



Published in final edited form as:

J Public Health Manag Pract. 2025 ; 31(5): 886–893. doi:10.1097/PHH.0000000000002155.

Factors associated with unsuccessful rabies tests in Utah, 2014–2023

Clarissa N. Keisling, MPH,

Will Boyd,

Hannah Rettler, MPH,

Heather Oltjen, DVM, MPH,

Kacy Nowak, MPH,

Kaona Ayres, MS,

Kim Kinnick-Hansen,

Jesse Harbour, MS,

William A. Lanier, DVM, MPH

Utah Department of Health and Human Services (Ms Keisling, Ms Rettler, Dr Oltjen, Ms Nowak, Ms Ayres, Ms Kinnick-Hansen, Mr Harbour, and Dr Lanier); Council of State and Territorial Epidemiologists (Ms Keisling); Virginia-Maryland College of Veterinary Medicine, Blacksburg, Virginia, United States Public Health Service (Mr Boyd); United States Public Health Service, Centers for Disease Control and Prevention, Office of Readiness and Response, Division of State and Local Readiness, Career Epidemiology Field Officer Program, (Dr Lanier).

Abstract

Context: Testing potentially rabid animals is crucial for providing accurate recommendations to prevent rabies infection. When a test of the animal is unsuccessful, (i.e., does not produce a positive or negative result) after a potential exposure, health officials cannot rule out rabies and must recommend rabies post-exposure prophylaxis (PEP), presenting an economic burden to patients and healthcare systems.

Objectives: To better understand factors associated with unsuccessful rabies tests to inform interventions that would reduce preventable unsuccessful testing.

Design: We performed tests of independence between unsuccessful test rates and frequently submitted animal and submitter types. We used Cochran-Mantel-Haenszel (CMH) tests to assess the significance of the association between unsuccessful tests and animal type and submitter type, while controlling for the effects of each. Stratified bivariate analyses identified specific factors driving significant CMH results.

Correspondence: Clarissa N. Keisling, MPH, Utah Department of Health and Human Services, 288 N 1460 W, Salt Lake City, UT 84116 (cnkeisling@utah.gov).

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the U.S. Centers for Disease Control and Prevention or the authors' affiliated institutions.

Financial disclosure: None

Conflicts of interest: The authors declare they have no conflicts of interest.

Results: Of 2 806 specimens submitted for rabies testing during January 2014–March 2023, 113 (4%) were unsuccessful. Bats, raccoons, and skunks each had higher unsuccessful test rates compared to dogs or cats (p-values <0.001–0.003) and together comprised 87 (77%) of the 113 unsuccessful tests. Submissions by citizens had a higher proportion of unsuccessful tests than submissions by animal control (p-value <0.001); animal control had the lowest unsuccessful test rate of all submitter types. Unsuccessful test rates differed when controlling for submitter type (p-value<0.001) and animal type (p-value=0.013). Submissions of bats by citizens had a significantly greater proportion of unsuccessful tests than submissions of bats by animal control (p-value: <0.001).

Conclusions: More than three-quarters of unsuccessful tests were attributed to bats, skunks, and raccoons, emphasizing the need to improve submission quality for these animals. We recommend training Utah rabies response partners on proper specimen handling and submission. Efforts should also focus on educating citizens to route submissions through trained rabies responders. Conducting focus groups with specific entities that have the lowest unsuccessful test rates could yield model submission practices.

Keywords

Rabies; Zoonoses; One Health Response; Public Health Education; Disease Prevention

Introduction

Rabies is a viral zoonosis that can be transmitted to humans in the saliva or mucus of infected (rabid) animals, typically through a bite. Though uncommon, the virus can also be spread to humans through a non-bite exposure, which occurs when saliva, brain tissue, or spinal fluid from an animal with rabies enters any scratch, abrasion, open wound, eyes, or the mouth.^{1,2,3} In humans, rabies is fatal almost 100% of the time, but is completely preventable with timely administration of the rabies post-exposure prophylaxis (PEP) treatment.^{3,4,5} In the United States, wildlife transmission of rabies to humans and domestic animals continues to present a threat to human and animal safety, with more than 90% of annual rabies cases reported to the US National Rabies Surveillance System occurring in wildlife species.^{6,7} In addition to the risk of direct transmission from wildlife to humans, virus spillover from wildlife populations to unvaccinated domestic animals frequently occurs, and instances of cats and dogs infected with non-canine rabies virus variants continue to occur in the United States.⁷ This is concerning given that vaccinated domestic animals serve as a crucial barrier for rabies transmission between wildlife and humans.^{7,8}

Bats are responsible for most human rabies deaths, but other reservoir hosts for rabies in the continental United States include raccoons, skunks, and foxes.⁷ An analysis of rabies trends during 1938–2018 revealed that, among the 89 human infections diagnosed in the United States, 62 (70%) were attributed to bats.⁹ In Utah, bats are the primary source of rabies virus and are the most frequently submitted animal for rabies testing.¹⁰ During the last decade, bats were almost exclusively the only animal to test positive for rabies in Utah, with the exception of two rabid foxes (2021 and 2020) and a skunk (2014), all three of which were infected with a bat variant of the virus.¹⁰

Following a potential rabies exposure, public health authorities coordinate with the exposed person(s), medical professionals, and animal control or wildlife agencies to assess the risk of rabies transmission. This often involves euthanizing the animal and submitting its brain tissue to the Utah Public Health Laboratory (UPHL) for rabies virus testing. Animal control, local health departments, wildlife officials, and other rabies response entities often submit animal specimens for rabies testing. In rare cases, individual citizens might directly submit specimens to UPHL.

To help mitigate the risk of rabies infection in humans, prompt, accurate rabies testing is crucial. Testing a potentially rabid animal after it exposes a human facilitates reliable public health recommendations and timely administration of PEP. When a suspected rabid animal tests negative, PEP can be avoided, reducing medical costs and financial burden to both the patient and the healthcare system. For domestic animals exposed to a potentially rabid animal, timely testing ensures the appropriate response based on the animal's vaccination status. Vaccinated animals require a 45-day home quarantine, while unvaccinated animals must undergo a 4- to 6-month isolation in a secure facility. A negative rabies test result can obviate the need for such measures and, for unvaccinated animals, eliminate the need for euthanasia or costly, long-term isolation.⁸

Rabies tests can be unsuccessful when submitted specimens are unsuitable or unfit for testing (e.g., desiccated, deteriorated, decomposed, or damaged) or do not produce reliable (positive or negative) test results. Specimens unfit for testing most often occur as a result of delayed sample submission. Specimens can also be deemed unfit for testing if they are not submitted per Utah's specimen submission guidelines, which include failure to refrigerate the specimen before transport, submitting a whole animal >12 inches instead of the intact head, or submitting a skull or head damaged by improper euthanasia (e.g., shot or clubbed in the head).¹¹ Due to the almost universally fatal nature of rabies, when health officials determine that a potential rabies exposure occurred and a test is unsuccessful, the tested animal must be assumed to be rabid and PEP is recommended.¹² This can lead to unnecessary PEP recommendations in situations where a successful, negative test could have ruled out the need for treatment, and contributes to the overall economic burden of rabies.^{13,14}

Animal rabies is a nationally notifiable condition in the United States, which means that routine public health reporting of positive and negative animal rabies test results to the U.S. Centers for Disease Control and Prevention is required.^{15,16,17} Although health jurisdictions routinely collect this information, a formal analysis of unsuccessful rabies tests, and the possible factors influencing unsuccessful tests, has not been reported. Our goal was to better understand the factors associated with unsuccessful rabies tests in Utah and to identify and target specific submitters (e.g., animal control, health professionals, veterinarians, etc.) for public health intervention.

Methods

We investigated the factors associated with unsuccessful tests, defined as animal specimens submitted for testing that are unsuitable for testing or do not produce reliable (positive or

negative) test results. We analyzed unsuccessful animal rabies testing data collected by the Utah Department of Health and Human Services (DHHS) during January 1, 2014–March 31, 2023 by (1) animal type and (2) submitter type. Animal rabies testing data are recorded on the rabies test request form, which must accompany specimens that are submitted to UPHL for rabies testing. Rabies test results are reported daily to epidemiologists in DHHS; information from the test request forms is recorded in the animal rabies testing database. To determine which animals were most frequently submitted, we created a rank-ordered list of animal species submitted for rabies testing based on the number of submissions received. We divided the list into quartiles and defined frequently submitted animal types as those that were in the ≥ 3 rd quartile of animal submissions. All other animals were grouped into the “other” animal type. There are multiple species of bats present in Utah; to simplify our analysis, we categorized all bat species into a single “bat” animal type.

We defined a submitter as an individual, agency, or other entity that submitted ≥ 1 animal specimen for rabies testing during the analysis period. We categorized submitting entities into seven submitter types: animal control/animal shelters (AC), local health department (LHD), Division of Wildlife Resources (DWR), diagnostic lab (LAB), private veterinarian (VET), citizens, and other/unknown. Among LHD and AC submitter types, we identified specific, frequently submitting entities using the criteria outlined above for frequent animal submission.

Statistical analysis

We performed descriptive analyses of unsuccessful rabies test rates for each frequently submitted animal type and submitter type in Microsoft Excel. We used the chi-square test (for independent samples of sufficient size) and Fisher’s exact test (for independent samples of small size) to investigate the difference in proportions of unsuccessful tests between frequently submitted animal types and between submitter types.¹⁸ We used the Cochran-Mantel-Haenszel (CMH) statistical test to assess the significance of the association between (1) animal type and proportion of unsuccessful tests while controlling for the effects of submitter type and (2) submitter type and proportion of unsuccessful tests while controlling for the effects of animal type. We performed bivariate analyses of unsuccessful animal test results stratified by submitter type and unsuccessful submitter type test results stratified by animal type to identify the specific factors driving significant results from the CMH analysis. Next, we investigated the difference in proportions of unsuccessful tests by animal type between the frequent LHD and AC submitters. We used R to perform all statistical tests. We used a significance level equal to 0.05 for all tests.

Human Participant Compliance Statement

This activity was reviewed by CDC, deemed not research, and was conducted consistent with applicable federal law and CDC policy.[§]

§ See e.g., 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. Sect. 241(d); 5 U.S.C. Sect. 552a; 44 U.S.C. Sect. 3501 et seq.

Results

During the study period, 2 806 animal specimens were submitted for rabies testing, of which 113 (4%) were unsuccessful. Frequently submitted animal types were, in this order, bats, dogs, cats, raccoons, skunks, mink, foxes, and coyotes (Table 1). Skunks had the highest unsuccessful test rate (10%; 6 of 58), followed by raccoons (7%; 17 of 246), foxes (7%; 1 of 15), other (6%; 5 of 84), mink (6%; 1 of 17), and bats (6%; 64 of 1,144 (Table 1). Bats, skunks, and raccoons together comprised 87 (77%) of the 113 unsuccessful tests (Table 1). Of the submitter types, AC submitted the most samples, followed by LHD, LAB, VET, DWR, citizens, and other/unknown. Citizens had the highest unsuccessful test rate (10.8%; 16 of 148) followed by other/unknown (6.7%; 3 of 45), LHD (4.7%; 28 of 595), DWR (3.7%; 6 of 163), LAB (3.5%; 10 of 286), VET (3.2%; 10 of 286), and AC (3.2%; 42 of 1 320) (Table 1).

Bat, raccoon, and skunk specimens had a significantly higher proportion of unsuccessful tests compared to dog and cat specimens, respectively (p-values <0.001–0.003). There was no significant difference in the proportion of unsuccessful tests between dog and cat specimens (p-value=0.3), nor significant differences between each of the frequently submitted wildlife animals (bats, raccoons, skunks, mink, fox, and coyotes). To increase sample size for subsequent analyses, we combined the frequently submitted animal types into three animal groups: domestic animals (dogs and cats), bats, and non-bat wildlife (raccoons, skunks, mink, foxes, and coyotes). Dogs and cats together had an unsuccessful test rate of 1.5% (19 of 1 229). Raccoons, skunks, mink, foxes, and coyotes together had an unsuccessful test rate of 7.2% (25 of 349).

Submissions by citizens had a significantly higher proportion of unsuccessful tests compared to submissions by all other submitter types (p-values: AC: <0.001; LAB: 0.005; DWR: 0.03; LHD: 0.009; VET: 0.004). There were no significant differences in the proportion of unsuccessful tests between each of the other submitter types. Given these results, the citizen submitter type was used as the reference group for comparison in subsequent bivariate analyses.

Of the 13 LHD submitters in Utah, four (30.8%) met the frequent submitter criteria. Of these, unsuccessful test rates ranged from 0.9% (2 of 234) to 14% (9 of 65). Of the 59 AC entities that submitted ≥ 1 specimen for rabies testing, 15 (25.4%) met the frequent submitter criteria. Of these, six had zero unsuccessful tests. Of the nine remaining frequent AC submitters, unsuccessful test rates ranged from 2% (3 of 178) to 17% (4 of 24).

CMH results.

The association between animal groups (domestic, bat, and non-bat wildlife) and proportion of unsuccessful tests, considering the effects of submitter type, was significant (CMH: $M^2=31.65$, $df=2$, $p\text{-value}<0.001$). The association between submitter type and proportion of unsuccessful tests, considering the effects of animal group, was also significant (CMH: $M^2=14.49$, $df=5$, $p\text{-value}=0.013$).

Stratified analysis.

When we stratified animal groups (domestic, bat, and non-bat wildlife) by submitter type, we found submissions of domestic animals by citizens had a significantly higher proportion of unsuccessful tests than submissions of domestic animals by AC (p-value=0.04). Submissions of bats by citizens also had a significantly higher proportion of unsuccessful tests than submissions of bats by AC, LHD, and DWR (p-values: <0.001, 0.03, and 0.02, respectively) (Table 2). When we stratified submitter type by animal group, there was no significant difference in the proportion of unsuccessful tests between domestic, bat, and non-bat wildlife groups for citizen submissions, nor for LAB and DWR (Table 3). Of the AC and LHD submissions, submissions of bats had a significantly higher proportion of unsuccessful tests than submissions of domestic animals (p-values: 0.001 and 0.02, respectively). Submissions of non-bat wildlife by AC compared to submissions of domestic animals by AC also had a significantly higher proportion of unsuccessful tests (p-value<0.001). Of the VET submissions, non-bat wildlife had a significantly higher proportion of unsuccessful tests than domestic animals (p-value=0.03) (Table 3).

Discussion

Submissions of bats, raccoons, and skunks had a significantly higher proportion of unsuccessful tests compared to submissions of dogs and cats, a finding that held true in the stratified analyses. Three-quarters of unsuccessful tests were attributed to bats, raccoons, and skunks, emphasizing the need to improve submission quality for these animals. Specifically, we observed a higher proportion of unsuccessful tests for bats and non-bat wildlife submitted by AC, LHD, and VET than for domestic animal submissions from these submitter types. This suggests that bats and non-bat wildlife might be more difficult to submit than domestic animals, even for well-trained rabies responders. Training on proper handling and submission of these species tailored for AC, LHD, and VET could help reduce unsuccessful tests.

We also found that the proportion of unsuccessful tests for citizen submissions was significantly higher than all other submitter types, which indicates that citizen submissions pose a particular issue of concern. Reasons for this finding likely include that members of the public are generally not as familiar with the proper procedures for collecting and preserving animal specimens for rabies testing compared to other rabies response partners (i.e., animal control, health professionals, and veterinarians). This lack of training can result in improper handling or delays in reporting, leading to sample degradation and increasing the likelihood of an unsuccessful test. Improper handling by untrained individuals might not only compromise the quality of the specimen, but also can lead to bites, scratches, or contact with saliva, presenting additional risk of human rabies infection.¹⁹

The concern regarding citizen submissions was also validated in the stratified analyses, which showed that submissions of domestic animals by citizens were significantly more likely to be unsuccessful than those by AC. Similarly, submissions of bats by citizens were significantly more likely to be unsuccessful than submissions of bats by AC, LHD, and DWR. This is particularly concerning given that bats are associated with high public health consequences in the United States, including a human death in Utah in 2018.^{9,20} This death,

as well as similar instances documented in other regions of the United States, emphasize the need for greater public health education and improved submission processes, especially regarding bats, to mitigate the risk of human rabies deaths.^{21,22,23,24}

Our results suggest that both animal and submitter type affect unsuccessful testing independently. Interestingly, the former comparison resulted in a higher CMH test statistic, which suggests that animal group (domestic, bat, and non-bat wildlife) might have a stronger influence on whether a test is unsuccessful, compared to submitter type. This observation could be attributed to inherent challenges in wildlife specimen collection and preservation compared to domestic animals. Wildlife might not be euthanized and/or recovered under ideal conditions and such specimens are often exposed to environmental elements (e.g., weather, scavengers, and decomposition factors), which can result in submissions of specimens unfit for testing. Although some wildlife specimens are collected and submitted by trained professionals, these environmental elements and variable conditions can result in submissions of specimens unfit for testing. Conversely, dogs and cats are often euthanized under controlled conditions (e.g., at a veterinary clinic or animal control facility) by professionals who are familiar with the specimen preparation process; this helps ensure that the brain tissue, the target for rabies testing, is properly preserved. The conditions in which domestic animal specimens are submitted can also facilitate prompt submission, further reducing the likelihood of specimen degradation due to decomposition and delayed submission.

Within LHD and AC submitting entities, we observed a wide range of unsuccessful test rates. This suggests that certain LHD and AC submitters might have more resources and staff available to facilitate response, and/or more robust procedures for sample collection, processing, and submission than other LHD and AC submitters. Conducting focus groups with LHD and AC submitters that had low unsuccessful test rates might help identify best practices and/or procedures that could be shared and adapted for other submitting entities. Focus groups are often used in public health as an interactive, collaborative, and context-rich method for gathering information about a particular health concern and could provide an opportunity to uncover diverse perspectives, explore complex issues, and provide insights into rabies response challenges across LHD and AC jurisdictions.^{25,26}

Limitations

The conclusions from this analysis should be considered in light of at least two limitations. First, we examined only two categorical factors in our analysis—animal type and submitter type. The likelihood of an unsuccessful test could also be affected by other factors, including seasonality, geographic location, quality of specimen at time of collection, and/or method of death. The inclusion of these additional variables might have resulted in a more complete understanding of how factors, including animal type and submitter type, are associated with unsuccessful tests. Future studies assessing more factors might shed additional light on how to reduce unsuccessful rabies tests in Utah.

Second, neither the status of the specimen at the time of collection nor the cause of unsuccessful testing are systematically recorded in Utah's rabies testing data. Hence, we

were unable to determine if a test was unsuccessful because the specimen was already unfit for testing (e.g., desiccated) at the time of collection or because it subsequently degraded due to improper handling after collection (e.g., shot or clubbed in the head or held at improper temperatures). Differentiating between these two could inform education of submitters on proper specimen submission, including when to refrain from submitting certain specimens (e.g., those that are already desiccated) and how to appropriately handle specimens (e.g., proper euthanasia), which could help reduce submission of unfit samples. Capturing data on the quality of the specimen at the time of collection and on the reason for unsuccessful testing in Utah's rabies testing system could help refine strategies to improve rabies testing outcomes.

Conclusion

Given the disease risk and economic burden of rabies in the United States, continued efforts to improve rabies surveillance, education, and collaboration between response partners is imperative. While previous studies have utilized rabies testing data for epidemiological reviews, here, we present an approach for analyzing state-level rabies testing data that can be adapted by other health jurisdictions to identify crucial knowledge gaps in rabies surveillance and response.^{27,28} Based on our findings, Utah rabies response partners could reduce unsuccessful tests by educating the general public to route submissions, particularly for bats, through a trained rabies response entity (e.g., AC, DWR, or LHD). Additionally, conducting focus groups with LHD and AC entities that have low unsuccessful test rates could help response partners identify model practices for successful submission that can be shared with other submitters.

Funding:

This study was supported in part by an appointment to the Applied Epidemiology Fellowship Program administered by the Council of State and Territorial Epidemiologists and funded by the Centers for Disease Control and Prevention Cooperative Agreement Number 1NU38OT000297-03-00.

References

1. Taxon Details | ICTV [Internet]. International Committee on Taxonomy of Viruses. Published October 11, 2023. https://ictv.global/taxonomy/taxondetails?taxnode_id=202201733
2. Orciari LA, Hanlon CA, Franka R. Rabies Virus In: Jorgensen JH, Pfaller MA, eds. Manual of Clinical Microbiology. 11th ed. 2015:1633–1643.
3. Fooks AR, Cliquet F, Finke S, Freuling CM, Hemachudha T, Mani RS, et al. Rabies. Nat Rev Dis Primers. 2017;3(1):1–9. doi:10.1038/nrdp.2017.91.
4. Rabies Postexposure prophylaxis (PEP). Medical care | rabies | CDC [Internet]. 2022 Published September 5, 2023. https://www.cdc.gov/rabies/medical_care/index.html
5. Preiss S, Chanthavanich P, Chen LH, Marano C, Buchy P, Van Hoorn R, et al. Post-exposure prophylaxis (PEP) for rabies with purified chick embryo cell vaccine: a systematic literature review and meta-analysis. Expert Rev Vaccines. 2018;17(6):525–545. doi:10.1080/14760584.2018.1473765. [PubMed: 29939085]
6. Velasco-Villa A, Reeder SA, Orciari LA, Yager PA, Franka R, Blanton JD, et al. Enzootic rabies elimination from dogs and reemergence in wild terrestrial carnivores, United States. Emerg Infect Dis 2008;14(12):1849–1854. doi:10.3201/eid1412.080876. [PubMed: 19046506]

7. Ma X, Bonaparte S, Corbett PWM, Orciari LA, Gigante CM, Kirby JD, et al. Rabies surveillance in the United States during 2021. *J Am Vet Med Assoc.* 2023;261(7):1045–1053. doi:10.2460/javma.23.02.0081. [PubMed: 36884381]
8. Brown C, Slavinski S, Ettestad P, Sidwa T, Sorhage FE. Compendium of animal rabies prevention and control, 2016. *J Am Vet Med Assoc.* 2016;248(5):505–517. doi:10.2460/javma.248.5.505. [PubMed: 26885593]
9. Pieracci EG, Pearson CM, Wallace RM, Blanton JD, Whitehouse E, Ma X, et al. Vital signs: trends in human rabies deaths and exposures — United States, 1938–2018. *MMWR Morb Mortal Wkly Rep.* 2019;68(23):524–528. doi:10.15585/mmwr.mm6823e1. [PubMed: 31194721]
10. Rabies Reports. Utah Epidemiology [Internet]. Accessed November 22, 2024. <https://epi.health.utah.gov/rabies-reports/>.
11. Utah Department of Health and Human Services Utah Public Health Laboratory. UPHL rabies test submission guidance [Internet]. 2023. Accessed November 22, 2024. <https://epi.health.utah.gov/wp-content/uploads/UPHL-Rabies-Specimen-Guidance-2023.pdf>.
12. Peterson D, Utah Department of Health Bureau of Epidemiology. Rabies Disease Plan [Internet]. Rabies: Utah Public Health Disease Investigation Plan. 2019:2–22. Accessed November 22, 2024. https://epi.health.utah.gov/wp-content/uploads/rabies_plan.pdf.
13. CDC. Cost of Rabies Prevention - Rabies [Internet]. Accessed November 3, 2024. <https://www.cdc.gov/rabies/location/usa/cost.html>.
14. Shwiff SA, Sterner RT, Jay MT, Parikh S, Bellomy A, Meltzer MI, et al. Direct and indirect costs of rabies exposure: a retrospective study in Southern California (1998–2002). *J Wildl Dis.* 2007;43(2):251–257. doi:10.7589/0090-3558-43.2.251. [PubMed: 17495309]
15. Public Health Reporting and National Notification for Animal Rabies [Internet]. 2010. Accessed November 10, 2024. <https://cdn.ymaws.com/www.cste.org/resource/resmgr/PS/09-ID-12.pdf>.
16. Centers for Disease Control and Prevention. Revision of the Surveillance Case Definition for Human Rabies [Internet]. Committee: Infectious Disease. 2010. Accessed November 10, 2024. <https://cdn.ymaws.com/www.cste.org/resource/resmgr/PS/10-ID-16.pdf>.
17. Council of State and Territorial Epidemiologists. Revision of public health reporting and timeframes for national notification for animal rabies [Internet]. 22-ID-06. Accessed November 10, 2024. https://cdn.ymaws.com/www.cste.org/resource/resmgr/ps/ps2022/22-ID-06_Animal_Rabies.pdf.
18. Nowacki A. Chi-square and Fisher's exact tests. *Cleve Clin J Med.* 2017;84(9 suppl 2):e20–5. doi:10.3949/ccjm.84.s2.04.
19. Liesener AL, Smith KE, Davis RD, Bender JB, Danila R, Neitzel DF, et al. Circumstances of bat encounters and knowledge of rabies among Minnesota residents submitting bats for rabies testing. *Vector Borne Zoonotic Dis.* 2006;6(2):208–215. doi:10.1089/vbz.2006.6.208. [PubMed: 16796518]
20. Peterson D, Barbeau B, McCaffrey K, Gruninger R, Eason J, Burnett C, et al. Human Rabies — Utah, 2018. *MMWR Morb Mortal Wkly Rep.* 2020;69(5):121–124. doi:10.15585/mmwr.mm6905a1 [PubMed: 32027626]
21. McNeil CS, Nagy S, Moonan C, Wallace RM, Vora NM, Dyer JL, et al. Community rabies knowledge and pet vaccination practices after a skunk rabies outbreak in Eddy County, New Mexico. *JAmVet Med Assoc.* 2015;246(11):1242–1247. doi:10.2460/javma.246.11.1242.
22. Palamar MB, Peterson MN, DePerno CS, Correa MT. Assessing rabies knowledge and perceptions among ethnic minorities in Greensboro, North Carolina. *J Wildl Manag.* 2013;77(7):1321–1326. doi:10.1002/jwmg.593.
23. Dato V, Campagnolo ER, Long J, Rupprecht CE. A systematic review of human bat rabies virus variant cases: evaluating unprotected physical contact with claws and teeth in support of accurate risk assessments. *PloS One.* 2016;11(7):e0159443. doi:10.1371/journal.pone.0159443. [PubMed: 27459720]
24. Kunkel A, Minhaj FS, Whitehill F, Austin C, Hahn C, Kieffer A, et al. Notes from the field: three human rabies deaths attributed to bat exposures — United States, August 2021. *MMWR Morb Mortal Wkly Rep.* 2022;71(1):31–32. doi:10.15585/mmwr.mm7101a5 [PubMed: 34990442]

25. Willis K, Green J, Daly J, Williamson L, Bandyopadhyay M. Perils and possibilities: achieving best evidence from focus groups in public health research. *Aust N Z J Public Health*. 2009;33(2):131–136. doi:10.1111/j.1753-6405.2009.00358.x. [PubMed: 19413855]
26. Kassié D, Randriafaraniaina V, Rakotoharinome V, Ravolatsara A. Local solutions towards rabies-related human mortality elimination by 2030 in the Menabe region (Madagascar). *Advances in Complementary & Alternative Medicine*. 2023;7(5):773–778. <https://crimsonpublishers.com/acam/pdf/ACAM.000677.pdf>.
27. Oertli EH, Wilson PJ, Hunt P, Sidwa TJ, Rohde RE. Epidemiology of rabies in skunks in Texas. *J Am Vet Med Assoc*. 2009;234(5):616–620. doi:10.2460/javma.234.5.616. [PubMed: 19250039]
28. Mayes B, Wilson PJ, Oertli EH, Hunt P, Rohde RE. Epidemiology of rabies in bats in Texas (2001–2010). *J Am Vet Med Assoc*. 2013;243(8):1129–1137. doi:10.2460/javma.243.8.1129. [PubMed: 24094260]

Implications for policy and practice

- Improving specimen submission quality, especially for bats, skunks, and raccoons, is critical for reducing unsuccessful tests and preventing unnecessary rabies post-exposure prophylaxis (PEP).
- Targeted training for local health departments, animal control, and private veterinarians on proper handling and submission of wildlife specimens is recommended.
- Efforts should focus on educating the public about rabies risks and to route submissions, especially for bats, through trained rabies responders.
- Focus groups with local health departments and animal control entities that have low unsuccessful test rates might reveal best practices that could be used to develop standardized protocols across jurisdictions, ultimately enhancing rabies response efforts.
- Strengthening collaboration among public health agencies, animal control, and other rabies responders could facilitate more consistent specimen quality and better public health outcomes.

TABLE 1.
Rates of unsuccessful rabies testing by frequently submitted animal type and submitter type, Utah, Jan 2014–Mar 2023.

	AC		LHD		LAB		VET		DWR		Citizen		Other/unknown		Row (Animal) Totals	
	% Unsuccessful (No)	(18 of 448)	% Unsuccessful (No)	(22 of 355)	% Unsuccessful (No)	(4 of 72)	% Unsuccessful (No)	(2 of 19)	% Unsuccessful (No)	(5 of 124)	% Unsuccessful (No)	(13 of 96)	% Unsuccessful (No)	(0 of 30)	% Unsuccessful (No)	(64 of 1144)
Bat	4.0%		6.2%		5.6%		10.5%		4.0%		13.5%		0%		5.6%	
Dog	0.3%	(1 of 342)	1.0%	(1 of 96)	2.5%	(2 of 81)	1.1%	(1 of 94)	0%	(0 of 1)	13.3%	(2 of 15)	0%	(0 of 2)	1.1%	(7 of 631)
Cat	1.6%	(5 of 317)	1.5%	(1 of 67)	3.9%	(3 of 76)	2.5%	(3 of 122)	0%	(0 of 1)	0%	(0 of 14)	0%	(0 of 1)	2.0%	(12 of 598)
Raccoon	7.4%	(11 of 148)	8.9%	(4 of 45)	0%	(0 of 18)	0%	(0 of 8)	6.7%	(1 of 15)	0%	(0 of 7)	20.0%	(1 of 5)	6.9%	(17 of 246)
Other	16.7%	(2 of 12)	0%	(0 of 8)	3.0%	(1 of 33)	0%	(0 of 2)	0%	(0 of 15)	11.1%	(1 of 9)	20.0%	(1 of 5)	6.0%	(5 of 84)
Skunk	10.8%	(4 of 37)	0%	(0 of 10)	0%	(0 of 2)	100%	(2 of 2)	0%	(0 of 2)	0%	(0 of 4)	0%	(0 of 1)	10.3%	(6 of 58)
Mink	0%	(0 of 9)	0%	(0 of 2)	0%	(0 of 1)	0%	(0 of 1)	0%	(0 of 2)	0%	(0 of 1)	100%	(1 of 1)	5.9%	(1 of 17)
Fox	16.7%	(1 of 6)	0%	(0 of 6)	0%	(0 of 2)	0%	(0 of 1)	0%	(0 of 0)	0%	(0 of 0)	0%	(0 of 0)	6.7%	(1 of 15)
Coyote	0%	(0 of 1)	0%	(0 of 6)	0%	(0 of 1)	0%	(0 of 0)	0%	(0 of 3)	0%	(0 of 2)	0%	(0 of 0)	0%	(0 of 13)
Column (Submitter) Totals	3.2%	(42 of 1320)	4.7%	(28 of 595)	3.5%	(10 of 286)	3.2%	(8 of 249)	3.7%	(6 of 163)	10.8%	(16 of 148)	6.7%	(3 of 45)	4.0%	(113 of 2806)

We categorized all bat species into a single “bat” animal type. All other animals were grouped into the “other” animal type, which included the following species: cow, ferret, gopher, llama, marmot, otter, ringtail, badger, beaver, deer, prairie dog, rat, weasel, bear, rabbit, mouse, muskrat, vole, horse, squirrel, bobcat, cougar, and unknown. Bolded spaces designate column and row totals. Abbreviations: AC, animal control/shelter; LHD, local health department; LAB, diagnostic laboratories; VET, private veterinarians; DWR, Division of Wildlife Resources.

TABLE 2.

Bivariate analyses of unsuccessful rabies testing within animal groups, stratified by submitter type, Utah, Jan 2014–Mar 2023.

Submitter Type	Animal Group		
	Domestic (n = 1226)	Bat (n = 1114)	Non-bat wildlife (n = 342)
<i>Citizen (n = 139)</i>	6.9% (2 of 29)	13.5% (13 of 96)	0% (0 of 14)
AC (n = 1308)	0.9% (6 of 659) p-value = 0.04	4.0% (18 of 448) p-value <0.001	8.0% (16 of 201) p-value = 0.61
LHD (n = 587)	1.2% (2 of 163) p-value = 0.11	6.2% (22 of 355) p-value = 0.03	5.8% (4 of 69) p-value = 1
LAB (n = 253)	3.2% (5 of 157) p-value = 0.3	5.6% (4 of 72) p-value = 0.15	0% (0 of 24) p-value = 1
VET (n = 247)	1.9% (4 of 216) p-value = 0.15	10.5% (2 of 19) p-value = 1	16.7% (2 of 12) p-value = 0.2
DWR (n = 148)	0% (0 of 2) p-value = 1	4.0% (5 of 124) p-value = 0.02	4.5% (1 of 22) p-value = 1

The citizen submitter type (italicized) was used as the comparison group for each bivariate analysis. Bolded values indicate a significant difference in the proportion of unsuccessful tests between the citizen submitter type and the comparison submitter type. Abbreviations: AC, animal control/shelter; LHD, local health department; LAB, diagnostic laboratories; VET, private veterinarians; DWR, Division of Wildlife Resources.

TABLE 3
Bivariate analyses of unsuccessful rabies testing within submitter types, stratified by animal group, Utah, Jan 2014–Mar 2023.

Animal Group	Submitter Type					
	AC (n = 1308)	LHD (n = 587)	LAB (n = 253)	VET (n = 247)	DWR (n = 148)	Citizen (n = 139)
<i>Domestic (n = 1226)</i>	0.9% (6 of 659)	1.2% (2 of 163)	3.2% (5 of 157)	1.9% (4 of 216)	0% (0 of 2)	6.9% (2 of 29)
Bat (n = 1114)	4.0% (18 of 448)	6.2% (22 of 355)	5.6% (4 of 72)	10.5% (2 of 19)	4.0% (5 of 124)	13.5% (13 of 96)
	p-value = 0.001	p-value = 0.02	p-value = 0.47	p-value = 0.08	p-value = 1	p-value = 0.52
Non-bat wildlife (n = 342)	8.0% (16 of 201)	5.8% (4 of 69)	0% (0 of 24)	16.7% (2 of 12)	4.5% (1 of 22)	0% (0 of 14)
	p-value <0.001	p-value = 0.07	p-value = 1	p-value = 0.03	p-value = 1	p-value = 1

The domestic animal group (*italicized*) was used as the comparison group for each bivariate analysis. **Bolded** values indicate a significant difference in the proportion of test cancellations between the domestic animal group and the comparison animal group. *Abbreviations:* AC animal control/shelter, LHD local health department, LAB diagnostic laboratories, VET private veterinarians, DWR Division of Wildlife Resources.