

Review

Capturing anaphylaxis through medical records

Are ICD and CPT codes sufficient?

Katherine L. Tuttle, MD ^{*,†}; Paige Wickner, MD, MPH ^{*,†,‡}^{*} Division of Allergy and Clinical Immunology, Department of Medicine, Brigham and Women's Hospital, Boston, Massachusetts[†] Harvard Medical School, Boston, Massachusetts[‡] Department of Quality and Safety, Brigham and Women's Hospital, Boston, Massachusetts

Key Messages

- Accurate anaphylaxis diagnosis is imperative for first-line treatment and providing high-quality and safe care. Programs to train front-line providers on recognition are imperative for anaphylaxis diagnosis, management, and coding.
- Anaphylactic shock-specific reimbursement codes, without associated algorithm use or retrospective chart review, have poor positive predictive value for anaphylaxis.
- Diagnosis underreporting and inaccurate recognition of anaphylaxis can cloud the pragmatic use of reimbursement codes to identify anaphylaxis in large administrative claims databases.
- We remain hopeful that ICD-11 reclassification and improvements in clinical decision support tools as well as education can further improve the accuracy of anaphylaxis detection.

ARTICLE INFO

Article history:

Received for publication September 12, 2019.

Received in revised form November 14, 2019.

Accepted for publication November 18, 2019.

ABSTRACT

Objective: The identification of anaphylaxis cases is imperative for optimal clinical provider knowledge deficiencies in diagnosis and treatment and the efficacy of reimbursement codes, such as International Classification of Diseases (ICD) and current procedural terminology (CPT) codes, in detecting anaphylaxis.

Data Sources: Pubmed.

Study Selections: Recent and clinically relevant literature on anaphylaxis and provider knowledge, ICD, CPT, Healthcare Common Procedural Coding System (HCPCS), and E-codes were selected and reviewed.

Results: Reimbursement codes are used to detect anaphylaxis in administrative claims databases. Inaccurate recognition of the diagnosis by providers, underreporting, and cause identification are challenges faced by health researchers using reimbursement codes for anaphylaxis case identification. Anaphylactic shock-specific ICD codes were noted to have a positive predictive value (PPV) of 52% to 53% of anaphylaxis events compared with physician chart review, which was improved to 63% to 67.3% when used in conjunction with anaphylaxis symptom-specific ICD, CPT, HCPCS, and E-codes 31, 34, and 35.

Conclusion: Education of providers to properly diagnose and treat anaphylaxis requires systematic and educational investments. The ICD codes specific to anaphylactic shock have suboptimal PPV to identify anaphylaxis in administrative claims databases. Use of algorithms incorporating other reimbursement codes improve the PPV, but they are limited by inaccurate diagnoses and underreporting of anaphylaxis. Future ICD-11 reclassification may improve anaphylaxis detection by reimbursement codes.

© 2019 American College of Allergy, Asthma & Immunology. Published by Elsevier Inc. All rights reserved.

Reprints: Dr. Paige Wickner, Brigham and Women's Hospital, Medicine, Department of Allergy and Immunology, Brigham and Women's Hospital 60 F, Boston, MA 02115; E-mail: pwickner@partners.org.

Disclosures: None.

Funding Sources: None.

Introduction

Anaphylaxis is a potentially life-threatening systemic reaction with varied clinical manifestations secondary to the release of multiple basophil and mast cell mediators.¹ In many cases,

mediator release is attributable to contact with an antigen, such as food, venom, or a drug. Anaphylaxis, as an acute hypersensitivity, is managed by different types of health care providers across the care continuum, frequently in the emergency department (ED).^{2,3} To generate a diagnosis of anaphylaxis, a provider must identify and coalesce history, physical examination findings, and clinical symptoms. Previous studies have found significant knowledge gaps in critical points of recognition,⁴ diagnosis,⁵ and correct use of epinephrine to treat anaphylaxis.^{6,7} Although diagnostic criteria exist,^{1,8,9} there is no gold standard or point of care testing for diagnosis of anaphylaxis.

Identification of anaphylaxis cases is imperative for optimal clinical care, accurate epidemiology and research studies, ensuring patient safety, and resource allocation. The prevalence of anaphylaxis in the United States was reported to be 1.6% of that of the general population,¹⁰ with increased rates of anaphylaxis hospitalizations from 20 to 25.1 per million population between 1999 and 2009.¹¹ Whether geographic variation in increases or stagnation in these rates¹² are true representation of disease variation vs reporting and coding practices is unclear. Fatal drug-induced anaphylaxis in the United States increased from 0.27 per million in 1999 to 2001 to 0.51 per million in 2008 to 2010.¹³ International patterns parallel those of the United States, with an increase in the prevalence of anaphylaxis hospitalizations reported in Australia.¹⁴ In addition to epidemiologic parameters, accurate diagnosis of anaphylaxis has broad clinical implications as well, including prompt administration of epinephrine and discharge epinephrine prescription.¹⁵

Reimbursement Codes for Identification of Anaphylaxis

Health researchers frequently use reimbursement codes, such as the *International Classification of Diseases (ICD)*, *Ninth-CM*, or *Tenth-CM* for case identification in population level databases. The ICD was first developed as the International List of Causes of Death, which was adopted by the International Statistics Institute in 1893.¹⁶ The World Health Organization expanded the ICD to include morbidity-related diagnoses in 1948.¹⁷ Various vintages of ICD codes are potent sources of morbidity- and mortality-related health data across multiple clinical care locations. The ICD-9-CM was first used in the United States in 1979 to classify morbidity-related diagnoses and procedures; the current version, ICD-10, was implemented for mortality statistics in the United States in 1999 and for morbidity diagnoses as ICD-10-CM in 2015.¹⁷

Selected ICD-9-CM and ICD-10-CM codes relating to anaphylaxis are compared in Table 1. Dizzying amounts of putative allergens can lead to anaphylaxis as well as physical or idiopathic causes; Table 1 illustrates common, selected codes frequently used in epidemiologic studies. In the ICD-9-CM and ICD-10-CM systems, anaphylaxis is classified in Chapter XIX: injury, poisoning, and certain other consequences of external causes, section: effects not elsewhere classified, and specifically in the ICD-9-CM as anaphylactic shock. This categorization may bias toward reporting of only severe cases of anaphylaxis,¹⁸ because anaphylaxis is a much broader clinical syndrome than simply shock. Symptoms that constitute anaphylaxis, such as urticaria, angioedema, bronchospasm, or abdominal pain/vomiting, also have distinct reimbursement codes in both ICD-9-CM and ICD-10-CM. Prior to 1993, the ICD-9-CM system did not have unique codes that identified food-induced anaphylaxis, and drug-induced anaphylaxis did not have a distinct code in any iteration of ICD-9-CM. Additionally, ICD-9-CM and ICD-10-CM do not have specific codes identifying anaphylaxis secondary to mast cell disorders or idiopathic anaphylaxis.

In addition to ICD-9-CM or ICD-10-CM allergy-specific codes, current procedural terminology codes (CPT) and external cause-of-injury codes (E-code) can be used in anaphylaxis case identification.

Table 1

List of Selected Allergy-Specific Reimbursement Codes Employed to Detect Anaphylaxis in Administrative Claims Databases^a

General allergy codes used in detection of anaphylaxis		
ICD-9-CM	Code description	ICD-10-CM
995.0	Anaphylactic shock, unspecified	T78.2XX
995.3	Allergy, unspecified	T78.40XX and T78.49XX
995.1	Angioneurotic edema	T78.3XX
708.9	Urticaria	L50.0-L50.9
519.11	Acute bronchospasm	J98.01
786.1	Stridor	R06.1
458.9	Hypotension	I95.89
Codes used in detection of food anaphylaxis		
ICD-9-CM	Code description	ICD-10-CM
693.1	Dermatitis due to food	L27.2
995.60	Anaphylactic shock or reaction due to unspecified food	T78.0XX
995.61	Anaphylactic shock or reaction due to peanuts	T78.01XX
995.62	Anaphylactic shock or reaction due to crustaceans	T78.02XX
995.63	Anaphylactic shock or reaction due to fruits and vegetables	T78.04XX
995.64	Anaphylactic shock or reaction due to tree nuts and seeds	T78.05XX
995.65	Anaphylactic shock or reaction due to fish	T78.03XX
995.66	Anaphylactic shock or reaction due to food additives	T78.06XX
995.67	Anaphylactic shock or reaction due to milk products	T78.07XX
995.68	Anaphylactic shock or reaction due to eggs	T78.08XX
995.69	Allergy due to other unspecified food	T78.09XX
Codes used in detection of insect sting anaphylaxis		
ICD-9-CM	Code description	ICD-10-CM
989.5	Toxic effect of venom or other arthropods	T63.4XX
Codes used in detection of drug or product anaphylaxis		
ICD-9-CM	Code description	ICD-10-CM
*	Anaphylactic shock to drug	T88.6XXX
999.4	Anaphylactic shock to serum	T80.5XX
995.4	Shock due to anesthesia	T88.2XX
693.0	Dermatitis due to drug	L27.0
Codes used in detection of other causes of anaphylaxis		
ICD-9-CM	Code description	ICD-10-CM
	Toxic effect of latex	T65.811-4XX
	Anaphylaxis to food additives (such as sulfite)	T59.1XX
	Anaphylaxis to immunizations	T80.5XX and T88.1XX
Procedure specific codes		
CPT	Code description	HCPCS
92950	Cardiopulmonary resuscitation	
	Administration of epinephrine	J0170 and J0170
	Administration of diphenhydramine	J1200

^aICD-10 codes often require additional complexity (initial encounter: A, subsequent encounter: D, or sequelae: S), which is abbreviated in this table after the general code as XX.

As intramuscular epinephrine is the first-line treatment for anaphylaxis¹⁹; nursing and pharmacy administration codes, such as Healthcare Common Procedure Coding System (HCPCS) for epinephrine are additional reimbursement codes employed in epidemiologic studies to detect anaphylaxis.

Benefits and Limitations of Reimbursement Codes in Epidemiologic Studies

Employing billing codes in population-level administrative claims databases to exclusively ascertain cases for epidemiologic and research studies has inherent benefits and challenges. The

ICD-9-CM and ICD-10-CM provide rich sources of standardized population-level data across all care locations in the United States over extended periods. The ICD-10-CM codes have been used to identify sentinel clinical events, such as inpatient bleeding events on anticoagulation,²⁰ and ICD9 codes for ventricular arrhythmias²¹ have yielded high sensitivity, specificity, and negative predictive value (NPV). In allergic diseases, ICD-9-CM code 995.1 (angioneurotic edema) exhibits a high positive predictive value (PPV; 90%–95.3%)²² for angiotensin-converting enzyme inhibitor angioedema.

However, use of the ICD classification system in administrative claims data has been found to have limitations in accuracy in specific types of conditions. Any administrative claims data set relies on the diagnosis claimed by the physician completing the encounter. Some diseases, such as sepsis and anaphylaxis, have multiple diagnostic guidelines for diagnosis. Accuracy can be compromised when the conditions themselves are collections of common symptoms, each of which themselves can be coded as primary or secondary, or the developed coding is distributed across varied codes. Like sepsis and anaphylaxis, cerebrovascular ischemia is a clinical diagnosis distributed across multiple different ICD-9-CM codes (433x–436x); in comparison with medical record review, certain codes were found to be significantly more accurate (434x–436x) than others (433x) in representing the true diagnosis.²³ Symptoms of anaphylaxis could be spread over multiple reimbursement codes claimed by the health care provider completing the encounter, such as urticaria, angioedema, or bronchospasm. Thus, both the nature of the disease and the available codes can influence the ability of the ICD-9-CM/ICD-10-CM code to reflect the disease in a patient population.

What Does Sufficiency Entail in Reference to Anaphylaxis Detection by Reimbursement Codes and what Are Specific Challenges Relating to Anaphylaxis?

In an ideal state, we define sufficiency in anaphylaxis reimbursement coding as 1) correct identification of symptoms of anaphylaxis and 2) use of a reimbursement code that identifies anaphylaxis by diagnosis and cause with high sensitivity, specificity, and negative/positive predictive value.

Although there will always be provider variability in coding diagnoses, anaphylaxis has 3 unique attributes that provide some challenges in the use of reimbursement codes for case identification: inaccurate recognition, underreporting, and cause identification, detailed in Figure 1.

Inaccurate Recognition

Anaphylaxis is an inaccurately recognized clinical entity, indicating a significant knowledge gap in the diagnosis. Analysis of allergic events reported to the National Electronic Injury Surveillance System from 34 hospitals in 2003 indicated that only 57% of food-related anaphylactic events on chart review received a coded diagnosis of anaphylaxis.²⁴ Foreign body aspiration, acute asthma, urticaria, vocal cord dysfunction, and anxiety disorders can present with similar symptoms.²⁵ In a 2013 case-based survey, 82% of United Kingdom trainee doctors indicated that they would administer epinephrine to a patient presenting with symptoms of foreign body inhalation.⁴ Because anaphylaxis encompasses varied symptoms, cognitive bias, such as anchoring bias, may contribute to the inaccurate recognition of anaphylaxis by providers.²⁶

Although no gold standard testing exists for anaphylaxis, tryptase, a major mast cell and basophil protease, released in serum after degranulation, is a highly specific biomarker of anaphylaxis.²⁷ In a recent study of 19,836 cases of drug-induced anaphylaxis, less than 0.8% had a tryptase level checked within 1 week of the anaphylactic event.²⁸ National guidelines^{1,29} state that

intramuscular epinephrine is the preferred acute treatment of anaphylaxis, and outpatient anaphylaxis management includes prescribing and obtaining an epinephrine autoinjector. A 2014 study of 716 episodes of drug-induced anaphylaxis treated in the ED or inpatient hospitalization noted that 8% of patients treated in the ED received epinephrine.³ A recent study of 159,172 patients identified using ICD-9-CM codes showed that epinephrine autoinjectors were prescribed in 16.2% of total cases.³⁰ Lack of tryptase measurement and epinephrine autoinjector prescribing indicate significant knowledge gaps in diagnostic markers and treatment in anaphylaxis.

These diagnostic challenges surrounding anaphylaxis lead to downstream effects on the entire health care system; in addition to suboptimal clinical treatment, immediate effects of inaccurate recognition of anaphylaxis include improper coding (Fig 2).

Underreporting

Because anaphylaxis comprises individual diagnoses, discharge coding could center on the individual symptom diagnostic codes and not anaphylaxis. In review of 211 cases of anaphylaxis in Rochester, Minnesota, 25% received less-specific allergy codes.³¹ In a national study of US ED visits from 1993 to 2004 for acute allergic reactions, only 1% of reactions were coded as anaphylaxis.³² In a single-center pediatric ED in Korea from 2012 to 2016, 87.5% of anaphylaxis cases (161/184) were not coded with the T78.2X ICD-10 code.³³ This may be attributable to a lack of provider recognition, because one cannot report a diagnosis that is not identified. However, underreporting may be secondary to inherent classification within the ICD. ICD-9 and 10-CM codes focus on anaphylactic shock, which may prompt providers to code for individual symptom diagnostic codes instead of anaphylaxis if the patient did not exhibit shock physiology.

Cause Identification

A causative allergen in anaphylaxis (if possible) is as important to identify as the diagnosis itself. In a study in Florida ED visits, only approximately 50% of the cases identified with ICD-9-CM codes 995.0 and 995.60–995.69 had an accompanying code identifying the potential allergen.³⁴ Allergists care for disorders of anaphylaxis without clear trigger, including idiopathic anaphylaxis and mast

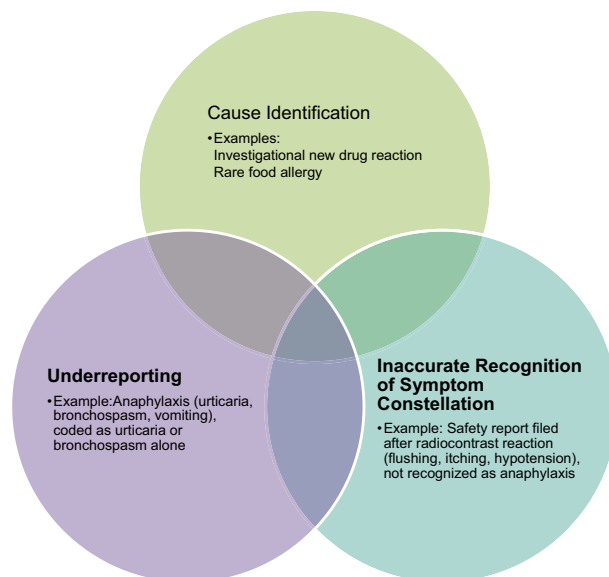


Figure 1. Diagnostic challenges in anaphylaxis detection.

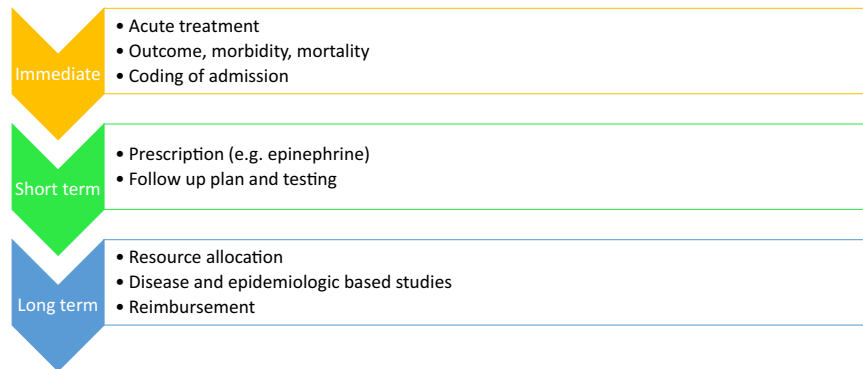


Figure 2. Downstream effects of improper anaphylaxis diagnosis.

cell disorders. However, in cases of triggered anaphylaxis, the putative allergen may not be immediately apparent to the physician treating the anaphylactic episode and therefore could not be captured in the claims-associated diagnostic codes within the immediate clinical encounter. Allergen may only be detected in a post hoc analysis of the event, often days to weeks after the event, in consultation with an allergist. If possible, allergen identification is imperative for future allergen avoidance; in a single-center study of medication-induced anaphylaxis, 15% of cases had a prior allergic reaction to a medication in a similar class.³⁵ Allergen identification is particularly important in the cases of stinging insect hypersensitivity, given the opportunity for life-saving treatment for the individual presenting patient. In a study of 954 cases of stinging insect anaphylaxis from 2002 to 2008, only 14% of patients received follow-up care from an allergist/immunologist, which could include venom immunotherapy.³⁶ Thus, an important short-term consequence of improper anaphylaxis diagnosis or cause identification includes lack of allergy/immunology referral (Fig 2).

Long-term consequences of improper anaphylaxis diagnosis, coding, and lack of cause identification impact epidemiology studies, but also basic and translational research and quality improvement research surrounding anaphylaxis (Fig 2).

ICD-9-CM Anaphylactic Shock Reimbursement Codes Alone Are Not Sufficient for Anaphylaxis Case Identification

Multiple studies have evaluated the accuracy of ICD-9-CM codes to identify cases of acute allergic reaction or anaphylaxis as well as mortality as compared with clinical chart review. Between 1999 and 2001, specific ICD-9-CM codes for acute allergic reaction identified 53% of patients with food allergy (vs 87% of patients with insect sting allergy).³⁷ In individuals younger than 18 years between 1991 and 1997 in the Washington State Group Health Cooperative, ICD-9-CM code 995.0 (anaphylactic shock) exhibited 55% PPV.² Another validation of ICD-9-CM code 995.0 in claims data from Kaiser Permanente of Northern California found that 52% of events were confirmed by chart review as anaphylactic shock, and 93% had probable, possible, or history of anaphylactic shock.³⁸

ICD-10-CM Codes Improve Anaphylaxis Case Identification, but Do Not Detect Anaphylaxis-Related Deaths

As noted in Table 1, ICD-10 codes offer more specific anaphylaxis-related diagnoses. Analysis of ICD-10 codes from a single ED in Thailand found a PPV of 88.4% for ICD-10 codes T78.0 through T78.2.³⁹ However, data from the Brazilian Mortality Information System from 2008 to 2010 indicate that none of anaphylaxis-related deaths were coded with anaphylactic shock-specific ICD-10 codes in the underlying cause of death field.¹⁷

Mitigation Strategies to Improve Anaphylaxis Case Identification

Mitigation strategies to improve anaphylaxis identification, including system-based clinical decision support (CDS), provider education, and algorithm-based approaches to detect cases, are detailed in Figure 3.

Algorithmic Approaches of Both ICD-9-CM and ICD-10-CM Improve Anaphylaxis Case Identification

In addition to using individual or groups of anaphylaxis-specific codes, health researchers have developed algorithms to accurately detect anaphylaxis cases in claims databases that involve specific ICD symptom codes, E-codes, and HCPCS codes. In a Food and Drug Administration Mini-Sentinel data partners study, an algorithm incorporating 3 criteria (A: inpatient or ED 995.0 or 995.4, B: outpatient 995.0 or 995.4 + 1 of the following codes: bronchospasm, stridor, hypotension, injection of epinephrine or diphenhydramine, cardiopulmonary resuscitation (CPR); or C: inpatient or ED 995.3 or 995.2 or E930-E949 AND 1 of the following codes: bronchospasm, stridor, administration of diphenhydramine AND 1 of the following codes: hypotension, CPR, administration of epinephrine) was cumulatively noted to have a PPV of 63.1%. If criterion A or B were used, PPV was 67.3%.⁴⁰ In a population-based analysis of ED visits in Florida 2005 to 2006,³⁴ an algorithm (Harduar-Morano) incorporating a specific combination of ICD-9-CM codes of signs and symptoms in anaphylaxis and ICD-9-CM 995.2, 995.3, or 995.4 codes or E-code E905x, identified 58% more anaphylaxis cases than by using ICD-9-CM codes for anaphylactic shock alone. The Harduar-Morano algorithm has been employed in subsequent studies to identify anaphylaxis cases using ICD coding structures. Positive predictive value and diagnostic utility increases if ICD codes for anaphylaxis signs and symptoms, medication administration codes, and procedure CPT codes are incorporated into the case identification algorithm.

Provider Education

Educational programs across the care continuum and anaphylaxis simulation programs are tools that can mitigate anaphylaxis knowledge gap among providers. A recent cohort study found that simulation education surrounding anaphylaxis improved medical student and resident knowledge of the diagnosis and treatment of anaphylaxis.⁴¹ At our institution, not only is anaphylaxis recognition and treatment core content for trainee educational conferences as well as local and national meetings, but we have continuous re-education programs and partnerships with our nursing colleagues in our infusion suites at Brigham and Women's Hospital and Dana Farber Cancer Institute. The authors additionally

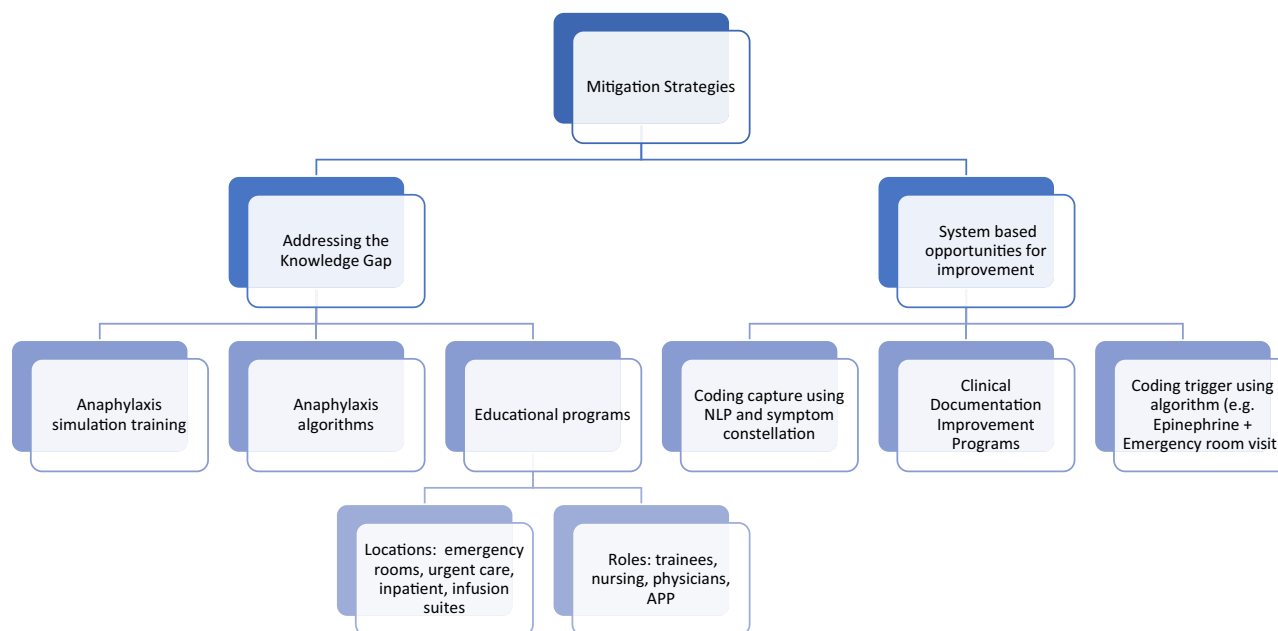


Figure 3. Mitigation strategies in addressing knowledge gap in anaphylaxis.

have completed quality improvement partnerships with our ED colleagues to standardize and improve our anaphylaxis algorithm for use by non-allergy/immunology-trained health care providers.

System-Based Improvement Measures

Health care system measures to improve the diagnosis and case identification of anaphylaxis include Clinical Documentation Improvement programs and CDS, such as coding capture and natural language processing. Initial investigations into natural language processing use for anaphylaxis are promising⁴² but require refinement before spread. A concise CDS tool surrounding anaphylaxis definitions in the ED was found to have 82% to 83% sensitivity and specificity of diagnosing anaphylaxis,⁴³ and the percentage of anaphylaxis patients treated with epinephrine increased from 33% to 51% in an ED after order set implementation.⁴⁴ At our institutions, we have built infusion order sets into our electronic health record that facilitate tryptase ordering and epinephrine dosing and availability, to optimize diagnosis and treatment of anaphylaxis.

Future Directions

Clinical decision support and ICD classification modifications show promise in the effort to accurately identify anaphylaxis cases. The Joint Allergy Academies' consortium and World Health Organisation governance have significantly updated the classifications of allergy and hypersensitivity conditions for the ICD-11 revision.⁴⁵ Anaphylaxis is 1 of 8 subheadings under allergic and hypersensitivity conditions, which is classified under "Diseases of the immune system." The anaphylaxis section has 7 comprehensive headings: anaphylaxis due to allergic reactions to food, drug-induced anaphylaxis, anaphylaxis due to insect venom, anaphylaxis provoked by physical factors, anaphylaxis due to inhaled allergens, anaphylaxis due to contact with allergens, and anaphylaxis secondary to mast cell disorder.⁴⁵ Field-testing methodology was applied to both ICD-10 and the proposed ICD-11; novel ICD-11 classification codes captured 71.5% of anaphylaxis cases as compared with 52.4% using ICD-10.⁴⁶ The ICD-11 codes were 94.8% accurate in classifying anaphylaxis-related causes of death in

Brazil.⁴⁷ The ICD-11 coding is anticipated to be in use for mortality metrics in 2022.

Conclusion

A pressing need in anaphylaxis is sustainable and spreadable programs to close the knowledge gap among providers in how to diagnose and manage anaphylaxis. Bridging this gap will improve safety for patients receiving first-line treatment, assist with prioritizing cause investigation, and aid in epidemiologic-based studies. Anaphylactic shock—specific reimbursement codes are not sufficient for case identification of anaphylaxis. Algorithms combining anaphylaxis-specific codes, anaphylaxis signs and symptom codes, HCPCS medication administration codes, and E-code greatly improve the PPV of the ICD-9-CM and ICD-10-CM anaphylactic shock—specific codes.

Reclassifying ICD codes to reflect the breadth of allergic and hypersensitivity disorders is a crucial next step but will not completely address inaccurate recognition or underreporting of anaphylaxis by coding providers. Further research focusing on improving education for providers, and utilization of CDS tools should aid in anaphylaxis recognition by billing providers and coders, further improving the accuracy of reimbursement and claims data coding and allowing for appropriate planning for resource utilization.

References

1. Lieberman P, Nicklas RA, Randolph C, et al. Anaphylaxis—a practice parameter update 2015. *Ann Allergy Asthma Immunol*. 2015;115(5):341–384.
2. Bohlke K, Davis RL, DeStefano F, et al. Epidemiology of anaphylaxis among children and adolescents enrolled in a health maintenance organization. *J Allergy Clin Immunol*. 2004;113(3):536–542.
3. Banerji A, Rudders S, Clark S, et al. Retrospective study of drug-induced anaphylaxis treated in the emergency department or hospital: patient characteristics, management and 1-year follow-up. *J Allergy Clin Immunol Pract*. 2014;2:46–51.
4. Plumb B, Bright P, Gompels MM, et al. Correction recognition and management of anaphylaxis: not much change over a decade. *Postgrad Med J*. 2015;91(1071):3–7.
5. Klein JS, Yocum MW. Under reporting of anaphylaxis in a community emergency room. *J Allergy Clin Immunol*. 1995;95:637–638.

6. Grossman SL, Baumann BM, Garcia Pena BM, et al. Anaphylaxis knowledge and practice preferences of pediatric emergency medicine physicians: a national survey. *J Pediatr*. 2013;163(3):841–846.
7. Wang J, Young MC, Nowak-Wegrzyn A. International survey of knowledge of food-induced anaphylaxis. *Pediatr Allergy Immunol*. 2014;25(7):644–650.
8. Sampson HA, Munoz-Furlong A, Campbell RL, et al. Second symposium on the definition and management of anaphylaxis: summary report—Second National Institute of Allergy and Infectious Disease/Food Allergy and Anaphylaxis Network symposium. *J Allergy Clin Immunol*. 2006;117:391.
9. Simon FE, Arduoso LR, Bilo MB, et al. World Allergy Organization guidelines for the assessment and management of anaphylaxis. *World Allergy Organ J*. 2011;4(2):13–37.
10. Wood RA, Camargo CA, Lieberman P, et al. Anaphylaxis in America: the prevalence and characteristics of anaphylaxis in the United States. *J Allergy Clin Immunol*. 2014;133(2):461–467.
11. Poulos LM, Waters AM, Correll PK, et al. Trends in hospitalizations for anaphylaxis, angioedema, and urticarial in Australia 1993–1994 to 2004–2005. *J Allergy Clin Immunol*. 2007;120:878–884.
12. Sheikh A, Alves B. Hospital admissions for acute anaphylaxis: time trend study. *BMC*. 2000;320:1441.
13. Mulla ZD, Lin RY, Simon MR. Perspectives on anaphylaxis epidemiology in the United States with new data and analyses. *Curr Allergy Asthma Rep*. 2011;11(1):37–44.
14. Ma L, Danoff TM, Borish L. Case fatality and population mortality associated with anaphylaxis in the United States. *J Allergy Clin Immunol*. 2014;133:1075–1083.
15. Jerschow E, Lin RY, Scaperotti MM, et al. Fatal anaphylaxis in the United States, 1999–2010: temporal patterns and demographic associations. *J Allergy Clin Immunol*. 2014;132:1318–1328.
16. Thomson H, Seith R, Craig S. Downstream consequences of diagnostic error in pediatric anaphylaxis. *BMC Pediatr*. 2018;18(1):40.
17. www.who.int/classifications/icd/en. Accessed July 15, 2019.
18. Tanno LK, Ganem F, Demoly P, Toscano CM, Bierrenbach AL. Under notification of anaphylaxis deaths in Brazil due to difficult coding under the ICD-10. *Allergy*. 2012;67:783–789.
19. Saff RR, Li Y, Santhanakrishnan N, et al. Identification of inpatient allergic drug reactions using ICD-9–CM codes. *J Allergy Clin Immunol Pract*. 2019;7:259–264.
20. McLean-Tooke AP, Bethune CA, Fay AC, Spickett GP. Adrenaline in the treatment of anaphylaxis: what is the evidence? *BMJ*. 2003;327(7427):1332–1335.
21. Joos C, Lawrence K, Jones AE, Johnson SA, Witt DM. Accuracy of ICD-10 codes for identifying hospitalizations for acute anticoagulation therapy-related bleeding events. *Thromb Res*. 2019;181:71–76.
22. Tamariz L, Harkins T, Nair V. A systematic review of validated methods for identifying ventricular arrhythmias using administrative and claims data. *Pharmacoepidemiol Drug Saf*. 2012;21(Suppl 1):148–153.
23. Brown NJ, Ray WA, Snowden M, Griffin MR. Black Americans have an increased rate of angiotensin converting enzyme inhibitor-associated angioedema. *Clin Pharmacol Ther*. 1996;60(1):8–13.
24. Benesch C, Witter DM, Wilder AL, Duncan PW, Samsa GP, Matchar DB. Inaccuracy of the ICD-9–CM in identifying the diagnosis of ischemic cerebrovascular disease. *Neurology*. 1997;49(3):660–664.
25. Jacobsen RC, Toy S, Bonham AJ, Salomone JA, Ruthstrom J, Gratton M. Anaphylaxis knowledge among paramedics: results of a national survey. *Prehosp Emerg Care*. 2012;16(4):527–534.
26. Ross MP, Ferguson M, Street D, Klontz K, Schroeder T, Luccioli S. Analysis of food-allergic and anaphylactic events in the National Electronic Injury Surveillance System. *J Allergy Clin Immunol*. 2008;121(1):166–171.
27. Sicherer SH, Simons FER. Epinephrine for first-aid management of anaphylaxis. *Pediatrics*. 2017;139(3):pii20164006.
28. Stiegler MP, Neelankavil JP, Canales C, Dhillon A. Cognitive errors detected in anaesthesiology: a literature review and pilot study. *Br J Anaesthesia*. 2012;108(2):229–235.
29. Decker WW, Campbell RL, Manivannan V, et al. The etiology and incidence of anaphylaxis in Rochester, Minnesota: a report from the Rochester Epidemiology Project. *J Allergy Clin Immunol*. 2008;122(6):1161–1165.
30. Gaeta TJ, Clark S, Pelletier AJ, Camargo CA. National study of US emergency department visits for acute allergic reactions 1993 to 2004. *Ann Allergy Asthma Immunol*. 2007;98:360–365.
31. Harduar-Morano L, Simon MR, Watkins S, Blackmore C. Algorithm for the diagnosis of anaphylaxis and its validation using population-based data on emergency department visits for anaphylaxis in Florida. *J Allergy Clin Immunol*. 2010;126:98–104.
32. Berg EA, Platts-Mills TA, Commins SP. Drug allergens and food: the cetuximab and galactose- α -1,3-galactose story. *Ann Allergy Asthma Immunol*. 2014;112(2):97–101.
33. Clark S, Gaeta TJ, Kamarthi GS, Camargo CA. ICD-9–CM coding of emergency department visits for food and insect sting allergy. *Ann Epidemiol*. 2006;16:696–700.
34. Iribarren C, Tolstykh IV, Miller MK, Eisner MD. Asthma and the prospective risk of anaphylactic shock and other allergy diagnoses in a large integrated health care delivery system. *Ann Allergy Asthma Immunol*. 2010;104(5):371–377.
35. Walsh KE, Cutrona SL, Foy S, et al. Validation of anaphylaxis in the Food and Drug Administration's Mini-Sentinel. *Pharmacoepidemiol Drug Saf*. 2013;22:1205–1213.
36. Lee S, Hardy C, Swanson MB, Harland K, Ahmed A, Ballas Z. Preliminary findings from a concise emergency department model to predict anaphylaxis and develop a clinical decision support tool. *J Allergy Clin Immunol Pract*. 2019;7(7):2479–2480.
37. Manivannan V, Hess EP, Bellamkonda VR, et al. A multifaceted intervention for patients with anaphylaxis increases epinephrine use in adult emergency department. *J Allergy Clin Immunol Pract*. 2014;2(3):294–299.
38. Tanno LK, Simons FE, Annesi-Maesano I, et al. Reaching multidisciplinary consensus on classification of anaphylaxis for the eleventh revision of the WHO ICD-11. *Orphanet J Rare Dis*. 2017;12:53.
39. Tanno LK, Molinari N, Bruel S, et al. Field-testing the new anaphylaxis' classification for the WHO ICD-11 revision. *Allergy*. 2017;72:820–826.
40. Tanno LK, Chalmers R, Bierrenbach AL, et al. Changing the history of anaphylaxis mortality statistics through the World Health Organization's International Classification of Diseases-11. *J Allergy Clin Immunol Pract*. 2019 Sep;144(3):627–633.