

Analysis of the Current Status of Injuries Caused by Dog-Related Animals in the Taihu Lake Region: A Quality Assessment of Post-Exposure Prophylaxis in 40,222 Cases (2023–2025) and Implications for Rabies-Free Areas

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Abstract

Background The Taihu Lake region, one of the most urbanized areas in the Yangtze River Delta, experiences a high prevalence of dog, cat, and other animal-related injuries but has reported no indigenous human rabies cases for many years. Against the backdrop of a resurgence of rabies cases in China during 2024–2025, any implicit decline in the quality of post-exposure prophylaxis (PEP) in zero-case areas would become a weak link that could ignite a resurgence of the epidemic. This study aimed to evaluate the quality of first-visit PEP for injuries caused by dog-related animals in the Taihu Lake region, reveal the risk of “prevention fatigue”—a silent decline in PEP quality in rabies-free areas—and propose targeted intervention strategies.

Methods We retrospectively included 40,222 first-visit cases of injuries caused by dog-related animals at our hospital from January 2023 to December 2025. The outcomes of interest were non-use of passive immunization in grade III exposures, failure of standard first-visit care, and delayed presentation. Multivariable logistic regression was used to examine the associations, and key interaction effects were tested.

Results Grade III exposures accounted for 60.5% (24,322/40,222) of all cases. Among these, the passive immunization rate was 55.5%, and the standard first-visit care rate was only 45.3%. Young adults (15–44 years, aOR=2.17), patients with scratches (vs. bites, aOR=1.20), and those with delayed presentation (aOR=1.49) constituted three overlapping high-risk groups. Interaction analysis revealed significant interactions for age group × injury type ($P<0.001$), animal × delayed presentation ($P<0.001$), and exposure site × delayed presentation ($P=0.019$), whereas the injury type × delayed presentation interaction was not significant ($P=0.179$). From 2023 to 2025, the passive immunization rate of grade III exposures increased from 52.8% to 60.1%, the standard first-visit care rate rose from 44.5% to 48.4%, and the delayed presentation rate declined from 37.9% to 31.9%, suggesting that systematic quality improvement has begun to reverse the trend of prevention fatigue.

Conclusions Prevention fatigue in rabies-free areas represents a real public health risk. There is still considerable room for improvement in the quality of first-visit PEP for injuries caused by dog-related animals. Young adults, patients with scratches, and those with delayed presentation constitute three overlapping protection gaps. We recommend that the passive immunization rate and the standard first-visit care rate be adopted as sentinel indicators of PEP quality in rabies-free areas, incorporated into routine evaluations by regional treatment training centers, and that differentiated intervention strategies be developed according to age, injury type, and season. Only by continuously identifying and closing every protection gap beneath the surface of a “rabies-free” status can the trend of prevention fatigue be gradually reversed.

Background

Rabies is a zoonotic infectious disease caused by the rabies virus, accounting for approximately 59,000 human deaths annually across more than 150 countries worldwide. Historically, China ranked second

globally in human rabies deaths, with a peak of 3,300 reported fatalities in 2007[1]. Through sustained efforts in dog management and the widespread availability of post-exposure prophylaxis, however, the annual number of cases in China has since declined dramatically, falling to a historic low of 122 in 2023. Unexpectedly, this downward trend was reversed in 2024: China reported 170 cases, an increase of approximately 39% compared with 2023—the first rebound in 17 years. The epidemic further expanded in 2025, with approximately 248 cases reported for the full year, representing an additional increase of about 48.5% over 2024[2]. The China CDC analysis noted that this resurgence was attributable to inadequate implementation of prevention measures, insufficient canine immunization coverage in rural communities, and diminished public awareness of rabies prevention strategies [3]. These three factors are precisely those most likely to accumulate silently in areas that have been free of cases for extended periods, thereby posing the greatest obstacle to the “last mile” of rabies elimination..

Clearly, there is still a long way to go to achieve the World Health Organization (WHO) global strategic goal of “zero human deaths from dog-mediated rabies by 2030[4].”

Standard post exposure prophylaxis (PEP) consists of thorough wound care, a full course of rabies vaccination, and, for category III exposures, passive immunization with rabies immunoglobulin (RIG) or a monoclonal antibody (mAb). When delivered appropriately, this regimen is virtually 100% effective in preventing the development of clinical rabies[5]. Nevertheless, the implementation of these measures is inevitably influenced by socioeconomic factors, including the exposed individual's awareness of rabies, access to healthcare, financial capacity, and treatment adherence.

The Taihu Lake region encompasses the core urban centers of the Yangtze River Delta, including Suzhou, Wuxi, and Changzhou. The area is economically developed, with widespread pet ownership and high healthcare accessibility; it also experiences a high frequency of injuries caused by dog-related animals. No indigenous human rabies case has been reported there for over a decade—a de facto elimination status. But does “zero cases” truly mean “zero risk”? Without the steady reminder of fatal cases, both healthcare workers and the public may become systematically less vigilant toward animal bites and scratches. Key PEP steps may then begin to erode, especially thorough wound care and timely passive immunization at the first visit[6].

Wuxi No.8 People's Hospital serves as a core animal injury treatment center in the Taihu Lake region, managing over 10,000 cases each year. Many of these involve grade III severe exposures or complex wounds referred from other hospitals. As the regional PEP service network has expanded, our routine surveillance data show that patient visits have been steadily redistributed, and the number seen at our hospital has progressively declined. Yet it is unclear whether the quality of standard first-visit care has kept pace with these shifts—systematic evidence remains absent. Against the backdrop of the rabies resurgence in China, this study retrospectively analyzed 40,222 first-visit cases of injuries caused by dog-related animals from 2023 to 2025, aiming to: (1) evaluate key PEP indicators—passive immunization rate, standard first-visit care rate, and delayed presentation rate; (2) identify high-risk populations and their interactions; (3) verify whether systematic quality improvement can reverse

prevention fatigue; (4) propose sentinel indicators and intervention strategies for maintaining elimination status in rabies-free areas.

Methods

Study design and population

This study adopted a retrospective cross-sectional design and was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline. The protocol was approved by the Ethics Committee of Wuxi No.8 People's Hospital (Southern Jiangsu Animal Injury Treatment Training Center) (Approval No.: (2026) Y-18). The requirement for informed consent was waived owing to the retrospective and anonymized nature of the data.

We enrolled all first-visit patients presenting to Wuxi No.8 People's Hospital between 1 January 2023 and 31 December 2025 with injuries caused by dog-related animals, including bites, scratches, or other injury types such as mucosal contamination.

Exclusion criteria were as follows:

- (1) Cases with only outpatient consultation without any clinical intervention;
- (2) Cases with a prior complete course of rabies vaccination;
- (3) Cases lacking tetanus vaccination or tetanus passive immunization;
- (4) Cases with over 30% missing values in core variables such as age, sex, and exposure grade.

A total of 40,222 first-visit cases were included in the final analysis.

Data source and variable definitions

Data were retrieved from the standardized electronic registration system of the rabies exposure prophylaxis clinic at Wuxi No.8 People's Hospital.

Demographic and temporal variables

Sex: male, female

Age group: 0–14 years (children), 15–44 years (young adults), 45–64 years (middle-aged adults), ≥65 years (older adults)

Visit year: 2023, 2024, 2025

Season: spring (March–May), summer (June–August), autumn (September–November), winter (December–February)

Exposure characteristics

Animal species: dog, cat, other

Injury type: scratch, bite, other

Exposure site: head/face, upper limb, lower limb, trunk, other

Exposure grade: Grade I, II, III. Grading was based on the WHO Expert Consultation on Rabies (Third Report, TRS 1012) and the National Regulation for Rabies Exposure Prophylaxis (2023 edition) [5,7].

Animal source: domestic, stray/wild, other

First-visit care quality indicators (outcome variables)

Wound care: thorough irrigation and disinfection of exposure wounds (yes/no)

Passive immunization: administration of RIG or mAb for Grade III exposures. Since the two preparations are clinically interchangeable, they were combined and uniformly defined as passive immunization [8].

Standard first-visit care: Grade III exposures satisfying both wound care and timely passive immunization (yes/no)

Delayed presentation: interval from injury to hospital visit >6 hours

Supplementary variable explanations

The standard five-dose rabies vaccination regimen requires multiple hospital visits. As subsequent doses may be completed at other medical institutions, a single-center database cannot fully verify full-course vaccination status. This study therefore focused on evaluating first-visit care quality and did not assess full vaccination completion.

The variable of wound number had a missing rate of 62.7% in the registration system and was excluded from further analysis.

Only 29 grade I exposure cases were recorded. These cases were assessed as grade I by clinicians according to current guidelines and therefore had no indication for PEP. Nevertheless, the patients requested rabies vaccination out of safety concerns. Because the number was limited, these cases were combined with grade II exposures for statistical analysis but separately documented to reflect real-world healthcare-seeking behavior.

Statistical Analysis

Continuous variables are presented as medians (IQR), and categorical variables as counts (percentages). We compared groups using the Mann–Whitney U test or χ^2 test. We used multivariable

logistic regression to estimate adjusted odds ratios (aOR) and 95% confidence intervals (CI), adjusting for sex, age group, season, animal species, exposure site, injury type, animal source, delayed presentation, exposure grade, and study year. Four interaction terms—injury type × delayed presentation, age group × injury type, animal species × delayed presentation, and exposure site × delayed presentation—were assessed by likelihood ratio tests. All analyses used Python 3.12 (statsmodels v0.14.6), and a two-sided $P < 0.05$ was taken as statistically significant.

Results

Basic Characteristics of the Study Population

A total of 40,222 first-visit cases were included, of which 60.5% ($n = 24,322$) were grade III. The median age was 31 years (IQR 18–46), and females slightly outnumbered males (54.2% vs. 45.8%). Cats accounted for 56.2% of injuries, and scratches and bites occurred in nearly equal proportions. Wound care was completed in 82.4% of cases, yet the overall rate of passive immunization was only 36.0%, and even among grade III exposures it reached just 55.5%. More than one-third of patients (35.3%) presented more than 6 hours after injury. Compared with grade II, grade III exposures involved more cat injuries (59.1% vs. 51.8%), head/facial injuries (6.4% vs. 2.7%), and stray/wild animal contact (22.5% vs. 18.5%), but a lower proportion of delayed presentation (32.2% vs. 40.0%); all differences were statistically significant (all $P < 0.001$) (Table 1).

Table 1. Baseline characteristics by exposure grade

Variable	Category	Total (N=40222)	Grade II (incl. I) (N=15900)	Grade III (N=24322)	Statistic	P
Age, Median (Q1,Q3)		31 (18, 46)	30 (13, 44)	32 (20, 48)	$z = -14.494$	<0.001
Sex	Female	21815 (54.2%)	8927 (56.1%)	12888 (53.0%)	$\chi^2 = 38.446$	<0.001
	Male	18407 (45.8%)	6973 (43.9%)	11434 (47.0%)		
Age group	15–44	20660 (51.4%)	7731 (48.6%)	12929 (53.2%)	$\chi^2 = 491.871$	<0.001
	0–14	8613 (21.4%)	4248 (26.7%)	4365 (17.9%)		
	45–64	8230 (20.5%)	3095 (19.5%)	5135 (21.1%)		
	≥65	2719 (6.8%)	826 (5.2%)	1893 (7.8%)		
Season	Summer	12630 (31.4%)	5375 (33.8%)	7255 (29.8%)	$\chi^2 = 275.045$	<0.001
	Spring	10418 (25.9%)	4530 (28.5%)	5888 (24.2%)		
	Autumn	9726 (24.2%)	3324 (20.9%)	6402 (26.3%)		
	Winter	7448 (18.5%)	2671 (16.8%)	4777 (19.6%)		
Animal	Cat	22618 (56.2%)	8234 (51.8%)	14384 (59.1%)	$\chi^2 = 357.799$	<0.001
	Dog	16860 (41.9%)	7500 (47.2%)	9360 (38.5%)		
	Other	744 (1.8%)	166 (1.0%)	578 (2.4%)		
Injury type	Bite	20104 (50.0%)	6920 (43.5%)	13184 (54.2%)	$\chi^2 = 466.693$	<0.001
	Scratch	19691 (49.0%)	8842 (55.6%)	10849 (44.6%)		
	Other	427 (1.1%)	138 (0.9%)	289 (1.2%)		
Exposure site	Upper limb	26787 (66.6%)	9441 (59.4%)	17346 (71.3%)	$\chi^2 = 1342.302$	<0.001
	Lower limb	8057 (20.0%)	4363 (27.4%)	3694 (15.2%)		

	Other	2526 (6.3%)	1195 (7.5%)	1331 (5.5%)		
	Head/Face	1979 (4.9%)	425 (2.7%)	1554 (6.4%)		
	Trunk	873 (2.2%)	476 (3.0%)	397 (1.6%)		
Animal source	Domestic	31401 (78.1%)	12799 (80.5%)	18602 (76.5%)	$\chi^2 = 91.929$	<0.001
	Stray/Wild	8421 (20.9%)	2949 (18.5%)	5472 (22.5%)		
	Unknown	400 (1.0%)	152 (1.0%)	248 (1.0%)		
Wound care	Yes	33148 (82.4%)	12736 (80.1%)	20412 (83.9%)	$\chi^2 = 96.706$	<0.001
	No	7074 (17.6%)	3164 (19.9%)	3910 (16.1%)		
Passive immunization (RIG/mAb)	No	25722 (64.0%)	14908 (93.8%)	10814 (44.5%)	$\chi^2 = 10133.874$	<0.001
	Yes	14500 (36.0%)	992 (6.2%)	13508 (55.5%)		
Delayed presentation (>6h)	No	26025 (64.7%)	9536 (60.0%)	16489 (67.8%)	$\chi^2 = 257.087$	<0.001
	Yes	14197 (35.3%)	6364 (40.0%)	7833 (32.2%)		

Grade I exposures (n=29) were combined with grade II exposures for analysis.

Annual and seasonal trends

Over the three years, annual visits dropped from 16,421 to 11,438, a decline of 30.3%. Passive immunization use rose steadily from 29.0% to 46.0%, while delayed presentation fell from 37.9% to 31.9% (both $P < 0.001$). Wound care completion remained largely unchanged, ranging between 81.5% and 83.3%. Injuries caused by cats declined from 57.6% to 53.9%, and those caused by dogs rose from 40.6% to 44.2% ($P < 0.001$). Scratches decreased from 50.0% to 46.7%, while bites increased from 49.0% to 52.1% ($P < 0.001$). Sex, age group, and exposure site distributions shifted as well, but only modestly (Table 2).

Seasonal fluctuations in monthly visits persisted across the three years, with a clear summer peak and winter trough each year, although the magnitude of the summer peak diminished with each successive year (Figure 1). Quality indicators for grade III exposures moved in the right direction: passive immunization use climbed from 52.8% to 60.1%, and standard first-visit care rose from 44.5% to 48.4%.

Yet the upward path was not uniform—standard first-visit care dipped to 42.8% in 2024 before recovering in 2025 (Figure 2).

Table 2. Annual trends (2023–2025)

Variable	Category	2023 (N=16421)	2024 (N=12363)	2025 (N=11438)	Statistic	P
Sex	Female	8909 (54.3%)	6669 (53.9%)	6237 (54.5%)	$\chi^2 = 0.824$	0.662
	Male	7512 (45.7%)	5694 (46.1%)	5201 (45.5%)		
Age group	0–14	3356 (20.4%)	2673 (21.6%)	2584 (22.6%)	$\chi^2 = 21.296$	0.002
	15–44	8561 (52.1%)	6330 (51.2%)	5769 (50.4%)		
	45–64	3414 (20.8%)	2520 (20.4%)	2296 (20.1%)		
	≥65	1090 (6.6%)	840 (6.8%)	789 (6.9%)		
Season	Autumn	4034 (24.6%)	2859 (23.1%)	2833 (24.8%)	$\chi^2 = 89.732$	<0.001
	Spring	4178 (25.4%)	3292 (26.6%)	2948 (25.8%)		
	Summer	5454 (33.2%)	3797 (30.7%)	3379 (29.5%)		
	Winter	2755 (16.8%)	2415 (19.5%)	2278 (19.9%)		
Animal	Cat	9455 (57.6%)	6993 (56.6%)	6170 (53.9%)	$\chi^2 = 37.925$	<0.001
	Dog	6672 (40.6%)	5133 (41.5%)	5055 (44.2%)		
	Other	294 (1.8%)	237 (1.9%)	213 (1.9%)		
Injury type	Bite	8043 (49.0%)	6106 (49.4%)	5955 (52.1%)	$\chi^2 = 34.719$	<0.001
	Other	165 (1.0%)	122 (1.0%)	140 (1.2%)		
	Scratch	8213 (50.0%)	6135 (49.6%)	5343 (46.7%)		
Exposure site	Head/Face	814 (5.0%)	595 (4.8%)	570 (5.0%)	$\chi^2 = 7.894$	0.444
	Lower limb	3247 (19.8%)	2459 (19.9%)	2351 (20.6%)		
	Other	1044 (6.4%)	812 (6.6%)	670 (5.9%)		
	Trunk	359 (2.2%)	264 (2.1%)	250 (2.2%)		

	Upper limb	10957 (66.7%)	8233 (66.6%)	7597 (66.4%)		
Animal source	Domestic	13237 (80.6%)	9579 (77.5%)	8585 (75.1%)	$\chi^2 =$ 180.026	<0.001
	Stray/Wild	3095 (18.8%)	2664 (21.5%)	2662 (23.3%)		
	Unknown	89 (0.5%)	120 (1.0%)	191 (1.7%)		
Wound care	No	2745 (16.7%)	2292 (18.5%)	2037 (17.8%)	$\chi^2 =$ 16.710	<0.001
	Yes	13676 (83.3%)	10071 (81.5%)	9401 (82.2%)		
Passive immunization	No	11654 (71.0%)	7886 (63.8%)	6182 (54.0%)	$\chi^2 =$ 837.642	<0.001
	Yes	4767 (29.0%)	4477 (36.2%)	5256 (46.0%)		
Delayed presentation (>6h)	No	10201 (62.1%)	8030 (65.0%)	7794 (68.1%)	$\chi^2 =$ 107.452	<0.001
	Yes	6220 (37.9%)	4333 (35.0%)	3644 (31.9%)		

Risk factors for non-use of passive immunization

Multivariable logistic regression analysis showed that, among the 24,322 cases with grade III exposures, Male (aOR = 1.11, 95% CI: 1.06–1.17, $P < 0.001$), age groups 15–44 years (aOR = 2.17, 2.01–2.34), 45–64 years (aOR = 2.12, 1.94–2.32), and ≥ 65 years (aOR = 1.71, 1.52–1.92), injury type Other (aOR = 1.58, 1.23–2.03), and delayed presentation > 6 h (aOR = 1.49, 1.41–1.58) were associated with higher odds of non-use of passive immunization. In contrast, Bite (aOR = 0.83, 0.78–0.89), Winter (aOR = 0.86, 0.80–0.94), Dog (aOR = 0.44, 0.34–0.55), Cat (aOR = 0.47, 0.37–0.60), Lower limb (aOR = 0.68, 0.63–0.74), Head/Face (aOR = 0.83, 0.74–0.93), Stray/Wild (aOR = 0.66, 0.50–0.86), and year 2025 (aOR = 0.81, 0.76–0.87) were associated with lower odds (all $P < 0.05$). No statistically significant differences were observed for Summer, Autumn, Trunk, Other exposure sites, Domestic, or the year 2024 compared with their respective reference categories ($P > 0.05$). (Table 3)

Table 3. Risk factors for non-use of passive immunization (Grade III, N=24,322)

Variable	Category	aOR (95% CI)	P
Sex	Female	1 (Reference)	–
	Male	1.11 (1.06–1.17)	<0.001
Age group	0–14	1 (Reference)	–
	15–44	2.17 (2.01–2.34)	<0.001
	45–64	2.12 (1.94–2.32)	<0.001
	≥65	1.71 (1.52–1.92)	<0.001
Season	Spring	1 (Reference)	–
	Summer	1.04 (0.97–1.12)	0.298
	Autumn	0.94 (0.87–1.01)	0.088
	Winter	0.86 (0.80–0.94)	<0.001
Animal	Other	1 (Reference)	–
	Dog	0.44 (0.34–0.55)	<0.001
	Cat	0.47 (0.37–0.60)	<0.001
Exposure site	Upper limb	1 (Reference)	–
	Lower limb	0.68 (0.63–0.74)	<0.001
	Head/Face	0.83 (0.74–0.93)	0.001
	Trunk	0.88 (0.72–1.09)	0.241
	Other	0.93 (0.83–1.04)	0.191
Injury type	Scratch	1 (Reference)	–
	Bite	0.83 (0.78–0.89)	<0.001
	Other	1.58 (1.23–2.03)	<0.001
Animal source	Other	1 (Reference)	–
	Domestic	1.10 (0.85–1.42)	0.489
	Stray/Wild	0.66 (0.50–0.86)	0.002
Delayed presentation	≤6 h	1 (Reference)	–
	>6 h	1.49 (1.41–1.58)	<0.001
Year	2023	1 (Reference)	–
	2024	1.05 (0.98–1.12)	0.179

2025	0.81 (0.76–0.87)	<0.001
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Risk factors for failure of standard first-visit care

Multivariable logistic regression identified age 15–44 years (aOR=1.71, 95%CI 1.59–1.84), age 45–64 years (aOR=1.71, 95%CI 1.57–1.86), and age ≥65 years (aOR=1.65, 95%CI 1.47–1.85) as independent risk factors for failure of first-visit care (all P<0.001). Males had a slightly higher risk than females (aOR=1.13, 95%CI 1.07–1.19, P<0.001). Summer exposures carried a 10% higher failure risk than spring exposures (aOR=1.10, 95%CI 1.02–1.18, P=0.008). Delayed presentation increased the risk by 24% (aOR=1.24, 95%CI 1.18–1.32, P<0.001). With scratch as the reference, bites were associated with a lower risk of failure (aOR=0.89, 95%CI 0.83–0.95, P<0.001). Compared with 2023, the risk of failure was 10% higher in 2024 (aOR=1.10, 95%CI 1.03–1.18, P=0.003) and 10% lower in 2025 (aOR=0.90, 95%CI 0.84–0.96, P=0.001) (Table 4).

Table 4. Risk factors for failure of standard first-visit care (Grade III, N=24322)

Variable	Category	aOR (95% CI)	P
Sex	Female	1 (Reference)	–
	Male	1.13 (1.07–1.19)	<0.001
Age group	0-14	1 (Reference)	–
	15-44	1.71 (1.59–1.84)	<0.001
	45-64	1.71 (1.57–1.86)	<0.001
	≥65	1.65 (1.47–1.85)	<0.001
Season	Spring	1 (Reference)	–
	Summer	1.10 (1.02–1.18)	0.008
	Autumn	0.96 (0.90–1.04)	0.325
	Winter	1.02 (0.94–1.10)	0.680
Animal	Other	1 (Reference)	–
	Dog	0.59 (0.49–0.70)	<0.001
	Cat	0.59 (0.49–0.70)	<0.001
Exposure site	Upper limb	1 (Reference)	–
	Lower limb	1.02 (0.95–1.10)	0.598
	Head/Face	1.15 (1.03–1.29)	0.010
	Trunk	1.21 (0.98–1.48)	0.075
	Other	1.17 (1.04–1.31)	0.009
Injury type	Scratch	1 (Reference)	–
	Bite	0.89 (0.83–0.95)	<0.001
	Other	1.35 (1.05–1.74)	0.021
Animal source	Other	1 (Reference)	–
	Domestic	0.91 (0.70–1.18)	0.468
	Stray/Wild	0.61 (0.47–0.80)	<0.001
Delayed presentation	≤6 h	1 (Reference)	–
	>6 h	1.24 (1.18–1.32)	<0.001
Year	2023	1 (Reference)	–
	2024	1.10 (1.03–1.18)	0.003

2025	0.90 (0.84–0.96)	0.001
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Risk factors for delayed presentation (>6 h)

Multivariable logistic regression identified 15–44 years as the strongest risk factor for delayed presentation (aOR=1.79, 95%CI 1.69–1.89), followed by 45–64 years (aOR=1.65, 95%CI 1.54–1.77) and ≥65 years (aOR=1.35, 95%CI 1.22–1.49; all P<0.001). Winter carried a 21% higher risk of delay than spring (aOR=1.21, 95%CI 1.14–1.29, P<0.001). Compared with scratches, bites were associated with a lower risk of delay (aOR=0.73, 95%CI 0.69–0.76, P<0.001). Grade III exposures had a 32% lower risk of delay than grade II exposures (aOR=0.68, 95%CI 0.65–0.71, P<0.001). Injuries caused by dogs were associated with a lower delay risk than those caused by other animals (aOR=0.55, 95%CI 0.47–0.65, P<0.001). Compared with 2023, the risk of delayed presentation was 10% lower in 2025 (aOR=0.90, 95%CI 0.86–0.95, P<0.001) (Table 5).

Table 5. Risk factors for delayed presentation (>6 h) (All cases, N=40222)

Variable	Category	aOR (95% CI)	P
Sex	Female	1 (Reference)	–
	Male	1.03 (0.99–1.07)	0.198
Age group	0-14	1 (Reference)	–
	15-44	1.79 (1.69–1.89)	<0.001
	45-64	1.65 (1.54–1.77)	<0.001
	≥65	1.35 (1.22–1.49)	<0.001
Season	Spring	1 (Reference)	–
	Summer	1.05 (1.00–1.11)	0.066
	Autumn	1.07 (1.01–1.14)	0.023
	Winter	1.21 (1.14–1.29)	<0.001
Animal	Other	1 (Reference)	–
	Dog	0.55 (0.47–0.65)	<0.001
	Cat	0.79 (0.68–0.93)	0.005
Exposure site	Upper limb	1 (Reference)	–
	Lower limb	0.81 (0.77–0.86)	<0.001
	Head/Face	0.91 (0.82–1.00)	0.055
	Trunk	0.95 (0.82–1.09)	0.455
	Other	1.03 (0.94–1.12)	0.547
Injury type	Scratch	1 (Reference)	–
	Bite	0.73 (0.69–0.76)	<0.001
	Other	2.08 (1.70–2.54)	<0.001
Exposure grade	Grade II	1 (Reference)	–
	Grade III	0.68 (0.65–0.71)	<0.001
Animal source	Other	1 (Reference)	–
	Domestic	0.93 (0.75–1.14)	0.478
	Stray/Wild	0.57 (0.46–0.71)	<0.001
Year	2023	1 (Reference)	–
	2024	0.98 (0.93–1.03)	0.464

2025	0.90 (0.86–0.95)	<0.001
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Interaction effects

The interaction between injury type and delayed presentation did not reach statistical significance (Figure 3, $P=0.179$). Regardless of whether presentation was delayed, bite carried a lower risk of non-use of passive immunization than scratch (non-delayed: $OR=0.80$, 95%CI 0.76–0.84; delayed: $OR=0.87$, 95%CI 0.81–0.94). Other injury types did not differ from scratch.

The interaction between age group and injury type was significant (Figure 4, $P<0.001$). Bite was associated with a lower risk than scratch across all age groups: 0–14 years ($OR=1.06$, 95%CI 0.97–1.16), 15–44 years ($OR=0.73$, 95%CI 0.69–0.77), 45–64 years ($OR=0.66$, 95%CI 0.60–0.73), and ≥ 65 years ($OR=0.65$, 95%CI 0.54–0.77). Among those aged ≥ 65 years, other injury types showed an elevated risk ($OR=5.19$, 95%CI 0.66–40.78), but the confidence interval was wide and the estimate should be interpreted with caution.

The interaction between animal species and delayed presentation was significant (Figure 5, $P<0.001$). Without delayed presentation, Dog and Cat did not differ meaningfully (Dog: $OR=1.03$, 95%CI 0.85–1.24; Cat: $OR=0.86$, 95%CI 0.71–1.03). When presentation was delayed, however, the risk rose substantially for Dog ($OR=1.83$, 95%CI 1.42–2.38) and modestly for Cat ($OR=1.28$, 95%CI 1.00–1.66).

The interaction between exposure site and delayed presentation was observed (Figure 6, $P=0.019$). Head/Face consistently carried the lowest risk (non-delayed: $OR=0.45$, 95%CI 0.40–0.50; delayed: $OR=0.36$, 95%CI 0.30–0.42), whereas Trunk and Other carried the highest risk (non-delayed: $OR=1.75$ and 1.45; delayed: $OR=1.73$ and 1.55). Delay did not increase risk for Head/Face injuries but modestly elevated the risk for limb and truncal exposures.

Discussion

During the three years of the rabies resurgence in China, the Taihu Lake region remained free of indigenous cases, yet among grade III exposures the passive immunization rate was only 55.5% and standard first-visit care just 45.3%. Young adults, patients with scratches, and those who delayed presentation overlapped substantially, forming three converging protection gaps.

This finding provides quantitative evidence from a zero-case region in China for the “last-mile” challenges in rabies elimination reviewed by Hampson et al.—particularly the risk that public awareness and clinical alertness may fade when cases disappear [9]. The standard first-visit care rate in this region, which remained consistently below 50%, mirrors at the micro-level the nationwide erosion of prevention awareness noted during the resurgence [3].

Young adults stood out as the most prominent high-risk group across all three outcomes: they were more than twice as likely as children to miss passive immunization and nearly 80% more likely to delay

seeking care. Lu et al. reported the same pattern in Shenzhen, where adults aged 31–40 years had the lowest full-course vaccination completion rate—driven by high mobility, time constraints, and low self-perceived risk [10]. Our interaction analyses further showed that young adults had the highest rate of passive immunization non-use after scratch injuries. Because young adults constitute the majority of China's urban migrant workforce, these results support cross-clinic vaccination policies and reminder systems tailored to this population.

This study is among the first to quantify the “scratch underestimation effect” using multivariable regression: among grade III exposures, scratch injuries carried a 20% higher risk of passive immunization non-use and a 47% higher risk of delayed presentation than bites. A 2024 analysis of nearly 10,000 cases from Sandun Town, Hangzhou, similarly found that cat scratches accounted for 59.9% of injuries but the RIG administration rate was only 7.7%, highlighting the systematic underestimation of scratch injuries in clinical practice [11]. The national resurgence analysis by Chen et al. noted that approximately 5% of rabies cases were caused by cats, whose scratches, being superficial, are more easily dismissed—a cognitive bias that extends well beyond any single institution [2]. When scratch and delayed presentation coincide, this bias is further amplified, creating the highest-risk combination for passive immunization non-use.

Delayed presentation increased the risk of passive immunization non-use by 49% (aOR=1.49) and the risk of failure of standard first-visit care by 24% (aOR=1.24). The risk of delay was 21% higher in winter than in spring (aOR=1.21), a seasonal pattern consistent with studies from Iran and parts of India—where cold weather impedes travel and heavy clothing conceals wounds, delaying adequate initial assessment [12,13]. Conversely, grade III exposures carried a 34% lower risk of delay than grade II exposures (aOR=0.66), suggesting that more severe injuries prompt earlier care-seeking.

PEP visits clustered heavily in summer and dropped sharply in winter, with the summer months accounting for 31.4% of all visits and winter only 18.5%. This mirrors what has been reported in single-center studies across China—peaks in the warm season, troughs in the cold [14]. Across the three years, the summer peak softened (33.2% in 2023, 30.7% in 2024, and 29.5% in 2025), and the winter share crept upward (16.8% in 2023, 19.5% in 2024, and 19.9% in 2025). Whether this “peak-flattening, trough-rising” shift reflects better public awareness in summer or more pets being kept indoors [15] remains an open question. Of note, standard first-visit care failed more often in summer than in spring (aOR 1.10), likely because quality of care slipped when patient volumes peaked. These seasonal rhythms point to two concrete windows for action: stockpile passive immunization products and adjust staffing by the end of April to handle the summer surge, and launch community campaigns each November urging people to seek care promptly, so that the exposure-to-visit interval shortens during the winter months [16].

Interaction analysis between animal species and delayed presentation revealed a counter-intuitive pattern. Without delay, Dog and Cat did not differ meaningfully in passive immunization non-use. Once presentation was delayed, however, the risk for Dog surged (OR 1.83), far outstripping the rise for Cat

(OR 1.28). This suggests that although dog bites initially command greater concern, the likelihood of forgoing passive immunization increases disproportionately once the immediate treatment window is missed. Regarding animal source, passive immunization use was higher among patients injured by stray or wild animals (aOR 0.66), reflecting a stronger risk consensus between clinicians and patients toward “animals of unknown origin.”

As a regional treatment and training center, our hospital saw grade III exposures account for 60.5% of all cases, well above the 40%–50% reported by general rabies clinics [17,18,19]. This figure reflects both the concentration of severe cases at regional centers and the gravity of the problem: even in our center, nearly half of the most severely injured patients did not receive standard protection. Primary-care clinics are unlikely to fare better. By comparison, studies from other regions in China have reported passive immunization rates among grade III exposures as low as 5.8%–21.9%, with national surveillance data averaging only about 15% [20,21]. Similar gaps exist elsewhere. As early as 2017, Venkatesan et al. observed in rural India that 67% of grade III wounds were treated with only 4% receiving immunoglobulins [22]. A recent study on rabies post-exposure prophylaxis in Delhi reported that only 26.9% of grade III dog bite cases received RIG or mAb [23]. Although the 55.5% rate at our center is substantially higher than these figures, the gradient itself underscores that the substantial gap in PEP quality is not unique to China—even at a relatively high-quality regional center, more than 40% of severe exposures remained incompletely protected.

Despite the overall suboptimal quality, multiple indicators improved substantially from 2023 to 2025. The passive immunization rate rose from 52.8% to 60.1%, and the risk of non-use dropped by 19% (aOR 0.81). Delayed presentation fell from 37.9% to 31.9%. This improvement stands in contrast to the national rabies resurgence and suggests that the continuous quality improvement efforts anchored in the Southern Jiangsu Animal Injury Treatment Training Center have begun to bear fruit. The across-the-board improvement in 2025 indicates that systematic training, monitoring, and feedback mechanisms can effectively counteract prevention fatigue even in settings devoid of the constant reminder of fatal cases. This experience may serve as a reference for other regions moving toward or having already achieved rabies elimination.

The unique value of this study lies in providing quantitative evidence for “prevention fatigue” from a region with zero indigenous cases, based on over 40,000 real-world cases, against the backdrop of a national resurgence [9]. The spatiotemporal clustering analysis by Chen et al. showed that the 2024 resurgence was concentrated in historically high-burden provinces such as Henan, Hunan, and Hubei, rather than spreading to new areas [2]. Yet the present data caution that a silent decline in PEP quality in historically low-burden areas may equally create fertile ground for resurgence. Accordingly, we recommend sustained public education on rabies prevention [24] and adoption of the passive immunization rate and the standard first-visit care rate as sentinel indicators of PEP quality in zero-case areas, incorporated into routine audits by regional treatment and training centers [25].

This study has several limitations. First, the single-center design limits the generalizability of the findings, although as the Southern Jiangsu Animal Injury Treatment Training Center, our data reflect the overall situation in the Taihu Lake region to a certain extent. Second, full-course rabies vaccination could not be tracked owing to fragmented information systems across clinics and off-site follow-up visits, and passive immunization use was determined based on text records in the electronic registry, which may have missed non-standard entries. Third, wound count was not analyzed because of a 62.7% missing rate, and patient socioeconomic variables such as education and income were not available. These limitations should be addressed in future multicenter prospective studies.

Conclusion

This study found that the risk of “prevention fatigue”—a silent decline in PEP quality—exists even in rabies-free areas. The Taihu Lake region, one of the most urbanized areas in China, has reported no indigenous cases for over a decade. Yet substantial gaps persist in passive immunization use and standard first-visit care among grade III exposures, with young adults, patients with scratches, and those who delayed presentation forming three overlapping protection gaps. Systematic quality improvement efforts based at the Southern Jiangsu Animal Injury Treatment Training Center have begun to reverse this trend, with multiple indicators showing across-the-board improvement in 2025 compared with 2023. We therefore recommend adopting the passive immunization rate and the standard first-visit care rate as sentinel indicators of PEP quality in zero-case areas and incorporating them into routine evaluations by regional training centers. The core message—that grade III scratches carry the same risk as grade III bites—should be reinforced at the point of care and in community health education. Differentiated interventions should also be implemented, targeting young adults and seasonal patterns of exposure.

Abbreviations

PEP: Post-exposure prophylaxis

RIG: Rabies immunoglobulin

mAb: Monoclonal antibody

WHO: World Health Organization

CDC: China Center for Disease Control and Prevention

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

aOR: Adjusted odds ratio

CI: Confidence interval

IQR: Interquartile range

OR: Odds ratio

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Wuxi No.8 People's Hospital (Southern Jiangsu Animal Injury Treatment Training Center) (Approval No.: (2026) Y-18). The requirement for informed consent was waived by the Ethics Committee owing to the retrospective and anonymized nature of the data. All methods were performed in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to them containing information that could compromise patient privacy.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Xin Wang: study design, data analysis, manuscript writing, and final review. Zhiwen Jia: data collection and assisted in revising the Discussion section. Rong Cao: scientific consultation, resources, and supervision. Xingyu Chen: participated in grant application and partial data verification. Mengying Li: participated in study design discussions. All authors critically reviewed the manuscript and approved the final version for submission.

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Figures

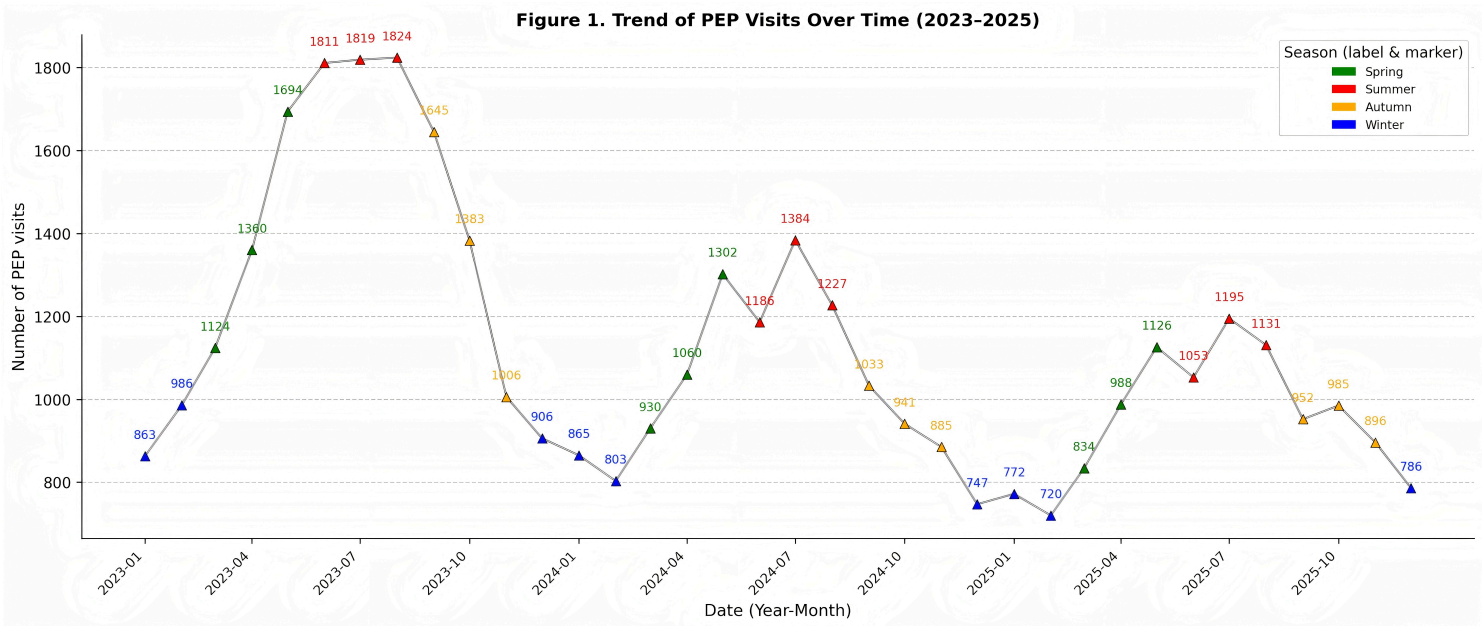


Figure 1

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Figure 2. Trends in quality indicators of Grade III PEP care, 2023-2025

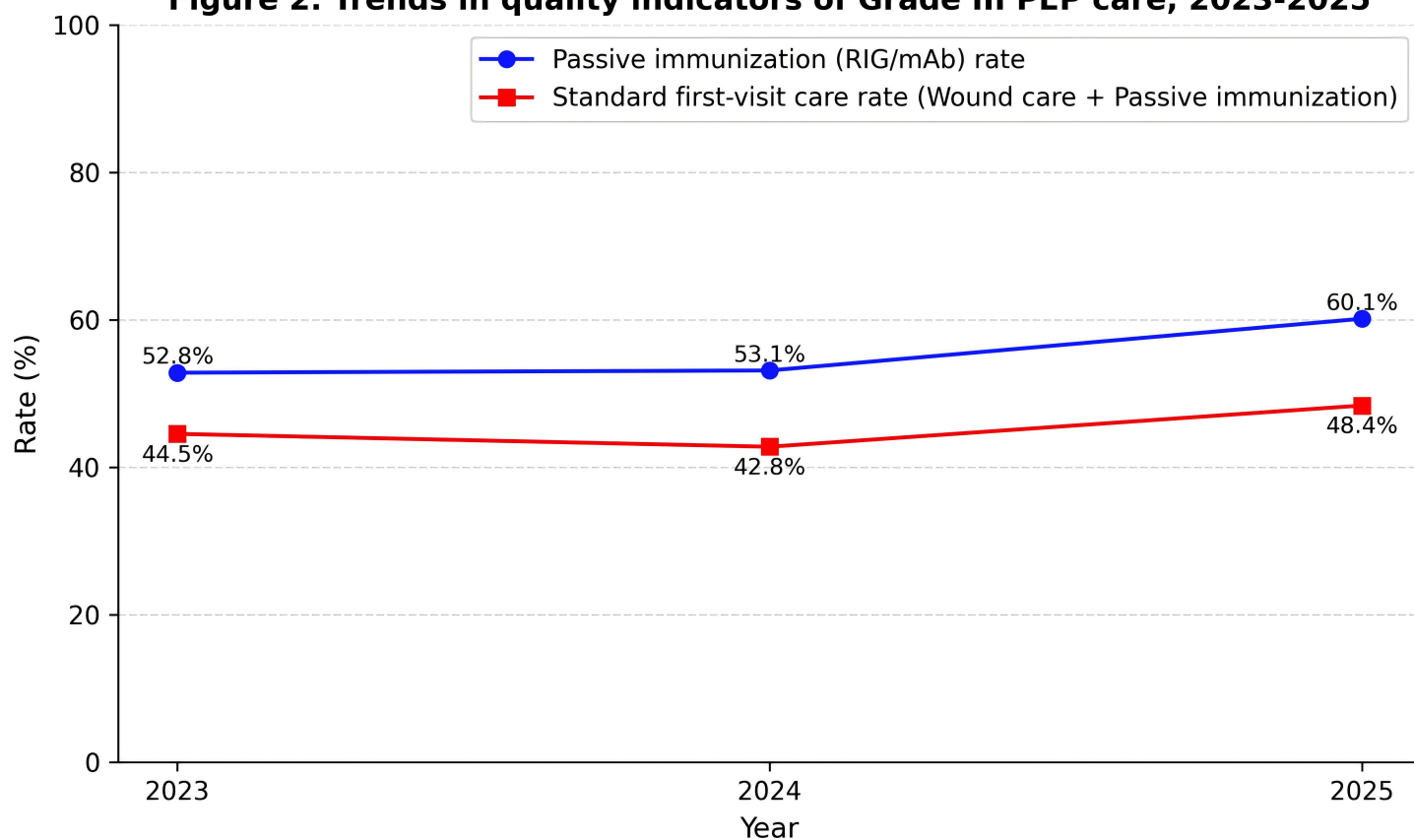


Figure 2

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Figure 3. Injury_type x Delayed_presentation (P_interaction = 0.179)

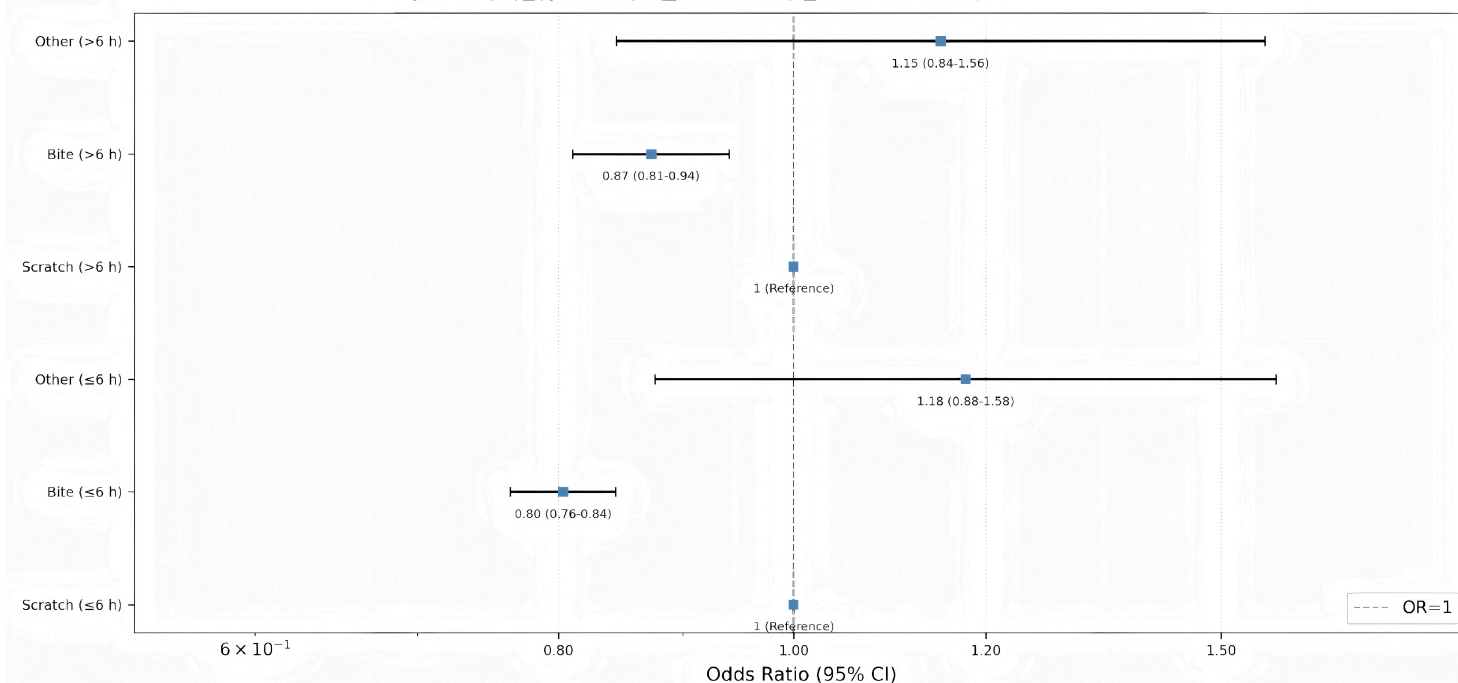


Figure 3

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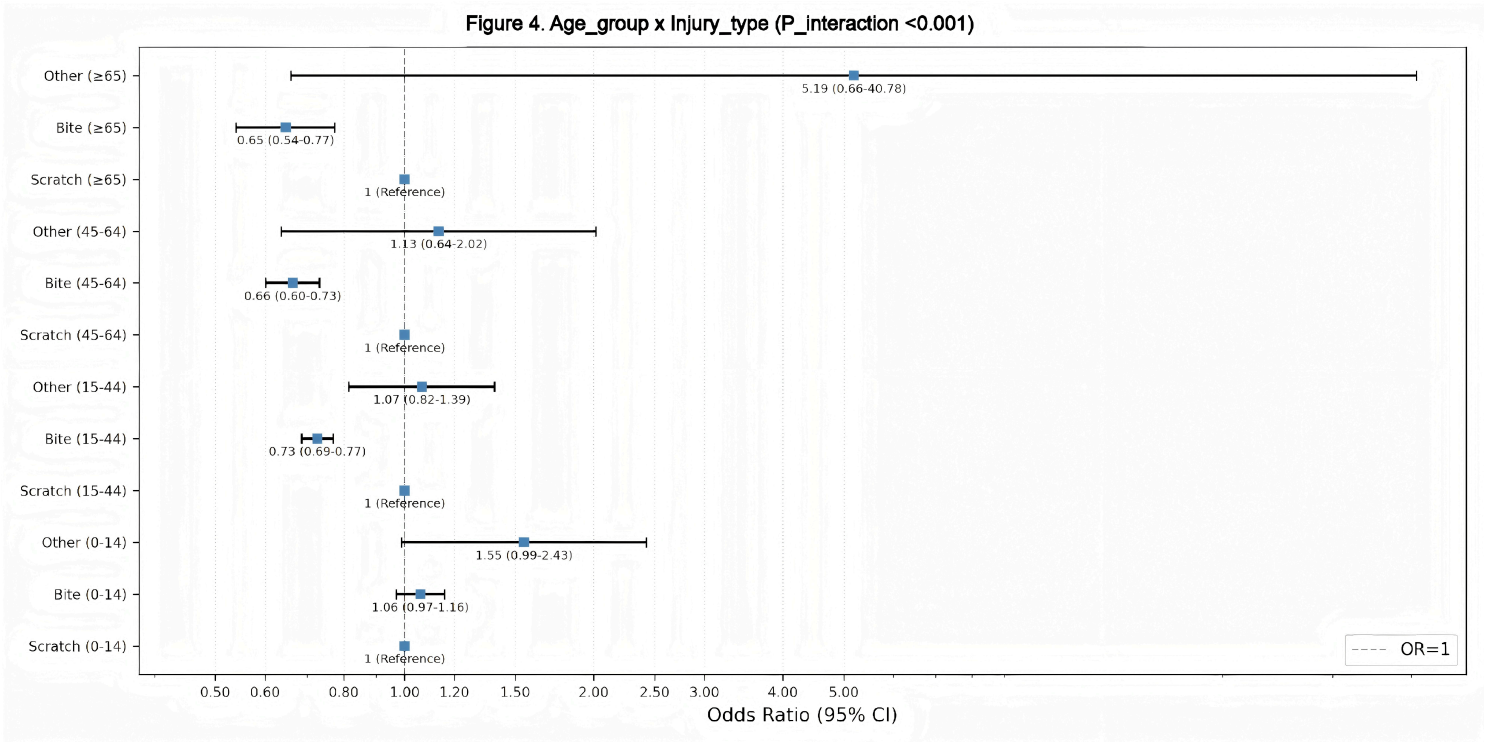


Figure 4

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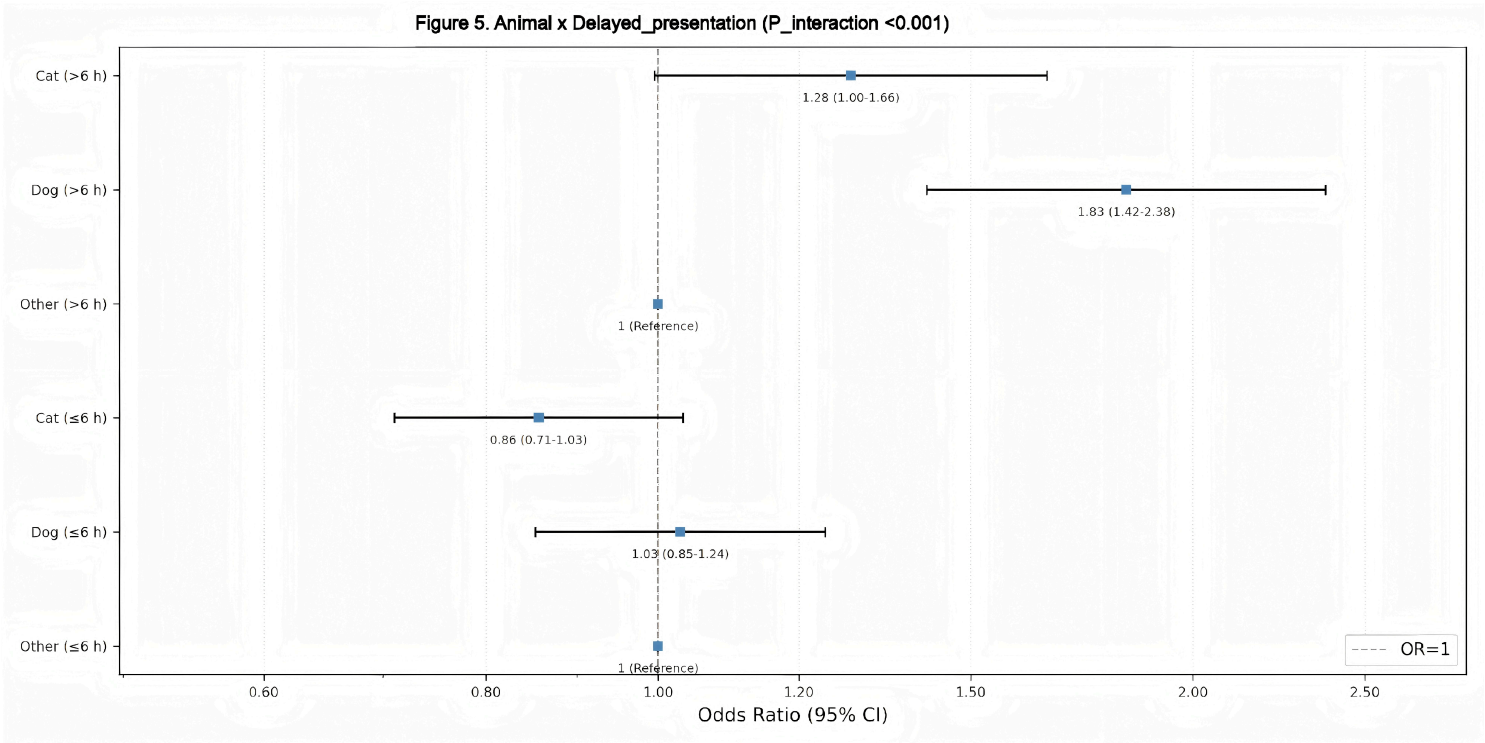


Figure 5

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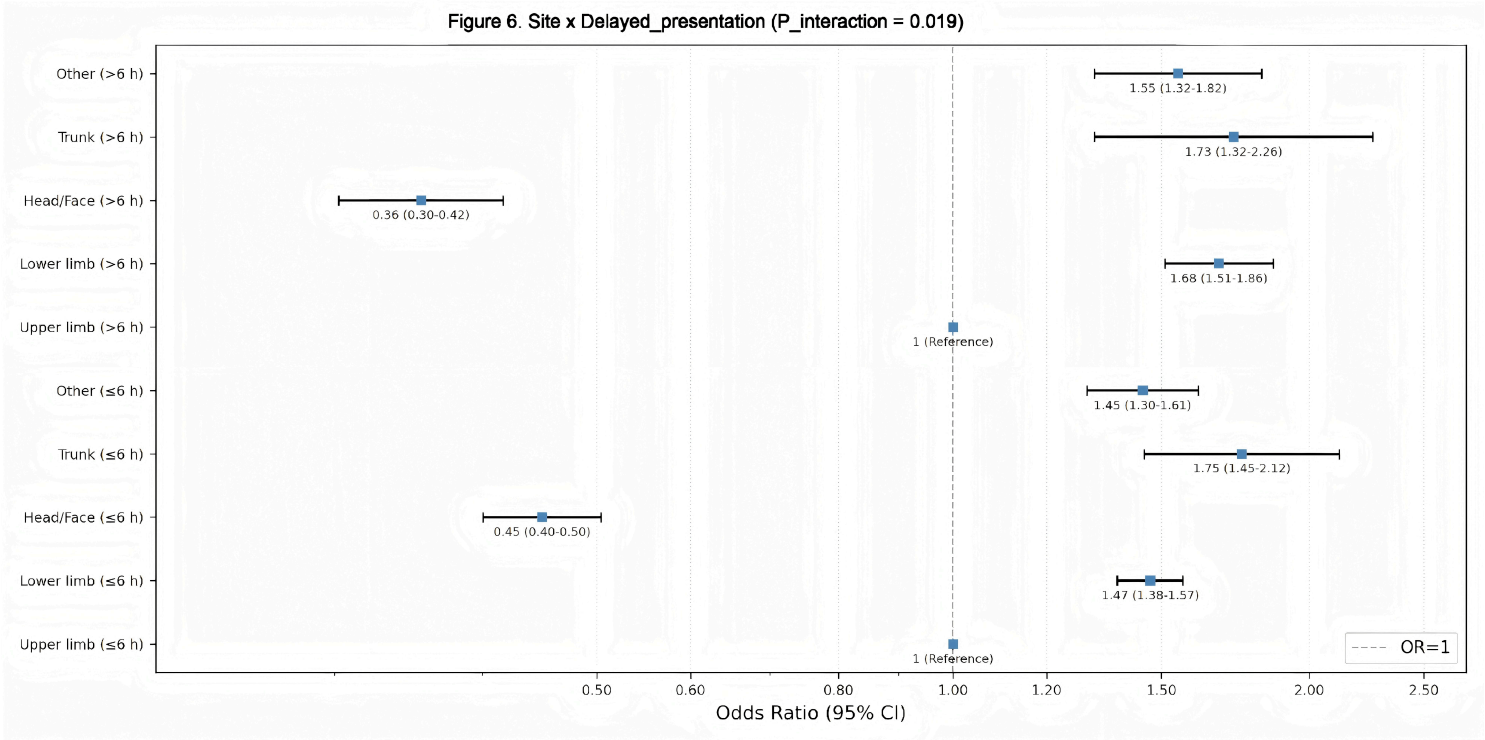


Figure 6

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