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To cite this article: Praopilad Srisuwarn, Sahaphume Srisuma, Charuwan Sriapha, Achara Tongpoo, Panee Rittilert, Aimon Pradoo, Yuvadee Tanpudsa & Winai Wananukul (2021): Clinical effects and factors associated with adverse clinical outcomes of hymenopteran stings treated in a Thai Poison Centre: a retrospective cross-sectional study, *Clinical Toxicology*, DOI: [10.1080/15563650.2021.1918705](https://doi.org/10.1080/15563650.2021.1918705)

To link to this article: <https://doi.org/10.1080/15563650.2021.1918705>



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CLINICAL RESEARCH



Clinical effects and factors associated with adverse clinical outcomes of hymenopteran stings treated in a Thai Poison Centre: a retrospective cross-sectional study

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ABSTRACT

Objective: To describe clinical effects and outcomes of hymenopteran stings and to explore the non-laboratory factors associated with adverse clinical outcomes, a composite outcome including death, respiratory failure requiring intubation, acute kidney injury (AKI) requiring dialysis and hypotension requiring vasopressor use.

Methods: A retrospective cross-sectional study was performed at the Ramathibodi Poison Center, a poison centre of a tertiary care hospital in Thailand. All cases of hymenopteran sting consultations from January 2015 to June 2019 were consecutively enrolled, and charts were reviewed. Demographics, initial clinical characteristics and outcomes were collected. Factors associated with adverse clinical outcome were explored.

Results: One hundred and fourteen hymenopteran stings cases (wasp 48%, bee 33%, hornet 14% and carpenter bee 8.8%) were included (median age, 36.5 years (interquartile range 9–55); male 63%). The prevalence of adverse clinical outcomes was 12.3% (95%CI 6.88–12.8). At initial presentation, 100% of cases had local skin reactions, 11.4% were clinical anaphylaxis, and 8% had red urine. Adverse clinical outcomes included death ($n=10$), respiratory failure requiring intubation ($n=9$), AKI requiring dialysis ($n=6$) and hypotension requiring vasopressor use ($n=2$). None of the patients with carpenter bee or hornet stings developed adverse clinical outcomes. In univariable analysis, urticaria, wheezing, red urine, wasp sting and sting number > 10 were significantly associated with adverse clinical outcomes. In multivariable analysis, red urine (adjusted OR 11.1 (95% CI 1.57–216)), wheezing (adjusted OR 16.7 (95% CI 1.43–402)) and a number of stings > 10 (adjusted OR 21.5 (95% CI 2.13–2557)) were significant.

Conclusions: Adverse clinical outcomes in hymenopteran stings were not uncommon among cases inquiring to a national Thai poison centre. At initial presentation, red urine, wheezing and a number of stings > 10 were significantly associated with adverse clinical outcomes. Larger epidemiologic studies are required to confirm these associations.

ARTICLE HISTORY

Received 16 February 2021
Revised 20 March 2021
Accepted 13 April 2021

KEYWORDS

Hymenoptera; wasp;
Thailand; insect bites and
stings; outcome

Introduction

The Hymenoptera subclade aculeata, which translates as “stinging wasps” in English, includes bees, wasps and ants, and is extremely diverse with more than 70000 species [1]. Members of the subclade sting in self-defence, and the clinical effects of the venoms can pose significant health problems for humans. Two common troublesome families are *Apidae* (bee) and *Vespidae* (wasp). Morphologically, the difference between the two families can be easily identified [2]. Investigation of the affected skin can also aid diagnosis. For example, bee stings typically remain in the skin of the victim while wasp stings do not [3].

The severity of clinical effects of one or multiple hymenopteran stings are varied and can be divided into local

inflammatory reaction, allergic manifestation, anaphylactic shock and systemic toxic reaction [4–6]. One or two stings usually cause a mild local reaction including redness or local swelling, which can easily be managed by oral analgesic agents unless the patient develops an allergic reaction. The clinical presentation of allergic reactions ranges from a large local reaction (i.e., urticaria and/or angioedema) to a severe life-threatening systemic reaction (e.g., anaphylactic shock). A swarm attack involving numerous stings can lead to severe systemic toxicity with outcomes such as rhabdomyolysis, haemolysis, noncardiogenic pulmonary oedema, transaminitis, renal failure and death [4,5,7].

The particular species in each area can evoke a wide range of clinical presentations. In Thailand, domestic bees were associated with less clinically severe effects compared

with domestic wasp species, namely *Vespa tropica* and *Vespa affinis*, which are known for their toxicity to humans [8,9]. Nevertheless, clinical studies providing an overview of demographics of victims of hymenopteran stings and their clinical presentations are limited [9,10]. Furthermore, the majority of cases with systemic effects have been reported from Asia and South America, where laboratory monitoring in remote rural area might not be available 24 h a day [11–13]. Hence, it is important that a tool for determining the severity should be kept as simple as possible to promote proper management in settings with such a resource limitation. Thus, we conducted a cross-sectional study primarily to describe the demographics, initial clinical effects, treatments and outcomes of patients with hymenopteran stings in Thailand. We also aimed to explore the patient characteristics and initial clinical effects associated with adverse clinical outcomes.

Method

Setting and design

This was a retrospective cross-sectional study of a convenience sample of all cases of hymenopteran stings reported to the Ramathibodi Poison Center (RPC), Bangkok, Thailand between 1 January 2015 and 30 June 2019. The RPC is a national poison centre receiving approximately 24000 human-exposure calls annually. The information scientists at the RPC receive the initial calls about hymenopteran sting attacks mostly from health care providers. The team of information scientists and toxicologists, verify the diagnoses of intoxication in all cases and then make follow-up calls to collect more data, monitor case progress, provide timely management recommendations and determine the outcome of cases. All cases are recorded into the RPC's toxic surveillance system database. Due to time constraints, reverification is performed approximately 40% of cases at daily meetings by a team of information scientists and toxicologists, include all cases with moderate to severe symptoms and cases with uncertainty.

The study was approved by Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (MURA2019/872). The need for informed consent was waived due to de-identification of patient data. This study was performed in accordance with the Declaration of Helsinki.

Cases with the final diagnosis of hymenopteran stings were abstracted from the RPC database. All electronic data files were reviewed. Characteristics of patients including age, sex, date, region, clinical scenario, initial clinical effects, laboratory results, treatments and outcomes were abstracted. The insect species were identified by an entomologist if the photograph of culprit species were available. If not, it was identified subjectively by the patient. Adverse clinical outcomes were a composite outcome of death, acute kidney injury (AKI) requiring renal replacement therapy, respiratory failure requiring intubation and hypotension requiring vasopressor use. Characteristics and initial clinical effects of cases with adverse clinical outcomes were compared with those without adverse outcomes.

AKI was defined as either rising serum creatinine level of ≥ 0.3 mg/dL or anuria. Hypotension was defined as systolic blood pressure of < 90 mmHg in adults > 10 years and 70 mmHg + $[2 \times \text{age in years}]$ in children aged from 1 to 10 years [14]. Rhabdomyolysis was defined as creatine phosphokinase (CPK) rising to 10 times above upper normal limit (> 1000 IU/L) or red urine without haematuria. Transaminitis was defined as aspartate aminotransferase (AST) or alanine aminotransferase (ALT) rising to three times above normal limit (> 120 IU/L). Anaphylactic shock was defined using the World Allergy organization criteria [14]. Sting number was categorized as a number of stings > 10 similar to a previous Chinese study [11].

Statistical analysis

Continuous data are presented as median (interquartile range) for nonparametrically distributed data, and categorical or ordinal data are presented as frequency (%). We explored factors associated with adverse clinical outcomes. If a patient experience more than one of the adverse outcomes defined in composite outcome, only one outcome event was counted for that patient. Univariable analysis of patient characteristics and initial clinical effects was performed using Firth's logistic regression with profile likelihood-based confidence intervals. Firth's logistic regression is a penalized likelihood-based method estimating penalized odds ratio for data with small sample size bias and separation [15,16]. In univariable analysis, a non-null profile likelihood-based 95% confidence interval was considered significant [17]. Multivariable analysis was performed using Firth's logistic regression analysis with a non-null profile likelihood-based 95% confidence interval considered significant. Multicollinearity diagnostics were performed, and a variance inflation factor > 5 or $r > 0.8$ were considered signs of multicollinearity. An *a priori* decision was made to include age and gender in the multivariable analysis based on the literature [18]. All analyses were performed using STATA version 16.1 (StataCorp LLC., College Station, TX).

Results

Case characteristics

One hundred and fourteen patients with hymenopteran stings sought advice from the RPC between 1 January 2015 and 30 June 2019. There were no missing data among the parameters collected and analysed as candidate predictors of adverse clinical outcomes and among adverse clinical outcomes used in the analysis. The median age was 36.5 years (interquartile range 9–55). Thirty-two patients (28%) were children under 15 years. Central Thailand was the region with the highest proportion of cases. The median time from exposure to arriving at hospital was 1 h (interquartile range 0.5–2). The number of cases was slightly higher during the monsoon season (Supplementary Figure 1). Of the 114 cases, the most common type of hymenopteran was wasp (48.2%), followed by bee (28.9%), hornet (14.0%) and carpenter bee

Table 1. Characteristics of hymenopteran sting attacks reported to Ramathibodi Poison Center between January 2015 and June 2019.

Characteristic	Total (N = 114)	Patients without adverse clinical outcomes (n = 100)	Patients with adverse clinical outcomes (n = 14)
Age, median (IQR), years	36.5 (9, 55)	36 (9.2, 54.2)	39 (7.5, 62.5)
Age < 15 years	32 (28.0)	27 (27.0)	5 (35.7)
Male	71 (62.3)	63 (63.0)	8 (57.1)
Time elapsed from bite to hospital, median (IQR), min	60 (30, 120)	60 (30, 120)	60 (60, 195)
Region			
North	15 (13.2)	11 (11.0)	4 (28.6)
Northeast	22 (19.3)	17 (17.0)	5 (35.7)
Central	30 (26.3)	29 (29.0)	1 (7.1)
East	13 (11.4)	12 (12.0)	1 (7.1)
West	12 (10.5)	11 (11.0)	1 (7.1)
South	21 (18.4)	20 (20.0)	2 (14.3)
Hymenopteran types			
Wasp	55 (48.2)	44 (44.0)	11 (78.6)
Bee	33 (28.9)	30 (30.0)	3 (23.5)
Hornet	16 (14.0)	16 (16.0)	0 (0)
Carpenter bee	10 (8.8)	10 (10.0)	0 (0)
Sting number > 10	55 (48.2)	44 (44.0)	11 (78.6)

Table 2. Initial clinical effects of hymenopteran sting attacks reported to Ramathibodi Poison Center between January 2015 and June 2019.

Initial clinical effect	Total (N = 114)	Patients without adverse clinical outcomes (n = 100)	Patients with adverse clinical outcomes (n = 14)
Skin signs			
Local effects (pain, redness, or swelling)	114 (100)	100 (100)	14 (100)
Urticaria	19 (16.7)	14 (14)	5 (35.7)
Chest symptoms			
Dyspnoea	5 (0)	5 (5.0)	0 (0)
Wheezing	13 (11.4)	6 (6.0)	7 (50.0)
Hypotension	5 (4.4)	3 (3.0)	2 (14.3)
Red urine	9 (7.9)	1 (1.0)	8 (57.1)
Gastrointestinal symptoms			
Nausea	2 (1.8)	1 (1.0)	1 (7.1)
Diarrhoea	2 (1.8)	1 (1.0)	1 (7.1)
Fever	4 (3.5)	3 (3.0)	1 (7.1)

Data are presented as n (%). Definitions of hypotension by age were aged 1 month–1 year: < 70 mmHg, 1–10 year: < (70 mm Hg + [2 × age in year]) and > 10 year: < 90 mmHg.

(8.8%) (Table 1). The prevalence of adverse clinical outcomes was 12.3% (95%CI 6.88, 12.8).

Clinical effects and treatments

Of the total of 114 patients, all (100%) presented to emergency departments with pain and local skin reaction characterised by redness and swelling. The next four most common clinical characteristics included urticaria (16.7%), clinical syndrome of anaphylaxis (11.4%), wheezing (11.4%) and red urine (7.9%) (Table 2). Of the 18 patients with respiratory symptoms (i.e., dyspnoea or wheezing), 9 were intubated and required mechanical ventilation.

The most common treatment was intravenous antihistamine (42%), followed by intravenous dexamethasone (36.8%) and intramuscular adrenaline (19.3%). Nine patients (27%) with bee stings underwent sting removal.

Fourteen patients (12.3%) developed AKI, 12 of whom had an elevated CPK level >1000 IU/L. Median peak CPK level was higher in AKI than non-AKI patients (35,700 versus 1937 IU/L, respectively; $p < 0.01$). Six patients with AKI underwent intermittent haemodialysis. No other renal replacement modality was reported. Median time-to-dialysis initiation was 1.5 days (interquartile range 1–4). Primary initiative criteria for dialysis were hyperkalaemia, severe acidosis and volume

overload. Three of six dialysis patients died. The 3 survivors were dependent on dialysis for 11, 20 and 51 days of follow-up.

Rhabdomyolysis was reported in 21 cases (18.4%), 12 of whom developed AKI. All 9 patients with initial red urine developed rhabdomyolysis. Urine alkalization was performed in 4 patients, 2 of whom survived without haemodialysis.

AST or ALT levels >120 IU/L were available in 17 cases (14.9%). Three patients had an isolated AST elevation. During the hospital course, the liver function test levels were most elevated during the first 24 h, declining sharply over the next 4 days and returning to normal within 2 weeks. No patients developed hepatic encephalopathy or liver failure.

A clinical impression of anaphylaxis was reported in 13 patients (11.4%), most of whom had >20 stings (Supplementary Table 1). Of the 13 patients with clinical impression of anaphylaxis, 5 developed hypotension. All suspected anaphylaxis cases were treated with adrenaline, dexamethasone and antihistamine.

Clinical outcomes

Of the 114 patients, 51 patients (44.7%) were hospitalised. The median length of hospital stay was 2 days (interquartile

Table 3. Firth's logistic regression analysis of factors associated with adverse clinical outcomes.

Characteristic	Univariate analysis Crude odds ratio (95%CI)	Multivariate analysis Adjusted odds ratio (95%CI)
Age	1.00 (0.98, 1.02)	0.99 (0.95, 1.02)
Male	0.77 (0.26, 2.32)	0.38 (0.08, 1.90)
Skin sign		
Urticaria	3.44 (1.05, 11.3)*	0.34 (0.02, 2.59)
Chest symptoms		
Dyspnoea	0.60 (0.03, 11.4)	
Wheezing	14.5 (4.01, 52.7)*	16.7 (1.43, 402)*
Hypotension	5.57 (0.99, 31.3)	
Gastrointestinal signs		
Nausea	7.37 (0.72, 76.0)	
Diarrhoea	7.37 (0.72, 76.0)	
Red urine	86.7 (12.9, 584)*	11.1 (1.57, 216)*
Fever	3.10 (0.42, 22.8)	
Wasp	4.17 (1.18, 14.7)*	5.14 (0.82, 72.0)
Number of stings > 10	34.0 (1.97, 585)*	21.5 (2.13, 2557)*

Adverse clinical outcome included death, acute kidney injury requiring renal replacement therapy, respiratory failure requiring intubation and hypotension requiring vasopressor use. Confidence intervals are profile likelihood-based. A non-null 95% confidence interval was considered significant in both univariable analysis and multivariable analysis. Significant independent variables are denoted by *. Definitions of hypotension by age were aged 1 month–1 year: <70 mmHg, 1–10 year: < (70 mmHg + [2 × age in year]), and >10 year: <90 mmHg. CI: confidence interval.

range 1–4). Adverse clinical outcomes were reported in 14 patients including death ($n=9$), ventilation support ($n=9$), haemodialysis ($n=6$) and vasopressor use ($n=2$). (Supplementary Table 1).

Of the 10 deaths (Supplementary Table 1), 4 of the deceased were aged <15 years. Sudden cardiac death was the main cause of death within the first 24 h. One patient developed ischaemic stroke within 24 h and later died from hospital-acquired pneumonia on day 16.

Only patients stung by bees or wasps developed adverse clinical outcomes. Two patients (12.5%) stung with >10 hornet stings developed dyspnoea and skin reaction without subsequent organ failure. All patients stung by carpenter bee suffered only local skin reaction.

Associations with adverse clinical outcomes

In univariable analysis, clinical clues and symptoms associated at first presentation to the emergency department significantly associated with adverse clinical outcomes were urticaria, wheezing, red urine, wasp sting and sting number >10 (Table 3). Multivariable analysis showed red urine (adjusted odds ratio 11.1 (95%CI 1.57, 216)), wheezing (adjusted odds ratio 16.7 (95%CI 1.43, 402)) and a number of stings >10 (adjusted odds ratio 21.5 (95%CI 2.13, 2557)) were significantly associated with adverse clinical outcomes.

Discussion

This cross-sectional study highlights the clinical outcomes of hymenopteran stings in Thailand. Adverse clinical outcomes of hymenopteran stings were not uncommon among the inquiries the RPC. The alarming signs significantly associated

with adverse clinical outcomes at initial presentation was red urine, wheezing and a number of stings >10.

Red urine is a sign of the presence of red blood cell haemoglobin or myoglobin in urine, reflecting the severity of cell lysis including haemolysis, rhabdomyolysis or coagulopathy, relating to the direct toxic effect caused by exposure to a certain amount of venom. This sign was presented in 10% of wasp-stung patients [11] and in up to 57% of cases complicated with AKI, of which the case fatality rate was one-third [7].

A number of stings >10 is another predictor of a poor clinical outcome. In the case of direct toxicity, the amount and potency of toxin appear to be correlated with degree of severity, which is not seen in anaphylaxis. A study extrapolating from animal models estimated that the number of stings leading to 50% mortality in a 70-kg man would be 1225 with *Apis mellifera* compared with only 220 in *Vespa mandarinia*. This could be explained by the difference in the amount and strength of toxin contained in each sting [4]. Diversity of species with uneven distribution also may contribute to distinctive patient characteristics between geographic regions. In Asia, native social wasps are notorious for death by poison with death after 10–250 stings having been reported [11,19]. In contrast, death by *Apis mellifera* toxin, particularly the Africanized honeybee, in Europe and the North and South America has been reported only if the sting number was in excess of 1000–2000 [20].

Wheezing is a common sign of anaphylaxis, but it can also be due to a direct toxic effect causing respiratory symptoms that mimic an allergic reaction through various mechanisms. In direct toxic effect, phospholipase A2, a main venom component, directly stimulates mast cells through a non-Ig E-mediated pathway, and phospholipase A2 also induces vasodilatation, acute lung injury and alveolar oedema, all of which can mimic the presentation of Ig E-mediated anaphylaxis [21,22]. An incorrect understanding of this sign as an anaphylaxis can interrupt the order of further laboratory tests. Currently, no known clinical signs have sufficient capacity to discriminate between direct toxic effect and anaphylaxis. Even a skin and soft tissue reaction, a local swelling, could also be seen in non-allergic reactions [3] while urticarial rash might be absent in around one-half of anaphylaxis cases [19,23]. Instead, a useful biomarker is serum tryptase level. Rising serum tryptase in the first few hours after stings, returning to normal on serial testing is a highly specific test for anaphylactic reaction with the caveat of a lack of sensitivity [24] and is not widely available in resource-limited settings. Nevertheless, adrenaline injection should not be withheld in suspicious cases regardless of aetiology. Referral for identification of hymenopteran venom allergy is possible 1–6 week after hospital discharge. Furthermore, avoidance of further exposure to the putative or confirmed culprit hymenopteran species and prompt accessibility to adrenaline injection are advisable.

As evaluating the effect of direct toxicity, such as rhabdomyolysis, haemolysis, and acute kidney injury, mostly requires laboratory investigation for guidance and as such testing may not be available 24 h a day in remote areas with

limited resources, presenting of these symptoms including red urine, string number more than 10 or wheezing could be an indicator of systemic toxicity requiring immediate treatment and prompt referral to a centre in which appropriate medical facilities are available.

The physician must exercise due caution as well as appropriate and timely managements according to the initial presentation associated with the hymenopteran sting attack. First, a patient with a presentation of red urine, which obviously indicates a high toxin burden, should be supervised in a health care facility setting in which intensive monitoring is available. Bolus with intravenous fluid is crucial to correct shock and to further prevent acute kidney injury complication due to myoglobin or haemoglobin deposition (pigmented cast nephropathy). If shock occurs, it usually does so not long after the associated stinging event. Electrocardiography, urine output, oxygen saturation and laboratory testing including complete blood count, coagulogram and electrolyte panel should be closely monitored and promptly corrected, particularly hyperkalaemia, as most of non-anaphylaxis deaths were most likely to occur in the early stages of hospitalization with the majority of deaths due to hyperkalaemia, massive haemorrhage and cardiac arrhythmia [11]. Monitoring is the most important in the first 24 h as 50% of deaths in the present study occurred during this period, and extended monitoring is appropriate according to the patient's status. Liver and renal function test should be checked, and haemodialysis should be initiated if conventional indications are fulfilled. Furthermore, there is a suggestion that corticosteroid and antihistamine might be

beneficial in cases of systemic intoxication [3,5,25]. If the number of sting is ≤ 10 , and the attack occurred at least 2 h prior without signs of anaphylaxis [26], the patient can be safely discharged as severe systemic allergic reaction or systemic intoxication are unlikely. Although definite species identification is best for determining the toxic component, often such identification is not possible in reality as the victim or bystanders are poor historians. Exactly counting the number of stings is also cumbersome and impractical, particularly in cases with a large number of stings. Moreover, the patient's condition, including comorbidities and body weight, may hinder the accurate assessment of the toxic dose response. Nevertheless, a simple prognostic tool including only initial presentation signs and symptoms could be a good, high-sensitivity screening tool to identify patients at high risk of an adverse outcome to encourage close monitoring. Nevertheless, the small sample size of the present study precluded precise assessment of the discrimination and calibration capacities of any set of candidate predictors of adverse outcomes, and we suggest that these assessments should not be performed by penalized generalised linear regression modelling methods because they may not be valid approaches for developing clinical prediction models [27]. Studies with larger numbers of events are required to perform discrimination and calibration capacity estimation by conventional binary logistic regression. Lack of awareness of the possibility of direct toxic effects may lead to an inadequate duration of observation and laboratory investigations before discharge from a health care facility, which can put patients at risk of adverse clinical outcomes. Patients with

Toxic effect	Non dose dependent (few sting) 	Dose dependent     
Pathophysiology	Type I hypersensitivity (Specific IgE-mediated)	Direct toxic effect  Cell membrane lysis ↑ vascular permeability
 Onset	Minute – 2 hours	Minute - days
 Clinical presentation	Skin GI CVS Lung Neuro Urticaria, angioedema, pruritus Nausea, vomiting, abdominal pain Chest tightness, arrhythmia, hypotension, cardiac arrest Dyspnea, wheezing, stridor bronchoconstriction Altered mental status, confusion Anaphylaxis	Skin GI CVS Lung Muscle Renal Blood Rare Edema, local reaction Transaminitis, hyperbilirubinemia (Direct +indirect bilirubinemia) Hypotension Non-cardiogenic pulmonary edema Rhabdomyolysis, myoglobinuria Acute tubular necrosis electrolyte imbalance (↑K, ↑P) Hemolysis, leukocytosis, thrombocytopenia, DIC, hemoglobinuria Pancreatitis , convulsion Systemic toxicity

Figure 1. A comparison of the early systemic effects of hymenopteran sting attacks between anaphylaxis and systemic toxicity reported from the literature [3-5,11,14]. Abbreviations: GI: gastrointestinal; CVS: cardiovascular; K: potassium; P: phosphate.

delayed onset usually came back 2 or 3 day later with multiple organ failure as the opportunity to prevent complication by prompt management was lost [2,28]. To assist prognostication of adverse clinical outcomes associated with hymenopteran stings, we summarize presenting clinical characteristics from the literature that may help discriminate between anaphylaxis and systemic toxicity in Figure 1.

Limitations

As a retrospective study from one poison centre, this study was affected by selection bias. For example, if the primary health care providers were confident in taking care of hymenopteran sting cases, they may not have consulted the RPC, especially regarding hymenopteran sting attacks associated with mild localised clinical effects. Similarly, incident cases may not have sought health care. Therefore, the prevalence of adverse clinical outcomes in the present study may be an underestimate of incidence. Future healthcare facility-based studies should be prospective and include primary and secondary centres. Larger observational epidemiologic studies are needed to confirm and more precisely estimate the prognostic value of the significant candidate prognostic factors. Finally, the results may lack generalisability to other regions with different hymenopteran species with toxins of varying clinical effects and severity compared to those in Thailand.

Conclusion

Adverse clinical outcomes of hymenopteran stings were not uncommon amongst inquiries to a this poison centre. Initial presenting signs of red urine, wheezing and a number of stings greater than 10 were significantly associated with developing adverse clinical outcomes. Large prospective multi-centred epidemiologic studies including all levels of health care facility are needed to confirm their prognostic value and explore other candidate prognostic factors.

Acknowledgements

The authors would like to thank Dr Anthony Tan for his assistance with editing the English language.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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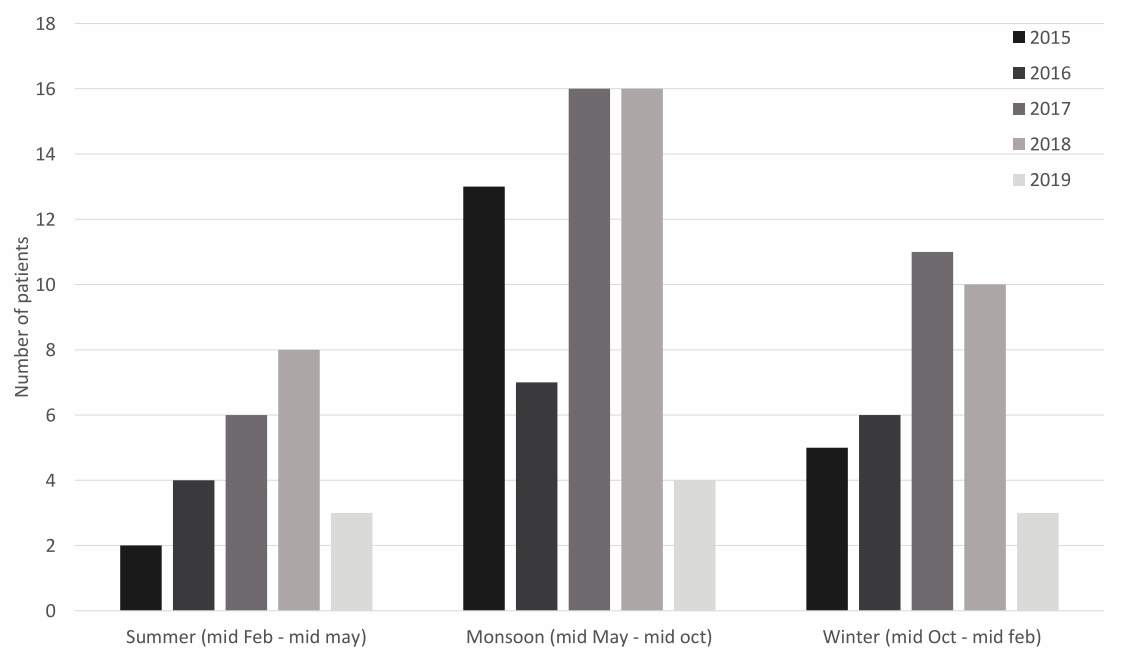
Supplementary Table 1. Hymenopteran sting patients with adverse clinical outcomes reported to Ramathibodi Poison Center between January 2015 and June 2019

Case no.	Age (years)	Sex	Insect type	Stings	Time to hospital (hours)	Time to death ^a (hours)	Initial Symptom				Complication			Composite outcome				Note
							Hypotension	Wheezing	Urticaria	Red urine	AKI	Rhabdomyolysis	Transaminitis	AKI requiring RRT	Respiratory failure requiring intubation	Hypotension requiring vasopressor	Death	
1	1.33	M	Wasp	>80	1	4	Yes	No	No	No	No	No data ^b	Yes	No	No	No	Yes	
2	1.75	F	Wasp	>30	1	7	No	No	No	No	No data ^b	No data ^b	No data ^b	No	No	No	Yes	
3	3	M	Wasp	20 - 30	1	15	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	
4	9	F	Wasp	>30	1	96	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Systemic bleeding
5	25	M	Wasp	>40	12	5.5	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	
6	37	M	Wasp	>100	0.5	8.5	No	Yes	Yes	Yes	Yes	Yes	No data ^b	No	Yes	No	Yes	
7	42	M	Bee	>20	1	44	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
8	60	M	Bee	>100	2.5	384	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Stroke
9	70	F	Bee	>100	0.5	72	No	Yes	Yes	No	Yes	Yes	No data ^b	No	Yes	No	Yes	

10	74	M	Wasp	>20	6	120	No	No	No	No	Yes	No data ^b	Yes	Yes	No	No	Yes
11	14	M	Wasp	100	No data	Alive	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No
12	41	F	Wasp	>10	2	Alive	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No
13	46	M	Wasp	50	1	Alive	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No
14	78	F	Wasp	>20	4	Alive	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No

Notes:- ^aTime to death: duration from envenomation to death; ^bNo record of lab results available. Abbreviations: AKI, acute kidney injury; F, female sex; M, male sex; RRT, renal replacement therapy

Supplementary Figure 1. Number of hymenopteran sting patients reported to Ramathibodi Poison Center between January 2015 and June 2019



Notes:- Mid Feb - mid May = pooled frequency of cases between 15 February to 15 May for each year; mid May - mid Oct = pooled frequency of cases between 16 May to 15 October for each year; and mid Oct - mid Feb = pooled frequency of cases between 16 October to 14 February for each year.