Risk factors for death and illness in dogs imported into the United States, 2010–2018

Emily G Pieracci[1], **Brian Maskery**[1], **Kendra Stauffer**[1,2], **Alida Gertz**[1], **Clive Brown**[1]

[1]Division of Global Migration and Quarantine, Centers for Disease Control and Prevention, Atlanta, Georgia

[2]US Department of Agriculture, Animal Plant and Health Inspection Service, Veterinary Services, Gainesville, FL

Abstract

CDC estimates 1 million dogs are imported into the United States annually. With the movement of large numbers of animals into the United States the risk of disease importation, especially emerging diseases, and animal welfare issues are of concern. Dogs that arrive to the United States ill or dead are investigated by public health authorities to ensure dogs are not infected with diseases of concern (such as rabies). We identified factors associated with illness and death in imported dogs and estimated the initial investigation cost to public health authorities. Dog importation data from the CDC's Quarantine Activity Reporting System were reviewed from 2010 to 2018. The date of entry, country of origin, port of entry, transportation method and breed were extracted to examine factors associated with illness and death in dogs during international travel. Costs for public health investigations were estimated from data collected by the Bureau of Labor Statistics and Office of Personal Management. Death or illness was more likely to occur in brachycephalic breeds (aOR = 3.88, 95%CI 2.74–5.51). Transportation of dogs via cargo (aOR = 2.41, 95%CI 1.57–3.70) or as checked baggage (aOR = 5.74, 95%CI 3.65–9.03) were also associated with death or illness. On average, 19 dog illnesses or deaths were reported annually from 2010 to 2018. The estimated annual cost to public health authorities to conduct initial public health assessments ranged from $2,071 to $104,648. Current regulations do not provide adequate resources or mechanisms to monitor the rates of morbidity and mortality of imported dogs. There are growing attempts to assess animal welfare and communicable disease importation risks. However, because the responsibility for dogs' health and wellbeing is overseen by multiple

Correspondence: Emily Pieracci, Division of Global Migration and Quarantine, Centers for Disease Control and Prevention, Atlanta, GA. ydi7@cdc.gov.

agencies it is challenging to coordinate implementation and enforcement measures. A joint federal agency approach to identify interventions that reduce dog morbidity and mortality during flights while continuing to protect US borders from public health and foreign animal disease threats could be beneficial.

Keywords

animal risk with air travel; animal travel; dog death; dog importation

1 INTRODUCTION

The Centers for Disease Control and Prevention (CDC) estimates 1 million dogs are imported into the United States every year; 700,000 via air and 300,000 via land-borders (CDC, 2019; McQuiston et al., 2008). With the movement of many animals into the United States the risk of disease importation and animal welfare issues are of concern, especially for new and emerging pathogens, such as rabies, brucellosis or leishmaniasis. The importation of dogs into the United States is governed by multiple federal agencies, including the US Department of Agriculture (USDA) and CDC, based on their mandated mission. Regulations, statutes, and laws cover varying aspects of dog importation, from safety of the animal while flying, to the prevention of importing zoonotic diseases such as rabies.

The CDC regulates the entry of dogs into the United States under Title 42 of the Code of Federal Regulation (CFR) § 71.51. The principal reason for regulating dog importations is to prevent the reintroduction and spread of the canine rabies virus variant (CRVV) into the United States. This is achieved through mandatory vaccination requirements for dogs prior to entry, and through public health investigations of dog deaths and illnesses during international travel into the United States.

Rabies is a deadly disease most commonly transmitted to humans from the bite of a rabid dog. Globally, CRVV accounts for 99% of human rabies deaths which disproportionately affect children under 15 years of age (Hampson et al., 2015). Although the United States was declared CRVV-free in 2007 (Velasco-Villa et al., 2017), CRVV is enzootic in more than 100 countries worldwide and continues to be a serious public health concern (Hampson et al., 2015). Roughly 100,000 dogs from CRVV-enzootic countries arrive in the United States each year (CDC, 2019). Since 2015, there have been four separate importations of rabid dogs which resulted in public health costs of $200,000–$500,000 per event (CDC, 2019; Raybern et al., 2020). Preventing the entry of dogs infected with CRVV into the United States is a public health priority for the CDC, and on July 14, 2021, CDC issued a temporary suspension for dogs entering the United States from countries with a high risk of CRVV (including dogs that have travelled to a high-risk country within the past 6 months) (CDC, 2021).

CDC requires dogs entering the United States to be healthy upon arrival. Dogs that arrive dead or ill are recorded in the Quarantine Activity Reporting System (QARS), an electronic record-keeping system maintained by CDC. CDC also tracks incidents of invalid rabies

vaccination certificates, animal death, and animal illness on international conveyances arriving in the United States. These incidents are referred to as 'deviations' because they do not meet CDC dog importation requirements.

CDC also requires transportation companies (i.e. air carriers, maritime vessels etc.) to report dog deaths and illnesses during inbound international travel to the United States. US Customs and Border Protection Officers and CDC Quarantine Public Health Officers inspect dogs upon arrival at US ports of entry when resources are available. Dogs exhibiting signs of illness (e.g. coughing, vomiting, diarrhoea, rash, neurologic signs) are referred to local veterinarians for a health assessment to ensure the dogs do not pose a public health threat. For dogs that die during transportation, CDC veterinary medical officers evaluate the medical history of the dog, including rabies vaccination history, country of origin, and whether the animal has bitten or scratched anyone in the 10 days preceding its death in order to determine whether a necropsy or post-mortem rabies testing are indicated (NASPHV, 2016). Necropsy and rabies testing are indicated when there is reasonable suspicion that the animal may have been infected with a communicable disease prior to death. The evaluation and treatment of ill dogs, as well as testing of dogs post-mortem, can be time consuming and costly for the importer, carrier, and federal, state and local public health agencies who work to prevent the importation of diseases into the United States. CDC does not collect data on dogs arriving in the United States if the dogs are healthy and, as applicable, have proof of current rabies vaccination or have not been in a high-risk country in the previous 6 months. Additionally, CDC does not collect data on domestic animal travel within the United States.

USDA is another federal agency which overseas animal importation. USDA oversees the health and fitness of animals prior to and during travel to mitigate the risk of illness, death or disease introduction. The USDA, Animal Plant and Health Inspection Services (APHIS), Animal Care (AC) works to ensure the humane treatment of animals covered by the Animal Welfare Act (AWA). The AWA set standards of humane care and treatment for the transportation, sale and handling of live dogs being imported for purposes of resale or adoption (USDA, 2020a).

The USDA, APHIS, Veterinary Services (VS) works to protect the United States from diseases that could threaten domestic livestock and food production animals. As a result, they have requirements for dogs to enter the United States that can include treatments for screwworm, tapeworm and foot and mouth disease depending on the dog's country of origin (USDA, 2020b).

We evaluated risk factors that may impact the likelihood of illness or death in dogs during international travel through retrospective data analysis. We also estimated the cost of veterinary evaluation and care of ill or dead dogs, and proposed actions that can be adopted by key stakeholders to ensure imported animals do not present a public health or foreign animal disease risk.

2 METHODS

CDC dog importation deviations reported in QARS for 1 January 2005 to 31 December 2018 were included in this evaluation. The data included all recorded international importations of dogs who were sick, dead, denied entry or were deemed healthy and issued confinement agreements. Prior to 2018, CDC issued confinement agreements for healthy dogs who did not have adequate rabies vaccination certificates. This process changed at the end of 2018, and this practice is no longer used; therefore, data from 2019 and later were excluded from this analysis. The date of entry, country of origin (high risk for CRVV vs. low risk or no-known risk for CRVV; CDC, 2020), port of entry, transportation method (hand-carried, cargo, checked baggage and land border crossing), and breed data, including brachycephalia, were extracted. Brachycephalic dog breeds are those with shortened snouts and facial skeletons, and examples include Pugs or French Bulldogs. There were limited data for dogs traveling via sea vessel; therefore, this evaluation focused on air and land transportation.

The protocol was reviewed and approved by the CDC's National Center for Emerging and Zoonotic Infectious Diseases and determined not to need review by the CDC's Institutional Animal Care and Use Committee; the evaluation was conducted consistent with applicable federal law and CDC policy.[1]

We categorized brachycephalic breeds as those recognized by the Humane Society Veterinary Medical Association and the American Kennel Club and included Affenpinscher, Boston Terrier, Brussels Griffon, Bulldog (American, English, French), Boxer, Cavalier King Charles Spaniel, Japanese Chin, Lhasa Apso, Mastiff (Brasileiro, Dogue de Bordeaux), Pekingese, Pug and Shih Tzu (Humane Society Veterinary Medical Association, 2017).

This evaluation analyzed demographic information including dog breed, size/weight based on standard breed sizes (American Kennel Club, 2017), health status, country of origin, transportation method (cargo, checked baggage, hand-carried and land border crossing) and month and year of travel.

Dogs that were denied entry due to invalid rabies vaccination certificates but were not noted in QARS to be sick or dead upon arrival were classified as healthy for the purposes of the health status analysis.

Detailed data about the types of investigations or diagnostic testing performed on dogs that became ill or died during travel were not available. In the absence of such data, we attempted to develop a plausible range of the potential costs based on publicly available data sources and personal communication between the authors and CDC's rabies laboratory (Emergency Vets USA, 2021; Cornell University Animal Health Diagnostics Center, 2021; Washington State University Veterinary Diagnostic Pathology lab, 2021; UC Davis Veterinary Hospital, 2021; Wisconsin Health Department, 2021; Kansas State University, 2021; Fedex, 2021; Pieracci personal communication with CDC Poxvirus and Rabies Branch laboratory) The cost estimates included a relatively large range, which was due to the heterogeneity of illnesses and deaths of dogs during the analysis period and in public health responses across different state and local jurisdictions. We utilized

Office of Personal Management General Schedule Hourly Salaries and Wages (Office of Personal Management, 2021). The consultations with state or local public health or animal officials were assumed to include an equal distribution of three occupation types: veterinarians, epidemiologists and registered nurses. The wage rates for each occupation were estimated using the average hourly wage for occupation codes: 19–1041, 29–1131, 53–1011 and 29–1141 available in the Bureau of Labor Statistics' Occupational Employment and Wage Statistics from May 2020 (Bureau of Labor Statistics, 2020). The hourly wage estimates were multiplied by two to account for non-wage benefits and overhead. Estimates for the treatment of ill dogs and the post-mortem evaluation of dead dogs was based on an average cost from multiple private companies, universities, and public health laboratories (Emergency Vets USA, 2021; Cornell University Animal Health Diagnostics Center, 2021; Washington State University Veterinary Diagnostic Pathology lab, 2021; UC Davis Veterinary Hospital, 2021; Wisconsin Health Department, 2021; Kansas State University, 2021; Fedex, 2021; Pieracci personal communication with CDC Poxvirus and Rabies Branch laboratory).

All data were exported from QARS and entered into a database for cleaning and analysis using STATA, Version 16 (STATACorp, College Station, TX).

Descriptive statistics were calculated. Univariate and multivariable logistic regression models were used to evaluate factors associated with health status outcomes (healthy vs. dead or ill). Univariate odds ratios were calculated for health status of the canine upon entry as the outcome measure (healthy vs. combined dead or ill). Exposures of interest thought likely to be associated with the outcome were included a priori in the multivariable analysis, including breed characterization (brachycephalic, non-brachycephalic), size of breed in pounds (25, 26–60, 61–100, 101), transportation method [hand-carried, cargo, checked baggage, land border crossing (car)] and risk status of country of origin (rabies high risk, rabies low risk). Month and year of entry had little impact on adjusted odds ratios for exposures of interest and were excluded from the final model. As missingness of data was likely not completely at random, dogs with missing values for breed and/or transportation methods were excluded from these analyses. Additionally, there were few observations between 2005 and 2010 ($n = 158$), and data recorded during this time are unlikely to be representative; therefore, data prior to 2010 were also excluded. p Values were two-sided with a significance threshold set at <.05.

3 | RESULTS

From 1 January 2010 to 31 December 2018, there were 13,891 reports for dog deviations filed in QARS. Of these, 176 (1.3%) contained reports of dog death or illness (92 deaths and 84 illnesses). There were approximately 9 illnesses and 10 deaths documented per year during 2010–2018 (Table 1).

Of the 92 dogs that died during transport, 37 (40%) had necropsies performed and 13 (14%) were tested for rabies. The most common causes of death were brachycephalic syndrome ($n = 17$) contributing to respiratory and vascular compromise, ill thrift (dehydration, hypoglycaemia, lethargy, diarrhoea, malnutrition) ($n = 5$) and infectious diseases (rabies,

distemper, parvovirus) ($n = 3$). Among the 84 ill dogs, medical notes were recorded in QARS for 58 (69%) dogs. Diagnoses included infectious diseases [H3N2 influenza (1), distemper (2), parvovirus (2), gastrointestinal parasites (5), mange (2), mycoplasma (1) and leishmaniasis (2)] in 15 dogs and ill thrift (dehydration, hypoglycaemia, lethargy, diarrhea, malnutrition) in 31 dogs. Twelve dogs arrived unresponsive or in critical condition; two with unknown underlying aetiologies were euthanized, and 10 recovered after hospitalization for heat stroke (3), vomiting (3), unresponsive (no underlying cause noted) (2), haemorrhagic gastroenteritis (1) and pneumonia (1).

Descriptive statistics for health status, breed, size, transportation method and country of origin based on rabies risk are shown in Table 1 for 1 January 2010 to 31 December 2018. Seventy-four per cent of dogs transported were non-brachycephalic and 39% of all dogs imported were breeds that are usually under 26 pounds. Many dogs were hand-carried (42%) and most dogs (86%) arrived from countries CDC does not consider to be high risk for CRVV.

There was an association between death or illness during travel and brachycephalic breeds compared to non-brachycephalic breed dogs after adjusting for other covariates (aOR = 3.88, 95%CI 2.74–5.51) (Table 2). Compared to hand carried via air travel, transportation via air cargo (aOR = 2.41, 95%CI 1.57–3.70) or via air as checked baggage (aOR = 5.74, 95% CI 3.65–9.03), but not via land border crossing (aOR = 0.27, 95%CI 0.04–1.95) were also associated with death or illness. Finally, traveling from high-risk countries for CRVV was also associated with death or illness compared to low-risk or CRVV-free countries (aOR = 1.54, 95% CI 1.09–2.18) (Table 2).

The costs for state, local and federal government response activities for ill or dead imported dogs were estimated to fall within a plausible range of $109–$5508 per illness or death corresponding to an annual cost range of $2071–$104,648 assuming an average of 19 events per year (Table 3). The average cost for importers and carriers to obtain medical care and diagnostic testing of ill dogs was estimated at $2979–$9712 and the cost per dead dog was estimated to be between $602 and $2600. With an estimate of 9 ill dogs and 10 dead dogs arriving each year, the annual plausible costs to importers and airlines were estimated at $32,831–$113,408 per year. The total plausible costs per year for all stakeholders was estimated at $34,902–$218,056. These costs do not include inspection and evaluation of dogs with inadequate rabies vaccination certificates and the subsequent costs of returning dogs denied entry to the country of departure.

4 DISCUSSION

The increased risk of death or illness in brachycephalic breeds (four times greater than non-brachycephalic dogs) is not surprising. Brachycephalic breeds, in addition to their shortened snouts and facial skeletons, are also characterized by multiple anatomical abnormalities including stenotic nares, elongated soft palates, everted laryngeal saccules/laryngeal collapse and hypoplastic trachea, all of which contribute to the development of brachycephalic obstructive airway syndrome (BOAS) (Lodato & Hedlund, 2012; Koch, 2003; Packer et al., 2015). As a result of BOAS, brachycephalic dogs are at higher risk of adverse

respiratory events because they have decreased capacity for thermoregulation and lower oxygen saturation levels than non-brachycephalic breeds (Davis et al., 2017; Koch, 2003; Lodato & Hedlund, 2012; Packer et al., 2015). Transporting brachycephalic dogs by any means when there is difficulty regulating environmental temperatures and ensuring adequate ventilation for prolonged periods of time could trigger a respiratory emergency. Without access to immediate medical care these dogs are at a greater risk of death. Travel restrictions for brachycephalic breeds and increased owner and carrier awareness of the risk of illness and death are critical to ensure the health and safety of brachycephalic breeds during air travel.

Similarly, all dogs were at 3–5 times greater risk of death or illness when transported via air cargo or air checked baggage (in the area below the wing of the aircraft where all the checked baggage is stored). This evaluation suggests that confining dogs for prolonged periods of time in the cargo areas of a plane could result in adverse health effects for the dog. This may be due to poor environmental temperature regulation, reduced ventilation, lack of food or water (especially in young dogs), increased stress or other unknown factors when transported via the cargo hold of a plane. Additional assessments are needed to determine how air carriers can reduce the risk of illness or death in animals transported as cargo and checked baggage. Improvements to the live animal cargo environment such as temperature control and breed restrictions have been implemented by many US-based air carriers; however, many international air carriers have yet to implement mitigation measures to reduce the risk of death or illness in dogs.

Participation in and compliance with organizations that have established guidelines for live animal transport and work to improve air travel for animals, such as the Animal Transportation Association (ATA), International Air Transport Association (IATA), or the International Pet and Animal Transportation Association (IPATA), should be encouraged for all airlines transporting live animals.

Dogs traveling from high-risk countries for CRVV (countries in which CRVV is enzootic) had more than two times greater risk of death or illness than dogs traveling from low-risk countries or CRVV free countries. The increased risk of death or illness in dogs arriving from high-risk countries seen in this evaluation may be an indirect proxy for animal health that is reflective of the overall health status of the animals in countries with lower human development indices. The human development index (HDI) is a composite measure of health, education, and income used by the United Nations Development Program (United Nations Development Program, 2020). Countries in which canine rabies is enzootic have significantly lower HDI scores than CRVV-free countries, suggesting that improvements to infrastructure, health care access and education may be needed before higher levels of dog vaccination can be achieved (Wallace et al., 2017). The improvements needed in many countries with lower HDI scores would presumably also lead to increased access to and availability of veterinary care and could arguably lead to improved overall human and animal health. Alternatively, the greater risk of death or illness in dogs from high-risk countries for CRVV may be due to inadequate veterinary inspection and care prior to travel, reduced adherence to safety guidelines by air carriers, or a combination of factors. Importers

and air carriers should consider additional steps to ensure dogs originating in high-risk countries are healthy enough to endure long periods of travel.

In addition to the animal health issues discussed above, illness or death in imported dogs can be costly for importers, air carriers, and public health agencies working to protect human and animal health. Importers (or air carriers if importers abandon the animal) can incur costs of $32,831–$113,408 per year to manage sick or dead animals, and state and federal agencies may incur costs of $2,071–$104,648 a year to conduct public heath investigations. These costs could be averted by identifying risk factors for dogs in the flight environment and working to mitigate those risks and reduce poor outcomes.

There were several limitations with this evaluation. First, without routine airline carrier data collection in QARS the authors cannot say whether the risk of death and illness may differ between airline carriers. Second, because data were not available, we used standard breed sizes rather than the actual weight of the animal for the size variable in this analysis. It is possible there are risks associated with the actual size or weight of the animal that we were not able to assess. Routine collection of weight and age data in QARS would help to further assess risk factors for animal death and illness in the future. Third, we were unable to ascertain the flight duration which may impact the risk of death or illness. Fourth, given the data are only collected when deviations are identified and we do not collect information on all dogs imported into the United States, the denominator for our data is unknown. As a surrogate for our comparison, we used healthy dogs that were otherwise flagged for paperwork issues, and data are thus subject to sampling bias. Fifth, we were unable to tell whether dogs hand-carried in the cabin and/or transported via land border crossing are more likely to be personal pets, and therefore, may have been healthier compared to dogs flown as cargo or checked baggage. However, we did note that small, underage dogs from high-risk countries for CRVV are routinely transported in importers' hand-carried luggage in the cabins. Death and illness of these dogs are unlikely to be captured in QARS unless CBP finds the dogs during passenger inspection upon arrival. Airlines are not required to track or report the number of dogs that fly in the cabin as hand-carried luggage; therefore, reports of illness and death may be less likely to occur as airlines may not know how many animals are flying in the cabin, and small, underage dogs being brought into the United States for resale that become ill or die during the flight are less likely to be reported by the importer. Therefore, the risk of death or illness may be greater than our data suggest for animals transported as hand-carried luggage. Finally, we were only able to estimate a plausible range for the costs associated with post-arrival care for dogs that become ill or examination of dogs that die during travel because CDC does not collect cost data.

Though current regulations, statutes and laws might help improve the safety of animals transported into the United States, they do not provide adequate mechanisms to monitor the rates of animal morbidity and mortality. There are minimal to no consequences for air carriers who violate animal transportation requirements or repeatedly import ill or dead animals. Existing federal regulations could potentially be strengthened to address these non-compliance issues and levy penalties, such as fines or suspensions of live animal imports, against air carriers that repeatedly violate animal transportation requirements. There are growing attempts by federal agencies, non-governmental agencies and animal

welfare organizations to assess the animal welfare, public health and communicable disease importation risks associated with the international transportation of dogs (Anderson et al., 2019; Polak, 2019). An issue that arises with assessing dog transportation on aircraft is that the responsibility for the dogs' health and well-being is overseen by multiple stakeholders with varying rules and regulations. A combined, inter-agency approach to identify potential dog transportation interventions that reduce morbidity and mortality during flights while continuing to protect US borders from public health and foreign animal disease threats could be beneficial. Additionally, public education to improve awareness among owners that demands for certain breeds as pets, or demand for pets purchased from overseas increases the chance of importing a foreign animal disease or witnessing poor outcomes for imported dogs.

Significant improvements in communicable disease surveillance and detection could occur with several changes which include (1) required reporting by air carriers on the number of animals they transport into the United States as cargo, checked baggage, and hand-carried baggage; (2) additional vaccination and diagnostic testing prior to entry based on the disease risk of the exporting country; (3) required, comprehensive communicable disease testing for any ill or dead dogs that arrive in the United States; (4) enhanced and coordinated screening by US government agencies for all live dog importations; (5) the establishment of government or private quarantine facilities for animals that arrive in the United States based on the disease risk of the exporting country. These changes could improve our ability to prevent, detect and respond to public health risks and foreign animal diseases that could negatively impact human health, our food safety and security and the health and welfare of domestic and wildlife animals in the country.

ACKNOWLEDGEMENTS

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

REFERENCES

American Kennel Club. (2017). Breed weight chart. Retrieved from akc.org.

Anderson MEC, Stull JW, & Weese JS (2019). Impact of dog transport on high-risk risk infectious diseases. Veterinary Clinics: Small Animal Practice, 49, 615–627. [PubMed: 30956001]

Bureau of Labor Statistics Occupational Employment and Wage Statistics. (2020). National Occupational Employment and Wage Estimates United States. Retrieved from: https://www.bls.gov/oes/current/oes_nat.htm

Centers for Disease Control and Prevention (CDC) (2019). Notice of temporary suspension of dogs entering the united states from Egypt. Federal Register, 84, 20628–32. Retrieved from: https://www.federalregister.gov/documents/2019/05/10/2019-09654/notice-of-temporary-suspension-of-dogs-entering-the-united-states-from-egypt

Centers for Disease Control and Prevention (CDC) (2021). Rabies vaccine certificate required when coming from these high-risk countries. Retrieved from: https://www.cdc.gov/importation/bringing-an-animal-into-the-united-states/high-risk.html

Centers for Disease Control and Prevention (CDC) (2020). Where is your dog coming from. Retrieved from: Where is Your Dog Coming From?, Bringing an Animal into U.S. Importation, CDC

Cornell University (2021). Animal Health Diagnostic Center. Retrieved from: https://www.vet.cornell.edu/animal-health-diagnostic-center

Davis MS, Cummings SL, & Payton ME (2017). Effect of brachycephaly and body condition score on respiratory thermoregulation of healthy dogs. Journal of the American Veterinary Medical Association, 251(10), 1160–1165. 10.2460/javma.251.10.1160 [PubMed: 29099251]

Emergency Vets USA (2021). Average cost of emergency vet visits in a city near you. Retrieved from emergencyvetsusa.com.

Fedex (2021). Rate and ship. Retrieved from: https://www.fedex.com/enus/online/rating.html#

Hampson K, Coudeville L, Lembo T, Sambo M, Kieffer A, Attlan M, et al. ; Global Alliance for Rabies Control Partners for Rabies Prevention (2015). Estimating the global burden of endemic canine rabies. PLOS Neglected Tropical Diseases, 9(4), e0003709. [PubMed: 25881058]

Humane Society Veterinary Medical Association (2017). The cost of cuteness: Health and welfare issues associated with brachycephalic dog breeds. Retrieved from hsvma.org

Kansas State University (2021). KSDVL online portal, Rabies suspect mammal DFA test. Retrieved from k-state.edu.

Koch D (2003). Brachycephalic syndrome in dogs. Compendium on continuing education for practicing veterinarian. North American Edition, 25(1), 48–55.

Lodato DL, & Hedlund CS (2012). Brachycephalic airway syndrome: Pathophysiology and diagnosis. Compendium: Continuing Education for Veterinarians, 34(7), E3.

McQuiston JH, Wilson T, Harris S, Bacon RM, Shapiro S, Trevino I, Sinclair J, Galland G, & Marano N (2008). Importation of dogs into the United States: Risks from rabies and other zoonotic diseases. Zoonoses and Public Health, 55, 421–426. 10.1111/j.1863-2378.2008.01117.x [PubMed: 18833595]

National Association of State Public Health Veterinarians (NASPHV) (2016). Compendium of animal rabies prevention and control, 2016. Journal of the American Veterinary Medical Association, 248(5), 505–517. [PubMed: 26885593]

Office of Personal Management (2021). General schedule hourly salaries and wages. Retrieved from: https://www.opm.gov/policy-dataoversight/pay-leave/salaries-wages/salary-tables/21Tables/html/ATL_h.aspx

Packer RMA, Hendriks A, Tivers M, & Bum CC (2015). Impact of facial conformation on canine health: Brachycephalic obstructive airway syndrome. PLoS One, 10(10), e0137496. [PubMed: 26509577]

Polak K (2019). Dog transport and infectious disease risk: An international perspective. Veterinary Clinics: Small Animal Practice, 49, 599–613. [PubMed: 30967255]

Raybern C, Zaldivar A, Tubach S, Ahmed FS, Moore S, Kintner C, Wallace RM, Mandra AM, Stauffer K, Condori RE, & Garrison I (2020). Rabies in a Dog Imported from Egypt – Kansas, 2019. Morbidity and Mortality Weekly Report, 69(38), 1374–1377. https://www.cdc.gov/mmwr/volumes/69/wr/mm6938a5.htm [PubMed: 32970659]

Wallace RM, Undurraga EA, Blanton JD, Ahmed FS, Moore S, Kintner C, Wallace RM, Mandra AM, Stauffer K, Condori RE, & Garrison I (2017). Elimination of Dog-Mediated Human Rabies Deaths by 2030: Needs assessment and alternatives for progress based on dog vaccination. Frontiers in Veterinary Science, 4(9), 10.3389/fvets.2017.00009

Washington State University (2021). Washington animal disease diagnostic laboratory tests and fees. Retrieved wsu.edu.

Wisconsin Department of Health Services (2021). Rabies: Animal testing. Retrieved from: https://www.dhs.wisconsin.gov/rabies/testing.htm

UC Davis Veterinary Medicine (2021). California Animal Health and Food Safety Lab System. Retrieved from ucdavis.edu.

United Nations Development Programme (2020). Human Development Reports. Human Development Index [PDF]. Retrieved from undp.org.

U.S. Department of Agriculture (USDA) (2020a). Animal Welfare Act. Retrieved from: https://www.aphis.usda.gov/aphis/ourfocus/animalwelfare/sa_awa

U.S. Department of Agriculture (USDA) (2020b). Pet travel- bringing dogs to the US. Retrieved from: https://www.aphis.usda.gov/aphis/pet-travel/bring-pet-into-the-united-states/pet-travel-dogs-into-us

Velasco-Villa A, Escobar LE, Sanchez A, Shi M, Streicker DG, Gallardo-Romero NF, Vargas-Pino F, Gutierrez-Cedillo V, Damon I, & Emerson G (2017). Successful strategies implemented towards the elimination of canine rabies in the Western Hemisphere. Antiviral Research, 143, 1–12. https://www.sciencedirect.com/science/article/pii/S0166354216306441?via%3Dihub [PubMed: 28385500]

TABLE 1

Demographics of imported dogs with records in CDC's Quarantine Activity Reporting System (QARS) database due to inadequate rabies vaccination, death or illness 2010–2018

	Healthy[†]	Sick or dead	Total
	N (%)	N (%)	N (%)
	13,715 (99)	176 (1)	13,891
Breed characterization			
Brachycephalic[‡]	3485 (25)	107 (61)	3592 (26)
Nonbrachycephalic	10,230 (75)	69 (39)	10,299 (74)
Size			
25 pounds	5310 (39)	69 (39)	5379 (39)
26–60 pounds	4225 (31)	78 (44)	4303 (31)
61–100 pounds	3244 (24)	20 (11)	3264 (24)
101 pounds	936 (7)	9 (5)	945 (7)
Transportation method			
Hand-carried	5769 (42)	30 (17)	5799 (42)
Cargo	5664 (41)	89 (51)	5753 (41)
Checked baggage	1672 (12)	56 (32)	1728 (12)
Land border crossing (Car)	610 (4)	1 (1)	611 (4)
Country of origin[§]			
Rabies low risk	11,756 (86)	126 (72)	11,882 (86)
Rabies high risk	1959 (14)	50 (28)	2009 (14)

CDC = Centers for Disease Control and Prevention.

[†]Incomplete rabies vaccination recorded and either denied entry or issued a CDC Confinement Agreement.

[‡]Brachycephalic breeds recognized by American Kennel Club: Affenpinscher, Boston Terrier, Brussels Griffon, Bulldog (American, English, French), Boxer, Cavalier King Charles Spaniel, Japanese Chin, Lhasa Apso, Mastiff, Pekingese, Pug and Shih Tzu.

[§]Based on the CDC's High-Risk for Rabies Country List for 2020.

TABLE 2

Risk factors for death or illness among all dogs imported into the United States, 2010–2018

Variable	Adjusted odds ratio[†]	p Value[*]	95% CI
Breed characterization			
Non-brachycephalic	Reference	Reference	–
Brachycephalic	**3.88**	**<.001**	**2.74-5.51**
Size			-
25 pounds	1.15	.626	0.66–1.99
26–60 pounds	1.48	.163	0.85–2.58
61–100 pounds	Reference	Reference	–
101 pounds	0.54	.156	0.23–1.26
Transportation method			
Hand-carried	Reference	Reference	–
Cargo	**2.41**	**<.001**	**1.57-3.70**
Checked baggage	**5.75**	**<.001**	**3.65-9.03**
Land border crossing (car)	0.265	.193	0.04–1.95
Country of origin			
Rabies low risk	Reference	Reference	
Rabies high risk	**1.54**	**.015**	**1.09-2.18**

[†] All variables in table included in adjusted logistic regression model.

[*] p Values < .05 were considered significant.

TABLE 3

Estimated costs associated with ill or dead dog importations (2021 USD)

Item/expense	Cost per activity/item	Cost per year[†]
Airport investigation upon arrival		
CDC quarantine station staff investigation time[‡] (1–3 staff GS9/11; 1 GS13)	30 min–8 h peranimal[§] ($83–$2619)	$1577–$49,761
CDC Zoonoses Team consultation time[¶] (1–2 staff GS13/14)	15 min–8 h peranimal[§] ($26–$1811)	$494–$34,409
Consultation time with state or local public health or animal health officials[††] [1–4 staff per event consulted (state epidemiologist, state public health veterinarian or state veterinarian)]	0 min–3 h peranimal[§] ($0–$1078)	$0–$20,478
Total initial investigation costs	**$109–$5508**	**$2071–$104,648**
Examination and treatment for ill dogs[‡‡]		
CBP-bonded transportation to veterinary clinic by carrier	1–4 h to identify vehicle and make transportation arrangements[¶¶] ($119–$954)	$1071–$8886
Arrangements: cargo manager (1–2) and staff (1–2 staff)[§§]		$270–$3222
Driver (1–2 cargo staff)[§§]	30 min–3 h[¶¶] (transport time to and from clinic) ($30–$358)	
Emergency veterinary examination	$100–150	$900–1350
Veterinary diagnostics	$530–1050	$4770–9450
Veterinary treatment (including hospitalization for 1–2 days)	$2200–7200	$19,800–64,800
Total cost for ill animal	**$2979–$9712**	**$26,811–$87,408**
Post-mortem evaluation for dogs[†††]		
CBP-bonded transportation to veterinary clinic by carrier	1–4 h to locate vehicle and make transportation arrangements[¶¶] ($119–$954)	$1190–$9540
Arrangements: cargo manager (1–2) and staff (1–2 staff)[§§]		$300–$3580
Driver (1–2 cargo staff)[§§]	30 min–3 h[¶¶] (transport time to and from clinic) ($30–$358)	
Necropsy (with brain extraction for rabies testing)[†††]	$150–615	$1500–6150
Shipment of sample to state public health laboratory, including shipping supplies (rabies testing only)[†††]	$75–125	$750–1250
Rabies testing at state public health laboratory[†††]	$49–194	$490–1940
Shipment of sample to CDC rabies laboratory (including shipping supplies)[†††]	$75–250	$750–2500
CDC confirmatory rabies testing (staff, equipment and supplies)[†††]	$104	$1040
Total cost for dead animal	**$602–$2600**	**$6020–$26,000**
Total cost for ill or dead animals per year (investigation costs + ill animal + dead animal)	–	$34,902–$218,056

CDC = Centers for Disease Control and Prevention; USD = US dollar; GS = general schedule; CBP = US Customs and Border Protection.

†
Average of 9 illnesses and 10 deaths per year based on 2010–2018 data from Centers for Disease Control and Prevention's Quarantine Activity Reporting System.

‡
For the lower bound we assumed 30 min of General Schedule (GS) level 9, step 5 (9–5) staff time and 45 min of GS 13–5. The upper bound estimate included an assumption of 24 h of GS 11–5 staff time and 8 h of GS 13–5 staff time. The wage rates for federal employees were estimated using the federal government's General Schedule for the Atlanta, GA area. Source: Office of Personal Management (2021) General Schedule Hourly Salaries and Wages. https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/salary-tables/21Tables/html/ATL_h.aspx. Accessed April 9, 2021. The hourly wage rate was multiplied by two to account for non-wage benefits and overhead. All estimates assume 19 events per year.

§
Time estimates for case investigations were based on data recorded in CDC's Quarantine Activity Reporting System (QARS). QARS captures all written and telephone correspondence between the importer, broker, airline and federal and state partner agencies for each case. Emails to federal and state partners, airlines, brokers and importers were estimated to take 15 min each. Veterinary clinic and pathology laboratory consultations, importer telephone communication, legal correspondence and state or local health department phone consultations were estimated to take 30 min each.

¶
For the lower bound we assumed 15 min of GS 13–5 staff time. The upper bound estimate included 8 h of GS 13–5 staff time and 8 h of GS 14–5 staff time using the same assumptions as for CDC quarantine station staff wage rates. Source: Office of Personal Management (2021) General Schedule Hourly Salaries and Wages. https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/salary-tables/21Tables/html/ATL_h.aspx. Accessed April 9, 2021. The hourly wage rate was multiplied by two to account for non-wage benefits and overhead.

††
The consultation with state of local public health or animal officials were assumed to include an equal distribution of three occupation types: veterinarians, epidemiologists, and registered nurses. The lower bound estimated included an average of 10 min of local government staff time per event and the upper bound estimate included 12 h of local government staff time per event. The wage rates for each occupation were estimated using the average hourly wages for occupation codes: 19–1041, 29–1131 and 29–1141 available in the Bureau of Labor Statistics' Occupational Employment and Wage Statistics. These hourly wage estimates were multiplied by 2 to account for non-wage benefits and overhead. May 2020 data set. Source: Bureau of Labor Statistics (2020) Occupational Employment and Wage Statistics May 2020 National Occupational Employment and Wage Estimates United States. https://www.bls.gov/oes/current/oes_nat.htm. Accessed April 9, 2021. To adjust into 2021 US dollars, we used the average annual wage increases from the 2018, 2019, 2020 data sets to estimate an average wage increase of 3.2% for these three job categories.

‡‡
All animal cost estimates available at: https://emergencyvetsusa.com/average-cost-of-emergency-vet-visits/. Veterinary diagnostics can include blood-work, point-of-care diagnostics, cytology, culture, radiographs and ultrasound. Veterinary treatment can include hospitalization with intravenous fluids, antibiotics or other pharmaceuticals, nutritional support and oxygen therapy.

§§
The lower bound estimated included an average of 10 min of aircraft cargo handling supervisors' time per event and the upper bound estimate included 12 h of local staff time per event. The wage rates for each occupation were estimated using the average hourly wage for occupation codes: 53–1011 available in the Bureau of Labor Statistics' Occupational Employment and Wage Statistics. These hourly wage estimates were multiplied by 2 to account for non-wage benefits and overhead. May 2020 data set. Source: Bureau of Labor Statistics (2020) Occupational Employment and Wage Statistics May 2020 National Occupational Employment and Wage Estimates United States. https://www.bls.gov/oes/current/oes_nat.htm. Accessed April 9, 2021. To adjust into 2021 US dollars, we used the average annual wage increases from the 2018, 2019, 2020 data sets to estimate an average wage increase of 4.0% for this job category.

¶¶
Time estimates for the transportation of sick or dead animals to veterinary facilities was estimated from email communications between airlines and cargo warehouse staff and CDC.

†††
Dead animal cost estimates available for 1. necropsy: https://www.vet.cornell.edu/animal-health-diagnostic-center/laboratories/anatomic-pathology/services, tests & fees (wsu.edu), CAHFS–Test & Fee Finder (ucdavis.edu); 2. rabies testing: https://www.dhs.wisconsin.gov/rabies/testing.htm, Catalog (k-state.edu), Emily Pieracci (personal communication with CDC Poxvirus and Rabies Branch) and 3. shipping: estimates obtained from a representative service (www.fedex.com).