Trauma Surgery & Acute Care Open

Mortality, hospital admission, and healthcare cost due to injury from venomous and non-venomous animal encounters in the USA: 5-year analysis of the National Emergency Department Sample

Joseph D Forrester, Jared A Forrester, Lakshika Tennakoon, Kristan Staudenmayer

Department of Surgery, Stanford University, Stanford, California, USA

Correspondence to
Dr Joseph D Forrester, Department of Surgery, Stanford University, Stanford, CA 94305, USA; jdf1@stanford.edu

Received 3 October 2018
Accepted 5 October 2018

To cite: Forrester JD, Forrester JA, Tennakoon L, *et al*. *Trauma Surg Acute Care Open* 2018;**3**:e000250.

ABSTRACT

Background Injuries due to encounters with animals can be serious, but are often discussed anecdotally or only for isolated types of encounters. We sought to characterize animal-related injuries presenting to US emergency departments (ED) to determine the impact of these types of injuries.

Methods All ED encounters with diagnosis codes corresponding to animal-related injury were identified using ICD-9-CM codes from the 2010 2014 National Emergency Department Sample (NEDS). Outcomes assessed included inpatient admission, mortality, and healthcare cost. Survey methodology was applied to univariate and multivariate analyses. Weighted numbers are presented.

Results There were 6 457 534 ED visits resulting from animal-related injuries identified. Bites from non-venomous arthropods (n=2 648 880; 41%), dog bites (n=1 658 295; 26%) and envenomation from hornets, wasps or bees (n=812 357; 13%) constitute the majority of encounters. There were 210 516 patients (3%) admitted as inpatients. Inpatient admission was most common for those suffering from venomous snakes or lizard bites (24%, n=10 332). Death was infrequent occurring in 1162 patients (0.02% of all ED presentations). The greatest number of deaths was due to bites from non-venomous arthropods (24% of deaths, n=278) whereas rat bites proved the most lethal (6.5 deaths per 10 000 bites). Among persons aged 85 years or greater, odds of hospital admission for any animal-related injury was 6.42 (95% CI 5.57 to 7.40) and the OR for death was 27.71 (95% CI 10.38 to 73.99). Female sex was associated with improved survival (OR 0.55, 95% CI 0.41 to 0.73) and lower rates of hospital admission (OR 0.77, 95% CI 0.75 to 0.79). The total healthcare cost for these animal encounters during the observed time period was $5.96 billion (95% CI $5.43 to $6.50 billion).

Conclusion The morbidity, mortality, and healthcare cost due to animal encounters in the USA is considerable. Often overlooked, this particular mechanism of injury warrants further public health prevention efforts.

Level of Evidence Level IV.

BACKGROUND

Injuries due to encounters with animals can be serious, but are often discussed anecdotally or only for isolated events. Animals can cause injury to humans through a variety of mechanisms including blunt force trauma through direct contact or crushing, as well as through biting, stinging, or envenomation. Animals causing injury include wild animals, domestic animals, and animals encountered in the workplace. In spite of recommendations from medical, veterinary, and public health bodies, injury associated with animal encounters remains a considerable public health issue.[1–4] Prior studies have estimated over a million emergency department (ED) visits annually as a result of animal-related encounters, with direct medical and work time lost estimated to be $1 to $2 billion annually.[5 6]

Much of the epidemiologic data describing morbidity and mortality from animal encounters have been through evaluation of county-level death certificates.[7–11] These studies are subject to limitations associated with county-level death certificate data including misclassification bias and data suppression. Other attempts at describing a wider epidemiology of patients presenting to EDs with an injury after an animal encounter have been limited by either small probability samples, or shorter time periods.[5 12] We sought to describe the broad, modern epidemiology of animal-related injury presenting to US EDs through an evaluation of animal-related morbidity, hospital admission, mortality and healthcare cost documented in the National Emergency Department Sample (NEDS).

METHODS

We performed a retrospective analysis of data from the Agency for Healthcare and Quality, Healthcare Cost and Utilization Project's (HCUP) NEDS from 2010–2011.[13] Whereas data for 2015 are available, the diagnosis codes are in International Classification of Diseases (ICD), 10th Revision versus ICD 9th Revision (ICD-9). To combine results over multiple years and to ensure consistency, we included data only until 2014. NEDS is the largest all-payer ED database in the USA, capturing both ED encounters that result in discharge or transfer and ED encounters that result in admission. Publicly available, NEDS is constructed using survey methodology from the HCUP State Emergency Department Databases and the State Inpatients Databases. The stratified unweighted sample includes approximately 20% of all US ED visits and when weighted provides national estimates of all ED visits in the USA. We identified all ED encounters with diagnosis codes corresponding to an injury incurred

as a result of an encounter with an animal (ICD-9-CM (ICD-9, Clinical Modification) codes E905.0, E905.1, E905.2, E905.3, E905.4, E905.5, E905.6, E905.8, E905.8, E905.9, E906.0, E906.1, E906.2, E906.3, E906.4, E906.5, E906.8, E906.9). Injuries acquired during an animal being ridden or between an animal and motor vehicle, motor cycle, or pedal cycle were excluded to focus the analysis on non-transportation-associated animal encounters.

The primary outcomes were mortality, inpatient admission, and cost. Variables included in the analysis were age, sex, region, payer status, income quartile, body region of injury, Injury Severity Score (ISS), length of stay, discharge destination, and cost of ED encounter or hospitalization. Injury characteristics, including ISS, were determined using the validated statistical package 'ICD Programs for Injury Categorization'.[14]

All statistical analyses used the NEDS sampling strata and discharge weights to produce nationally weighted patient-level estimates and 95% CIs that account for clustering of patients among hospitals. The US population as reported by the US Census Bureau was used for national estimates.[15] Pearson's χ^2 was used for comparison of univariate analysis. Multivariate logistic regression was performed compensating for survey methodology. The Hosmer-Lemeshow test was used to ensure multivariate logistic regression model validity when appropriate, and the area under the receiver operating characteristic curve was used to optimize each model. Stata V.12.0 (StataCorp, College Station, TX) was used for all statistical analyses. A p value <0.05 was considered significant. Reported values are weighted unless otherwise specified. The study was classified as exempt after institutional review board review as it contained no identifiable data.

RESULTS

During the 5-year time period, 6 457 534 ED admissions were identified with an animal-related injury (table 1). This corresponded to 1 291 507 (±52 476) persons presenting to EDs with animal-related injuries annually. This amounts to 19 animal-related injuries per 10 000 patient-ED visits and 410 animal-related injuries per 100 000 population. Bites from non-venomous arthropods (n=2 648 880; 41%), dog bites (n=1 658 295; 26%) and envenomation from hornets, wasps or bees (n=812 357; 13%) constitute the majority of encounters. Mean patient age was 30.8 years (95% CI 30.4 31.2 years) and 3 365 667 were female although the age and sex distribution of patients varied considerably based on animal encountered.

More patients presented to EDs located in the South region than other regions (n=2 741 223; 42%). Envenomation due to scorpions (87%), as well as centipedes and millipedes (83%), occurred more commonly in the West region. The primary payer source for most patients was either private insurance (n=2 118 071; 33%) or Medicaid (n=2 070 285; 32%). More patients (n=2 180 709; 34%) were in the lowest 25% household income for their zip code. Bites from venomous snakes and lizards, spiders and other venomous arthropods tended to occur among patients with a lower household income. Most (n=6 290 284, 97%) animal encounters resulted in injuries to multiple body regions.

Of those seen in EDs, 210 516 (3%) patients were admitted. Bites from non-venomous arthropods accounted for almost one-third of these admissions (56 826 admissions, 26%) and represented the greatest proportion of admissions for animal-related injuries. However, when considering the likelihood of admission by mechanism, patients were most often admitted after a bite from a venomous snake or lizard (24% admission rate). Only 1162 deaths were reported (0.02% of all ED presentations) during the 5-year period; 820 (71%) occurred after admission. The greatest number of deaths was reported after bites from non-venomous arthropods (n=278). However, when considering death rates by mechanism, the highest frequency of death was noted after a rat bite (6.5 deaths per 10 000 bites resulting in presentation), followed by bites from venomous snakes or lizards (6.4 deaths per 10 000 bites resulting in presentation) and dog bites (6.1 deaths in 10 000 bites resulting in presentation).

Characteristics associated with inpatient admission after multivariate logistic regression are shown in table 2. Increasing age was associated with greater odds of both hospital admission and death. Among persons aged 85 years or greater, odds of hospital admission for any animal-related injury was 6.42 (95% CI 5.57 to 7.40) and the OR for death was 27.71 (95% CI 10.38 to 73.99). Female sex was associated with improved survival (OR 0.55, 95% CI 0.41 to 0.73) and lower rates of hospital admission (OR 0.77, 95% CI 0.75 to 0.79). Whereas higher household income was associated with increased odds of admission (OR 1.14, 95% CI 1.06 to 1.23 for upper middle-income quartile, and OR 1.25, 95% CI 1.15 to 1.36 for highest income quartile), no income bracket was associated with greater likelihood of mortality.

Injury patterns were also assessed. Isolated abdominal injuries were associated with the greatest rates of hospital admission (OR 9.51, 95% CI 7.61 to 11.89) and death (OR 5.15, 95% CI 1.39 to 18.99). ISS >15 was associated with higher rates of hospital admission (OR 14.63, 95% CI 11.35 to 18.87) and death (OR 39.93, 95% CI 12.36 to 87.74). All animal encounters had lower odds of hospital admission than encounters after encounters with venomous snakes and lizards (referent, p<0.001). Dog bites (OR 0.28, 95% CI 0.11 to 0.70), bites from other animals (OR 0.22, 95% CI 0.08 to 0.61), bites from non-venomous arthropods (OR 0.27, 95% CI 0.11 to 0.70), and other unspecified injuries caused by animals (OR 0.28, 95% CI 0.09 to 0.83) had significantly lower odds of death than after an encounter with a venomous snake or lizard (referent).

The total healthcare cost for these animal encounters during the observed time period was $5.96 billion (95% CI $5.43 to $6.50 billion); this value does not include physician, outpatient, or rehabilitation costs. The majority (approximately 60%) of all costs were a result of three types of animal encounters: (1) dog bites ($1.36 billion, 95% CI $1.31 to $1.40 billion), 23% of all costs; (2) bites from non-venomous arthropods ($1.33 billion, 95% CI $1.29 billion to $1.37 billion), 22% of all costs; and (3) venomous snakes and lizards ($898 million, 95% CI $852 million to $945 million), 15% of all costs.

DISCUSSION

Animal-related injuries are an underappreciated and increasing burden to the US healthcare system. Data from National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) from 2001 to 2010 showed an animal-related injury rate of 340 injuries per 100 000 people, and an estimate of NEDS data from 2006 to 2008 reported an animal-related injury frequency of 358 per 100 000 people.[5 6] Our larger, more modern analysis estimated 410 injuries per 100 000 population; this increased number of injuries may be a consequence of the larger sample size of reporting EDs in NEDS, or could represent a true increase in the burden of animal-related injuries, or both.[5]

Table 1 Epidemiology of patients presenting to emergency department with venomous and non-venomous animal-related injuries, weighted values—USA, 2010–2014

	Venomous snakes and lizards (E-905.0)	Venomous spiders (E-905.1)	Scorpions (E905.2)	Hornets, wasps, bees (E905.3)	Centipede and venomous millipedes (E905.4)	Other venomous arthropods (E905.5)	Venomous marine animals and plants (E905.6)	Other sting or bite, specified (E905.8)	Sting or venomous bite not otherwise specified (E905.9)
n (% total animal encounters)	43 911 (1)	164 667 (3)	34 870 (1)	812 357 (13)	6135 (0)	142 066 (2)	34 871 (1)	3100 (0)	40 037 (1)
Mean age in years (95% CI)	37.2 (36.8 to 37.6)	33.7 (33.5 to 33.9)	31.8 (31.2 to 32.3)	35.2 (35.1 to 35.3)	39.2 (37.8 to 40.6)	29.0 (28.7 to 29.2)	31.2 (30.8 to 31.7)	30.1 (28.4 to 31.8)	30.6 (30.1 to 31.1)
Age category (years)									
0–17	8389 (19)	28 602 (17)	12 375 (35)	219 905 (27)	1101 (18)	53 646 (38)	9625 (28)	1125 (36)	13 709 (34)
18–44	18 713 (43)	91 658 (55)	12 375 (35)	299 459 (37)	2461 (40)	50 415 (35)	16 684 (48)	1191 (38)	15 667 (39)
45–64	12 906 (29)	37 053 (22)	6513 (18)	201 149 (25)	1814 (29)	25 854 (18)	7059 (20)	556 (18)	7834 (19)
65–74	2646 (6)	5915 (4)	2605 (7)	59 504 (7)	466 (8)	8402 (6)	1283 (4)	185 (6)	2219 (5)
75–84	1097 (2)	2210 (1)	1303 (4)	26 518 (3)	285 (5)	3555 (2)	205 (1)	86 (3)	979 (2)
>85	161 (0)	520 (0)	345 (1)	7115 (1)	71 (1)	840 (1)	15 (0)	21 (1)	274 (1)
Male (%)	29 704 (68)	82 656 (50)	15 498 (44)	453 319 (56)	2648 (43)	67 158 (47)	20 664 (59)	1614 (51)	19 373 (48)
Region									
Northeast	649 (1)	7810 (5)	78 (0)	158 461 (19)	267 (4)	10 326 (7)	1471 (4)	983 (31)	4193 (10)
Mid-west	3697 (8)	31 239 (19)	236 (1)	188 860 (23)	137 (2)	13 553 (9)	768 (2)	262 (8)	5896 (14)
South	32 431 (74)	91 115 (55)	4276 (12)	333 092 (41)	651 (11)	98 825 (69)	23 034 (66)	1310 (41)	24 239 (60)
West	7134 (16)	35 795 (22)	30 925 (87)	133 236 (16)	5143 (83)	20 007 (14)	9597 (28)	609 (19)	6355 (16)
Payer data									
Medicare	5181 (12)	17 572 (11)	4539 (13)	115 072 (14)	712 (11)	16 262 (11)	1804 (5)	383 (12)	4434 (11)
Medicaid	7676 (17)	48 812 (29)	9867 (28)	221 739 (27)	1814 (29)	49 435 (35)	4896 (14)	1055 (33)	13 142 (32)
Private insurance	16 631 (38)	41 652 (25)	13 815 (39)	301 256 (37)	2786 (45)	42 931 (30)	19 970 (57)	1055 (33)	12 485 (31)
Self-pay	10 234 (23)	46 859 (28)	5263 (15)	120 890 (15)	648 (10)	24 718 (17)	6184 (18)	541 (17)	7885 (19)
No charge	479 (1)	1952 (1)	190 (1)	3620 (0)	19 (0)	911 (1)	277 (1)	5 (0)	270 (1)
Other	3710 (8)	9112 (5)	1842 (5)	51 072 (6)	221 (4)	8456 (6)	1740 (5)	126 (4)	2366 (6)
Household income compared with patient's ZIP code									
0–25th	17 015 (39)	72 607 (44)	9867 (28)	258 918 (32)	766 (12)	57 085 (40)	6487 (19)	418 (13)	16 404 (40)
26th–50th	11 780 (27)	46 676 (28)	9207 (26)	229 789 (28)	975 (16)	40 867 (29)	8789 (25)	418 (13)	11 155 (27)
51st–75th	9162 (21)	30 469 (18)	8550 (24)	175 417 (22)	2995 (48)	27 893 (20)	9462 (27)	418 (13)	7874 (19)
76th100th	5955 (14)	16 207 (10)	7892 (22)	149 525 (18)	1463 (24)	16 866 (12)	10 137 (29)	1910 (60)	5249 (13)
Injury burden									
Isolated head/neck	17 (0)	47 (0)	9 (0)	647 (0)	–	124 (0)	17 (0)	6 (0)	47 (0)
Isolated face	–	5 (0)	–	10 (0)	–	3 (0)	–	–	–
Isolated chest	–	6 (0)	–	37 (0)	–	21 (0)	–	–	–
Isolated abdomen	–	31 (0)	–	34 (0)	–	9 (0)	–	–	5 (0)

Continued

Table 1 Continued

	Venomous snakes and lizards (E-905.0)	Venomous spiders (E-905.1)	Scorpions (E905.2)	Hornets, wasps, bees (E905.3)	Centipede and venomous millipedes (E905.4)	Other venomous arthropods (E905.5)	Venomous marine animals and plants (E905.6)	Other sting or bite, specified (E905.8)	Sting or venomous bite not otherwise specified (E905.9)
Isolated extremity	256 (1)	520 (0)	21 (0)	1358 (0)	3 (0)	221 (0)	376 (1)	150 (5)	104 (0)
Isolated external	23 (0)	234 (0)	23 (0)	543 (0)	15 (0)	208 (0)	24 (0)	7 (0)	33 (0)
Multiple body regions	43 615 (99)	165 115 (99)	34 871 (100)	811 020 (100)	6181 (100)	142 126 (100)	34 454 (99)	3001 (95)	40 493 (100)
Injury Severity Score >15	15 (0)	65 (0)	4 (0)	194 (0)	–	71 (0)	11 (0)	–	10 (0)
Hospitalized (%)	10 332 (24)	16 790 (10)	458 (1)	9041 (1)	187 (3)	2712 (2)	568 (2)	103 (3)	839 (2)
Fatalities per 10 000 patient visits (%)	28 (6)	71 (4)	4 (1)	200 (2)	–	48 (3)	–	–	13 (3)
Mean ED and inpatient cost, US$ (range)	86 333 (242–1 813 253)	26 975 (474–951 618)	31 322 (905–253 511)	20 598 (117–746 799)	17 595 (4076–122 027)	27 290 (2175–1 099 120)	25 032 (2127–214 107)	25 422 (2312–151 777)	22 883 (485–173 026)
Total ED and inpatient cost, US$ (95% CI)	898 000 000 (852 000 000 to 945 000 000)	450 000 000 (428 000 000 to 47 300 000)	1 430 000 (11 100 000 to 17 400 000)	189 000 000 (170 000 000 to 209 000 000)	3 245 584 (1 824 491 to 4 666 678)	74 100 000 (62 000 000 to 86 300 000)	14 000 000 (11 300 000 to 16 600 000)	2 675 194 (1 098 074 to 4 252 314)	19 600 000 (15 600 000 to 23 700 000)

	Dog bite (E906.0)	Rat bite (E906.1)	Bite of non-venomous snake or lizard (E906.2)	Bite of other animals except arthropods (E906.3)	Bite of non-venomous arthropods (E906.4)	Bite by unspecified animal (E906.5)	Other specified injury caused by animal (E906.8)	Unspecified injury caused by animal (E906.9)
n (% total animal encounters)	1 658 295 (26)	14 852 (0)	15 498 (0)	422 968 (7)	2 648 880 (41)	47 140 (1)	345 478 (5)	21 310 (0)
Age (95% CI)	30.7 (30.7 to 30.8)	30.7 (30.0 to 31.5)	32.2 (31.7 to 33.0)	44.3 (44.2 to 44.5)	25.8 (25.8 to 25.9)	36.0 (35.5 to 36.4)	38.8 (38.7 to 39.0)	39.3 (38.6 to 40.1)
Age category (years)								
0–17	580 790 (35)	4900 (33)	4446 (29)	55 224 (13)	1 141 046 (43)	12 338 (26)	77 490 (22)	4977 (23)
18–44	596 312 (36)	5727 (39)	6538 (42)	149 429 (35)	916 324 (35)	17 533 (37)	1 23 339 (36)	7018 (33)
45–64	347 957 (21)	2863 (19)	3465 (22)	134 486 (32)	421 677 (16)	12 338 (26)	89 114 (26)	5551 (26)
65–74	80 845 (5)	827 (6)	719 (5)	46 128 (11)	105 258 (4)	3247 (7)	26 476 (8)	1850 (9)
75–84	40 746 (2)	414 (3)	281 (2)	27 937 (7)	51 015 (2)	1688 (4)	18 727 (5)	1212 (6)
>85	14 229 (1)	121 (1)	48 (0)	12 994 (3)	13 561 (1)	643 (1)	10 332 (3)	702 (3)
Male (%)	854 978 (51)	7103 (48)	9686 (62)	142 712 (33)	1 207 559 (46)	22 601 (47)	145 295 (42)	9041 (42)
Region								
Northeast	324 152 (20)	3569 (24)	1433 (9)	101 352 (24)	568 263 (21)	10 474 (22)	62 024 (18)	4957 (23)
Mid-west	350 680 (21)	1976 (13)	2019 (13)	99 402 (23)	511 437 (19)	10 474 (22)	92 391 (27)	5601 (26)
South	611 426 (37)	5800 (39)	10 419 (67)	140 333 (33)	1 223 703 (46)	20 292 (42)	118 235 (34)	7082 (33)
West	374 620 (23)	3506 (24)	1628 (11)	85 110 (20)	345 478 (13)	6546 (14)	72 828 (21)	3670 (17)
Payer data								
Medicare	170 164 (10)	1838 (12)	1746 (11)	100 733 (24)	249 139 (9)	7140 (15)	64 660 (19)	4349 (21)
Medicaid	440 615 (27)	5196 (35)	3749 (24)	71 488 (17)	1 111 445 (42)	11 035 (23)	66 600 (19)	4541 (21)
Private insurance	628 895 (38)	3865 (26)	5366 (35)	169 621 (40)	690 619 (26)	18 824 (39)	142 252 (41)	8314 (39)
Self-pay	290 508 (17)	2725 (18)	3233 (21)	49 391 (12)	471 170 (18)	7140 (15)	43 969 (13)	2366 (11)
No charge	9059 (1)	88 (1)	110 (1)	2470 (1)	16 136 (1)	272 (1)	1487 (0)	89 (0)

Continued

Table 1 Continued

	Dog bite (E906.0)	Rat bite (E906.1)	Bite of non-venomous snake or lizard (E906.2)	Bite of other animals except arthropods (E906.3)	Bite of non-venomous arthropods (E906.4)	Bite by unspecified animal (E906.5)	Other specified injury caused by animal (E906.8)	Unspecified injury caused by animal (E906.9)
Other	121 638 (7)	1140 (8)	1294 (8)	32 495 (8)	110 370 (4)	3375 (7)	26 511 (8)	1471 (7)
Household income compared with patient's ZIP code								
0–25th	484 584 (29)	5475 (37)	5535 (36)	101 352 (24)	1 031 914 (39)	14 402 (30)	93 809 (27)	6618 (31)
26th–50th	448 450 (27)	4520 (27)	4558 (29)	118 893 (28)	738 742 (28)	13 092 (27)	104 808 (30)	6618 (31)
51st–75th	392 958 (24)	3084 (21)	3256 (21)	109 148 (26)	523 060 (20)	10 474 (22)	82 165 (24)	4632 (22)
76th–100th	334 885 (20)	2131 (16)	2149 (14)	96 803 (23)	355 164 (13)	9819 (21)	64 696 (19)	3441 (16)
Injury burden								
Isolated head/neck	5173 (0)	14 (0)	–	436 (0)	2131 (0)	98 (0)	14 881 (4)	834 (4)
Isolated face	970 (0)	5 (0)	4 (0)	32 (0)	65 (0)	4 (0)	2135 (1)	60 (0)
Isolated chest	342 (0)	–	–	37 (0)	129 (0)	9 (0)	4012 (1)	129 (1)
Isolated abdomen	401 (0)	–	–	36 (0)	220 (0)	11 (0)	2588 (1)	52 (0)
Isolated extremity	38 800 (2)	135 (0)	197 (1)	12 358 (3)	4586 (0)	843 (2)	34 938 (10)	2053 (10)
Isolated external	3686 (0)	4 (0)	9 (0)	911 (0)	27 773 (1)	84 (0)	305 (0)	35 (0)
Multiple body regions	1 611 505 (97)	14 695 (99)	15 288 (99)	412 386 (97)	2 613 975 (99)	46 737 (98)	286 620 (83)	17 969 (85)
Injury Severity Score >15	594 (0)	–	–	32 (0)	355 (0)	14 (0)	2196 (2)	77 (0)
Hospitalized (%)	48 432 (3)	381 (3)	304 (2)	41 328 (10)	56 826 (2)	1292 (3)	20 664 (6)	646 (3)
Fatalities (per 10 000 patient visits)	232 (1)	10 (7)	–	71 (2)	278 (1)	11 (2)	194 (6)	4 (2)
Median ED and inpatient cost, US$ (range)	28 590 (485–1 407 076)	26 995 (2131–290 436)	28 277 (2359–206 157)	20 057 (440–802 948)	23 699 (115–971 716)	27 053 (2875–545 662)	36 460 (183–893 370)	29 121 (2430–392 672)
Total ED and inpatient cost, US$ (95% CI)	1 360 000 000 (1 310 000 000 to 1 400 000 000)	10 100 000 (6 853 928 to 13 400 000)	8 570 608 (5 968 741 to 11 200 000)	806 000 000 (784 000 000 to 827 000 000)	1 330 000 000 (1 290 000 000 to 1 370 000 000)	34 900 000 (27 100 000 to 42 700 000)	732 000 000 (701 000 000 to 763 000 000)	18 800 000 (14 300 000 to 23 300 000)

ED, emergency department.

Table 2 Multivariate analysis of variables predictive of hospital admission and death after an animal encounter resulting in an emergency department visit—USA, 2010–2014

	Hospital admission*			Death†		
	OR	P values	95% CI	OR	P values	95% CI
Age group (years)						
0–17	Referent	–	–	Referent	–	–
18–44	1.91	<0.001	1.70 to 2.14	1.31	0.4	0.67 to 2.56
45–64	3.63	<0.001	3.22 to 4.10	5.60	<0.001	2.91 to 10.77
65–74	3.48	<0.001	3.04 to 3.97	7.03	<0.001	2.77 to 17.86
75–84	4.54	<0.001	3.95 to 5.21	11.98	<0.001	4.84 to 29.64
>85	6.42	<0.001	5.57 to 7.40	27.71	<0.001	10.38 to 73.99
Sex						
Female	0.77	<0.001	0.75 to 0.79	0.55	<0.001	0.41 to 0.73
Hospital region						
Northeast	Referent	–	–	–	–	–
Mid-west	0.89	0.1	0.77 to 1.04	–	–	–
South	1.08	0.2	0.94 to 1.25	–	–	–
West	1.07	0.5	0.90 to 1.26	–	–	–
Payer status						
Medicare	Referent	–	–	Referent	–	–
Medicaid	0.75	<0.001	0.71 to 0.79	0.73	0.4	0.33 to 1.60
Private insurance	0.67	<0.001	0.64 to 0.70	0.56	0.06	0.30 to 1.01
Self-pay	0.55	<0.001	0.52 to 0.58	0.79	0.5	0.40 to 1.56
No charge	1.69	<0.001	1.38 to 2.07	NA	NA	NA
Other	0.69	<0.001	0.63 to 0.75	0.75	0.5	0.36 to 1.59
Household income						
0–25th	Referent	–	–	Referent	–	–
26th–50th	1.01	0.6	0.96 to 1.07	1.27	0.2	0.90 to 1.78
51st–75th	1.14	<0.001	1.06 to 1.23	1.11	0.6	0.74 to 1.66
76th–100th	1.25	<0.001	1.15 to 1.36	1.05	0.8	0.68 to 1.62
Injury location						
Isolated head/neck	Referent	–	–	Referent	–	–
Isolated face	3.36	<0.001	2.57 to 4.37	1.30	0.8	0.18 to 9.16
Isolated chest	3.19	<0.001	2.55 to 3.99	0.78	0.7	0.20 to 3.03
Isolated abdomen	9.51	<0.001	7.61 to 11.89	5.15	0.01	1.39 to 18.99
Isolated extremity	2.19	<0.001	1.87 to 2.56	0.72	0.5	0.25 to 2.06
Isolated external	1.77	<0.001	1.48 to 2.12	0.10	0.04	0.01 to 0.85
Multiple body regions	0.44	<0.001	0.38 to 0.52	0.17	0.001	0.06 to 0.47
Injury Severity Score >15	14.63	<0.001	11.35 to 18.87	39.93	<0.001	12.36 to 87.74
Type of encounter						
Venomous snakes and lizards	Referent	–	–	Referent	–	–
Venomous spiders	0.40	<0.001	0.35 to 0.45	0.98	1.0	0.36 to 2.70
Scorpions	0.04	<0.001	0.03 to 0.06	NA	NA	NA
Hornets, wasps, bees	0.04	<0.001	0.03 to 0.04	0.44	0.09	0.17 to 1.13
Centipede and venomous millipedes	0.06	<0.001	0.04 to 0.10	NA	NA	NA
Other venomous arthropods	0.07	<0.001	0.06 to 0.08	0.81	0.7	0.28 to 2.38
Venomous marine animals and plants	0.05	<0.001	0.04 to 0.07	NA	NA	NA
Other sting or bite, specified	0.12	<0.001	0.06 to 0.23	NA	NA	NA
Sting or venomous bite not otherwise specified	0.08	<0.001	0.06 to 0.09	0.78	0.7	0.18 to 3.29
Dog bite	0.09	<0.001	0.08 to 0.11	0.28	0.006	0.11 to 0.70
Rat bite	0.09	<0.001	0.07 to 0.11	1.38	0.7	0.27 to 7.14
Bite of non-venomous snake or lizard	0.06	<0.001	0.05	NA	NA	NA
Bite of other animals except arthropods	0.26	<0.001	0.23 to 0.30	0.22	0.004	0.08 to 0.61
Bite of non-venomous arthropods	0.08	<0.001	0.07 to 0.09	0.27	0.007	0.11 to 0.70

Continued

Table 2 Continued

	Hospital admission*			Death†		
	OR	P values	95% CI	OR	P values	95% CI
Bite by unspecified animal	0.08	<0.001	0.06 to 0.10	0.40	0.3	0.08 to 2.11
Other specified injury caused by animal	0.11	<0.001	0.10 to 0.12	0.28	0.02	0.09 to 0.83
Unspecified injury caused by animal	0.06	<0.001	0.04 to 0.07	0.14	0.08	0.01 to 1.23

NA, not applicable.
*Area under the receiver operating characteristic curve=0.772.
†Area under the receiver operating characteristic curve=0.858.

Despite this increase in the number of animal-related injuries, inpatient admission rates after animal-related encounters have remained relatively stable during the last two decades. Data from NEISS-AIP identified 1.8% of patients were admitted as inpatients whereas NEDS data from 2006 to 2008 reported an inpatient admission rate of 4.4%.[5 6] The 3% hospital admission rate observed in our 2010 to 2014 NEDS sample is consistent with both of these prior reports.[6] The relatively stable inpatient admission rate over time indicates that increases in ED presentations from animal encounters may not be due to increased severity of animal encounters, but due to greater frequency of encounters overall. Unfortunately, ISS was not reported from either prior study, so direct comparisons of illness severity between the studies are limited.[5 6]

Despite the stable admission rate for non-lethal injuries, mortality rates were higher when controlling for population in our study than in prior studies. Previous estimates of mortality associated with animal-related encounters have ranged from 157 to 201 deaths annually corresponding to 0.655 0.688 deaths per million persons per year (table 3),[8–11] compared with the 232 annual deaths (0.738 deaths per million persons per year) identified through NEDS. The slightly greater fatality rate identified in our analysis may be a result of increased capture associated with the NEDS data set, a true increase in the mortality rate attributable to animal-related injuries, or inaccurate attribution of deaths to animal-related injuries. All prior assessments of animal-related fatalities have relied on county-level death certificate data rather than survey-based healthcare data, and in these data series some deaths are suppressed.[8–11] Taking into account differences in the data used to generate existing mortality estimates, we suspect that the observed increase in mortality represents an artifact of increased capture with NEDS and variation in methodology from prior death certificate-based evaluations, particularly given the stable hospital admission rate seen over time.

There are few available estimates of the cost of animal-related injuries in the USA, but existing estimates convey a considerable economic burden. The Centers for Disease Control and Prevention Web-Based Injury Statistics Query and Reporting System (WISQARS) database estimated for 2010 that a total lifetime cost of $2.3 billion was spent on hospitalization for combined medical and work loss cost attributable to bites and stings, with an additional $7.7 billion spent on treatment of persons presenting with bites and stings treated in the ED and released.[16] This sample represents approximately 94% of all animal-related injuries identified through NEDS. Importantly, the WISQARS estimate does not include persons injured through non-bite or mechanisms such as blunt force injury, nor deaths attributable to animal-related injuries.[16] A study evaluating work-related injuries from animal-related injuries between 2011 and 2014 identified economic losses of $222 million from work-related animal-related fatalities and $2.8 billion from work-related animal-related injuries during that time period.[17] That study identified 71 682 injuries (222 fatalities and 71 460 non-fatal injuries), only 1.4% of the injuries identified through our NEDS study during the same time period.[17] Our reported total annual cost of $1.2 billion estimate similarly does not include physician charges, outpatient costs, cost of work lost, or injury rehabilitation and therefore likely underestimates the healthcare cost associated with animal-related injuries. Extrapolating from these prior studies, the estimated cost of animal-related injury should be more than $13 billion annually.

Table 3 Annual fatality estimates from animal-related encounters—USA

Study	Time period	Annual deaths	Deaths per million person-years
Langley and Morrow [8]	1979–1990	157	0.657
Langley [9]	1991–2001	177	0.655
Forrester *et al* [10]	1999–2007	200	0.688
Forrester *et al* [11]	2008–2015	201	0.641
Forrester, Forrester, Tennakoon, Staudenmayer	2010–2014	232	0.738

Injuries due to mountain lions, bears, alligators, and venomous snakes among other wild animals attract considerable media attention and are associated with dramatic morbidity and mortality.[18–22] As available habitat for these animals increasingly overlaps with human development and recreational activities, it is expected encounters with these animals may increase and could result in increased animal-related injuries.[21 22] However, injuries associated with venomous and non-venomous arthropods are considerably more frequent accounting for two-thirds of animal-related injuries in some series.[5 6] Concerningly, these arthropod encounters are likely to increase based on habitat availability and climate change,[23–27] and consequently may be more likely to result in a greater economic and healthcare burden than other more dramatic, but less common, animal encounters in the future. Given that venomous and non-venomous arthropod injuries occurred more frequently among persons in the lower income quartile, increases in arthropod-related injury may disproportionately affect persons more influenced by cost of healthcare and lost wages.

There are several limitations to this study. First, only animal encounters in the USA were evaluated, limiting extrapolation to other countries. Second, there may be misclassification bias associated with using ICD-9 codes; the validity of the codes depends on the quality of coders at each participating institution. Third, NEDS reports event-level data but does not have unique identifiers for specific individuals. A person injured by an animal several times during the course of a year would be counted as multiple people, rather than multiple encounters. This could lead to overestimation of the number of animal-related injuries. Fifth, with the exception of dog-related injuries, categorization

of injury at the species level was not possible given dependence on ICD-9 coding. Sixth, ED encounters due to arthropodborne diseases such as Lyme disease or West Nile virus were not explicitly captured in this analysis, which may lead to underestimation of the disability and mortality associated with arthropods. Finally, although NEDS is the most comprehensive survey of EDs in the USA, there may be sampling error leading to overestimation or underestimation of animal-related injury.

CONCLUSIONS

Animal-related injuries can be caused by a variety of mechanisms and the healthcare and economic costs of these injuries are substantial. Whereas hospital admission and mortality rates after injury have remained relatively stable during the last 20 years, the frequency of persons with animal-related injuries presenting to the ED has increased. The healthcare cost of persons presenting to the ED with animal-related injuries is considerable, approximately $1.2 billion a year not accounting for physician fees or subsequent healthcare costs. Understanding the burden of animal-related injuries in the USA and developing effective public health prevention measures is critical now given animal-related injuries are projected to increase.

Contributors JDF and KS: writing, data analysis, data interpretation; JAF: writing, data interpretation; LT: data collection, data analysis.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent Not required.

Provenance and peer review Commissioned; internally peer reviewed.

Data sharing statement No additional unpublished data are available.

REFERENCES

1. Hendricks KJ, Adekoya N. Non-fatal animal related injuries to youth occurring on farms in the United States, 1998. *Inj Prev* 2001;7:307–11.
2. American Veternary Medical Association. Dog Bite Prevention. 2018. https://www.avma.org/public/Pages/Dog-Bite-Prevention.aspx (6 Jul 2018).
3. Centers for Disease Control and Prevention. Preventing Dog Bites. 2018. https://www.cdc.gov/features/dog-bite-prevention/ (July 6 2018).
4. National Farmers Union. Livestock Handling. 2018. https://nfu.org/farmsafety/#chapter6 (July 6 2018).
5. Langley R, Mack K, Haileyesus T, Proescholdbell S, Annest JL. National estimates of noncanine bite and sting injuries treated in US Hospital emergency departments, 2001-2010. *Wilderness Environ Med* 2014;25:14–23.
6. Langley RL. Animal-Related injuries resulting in emergency department visits and hospitalizations in the United States, 2006-2008. *Human-Wildlife Interactions* 2012;6:123–36.
7. Ennik F. Deaths from bites and stings of venomous animals. *West J Med* 1980;133:463–8.
8. Langley RL, Morrow WE. Deaths resulting from animal attacks in the United States. *Wilderness Environ Med* 1997;8:8–16.
9. Langley RL. Animal-related fatalities in the United States-an update. *Wilderness Environ Med* 2005;16:67–74.
10. Forrester JA, Holstege CP, Forrester JD. Fatalities from venomous and nonvenomous animals in the United States (1999-2007). *Wilderness Environ Med* 2012;23:146–52.
11. Forrester JA, Weiser TG, Forrester JD. An update on fatalities due to venomous and nonvenomous animals in the United States (2008-2015). *Wilderness Environ Med* 2018;29:36–44.
12. Adams A, Sutton JP, Elixhauser A. *Emergency department visits and hospitalizations associated with animal injuries, 2009: statistical brief #134. Healthcare Cost and Utilization Project (HCUP) statistical briefs*. Rockville MD: Agency for Healthcare Research and Quality US, 2006.
13. HCUP Nationwide Emergency Department Sample (NEDS). *Healthcare Cost and Utilization Project HCUP*. Rockville MD: 2010-2014 Agency for Healthcare Research and Quality.
14. David Clark E. ICDPIC Version 3.0; ICD-9-CM Trauma within STATA version 11.2.
15. United States Census Bureau. National Population Totals and Components of Change: 2010-2017. 2018. https://www.census.gov/data/tables/2017/demo/popest/nation-total.html (10 Jul 2018).
16. Centers for Disease Control and Prevention. Data & Statistics (WISQARS™): Cost of Injury Reports. 2018. https://www.cdc.gov/injury/wisqars/cost/index.html (10 Jul 2018).
17. Barros N, Langley R. Fatal and non-fatal animal-related injuries and illnesses to workers, United States, 2011-2014. *Am J Ind Med* 2017;60:776–88.
18. California Department of Fish and Wildlife. Verified Mountain Lion Attacks on Humans in California (1986 through 2014). 2018. https://www.wildlife.ca.gov/Conservation/Mammals/Mountain-Lion/Attacks (10 Jul 2018).
19. US National Park Service. Bear-Inflicted Human Injuries & Fatalities in Yellowstone. 2018. https://www.nps.gov/yell/learn/nature/injuries.htm (10 Jul 2018).
20. Langley RL. Alligator attacks on humans in the United States. *Wilderness Environ Med* 2005;16:119–24.
21. Langley RL. Adverse encounters with alligators in the United States: an update. *Wilderness Environ Med* 2010;21:156–63.
22. Chippaux JP. Incidence and mortality due to snakebite in the Americas. *PLoS Negl Trop Dis* 2017;11:e0005662.
23. Rochlin I, Faraji A, Ninivaggi DV, Barker CM, Kilpatrick AM. Anthropogenic impacts on mosquito populations in North America over the past century. *Nat Commun* 2016;7:13604.
24. Schwartz AM, Hinckley AF, Mead PS, Hook SA, Kugeler KJ. Surveillance for lyme disease - United States, 2008-2015. *MMWR Surveill Summ* 2017;66:1–12.
25. Rosenberg R, Lindsey NP, Fischer M, Gregory CJ, Hinckley AF, Mead PS, Paz-Bailey G, Waterman SH, Drexler NA, Kersh GJ, *et al*. Vital Signs: trends in reported vectorborne disease cases - United States and territories, 2004-2016. *MMWR Morb Mortal Wkly Rep* 2018;67:496–501.
26. Kugeler KJ, Farley GM, Forrester JD, Mead PS. Geographic distribution and expansion of human lyme disease, United States. *Emerg Infect Dis* 2015;21:1455–7.
27. Campbell-Lendrum D, Manga L, Bagayoko M, Sommerfeld J. Climate change and vector-borne diseases: what are the implications for public health research and policy? *Philos Trans R Soc Lond B Biol Sci* 2015;370:20130552.