Malignancy and specific allergen immunotherapy: the results of a case series. *Int Arch Allergy Immunol* 2011; 156:313-9.
35. Pfaar O, Bachert C, Bufe A, Buhl R, Ebner C, Eng P, et al. Guideline on allergen-specific immunotherapy in IgE-mediated allergic diseases: S2k Guideline of the German Society for Allergology and Clinical Immunology (DGAKI), the Society for

- Pediatric Allergy and Environmental Medicine (GPA), the Medical Association of German Allergologists (AeDA), the Austrian Society for Allergy and Immunology (OGAI), the Swiss Society for Allergy and Immunology (SGAI), the German Society of Dermatology (DDG), the German Society of Oto- Rhino-Laryngology, Head and Neck Surgery (DGHNO-KHC), the German Society of Pediatrics and Adolescent Medicine (DGKJ), the Society for Pediatric Pneumology (GPP), the German Respiratory Society (DGP), the German Association of ENT Surgeons (BV-HNO), the Professional Federation of Paediatricians and Youth Doctors (BVKJ), the Federal Association of Pulmonologists (BDP) and the German Dermatologists Association (BVDD). *Allergo J Int* 2014; 23:282-319.
36. Livingston MG, Livingston HM. Monoamine oxidase inhibitors. An update on drug interactions. *Drug Saf* 1996; 14:219-27.
 37. Lockey RF, Turkeltaub PC, Baird-Warren IA, Olive CA, Olive ES, Peppe BC, et al. The Hymenoptera venom study I, 1979-1982: demographics and history-sting data. *J Allergy Clin Immunol* 1988; 82:370-81.
 38. Stritzke AI, Eng PA. Age-dependent sting recurrence and outcome in immunotherapy-treated children with anaphylaxis to Hymenoptera venom. *Clin Exp Allergy* 2013; 43:950-5.
 39. Metzger WJ, Turner E, Patterson R. The safety of immunotherapy during pregnancy. *J Allergy Clin Immunol* 1978; 61:268-72.
 40. Schwartz HJ, Golden DB, Lockey RF. Venom immunotherapy in the Hymenoptera-allergic pregnant patient. *J Allergy Clin Immunol* 1990; 85:709-12.
 41. Randolph CC, Reisman RE. Evaluation of decline in serum venom-specific IgE as a criterion for stopping venom immunotherapy. *J Allergy Clin Immunol* 1986; 77:823-7.
 42. Golden DB, Johnson K, Addison BI, Valentine MD, Kagey-Sobotka A, Lichtenstein LM. Clinical and immunologic observations in patients who stop venom immunotherapy. *J Allergy Clin Immunol* 1986; 77:435-42.
 43. Mosbech H, Muller U. Side-effects of insect venom immunotherapy: results from an EAACI multicenter study. *European Academy of Allergology and Clinical Immunology. Allergy* 2000; 55:1005-10.
 44. van Anrooij B, van der Veer E, de Monchy JG, van der Heide S, Kluin-Nelemans JC, van Voorst Vader PC, et al. Higher mast cell load decreases the risk of Hymenoptera venom-induced anaphylaxis in patients with mastocytosis. *J Allergy Clin Immunol* 2013; 132:125-30.
 45. Bonadonna P, Zanotti R, Caruso B, Castellani L, Perbellini O, Colarossi S, et al. Allergen specific immunotherapy is safe and effective in patients with systemic mastocytosis and Hymenoptera allergy. *J Allergy Clin Immunol* 2008; 121:256-7.
 46. Gonzalez de Olano D, Alvarez-Twose I, Esteban-Lopez MI, Sanchez-Munoz L, de Durana MD, Vega A, et al. Safety and effectiveness of immunotherapy in patients with indolent systemic mastocytosis presenting with Hymenoptera venom anaphylaxis. *J Allergy Clin Immunol* 2008; 121:519-26.
 47. Bonadonna P, Gonzalez-de-Olano D, Zanotti R, Riccio A, De Ferrari L, Lombardo C, et al. Venom immunotherapy in patients with clonal mast cell disorders: efficacy, safety, and practical considerations. *J Allergy Clin Immunol Pract* 2013; 1:474-8.
 48. Krishna MT, Ewan PW, Diwakar L, Durham SR, Frew AJ, Leech SC, et al. Diagnosis and management of hymenoptera venom allergy: British Society for Allergy and Clinical Immunology (BSACI) guidelines. *Clin Exp Allergy* 2011; 41:1201-20.
 49. Oude Elberink JN, de Monchy JG, Golden DB, Brouwer JL, Guyatt GH, Dubois AE. Development and validation of a health-related quality-of-life questionnaire in patients with yellow jacket allergy. *J Allergy Clin Immunol* 2002; 109:162-70.

50. Oude Elberink JN, De Monchy JG, Van Der Heide S, Guyatt GH, Dubois AE. Venom immunotherapy improves health-related quality of life in patients allergic to yellow jacket venom. *J Allergy Clin Immunol* 2002; 110:174-82.
51. Fischer J, Teufel M, Feidt A, Giel KE, Zipfel S, Biedermann T. Tolerated wasp sting challenge improves health-related quality of life in patients allergic to wasp venom. *J Allergy Clin Immunol* 2013.
52. Oude Elberink JN, van der Heide S, Guyatt GH, Dubois AE. Immunotherapy improves health-related quality of life of adult patients with dermal reactions following yellow jacket stings. *Clin Exp Allergy* 2009; 39:883-9.
53. Oude Elberink JN, van der Heide S, Guyatt GH, Dubois AE. Analysis of the burden of treatment in patients receiving an EpiPen for yellow jacket anaphylaxis. *J Allergy Clin Immunol* 2006; 118:699-704.
54. Findeis S, Craig T. The relationship between insect sting allergy treatment and patient anxiety and depression. *Allergy Asthma Proc* 2014; 35:260-4.
55. Confino-Cohen R, Melamed S, Goldberg A. Debilitating beliefs and emotional distress in patients given immunotherapy for insect sting allergy: a prospective study. *Allergy Asthma Proc* 2009; 30:546-51.
56. Stapel SO, Waanders-Lijster de Raadt J, van Toorenenbergen AW, de Groot H. Allergy to bumblebee venom. II. IgE cross-reactivity between bumblebee and honeybee venom. *Allergy* 1998; 53:769-77.
57. Stern A, Wuthrich B, Mullner G. Successful treatment of occupational allergy to bumblebee venom after failure with honeybee venom extract. *Allergy* 2000; 55:88-91.
58. Bilo MB, Antonicelli L, Bonifazi F. Purified vs. nonpurified venom immunotherapy. *Curr Opin Allergy Clin Immunol* 2010; 10:330-6.
59. Alessandrini AE, Berra D, Rizzini FL, Mauro M, Melchiorre A, Rossi F, et al. Flexible approaches in the design of subcutaneous immunotherapy protocols for Hymenoptera venom allergy. *Ann Allergy Asthma Immunol* 2006; 97:92-7.
60. Rueff F, Wolf H, Schnitker J, Ring J, Przybilla B. Specific immunotherapy in honeybee venom allergy: a comparative study using aqueous and aluminium hydroxide adsorbed preparations. *Allergy* 2004; 59:589-95.
61. Bilo MB, Severino M, Cilia M, Pio A, Casino G, Ferrarini E, et al. The VISYT trial: Venom Immunotherapy Safety and Tolerability with purified vs nonpurified extracts. *Ann Allergy Asthma Immunol* 2009; 103:57-61.
62. Incorvaia C, Frati F, Dell'Albani I, Robino A, Cattaneo E, Mauro M, et al. Safety of hymenoptera venom immunotherapy: a systematic review. *Expert Opin Pharmacother* 2011; 12:2527-32.
63. Bilo MB, Cinti B, Brianzoni MF, Braschi MC, Bonifazi M, Antonicelli L. Honeybee venom immunotherapy: a comparative study using purified and nonpurified aqueous extracts in patients with normal Basal serum tryptase concentrations. *J Allergy (Cairo)* 2012; 2012:869243.
64. Stoevesandt J, Hofmann B, Hain J, Kerstan A, Trautmann A. Single venom-based immunotherapy effectively protects patients with double positive tests to honey bee and *Vespula* venom. *Allergy Asthma Clin Immunol* 2013; 9:33.
65. Berchtold E, Maibach R, Muller U. Reduction of side effects from rush-immunotherapy with honey bee venom by pretreatment with terfenadine. *Clin Exp Allergy* 1992; 22:59-65.
66. Brockow K, Kiehn M, Riethmuller C, Vieluf D, Berger J, Ring J. Efficacy of antihistamine pretreatment in the prevention of adverse reactions to Hymenoptera immunotherapy: a prospective, randomized, placebo-controlled trial. *J Allergy Clin Immunol* 1997; 100:458-63.

67. Reimers A, Hari Y, Muller U. Reduction of side-effects from ultrarush immunotherapy with honeybee venom by pretreatment with fexofenadine: a double-blind, placebo-controlled trial. *Allergy* 2000; 55:484-8.
68. Muller UR, Jutel M, Reimers A, Zumkehr J, Huber C, Kriegel C, et al. Clinical and immunologic effects of H1 antihistamine preventive medication during honeybee venom immunotherapy. *J Allergy Clin Immunol* 2008; 122:1001-7 e4.
69. Muller U, Hari Y, Berchtold E. Premedication with antihistamines may enhance efficacy of specific-allergen immunotherapy. *J Allergy Clin Immunol* 2001; 107:81-6.
70. Kontou-Fili K. High omalizumab dose controls recurrent reactions to venom immunotherapy in indolent systemic mastocytosis. *Allergy* 2008; 63:376-8.
71. Schulze J, Rose M, Zielen S. Beekeepers anaphylaxis: successful immunotherapy covered by omalizumab. *Allergy* 2007; 62:963-4.
72. Stretz E, Oppel EM, R awer HC, Chatelain R, Mastnik S, Przybilla B, et al. Overcoming severe adverse reactions to venom immunotherapy by using anti-IgE antibodies in combination with a high maintenance dose. *Clin Exp Allergy* 2017.
73. Golden DB, Valentine MD, Kagey-Sobotka A, Lichtenstein LM. Regimens of Hymenoptera venom immunotherapy. *Ann Intern Med* 1980; 92:620-4.
74. Yunginger JW, Paull BR, Jones RT, Santrach PJ. Rush venom immunotherapy program for honeybee sting sensitivity. *J Allergy Clin Immunol* 1979; 63:340-7.
75. Gillman SA, Cummins LH, Kozak PP, Jr., Hoffman DR. Venom immunotherapy: comparison of "rush" vs "conventional" schedules. *Ann Allergy* 1980; 45:351-4.
76. Laurent J, Smiejan JM, Bloch-Morot E, Herman D. Safety of Hymenoptera venom rush immunotherapy. *Allergy* 1997; 52:94-6.
77. Sturm G, Kranke B, Rudolph C, Aberer W. Rush Hymenoptera venom immunotherapy: a safe and practical protocol for high-risk patients. *J Allergy Clin Immunol* 2002; 110:928-33.
78. van der Zwan JC, Flinterman J, Jankowski IG, Kerckhaert JA. Hyposensitisation to wasp venom in six hours. *Br Med J (Clin Res Ed)* 1983; 287:1329-31.
79. Bernstein JA, Kagen SL, Bernstein DI, Bernstein IL. Rapid venom immunotherapy is safe for routine use in the treatment of patients with Hymenoptera anaphylaxis. *Ann Allergy* 1994; 73:423-8.
80. Birnbaum J, Charpin D, Vervloet D. Rapid Hymenoptera venom immunotherapy: comparative safety of three protocols. *Clin Exp Allergy* 1993; 23:226-30.
81. Roll A, Hofbauer G, Ballmer-Weber BK, Schmid-Grendelmeier P. Safety of specific immunotherapy using a four-hour ultra-rush induction scheme in bee and wasp allergy. *J Investig Allergol Clin Immunol* 2006; 16:79-85.
82. Malling HJ, Djurup R, Sondergaard I, Weeke B. Clustered immunotherapy with Yellow Jacket venom. Evaluation of the influence of time interval on in vivo and in vitro parameters. *Allergy* 1985; 40:373-83.
83. Tarhini H, Knani J, Michel FB, Bousquet J. Safety of venom immunotherapy administered by a cluster schedule. *J Allergy Clin Immunol* 1992; 89:1198-9.
84. Lockey RF, Turkeltaub PC, Olive ES, Hubbard JM, Baird-Warren IA, Bukantz SC. The Hymenoptera venom study. III: Safety of venom immunotherapy. *J Allergy Clin Immunol* 1990; 86:775-80.
85. Korosec P, Ziberna K, Silar M, Dezman M, Celesnik Smodis N, Rijavec M, et al. Immunological and clinical factors associated with adverse systemic reactions during the build-up phase of honeybee venom immunotherapy. *Clin Exp Allergy* 2015; 45:1579-89.
86. Roumana A, Pitsios C, Vartholomaios S, Kompoti E, Kontou-Fili K. The safety of initiating Hymenoptera immunotherapy at 1 microg of venom extract. *J Allergy Clin Immunol* 2009; 124:379-81.

87. Hunt KJ, Valentine MD, Sobotka AK, Benton AW, Amodio FJ, Lichtenstein LM. A controlled trial of immunotherapy in insect hypersensitivity. *N Engl J Med* 1978; 299:157-61.
88. Golden DB, Kagey-Sobotka A, Valentine MD, Lichtenstein LM. Dose dependence of Hymenoptera venom immunotherapy. *J Allergy Clin Immunol* 1981; 67:370-4.
89. Goldberg A, Confino-Cohen R. Bee venom immunotherapy - how early is it effective? *Allergy* 2010; 65:391-5.
90. Hoffman DR, Jacobson RS. Allergens in hymenoptera venom XII: how much protein is in a sting? *Ann Allergy* 1984; 52:276-8.
91. Rueff F, Wenderoth A, Przybilla B. Patients still reacting to a sting challenge while receiving conventional Hymenoptera venom immunotherapy are protected by increased venom doses. *J Allergy Clin Immunol* 2001; 108:1027-32.
92. Bousquet J, Menardo JL, Velasquez G, Michel FB. Systemic reactions during maintenance immunotherapy with honey bee venom. *Ann Allergy* 1988; 61:63-8.
93. Bonifazi F, Jutel M, Bilo BM, Birnbaum J, Muller U. Prevention and treatment of hymenoptera venom allergy: guidelines for clinical practice. *Allergy* 2005; 60:1459-70.
94. Simioni L, Vianello A, Bonadonna P, Marcer G, Severino M, Pagani M, et al. Efficacy of venom immunotherapy given every 3 or 4 months: a prospective comparison with the conventional regimen. *Ann Allergy Asthma Immunol* 2013; 110:51-4.
95. Goldberg A, Confino-Cohen R. Maintenance venom immunotherapy administered at 3-month intervals is both safe and efficacious. *J Allergy Clin Immunol* 2001; 107:902-6.
96. Cavallucci E, Ramondo S, Renzetti A, Turi MC, Di Claudio F, Braga M, et al. Maintenance venom immunotherapy administered at a 3-month interval preserves safety and efficacy and improves adherence. *J Investig Allergol Clin Immunol* 2010; 20:63-8.
97. Goldberg A, Confino-Cohen R. Effectiveness of maintenance bee venom immunotherapy administered at 6-month intervals. *Ann Allergy Asthma Immunol* 2007; 99:352-7.
98. Reisman RE. Duration of venom immunotherapy: relationship to the severity of symptoms of initial insect sting anaphylaxis. *J Allergy Clin Immunol* 1993; 92:831-6.
99. Lerch E, Muller UR. Long-term protection after stopping venom immunotherapy: results of re-stings in 200 patients. *J Allergy Clin Immunol* 1998; 101:606-12.
100. Keating MU, Kagey-Sobotka A, Hamilton RG, Yunginger JW. Clinical and immunologic follow-up of patients who stop venom immunotherapy. *J Allergy Clin Immunol* 1991; 88:339-48.
101. Golden DB, Kwiterovich KA, Kagey-Sobotka A, Valentine MD, Lichtenstein LM. Discontinuing venom immunotherapy: outcome after five years. *J Allergy Clin Immunol* 1996; 97:579-87.
102. Golden DB, Kwiterovich KA, Kagey-Sobotka A, Lichtenstein LM. Discontinuing venom immunotherapy: extended observations. *J Allergy Clin Immunol* 1998; 101:298-305.
103. Bilo MB, Kamberi E, Tontini C, Marinangeli L, Cognigni M, Brianzoni MF, et al. High adherence to hymenoptera venom subcutaneous immunotherapy over a 5-year follow-up: A real-life experience. *J Allergy Clin Immunol Pract* 2016; 4:327-9 e1.
104. Blaauw PJ, Smithuis LO. The evaluation of the common diagnostic methods of hypersensitivity for bee and yellow jacket venom by means of an in-hospital insect sting. *J Allergy Clin Immunol* 1985; 75:556-62.
105. van der Linden PW, Hack CE, Struyvenberg A, van der Zwan JK. Insect-sting challenge in 324 subjects with a previous anaphylactic reaction: current criteria for

- insect-venom hypersensitivity do not predict the occurrence and the severity of anaphylaxis. *J Allergy Clin Immunol* 1994; 94:151-9.
106. Rueff F, Przybilla B, Muller U, Mosbech H. The sting challenge test in Hymenoptera venom allergy. Position paper of the Subcommittee on Insect Venom Allergy of the European Academy of Allergology and Clinical Immunology. *Allergy* 1996; 51:216-25.
 107. Kohler J, Blank S, Muller S, Bantleon F, Frick M, Huss-Marp J, et al. Component resolution reveals additional major allergens in patients with honeybee venom allergy. *J Allergy Clin Immunol* 2014; 133:1383-9, 9 e1-6.
 108. Frick M, Fischer J, Helbling A, Rueff F, Wiczorek D, Ollert M, et al. Predominant Api m 10 sensitization as risk factor for treatment failure in honey bee venom immunotherapy. *J Allergy Clin Immunol* 2016.
 109. Blank S, Seismann H, Michel Y, McIntyre M, Cifuentes L, Braren I, et al. Api m 10, a genuine *A. mellifera* venom allergen, is clinically relevant but underrepresented in therapeutic extracts. *Allergy* 2011.
 110. Cadario G, Marengo F, Raghino E, Rossi R, Gatti B, Cantone R, et al. Higher frequency of early local side effects with aqueous versus depot immunotherapy for hymenoptera venom allergy. *J Investig Allergol Clin Immunol* 2004; 14:127-33.
 111. Haugaard L, Norregaard OF, Dahl R. In-hospital sting challenge in insect venom-allergic patients after stopping venom immunotherapy. *J Allergy Clin Immunol* 1991; 87:699-702.
 112. Muller U, Berchtold E, Helbling A. Honeybee venom allergy: results of a sting challenge 1 year after stopping successful venom immunotherapy in 86 patients. *J Allergy Clin Immunol* 1991; 87:702-9.
 113. Golden DB, Kagey-Sobotka A, Lichtenstein LM. Survey of patients after discontinuing venom immunotherapy. *J Allergy Clin Immunol* 2000; 105:385-90.
 114. Bilo MB, Cichocka-Jarosz E, Pumphrey R, Oude-Elberink JN, Lange J, Jakob T, et al. Self-medication of anaphylactic reactions due to Hymenoptera stings - An EAACI Task Force Consensus Statement. *Allergy* 2016.
 115. Kontou-Fili K, Filis CI. Prolonged high-dose omalizumab is required to control reactions to venom immunotherapy in mastocytosis. *Allergy* 2009; 64:1384-5.
 116. Soriano Gomis V, Gonzalez Delgado P, Niveiro Hernandez E. Failure of omalizumab treatment after recurrent systemic reactions to bee-venom immunotherapy. *J Investig Allergol Clin Immunol* 2008; 18:225-6.
 117. van Halteren HK, van der Linden PW, Burgers JA, Bartelink AK. Discontinuation of yellow jacket venom immunotherapy: follow-up of 75 patients by means of deliberate sting challenge. *J Allergy Clin Immunol* 1997; 100:767-70.
 118. Golden DB. Long-term outcome after venom immunotherapy. *Curr Opin Allergy Clin Immunol* 2010; 10:337-41.
 119. van Halteren HK, van der Linden PW, Burgers SA, Bartelink AK. Hymenoptera sting challenge of 348 patients: relation to subsequent field stings. *J Allergy Clin Immunol* 1996; 97:1058-63.
 120. Franken HH, Dubois AE, Minkema HJ, van der Heide S, de Monchy JG. Lack of reproducibility of a single negative sting challenge response in the assessment of anaphylactic risk in patients with suspected yellow jacket hypersensitivity. *J Allergy Clin Immunol* 1994; 93:431-6.
 121. Urbanek R, Kemeny DM, Richards D. Sub-class of IgG anti-bee venom antibody produced during bee venom immunotherapy and its relationship to long-term protection from bee stings and following termination of venom immunotherapy. *Clin Allergy* 1986; 16:317-22.

122. Golden DB, Lawrence ID, Hamilton RH, Kagey-Sobotka A, Valentine MD, Lichtenstein LM. Clinical correlation of the venom-specific IgG antibody level during maintenance venom immunotherapy. *J Allergy Clin Immunol* 1992; 90:386-93.
123. Varga EM, Francis JN, Zach MS, Klunker S, Aberer W, Durham SR. Time course of serum inhibitory activity for facilitated allergen-IgE binding during bee venom immunotherapy in children. *Clin Exp Allergy* 2009; 39:1353-7.
124. Mobs C, Muller J, Rudzio A, Pickert J, Blank S, Jakob T, et al. Decline of Ves v 5-specific blocking capacity in wasp venom-allergic patients after stopping allergen immunotherapy. *Allergy* 2015; 70:715-9.
125. Erzen R, Kosnik M, Silar M, Korosec P. Basophil response and the induction of a tolerance in venom immunotherapy: a long-term sting challenge study. *Allergy* 2012.
126. Erdmann SM, Sachs B, Kwiecien R, Moll-Slodowy S, Sauer I, Merk HF. The basophil activation test in wasp venom allergy: sensitivity, specificity and monitoring specific immunotherapy. *Allergy* 2004; 59:1102-9.
127. Zitnik SE, Vesel T, Avcin T, Silar M, Kosnik M, Korosec P. Monitoring honeybee venom immunotherapy in children with the basophil activation test. *Pediatr Allergy Immunol* 2012; 23:166-72.
128. Celesnik N, Vesel T, Rijavec M, Silar M, Erzen R, Kosnik M, et al. Short-term venom immunotherapy induces desensitization of FcepsilonRI-mediated basophil response. *Allergy* 2012; 67:1594-600.
129. Shamji MH, Layhadi JA, Scadding GW, Cheung DK, Calderon MA, Turka LA, et al. Basophil expression of diamine oxidase: a novel biomarker of allergen immunotherapy response. *J Allergy Clin Immunol* 2015; 135:913-21 e9.
130. Shamji MH, Francis JN, Wurtzen PA, Lund K, Durham SR, Till SJ. Cell-free detection of allergen-IgE cross-linking with immobilized phase CD23: inhibition by blocking antibody responses after immunotherapy. *J Allergy Clin Immunol* 2013; 132:1003-5 e1-4.
131. Boyle RJ, Elremeli M, Hockenhull J, Cherry MG, Bulsara MK, Daniels M, et al. Venom immunotherapy for preventing allergic reactions to insect stings. *Cochrane Database Syst Rev* 2012; 10:CD008838.

Box 1. Key terms	
Allergen immunotherapy (AIT)	Repeated allergen administration at regular intervals to modulate immune response in order to reduce symptoms and the need of medication for clinical allergies. This is also sometimes known as allergen specific immunotherapy, desensitization, hyposensitization, or allergy vaccination
Aqueous venom preparations	Lyophilized venom, which is reconstituted in (albumin-containing) saline diluent.
Depot venom preparations	Venom preparation adsorbed onto aluminium hydroxide or L-tyrosine.
Purified venom preparations	Venom preparations where irritant low-molecular components <1000 Dalton are removed.
Venom immunotherapy (VIT)	AIT where insect venom preparations are administered as a series of subcutaneous injections to eliminate systemic allergic reactions after insect stings.

Box 2: Assigning levels of evidence and recommendations [Oxford Centre for Evidence-based Medicine]

Level of evidence

Level I	Systematic reviews, meta-analysis, randomized controlled trials
Level II	Two groups, nonrandomized studies (e.g., cohort, case-control)
Level III	One group nonrandomized (e.g., before and after, pretest, and post-test)
Level IV	Descriptive studies that include analysis of outcomes (single-subject design, case series)
Level V	Case reports and expert opinion that include narrative literature, reviews, and consensus statements

Grades of recommendation

Grade A	Consistent level I studies
Grade B	Consistent level II or III studies or extrapolations from level I studies
Grade C	Level IV studies or extrapolations from level II or III studies
Grade D	Level V evidence or troublingly inconsistent or inconclusive studies at any level

Strength of recommendations

Strong	Evidence from studies at low risk of bias /high quality studies
Moderate	Evidence from studies at moderate risk of bias /moderate quality studies
Weak	Evidence from studies at high risk of bias /low quality studies

Recommendations are phrased according to the strength of recommendation: strong: “is recommended”; moderate: “can be recommended”; weak: “may be recommended in specific circumstances”; negative: “can not be recommended”.

Box 3 Summary

- VIT is recommended in children and adults with detectable sensitization and systemic sting reactions exceeding generalized skin symptoms.
- VIT is recommended in adult patients with systemic sting reactions confined to generalized skin symptoms if quality of life is impaired
- VIT is not recommended in individuals with incidentally detected sensitization and no systemic symptoms
- Patients with severe initial sting reactions, high skin test reactivity, and high venom specific IgE levels are not associated with a higher risk of adverse events
- Pre-treatment with H₁ antihistamines is recommended as it reduces large local reactions and to some extent also systemic adverse events
- VIT should be performed for at least three years. In patients with severe initial sting reactions, at least a five year treatment is recommended
- Life-long VIT may be recommended in highly exposed patients with honeybee venom allergy, patients with very severe initial sting reactions (Muller grade IV or grade III-IV according to Ring & Messmer), and patients with systemic side-effects during VIT as they are major risk factors for relapse
- All available diagnostic tests, including determination of venom specific IgE, IgG, BAT response and allergen-blocking capacity, are not able to estimate the individual risk for relapse
- Sting challenges are the most reliable method to evaluate effectiveness of VIT

Box 4 Key messages for primary care practitioners about referral to allergy services for venom immunotherapy

- Venom immunotherapy is very effective in preventing future systemic reactions to honeybee, wasp, and ant stings
- Refer patients to an allergist with experience in venom immunotherapy for assessment as below. If unsure on review seek advice from your local allergy centre
- Venom immunotherapy is recommended in individuals with
 - systemic sting reactions exceeding generalized skin symptoms
 - generalized skin symptoms only (including urticaria/angioedema) if quality of life is impaired
- Venom immunotherapy is not recommended in individuals with
 - only local reactions, including large ones (defined as a swelling exceeding a diameter of 10 cm lasting longer than 24 hours)
 - incidentally detected sensitization and without any systemic allergic symptoms
- A careful personal history should be taken (culprit insect, characterization of sting reactions, emergency and concomitant medication) and, if possible, venom specific-IgE should be determined before patients are referred to an allergist
- Negative test results are possible in patients with insect venom allergy. If there were clear symptoms of anaphylaxis after a sting, patients should be referred to an allergist
- Large local reaction typically develop within 24 hours and should be treated with oral antihistamines and corticosteroids but not oral antibiotics. No further follow-up is needed.
- Quality of life is impaired in many patients who only carry an adrenaline autoinjector and do not receive venom immunotherapy

Table1. Recommendations: indications for VIT

Recommendations for individuals with venom allergy	Evidence level	Grade of recommendation	Strength of recommendation	Other considerations	Key references
VIT is recommended in adults and children with detectable sensitization and systemic sting reactions exceeding generalized skin symptoms	I (III for children)	A (B for children)	Strong-to-moderate for adults based on two high quality SR. ^{1 131} Weak for children based on one low quality CBA ¹⁵ and one low quality RCT study that included children ⁸⁷	Carrying an AAI without VIT negatively impacts on health-related QoL	Dhami 2017 ¹ Boyle 2012 ¹³¹ Golden 2004 ¹⁵ Hunt 1978 ⁸⁷
VIT is recommended in adult patients with systemic sting reactions confined to generalized skin symptoms if quality of life is impaired	I	A	Strong-to-moderate based on one high quality SR ¹ and two adult RCTs of moderate quality ^{50, 52}	Carrying an AAI without VIT negatively impacts on health-related QoL	Dhami 2017 ¹ Oude Elberink 2002 and 2009 ^{50, 52}
VIT can be recommended in adults with recurrent, troublesome LLR to reduce the duration and size of future LLR	II	B	Moderate/low based on one open, controlled trial of venom allergic adults with LLR ¹⁹	Cost/benefit profile should be considered for this indication. No pediatric data	Golden 2009 ¹⁹
VIT is not recommended in individuals with incidentally detected sensitization to insect venom and no clinical symptoms	IV	C	Weak based on one case series and expert consensus ¹⁸	Asymptomatic sensitization is very common	Sturm 2014 ¹⁸
VIT is not recommended in patients with unusual reactions that do not represent immediate type systemic reactions	V	D	Weak, as no studies have focused on this. Expert consensus	Reactions of non-allergic nature following Hymenoptera stings require neither diagnostic testing nor administration of VIT	Expert consensus

Table 2. Recommendations: VIT in patients with special conditions

Recommendations for individuals with venom allergy	Evidence level	Grade of recommendation	Strength of recommendation	Other considerations	Key references
VIT can be recommended in patients with cardiovascular disease but the underlying disease should be stabilized before initiation	V	D	Weak based on reviews of expert opinions and one case series study ²⁰		Pitsios 2015 ²⁰
Beta-blocker therapy may be continued during VIT but the patient should be informed about possible risks	IV	C	Weak based on two case series studies ^{26 24} and expert consensus	Stopping beta-blocker may even harmful for some patients	Ruëff 2009 ²⁶ Ruëff 2010 ²⁴
ACE inhibitor therapy may be continued during VIT but the patient should be informed about possible risks	IV	C	Weak based on two case series studies ^{25 24} and expert consensus		Stoevesandt 2014 ²⁵ Ruëff 2010 ²⁴
VIT can be recommended in high risk venom allergic patients when malignant disease is stable or in remission	IV	C	Weak based on one case series study ³⁴ and expert consensus		Wöhrl 2011 ³⁴
VIT can be recommended in patients with organ-specific autoimmune disorders when the underlying disease is stabilized	V	D	Weak based on expert consensus	Immune-suppressive medication may negatively influence effectiveness of VIT	Expert consensus
VIT cannot be recommended in patients with active, multi-system autoimmune disorders	V	D	Weak based on expert consensus		Expert consensus
Treatment with MAOIs is not a contraindication for VIT but caution is recommended with the use of adrenaline	V	D	Weak based on case reports and expert consensus	MAOIs are nowadays rarely prescribed	Expert consensus
VIT in children below 5 years of age should only be considered in the event of severe sting reactions and when the child is likely to be co-operative	IV	C	Weak based on one case series ³⁸ and expert consensus		Stritzke 2013 ³⁸
VIT should not be initiated during pregnancy, but well-tolerated ongoing VIT can be continued during pregnancy	IV	C	Weak based on case series studies ^{39 40}		Metzger 1978 ³⁹ Schwartz 1990 ⁴⁰
VIT may be recommended in patients with underlying systemic mastocytosis as it is safe and effective	IV	C	Weak based on two case series ^{45 47}	In few patients, side effects can be more frequent and severe	Bonadonna 2008 ⁴⁵ , 2013 ⁴⁷

Table 3. Recommendations: preparation and venom dose, pre-treatment with antihistamines, duration of treatment, carriage of adrenaline autoinjectors during/after VIT

Recommendations for individuals with venom allergy	Evidence level	Grade of recommendation	Strength of recommendation	Other considerations	Key reference
Purified venom preparations can be recommended as they have a lower frequency of local and systemic adverse events than non-purified aqueous preparations	I	B	Weak to moderate based on one RCT of moderate/low quality ⁶³		Bilo 2012 ⁶³
For the majority of patients, VIT with one venom may be recommended as sufficient for protection. In patients with a history of systemic stinging reactions to different insects or with severe initial reactions and clearly double positive tests, VIT with two venoms (i.e. <i>Apis mellifera</i> and <i>Vespula</i> or <i>Vespula</i> and <i>Polistes</i>) is recommended.	IV	C	Weak based on one case series study ⁶⁴ and expert consensus		Stoevesandt 2013 ⁶⁴
Two venoms can be administered simultaneously in the left and right arm, respectively. However, in the case of systemic adverse events, VIT should be continued with 30 minute intervals between injections	V	D	Weak based on expert consensus		Expert consensus
Pre-treatment with H ₁ antihistamines is recommended as it reduces large local reactions and to some extent also systemic adverse events	I	A	Strong to moderate based on four RCTs, two of them were of high quality ^{68 67} , two of moderate quality ^{66 65}		Müller 2008 ⁶⁸ Reimers 2000 ⁶⁷ Brockow 1997 ⁶⁶ Berchtold 1992 ⁶⁵
It is recommended to administer a standard maintenance dose of 100µg venom	II	B	Weak to moderate based on one CCT of moderate/low quality ⁸⁸		Golden 1981 ⁸⁸
If patients still react to field stings or sting challenges, a dose increase to 200µg of venom can be recommended	IV	C	Weak based on one case series study ⁹¹		Ruëff 2001 ⁹¹
It may be recommended to give injections every 4 weeks in the first year of treatment, every 6	V	D	Weak based on expert consensus ⁹³		Bonifazi 2005 ⁹³

weeks in the second year, and in case of a 5 year treatment every 8 weeks from year 3-5					
In the case of life-long therapy, 12 week intervals may be still safe and effective	II	C	Moderate based on one CCT ⁹⁴ and one CBA ⁹⁵ study		Simioni 2013 ⁹⁴ Goldberg 2001 ⁹⁵
It can be recommended to perform VIT for at least 3 years. In patients with severe initial sting reactions, at least a 5-year treatment is recommended	IV	C	Weak based on case series studies ^{98 99 101}		Reisman 1993 ⁹⁸ Lerch 1998 ⁹⁹ Golden 1996 ¹⁰¹
Life-long VIT may be recommended in highly exposed patients with bee venom allergy, patients with very severe initial sting reactions (Muller grade IV or grade III-IV according to Ring & Messmer), and patients with systemic side-effects during VIT as they are major risk factors for relapse.	IV	C	Weak based on case series studies ^{31 8 98}		Ruëff 2013 ³¹ ; 2014 ⁸ Reismann 1993 ⁹⁸
During and after VIT, AAI cannot be recommended in patients with mild to moderate initial sting reactions without risk factors for relapse	V	D	Weak based on expert consensus		Expert consensus
During and after VIT, AAI may be recommended in patients at risk of multiple stings or with risk factors for relapse	V	D	Weak based on expert consensus		Expert consensus

Table 4. Recommendations: risk factors and management of side effects, risk factors for relapse

Recommendations for individuals with venom allergy	Evidence level	Grade of recommendation	Strength of recommendation	Other considerations	Key references
It may be recommended that patients treated with bee venom and those on rapid up-dosing protocols should be closely observed for side effects as they are at a higher risk of experiencing adverse events	IV	C	Weak based on case series studies ^{24 43}	The intake of beta-blockers or ACE inhibitors are not risk factors for adverse events during VIT. Also most of the mastocytosis patients tolerate VIT well	Ruëff 2010 ²⁴ Mosbech 2000 ⁴³
It may be recommended that patients with severe initial sting reactions, high skin test reactivity, and high venom specific IgE levels do not require special precautions during VIT, as they are not associated with a higher risk of adverse events	IV	C	Weak based on case series studies ²⁵ ^{24 84}		Stoevesandt 2014 ²⁵ Ruëff 2010 ²⁴ Lockey 1990 ⁸⁴
In case of VIT- related systemic adverse events during build-up phase, a temporary reduction of the venom dose (e.g. going one to two steps back in the protocol) may be recommended to avoid further adverse events	V	D	Weak based on expert consensus		Expert consensus
In case of repeated systemic adverse events during up-dosing, pre-treatment with Omalizumab may be recommended	V	D	Weak based on case reports ^{70 71, 72}		Stretz 2017 ⁷² Kontou-Fili 2008 ⁷⁰ Schulze 2007 ⁷¹
In case of VIT related LLR, it may be recommended to split dose in 2 injections or change injection site but not necessarily to reduce venom dose	V	D	Weak based on expert consensus		Expert consensus
Life-long VIT may be recommended in patients who relapsed after stopping VIT	V	D	Weak based on expert consensus		Expert consensus
It may be recommended to avoid insect stings during build-up phase by abiding by preventive measures (eg stop beekeeping) until maintenance dose is reached	V	D	Weak based on expert consensus		Expert consensus

Table 5. Recommendations: monitoring of VIT

Recommendations for individuals with venom allergy	Evidence level	Grade of recommendation	Strength of recommendation	Other considerations	Key references
In adults, a sting challenge can be recommended as the most reliable method to evaluate effectiveness of VIT	IV	C	Weak based on case series studies ^{117 101}		Van Halteren 1997 ¹¹⁷ Golden 1996 ¹⁰¹
If no sting challenge can be performed, it may be recommended to record outcomes of field stings to evaluate effectiveness of VIT	V	D	Weak based on expert consensus		Expert consensus
It may not be recommended to determine venom specific IgE, IgG levels, BAT response and allergen-blocking capacity to estimate the individual risk for relapse	IV	C	Weak based on case series studies ^{99 112 100}		Lerch 1998 ⁹⁹ Müller 1991 ¹¹² Keating 1991 ¹⁰⁰

Table 6. Gaps in evidence

Gaps	Plan to address	Priority
Optimal duration of VIT in children and adults (for example, 3 versus 5 years or longer)	RCTs	High
Evaluation of biomarkers such as sting challenges, component-resolved diagnosis, and BAT (inhibition) in assessing the clinical efficacy of VIT	Prospective studies	High
Identification of biomarkers for the risk assessment for side effects and relapse	Prospective studies	High
Comparison of different VIT up-dosing schedules, maintenance doses, and maintenance intervals in adults/children in terms of efficacy both short and long-term	RCTs	High
Safety and efficacy of VIT in patients taking antihypertensive drugs (beta-blockers, ACEI)	Observational studies	High
Safety and efficacy of VIT in patients with elevated serum tryptase/mastocytosis verified by sting challenges	RCTs	High
Comparison of purified and non-purified bee venom preparations in respect of safety and efficacy verified by sting challenges	RCTs	High
Safety of the simultaneous application of two or more venoms during up-dosing and maintenance phase	RCTs	High
Value of VIT on health-related quality of life compared to AAI in children and their parents	RCTs	Medium
Assessing the cost-effectiveness of VIT	Cost-effectiveness analysis of RCT	Medium
Safety of VIT in adults and children with concomitant disease such as cardiovascular disease	Observational trials	Medium

Table 7. Barriers and facilitators to implementation, audit criteria and resource implications of recommendations

First-line intervention: VIT for venom allergic individuals	Barriers to implementation	Facilitators to implementation	Audit criteria	Resource implications
<p>Venom immunotherapy is highly clinically effective in adults and children with moderate to severe allergic reactions to hymenoptera stings</p>	<p>Failure to recognize severe allergic reactions (anaphylaxis) following hymenoptera stings Lack of knowledge amongst patients, caregivers and professionals about the availability of venom immunotherapy Concerns about side-effects The hope that allergic reactions will subside with time or symptomatic treatments only (e.g. AAI, antihistamines/ glucocorticosteroids)</p>	<p>Education and training of emergency care doctors, general practitioners and other physicians on venom allergy and its grades of severity Information about need of follow-up visits with clinical allergists for diagnosis and management of venom allergy Information sheets for patients and caregivers</p>	<p>Proportion of adults and children with moderate to severe SSR who are treated with VIT Proportion of adults and children experience relapses and/or side effects while on VIT</p>	<p>Venom allergen immunotherapy (VIT) needs to be prescribed by clinical allergists and made available to patients. Patient education about self-treatment with adrenaline (AAI) before starting VIT is important and requires availability of trainer devices</p>
<p>VIT is recommended in adult patients with systemic sting reactions confined to generalized skin symptoms if quality of life is impaired</p>	<p>Lack of knowledge amongst physicians, including clinical allergists about the indication of venom immunotherapy in these circumstances</p>	<p>Education and training of physicians, and allergy specialists Information sheets for patients</p>	<p>Proportion of patients experiencing impairment of QoL when venom allergy is confined to skin only who are treated with VIT</p>	<p>Education and training of both physicians and patients Cost /Benefit profile needs to be established</p>

<p>Life-long VIT can be recommended in highly exposed patients with bee venom allergy, patients with very severe initial sting reactions (Muller grade IV or grade III-IV according to Ring & Messmer), and patients with systemic side-effects during VIT as they are major risk factors for relapse.</p>	<p>Lack of resources (professional and financial) Adherence to life-long VIT unrealistic</p>	<p>Provision of insurance cover for life-long VIT within Europe Education and training of clinical allergists Education of patients in terms of sting exposure risk behavior; patient leaflets, smartphone “shot” reminder apps etc.</p>	<p>Proportion of patients who adhere to life-long (or prolonged, i.e. > 5 years) VIT and proportion of patients consecutively tolerate hymenoptera stings</p>	<p>Equipment of specialized allergy centers with skilled staff for successful administration of VIT Safety measures in place to minimize side effects in high risk patients</p>
<p>Pre-treatment with H₁ antihistamines is recommended as it reduces large local reactions and to some extent also systemic adverse events</p>	<p>Lack of knowledge amongst health care professionals regarding pre-treatment Reluctance of patients Additional costs for health care system</p>	<p>Education of healthcare professionals, and patients</p>	<p>Proportion of patients with VIT who have antihistamine pre-treatment</p>	<p>Prescription of antihistamines to be taken by patients prior to VIT</p>
<p>AAI during and after VIT is recommended only in patients at risk of multiple stings or with risk factors for relapse</p>	<p>Lack of knowledge amongst health care professionals in terms of (non) prescribing AAI Risk behavior and misconception of patients</p>	<p>Education of healthcare professionals, and patients</p>	<p>Proportion of high risk patients carrying and administering intramuscular (AAI) during or after VIT</p>	<p>Time to educate and train physicians and patients</p>