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Characterizing shelter intake, length of stay, and outcomes among free-ranging dogs in animal welfare organizations in India

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Abstract

Background- Countries in Global South carry the economic and social burden of unmanaged and understudied populations of free-ranging dogs globally. However, veterinary, shelter science and behaviour research fields are dominated by research from Global North countries and cater to a partial perspective. In this exploratory study, we try to bridge the gap of this divide by investigating the intake and outcome patterns of admitted free-ranging dogs in animal rescue organizations in India by analysing diverse data from over 24,000 records. We identify critical trends in admission causes, clinical burdens, and animal survival rates across from four geographically and institutionally distinct animal shelters in India between 2018 and 2022.

Results- Average shelter intake volume grew by approximately 35% per year over the study period. Physical trauma emerged as the primary driver of admissions across all sites, regardless of regional differences in climate or urbanisation. While live outcomes generally exceeded non-live outcomes in most shelters, non-live outcomes (death and euthanasia) occurred at high rates (40-60%), substantially higher than reported Global North benchmarks. Survival was strongly associated with clinical presentation: neurological cases, most plausibly linked to endemic rabies and distemper, carried the poorest prognosis, with a median survival time of only one day. Systemic, gastrointestinal, and musculoskeletal conditions also carried significantly higher hazards for non-live outcomes. The

overall median length of stay was 8 days, though hospitalization duration varied significantly, with oncological cases requiring the longest care.

Conclusion- The findings characterise Indian shelters not as rehoming centres as a downstream safety net, for animal welfare crises originating from a lack of upstream population management, vaccination coverage, and injury prevention infrastructure. Furthermore, the study identifies the absence of standardised data collection as a fundamental barrier to evidence-based policy, highlighting an urgent need for shared data standards to improve animal welfare and public health outcomes across the Indian animal rescue sector. Ultimately, this study aims to provide a foundational evidence base and proof-of-concept for evaluating shelter science and canine welfare in Global South and other countries facing similar issues.

Keywords

Free-ranging dogs; intake-outcome patterns; Global South; animal welfare; shelter dogs

Background

India is home to an estimated 62 million free-ranging dogs (1), one of the largest such populations in the world, and these animals are a omnipresent feature of the country's urban landscape. They sleep on pavements, forage around homes and markets, navigate traffic, solicit food from people and inhabit the same neighbourhoods as the people. Yet their relationship with the human communities is rarely straightforward (2,3). Dogs in Indian urban environments span a wide continuum of human 'ownership'/caregiving- from living in homes as pets via adoption, to community-owned animals that are fed and cared for by neighbourhood residents, to entirely unowned individuals with no consistent human relationship and no reliable access to food, shelter, or veterinary attention (4,5). This spectrum has important implications for welfare. Animals at the unowned end of the spectrum face the greatest exposure to injury, disease, and nutritional stress, yet are the least likely to receive any form of care unless they come into contact with a concerned human or an organised rescue facility. Community-owned dogs fare comparatively better, due to continuous check by their human caregivers. When injury or illness becomes severe enough to be noticed, the shelter is typically the first and only point

at which a free-ranging dog in India will encounter a veterinarian. From human safety and animal welfare perspectives, developing and emerging economies bear the burden of unmanaged canine populations, severe welfare crises and associated zoonotic diseases (6).

India has governed the treatment of animals through formal legislation for well over a century. The first Society for the Prevention of Cruelty to Animals was founded in Calcutta in 1861, and the Prevention of Cruelty to Animals Act of 1960 established the statutory foundation for animal welfare, across contexts ranging from wildlife and working animals to companion species. The management of street dogs specifically is addressed by the Animal Birth Control Rules of 2001, most recently amended in 2023, which mandate a Catch, Neuter, Vaccinate, and Return (CNVR) approach to population management and provide legal protections for community members who feed or care for neighbourhood dogs (7). While the framework is relatively comprehensive on paper, in practice, however, implementation is deeply uneven across states and municipalities. Neutering and anti-rabies vaccination coverage consistently falls well short of the thresholds, typically estimated at 70% or above, needed to achieve meaningful population stabilisation or interrupt disease transmission chains (8,9).

The public health dimension of this situation cannot be separated from the animal welfare. India carries the world's largest national burden of human rabies mortality, accounting for an estimated 35% of global deaths from the disease annually, with free-ranging dogs as the primary reservoir and vector (10). Beyond rabies, FRDs are also implicated in the transmission of leptospirosis, gastrointestinal zoonoses including toxocariasis and giardiasis, and ectoparasite-borne diseases that affect substantial numbers of people in low-income urban communities (11). A population of millions of insufficiently vaccinated, reproductively intact, and nutritionally stressed animals living in close proximity to humans constitutes a shared public health challenge as much as it does an animal welfare problem. This framing matters for how shelter data should be interpreted. The dogs arriving at Indian rescue organizations are not primarily surrendered pets or strays from caring households or animals picked up as a measure of ‘straying’ or population control. They are animals presenting the downstream clinical consequences of an incompletely managed population problem.

Understanding what Indian shelters are, and how they differ from the facilities described in most of the published shelter medicine literature from the Global North is essential. There are approximately 3,678 registered animal welfare organisations in India, alongside a far larger number of unregistered bodies operating at the local and community level. These organisations are not animal control agencies (12). They do not impound dogs for population management purposes, they may not routinely accept owner surrenders of healthy animals, and with very few exceptions they do not euthanise animals for reasons of space or behaviour. Euthanasia in the Indian shelter context is legally reserved for animals that are mortally incurable or confirmed or strongly suspected to be rabid- a categorical difference from the open-admission shelter model prevalent in North America and parts of Europe, where euthanasia has historically been a routine population management tool (13–16) and where most of the comparative literature originates. Indian shelters respond to distress calls from concerned members of the public, admit animals subject to available space and clinical capacity, provide treatment, and discharge animals back to their original territories following recovery. Adoption from shelters occurs, but remains relatively uncommon in India (17). Housing is typically mixed, with some animals in kennels or enclosures and others moving freely within the premises, with placement decisions driven by clinical severity, isolation requirements, or post-operative care needs. These are welfare facilities with limited staff and constrained resources, often with minimal government funding or community support, and ultimately attend to cases that a properly resourced upstream population management system would substantially reduce (12).

Despite the scale of the problem and the central role of shelters, the quantitative evidence for free-ranging dog welfare outcomes in Indian shelters, or rather shelters in the Global South countries, is almost entirely absent. The broader shelter and shelter medicine literature is dominated by data from North America, the United Kingdom, and Australia (18–23), countries where animals, institutions, and social and legal frameworks surrounding both differ fundamentally from the Indian setting. Therefore, direct comparisons or inference is rarely meaningful. In the broader Global South, published quantitative analyses of shelter intake and outcome data remain scarce. The few available direct or derived studies from Asia (24,25), Latin America (26–28) and sub-Saharan Africa (29,30) document

zoonotic burden and population management measures compared to Global North benchmarks in shelter science. To the best of our knowledge, no equivalent study has been conducted for India. This lacuna has real consequences for animals. Without such baseline data on intake demographics, cause of intake, and outcomes, shelter managers cannot refine or reform their practices, policymakers cannot make evidence-driven decisions about resource allocation, and whether interventions such as vaccination campaigns, CNVR programmes, etc. have any measurable effect on free-ranging dog welfare at the population level.

The absence of any shared minimum data standard across Indian animal welfare organisations adds a further structural obstacle. Each shelter has its own independently developed record-keeping system, where various levels of details such as intake cause, animal demographics, and outcomes in incompatible formats and vocabularies may be recorded. Such individual databases cannot be readily combined across shelters without substantial post-hoc harmonisation work. This fragmentation is not unique to India, as it has been identified as a barrier to evidence synthesis in shelter science globally. However, such problems are particularly acute in a country with thousands of organisations, enormous geographic and operational diversity, and no regulatory requirement to collect or report standardised data. The consequence is that even where individual shelters maintain detailed records, as the organisations involved in this study do, those records exist as isolated information islands rather than as components of a shared evidence base.

In this exploratory study, we address this gap by analysing intake and outcome records from four animal rescue shelters distributed across geographically and institutionally distinct regions of India. The records span a combined operational window from 2018 to 2022 and encompass 24,421 dog intake records. We investigated temporal trends in intake volume, the causes of admission and their co-occurrence patterns, factors associated with length of stay, and the relationship between intake cause and survival outcome. To the best of our knowledge, this is the first study from India, and one of the first from the Global South, to focus on a multi-site quantitative analysis of trends in clinical intake and outcome patterns among free-ranging dogs in shelters in India. Beyond the epidemiological findings, the study offers a proof of concept for what can become analytically possible when

heterogeneous shelter records are harmonised to a shared structure, and provides an important evidence base for understanding variation and gaps in shelter function, clinical burden, and outcome variation in the Indian animal welfare sector.

Methodology

Data acquisition

Request for participation in this study was sent out to more than 40 shelters across India. These shelters were chosen based on online presence, recent social media activity (to rule out shelters which may not be functional at the time of the study) and infrastructure (must be a shelter/rescue organization with physical infrastructural presence and staff). Three shelters responded expressing interest in participating in the study and maintained electronic records in Microsoft Excel format. Following a signed data-sharing agreement between each shelter's management and the lead author, records were shared via email. A fourth organisation did not maintain a structured database but posted individual case updates including intake, treatment progress, and outcome, on a public social media page; data from this shelter were compiled from these posts after formal permission was obtained from the organisation's leadership. All other shelters approached either declined to participate, were unable to commit to data sharing given limited staff capacity, maintained only paper-based records that could not be feasibly digitised within the study timeline, or did not respond to repeated contact. To protect participating organisations from identification and any resulting reputational risk, each shelter has been anonymised throughout this manuscript and is referred to by a coded label (Shelter A (Shlt_A), Shelter B (Shlt_B), Shelter C (Shlt_C) and, Shelter D (Shlt_D)).

The four participating shelters span a geographically and climatically diverse cross-section of India, which we consider a meaningful strength of the dataset rather than an incidental feature. Shelter A operates in a mid-sized city in western India, in a semi-arid region characterised by hot summers, a pronounced monsoon season, and a substantial seasonal tourism economy built around the city's historic lakes and palaces. Shelter B is situated in a hill station in the northern Himalayan foothills, at a considerably higher elevation and cooler climate than the other three sites, with a large itinerant and

seasonal tourist and pilgrim population. Shelter C is based in a major metropolitan centre in southern India, one of the country's largest cities and a significant technology and industrial hub, where free-ranging dogs navigate an intensely urbanised environment with high-density traffic and large-scale construction activity. Shelter D operates in a peri-urban district in eastern India bordering a large metropolitan area, a setting that combines urban and semi-rural characteristics and extend their services to areas beyond their own municipal jurisdiction.

This geographic spread in the combined dataset captures free-ranging dog populations experiencing markedly different climates, elevations, human population densities, traffic conditions, and degrees of urbanisation. We regard this diversity as valuable for the generalisability of the study's findings, since it reduces the likelihood that any single pattern observed reflects an idiosyncrasy of one city's geography or climate rather than a broader feature of free-ranging dog welfare across India. At the same time, four shelters drawn from a national landscape of thousands of registered and unregistered organisations cannot be considered representative of the country as a whole, and this limitation is addressed explicitly later in the Discussion.

Data processing

Following data acquisition, all records were imported into R (version 4.4.1; R Core Team, 2024) and subjected to a multi-stage cleaning and standardisation pipeline before analysis. Each shelter had developed its recording system independently, resulting in four different file formats, vocabularies, and date conventions. For all shelters, the dates were combined programmatically to yield a single ISO-format exit date, with failed reconstructions left as missing. For Shelter C, a supplementary remarks column contained exit dates recorded by clinical staff in a range of formats, including DD/Mon/YYYY, DD/MM/YYYY, and natural-language expressions such as "same day," "dead on arrival," and narrative notes prefixed by status codes (e.g., "E- 14/Aug/2022" for euthanasia, "D-04/08/2022" for death). Each format was matched by a dedicated regular expression pattern, and "same day" or equivalent expressions were mapped to the entry date, yielding LOS = 0. For cases where Shelter C's dedicated Release Date column contained a valid date, that value was used in

preference to the remarks-derived date. Any information on people (including rescuers, fosters, or potential adopters) were stripped before parsing.

Outcome terminology differed across shelters and was harmonised to eight categories before analysis: Released, Died, Euthanised, Adopted, Permanent Resident, Escaped, Fostered, and In Care. For survival analysis, outcomes were dichotomised as event (Died or Euthanised) or right-censored (all live exits). Two competing risk codes were additionally assigned for Fine-Gray regression: Died = 1, Euthanised = 2, and all live exits = 0.

Cause-of-Entry Classification

Each shelter recorded intake cause using an independent vocabulary that ranged from 44 controlled atomic terms (Shelter A) to entirely free-form text (Shelter C). The raw entries across all four shelters collectively yielded over 700 unique text fragments, many of which represented spelling variants, typographical errors, abbreviations, or multi-concept compound entries describing the same underlying clinical presentation. Standardisation proceeded in two stages.

In the first stage, multi-concept compound entries were decomposed before splitting on the comma delimiter. Shelter C entries frequently embedded multiple clinical concepts within a single comma-delimited field (for example, "Wounds, Abscess, Boils" as a single concept cluster, or "Not Eating and Vomiting" as a compound complaint), and additionally used slash (/), ampersand (&), and plus-sign (+) characters as alternative delimiters. A set of regular-expression substitutions was applied to collapse known compound terms into single canonical tokens before comma-splitting, and secondary splitting on these additional delimiters was applied thereafter.

In the second stage, all atomic tokens were mapped to canonical terms through a comprehensive normalisation dictionary constructed for this dataset. Each canonical term was then assigned to two classification axes adapted from the Veterinary Nomenclature (VeNom) coding system and the International Classification of Diseases (ICD) framework (Table 1). The first axis, Body System, classified the anatomical or physiological domain of the presentation into eleven categories. The second axis, Aetiology, classified the primary causal mechanism into eight categories. Dogs

presenting with multiple concurrent causes received a multi-label profile. For models requiring a single predictor, a dominant body system was assigned to each dog using a clinically informed priority hierarchy ordered by acuity: NEURO > MUSCULO > ONCO > DERM > GASTRO > RESP > REPRO > OPHTHALMO > SYSTEMIC > WELFARE > BEHAV.

Table 1. Dominant Body System Classification Terminology- Categories were adapted from the VeNom (Veterinary Nomenclature) coding system and the ICD body-system framework. Dogs presenting with multiple concurrent causes received a multi-label profile across categories; for statistical models requiring a single predictor, a "dominant body system" was assigned using a clinically informed acuity-based priority hierarchy: NEURO > MUSCULO > ONCO > DERM > GASTRO > RESP > REPRO > OPHTHALMO > SYSTEMIC > WELFARE > BEHAV.

Abbreviation	Full term	Conditions covered
MUSCULO	Musculoskeletal	Leg/limb injuries, fractures, spinal injuries, hip/spinal-hip injuries, head injuries (jaw, skull), paralysis (orthopaedic), gait abnormalities/inability to walk, joint dislocation, amputation
DERM	Dermatological / Integumentary	Wounds, lacerations, abscesses, maggot-infested wounds (myiasis), mange, tick/flea infestation, skin infections, allergic dermatitis, ear infections/injuries, bite wounds (dog fight, animal attack)
GASTRO	Gastrointestinal	Anorexia/not eating, vomiting, diarrhoea, parvoviral enteritis, rectal prolapse, intestinal obstruction, abdominal distension/ascites, hernia, generalised stomach problems
NEURO	Neurological	Rabies-suspect presentation (salivating, abnormal/aggressive behaviour, circling), seizures,

		canine distemper (neurological phase), paralysis of neurological origin, ataxia, ambiguous CNS signs
ONCO	Oncological	Tumours (general), canine transmissible venereal tumour (TVT), mammary tumours, vaginal growths (VG), lipomas, other neoplastic masses
OPHTHALMO	Ophthalmological	Eye injuries, eye infections, blindness, ocular discharge/bleeding
REPRO	Reproductive / Genitourinary	Pregnancy complications, vaginal/uterine prolapse, pyometra, penile/vaginal discharge or injury, dystocia, genital tumours (non-neoplastic reproductive pathology)
RESP	Respiratory	Coughing, breathing difficulty, nasal discharge/bleeding, pneumonia-like symptoms, throat infection
SYSTEMIC	Systemic / Non-specific	Generalised weakness/lethargy, fever, tick-borne fever, malnutrition/emaciation, dehydration, old age-related decline, kidney/liver problems, poisoning, non-specific "sickness"
WELFARE	Welfare / Management Context	Animal Birth Control (ABC) sterilisation intake, vaccination-only visits, cruelty cases, abandonment, confiscation, orphaned/neonatal admissions, post-operative/follow-up care, inter-shelter transfers
BEHAV	Behavioural	Aggression (without confirmed neurological cause), human-directed biting incidents, other behaviourally flagged presentations not attributable to a physical or neurological condition

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Data Exclusions and Final Dataset

Records with a negative LOS, indicating an exit date recorded earlier than the entry date, were classified as data entry errors and excluded from all analyses involving LOS (n = 19). Records with implausible entry years, defined as years before 2015 or after 2025, were excluded from temporal and survival analyses (n = 4, all from Shelter B). The age class Old, recorded for only 31 individuals across the entire dataset (0.16% of age-recorded cases), was collapsed into the 'Adult' category for all regression models to avoid sparse-cell instability (the substantive results were unaffected by this decision, as a sensitivity model retaining Old as a separate level produced nearly identical coefficients). The final combined dataset comprised 24,421 records from four shelters. Patterns of missingness by variable and shelter are reported in the Results section and Supplementary Table S1.

Statistical analysis

Descriptive statistics for demographic variables were reported as counts and percentages, with chi-square tests used to assess deviation from a 1:1 sex ratio and the association between age class and outcome within each shelter. Effect sizes were reported as Cramér's V for all chi-square tests. Multiple comparisons across shelters were corrected using the Benjamini-Hochberg (BH) false discovery rate procedure throughout. Body system co-occurrence was quantified using the Jaccard similarity index for all pairs of the eleven classified body systems, and a weighted undirected network was constructed retaining edges with Jaccard index ≥ 0.05. Network modularity was estimated using the fast-greedy community detection algorithm. Temporal trends in annual intake counts were modelled using a negative binomial generalised linear mixed-effects model (GLMM) with year (centred on 2019) and shelter as fixed effects and shelter as a random intercept, fitted via the *glmmTMB* package; exponentiated coefficients are reported as incidence rate ratios. The temporal trend in the proportion of non-live outcomes was modelled using a binomial GLMM with the same fixed and random effect structure, yielding odds ratios.

Length of stay was analysed in three complementary ways. First, a binomial GLMM with shelter as a random intercept was used to model the probability of a same-day exit (LOS = 0) as a function of

dominant body system, constituting the hurdle component of the analysis; same-day and multi-day cases were treated as a qualitatively distinct clinical phenomenon and analysed separately. Second, a Kruskal-Wallis test with post-hoc Dunn pairwise comparisons (BH correction) was applied to LOS > 0 as a non-parametric overall test of body system differences. Third, a negative binomial GLMM was fitted to LOS > 0 with dominant body system as a fixed effect and shelter as a random intercept (n = 17,406; Shelter B excluded due to absent exit date data), with 'Dermatological' presentations as the reference category; model adequacy was assessed using the *DHARMa* package. A sensitivity analysis excluding records with LOS > 365 days (n = 35) was conducted to evaluate the influence of extreme outliers. To additionally examine the effect of sex and age class on LOS, a log-normal linear model was fitted to records with both covariates available (Shelter A and Shelter D only; n = 1,320), using log1p-transformed LOS as the outcome and shelter as a fixed factor. Estimated marginal means and 95% confidence intervals were derived from all models using the *emmeans* package, back-transformed to the response scale.

Time from shelter entry to a non-live outcome (death or euthanasia) was analysed using both cause-specific hazard and competing-risk approaches. Competing-risk cumulative incidence functions were estimated to quantify the probability of a non-live outcome over time across dominant body-system categories, treating live outcomes as competing events. The median time to 50% cumulative incidence was defined as the earliest time at which the estimated cumulative incidence of a non-live outcome reached 50% for each body-system category and was obtained directly from the cumulative incidence function. Differences between cumulative incidence functions were assessed using Gray's test, and pointwise 95% confidence intervals were calculated for cumulative incidence estimates. Mixed-effects Cox proportional hazards regression models were fitted to estimate cause-specific hazards with dominant body system and sex as fixed effects and shelter included as a random intercept to account for clustering of animals within shelters. Because of small sample sizes, behavioural, respiratory, reproductive and ophthalmological categories were combined into an "Other" category for regression analyses. Older animals were excluded from multivariable models owing to low sample size, and cases with missing sex information were omitted. Hazard ratios (HRs) with 95% confidence intervals

were calculated for all fixed effects, and *P*-values were adjusted for multiple comparisons using the Benjamini-Hochberg false discovery rate (FDR) procedure. The proportional hazards assumption was evaluated using Schoenfeld residuals from an equivalent Cox model stratified by shelter. All processing and analysis were performed in R (version 4.4.1) using the packages *tidyverse, lubridate, glmmTMB, survival, survminer, coxme, cmprsk, igraph, ggraph, DHARMa, emmeans, moments, dunn.test,* and *patchwork*.

Results

Dataset Composition and Missingness

The final analytical dataset comprised 24,421 intake records from four shelters representing four geographically distinct regions of India (Table 2). Shelter A contributed the majority of records (n = 18,085; 74.1%), followed by Shelter C (n = 4,361; 17.9%), Shelter B (n = 1,376; 5.6%), and Shelter D (n = 599; 2.5%). Patterns of data availability differed substantially across shelters and variables (Supplementary Table S1). Sex was missing for 92.3% of Shelter A records and 72.8% of Shelter C records; only 7.7% of Shelter A intakes and 27.2% of Shelter C intakes had sex documented. Shelter C recorded no age class information for any of its 4,361 cases. Shelter B lacked exit date data for 100% of its records, making length of stay wholly unavailable for that shelter. Shelter D was missing exit date data for 60.1% of its records. These patterns of missingness were non-random and are treated as explicit analytical constraints throughout.

Table 2. Demographic details of admitted dogs across 3 years in four animal shelters in India. Numbers of live and non-live outcomes are based on available data and the totals may not match the total number of entries.

Shelter	Total no. of entries	#Dogs recorded as Males	#Dogs recorded as females	#Dogs recorded as 'young'	#Dogs recorded as 'adult'	#Dogs recorded as 'old'	#Non-live outcomes recorded	#Live outcomes recorded

Shlt_A	18085	720	667	9135	8933	15	8113 (44.86%)	9950 (55.01%)
Shlt_B	1376	700	676	487	818	0	285 (20.71%)	206 (14.97%)
Shlt_C	4361	655	530	0	0	0	1947 (44.65%)	2231 (51.16%)
Shlt_D	599	236	234	80	491	16	113 (18.86%)	141 (23.54%)

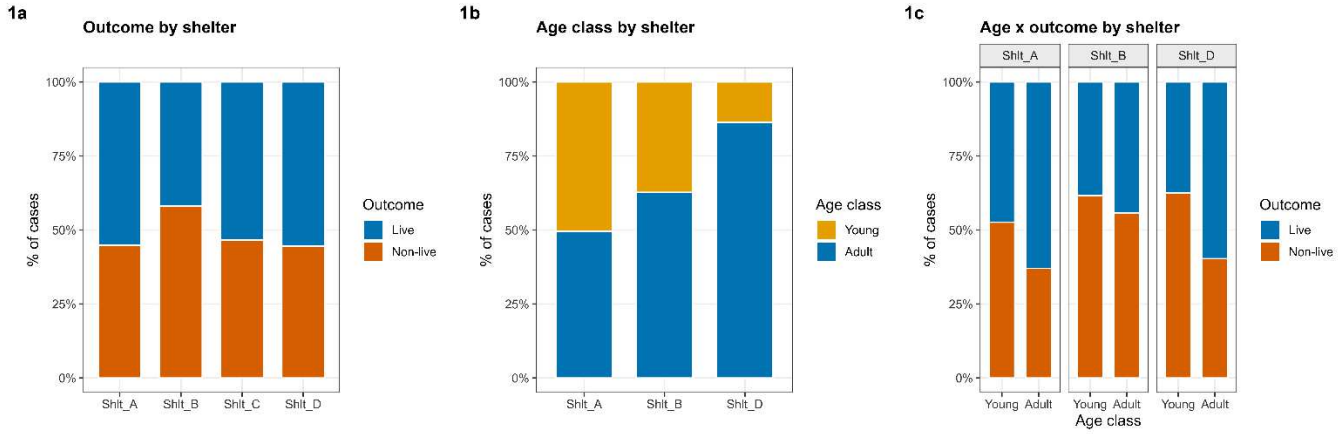
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297 Demographic Trends

298 Among the 4,418 records with sex documented, males were slightly more numerous than females
299 across the dataset as a whole (2,311 male vs 2,107 female). The sex ratio did not differ significantly
300 from parity at Shelter A (51.9% male; χ^2= 2.03, p = 0.16, Cramér's V = 0.04), Shelter B (50.9% male;
301 χ^2= 0.42, p = 0.52, V = 0.02), or Shelter D (50.2% male; χ^2 = 0.009, p = 0.926, V = 0.004). At Shelter
302 C, a statistically significant male skew was observed among the 1,185 dogs with sex recorded (55.3%
303 male; χ^2= 13.2, p = <0.01, V = 0.105, BH-adjusted p = 0.001). Because these records derive
304 exclusively from the August to December 2022 intake period at Shelter C, this result reflects a
305 specific temporal window and should not be generalised to the full 2019 to 2022 intake population at
306 that shelter. The proportion of dogs with live and non-live outcomes was broadly similar across the
307 four participating shelters, although Shelter B had the highest proportion of non-live outcomes.
308 Overall, live outcomes exceeded non-live outcomes in three of the four shelters, indicating generally
309 comparable outcome distributions despite differences in shelter populations and caseloads (Figure 1a).
310 Age class was recorded for 19,975 dogs across Shelter A, Shelter B, and Shelter D; Shelter C had no
311 age data (Figure 1b). Adults (8 months to 8 years) and young animals (up to 8 months) were present in
312 nearly equal proportions (Adult: n = 10,242, 51.3%; Young: n = 9,702, 48.6%). Old individuals (over
313 8 years) were markedly rare, comprising only 31 records (0.16%). Age class was significantly
314 associated with outcome at Shelter A (n = 18,061 with both variables recorded; χ^2 = 457.01, df = 2,

Cramér's V = 0.16, BH-adjusted p < 0.001), with young animals experiencing disproportionately high non-live rates relative to adults. The association at Shelter D was also significant but smaller in effect (n = 254; $\chi^2 = 7.84$, V = 0.18, BH-adjusted p = 0.02). The chi-square test for Shelter B returned a non-finite statistic, most likely reflecting incomplete outcome recording rather than a genuine absence of age-outcome association (Figure 1c).

Figure 1. Panel graph showing a) Proportion of live and non-live outcomes, b) age class distribution on admitted dogs in four Indian animal rescue shelters across three years and c) outcomes by age class across shelters. The proportion of live versus non-live outcomes and the age composition of admitted dogs varied among shelters. Adult dogs comprised the majority of admissions across all shelters, while non-live outcomes ranged from approximately 40-60% of cases. Outcome data were modeled based on available cases.

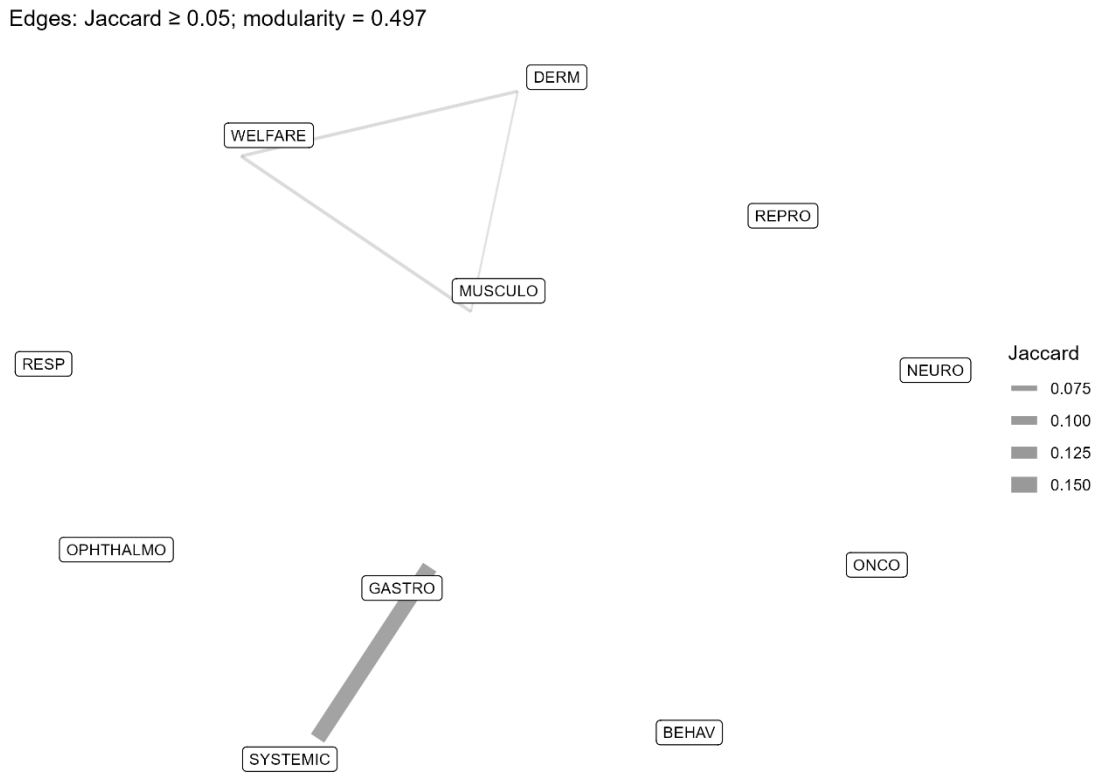


Co-occurrence of Intake Causes

Body system co-occurrence was quantified using the Jaccard similarity index for all pairs of the eleven classified body systems, and a weighted undirected network was constructed retaining only edges with Jaccard index ≥ 0.05 (Figure 2). The resulting network comprised 11 nodes and 4 edges, with a network modularity of 0.497, indicating moderate community structure. The strongest pairwise association was between Gastrointestinal and Systemic presentations (Jaccard = 0.15). The next strongest associations were between Welfare context and Musculoskeletal presentations (Jaccard = 0.06), Welfare context and Dermatological presentations (Jaccard = 0.06), and Musculoskeletal and

Dermatological presentations (Jaccard = 0.053), all consistent with dogs presenting with a traumatic intake context alongside concurrent physical injuries across multiple body systems. All other body system pairs fell below the 0.05 threshold. Neurological presentations showed the greatest network isolation, co-occurring above threshold with no other body system.

Figure 2. Network graph showing co-occurring body systems involved in admitted cases in free-ranging dogs entering shelters. Most body systems showed little overlap at admission, indicating that dogs were generally presented with a single dominant condition. The strongest co-occurrence was observed between systemic and gastrointestinal conditions, with weaker links among musculoskeletal, welfare, and dermatological conditions.



Temporal Trends in Intakes and Outcomes

Annual intake counts increased significantly over the study period (Figure 3, Table 3). A negative binomial GLMM with shelter as a random intercept and year (centred on 2019) as the continuous predictor estimated an incidence rate ratio of 1.35 per year (95% CI: 1.05 to 1.73; p = 0.02), indicating

that average shelter intake volume grew by approximately 35% per year across the study period after accounting for baseline shelter-level differences. This growth was most pronounced at Shelter A, which expanded from 1,533 intakes in 2018 to 7,537 in 2019 (an increase of 392%) and 9,015 in 2020 (a further 19.6%). Shelter C first contributed data in 2020 (n = 1,133) before declining in 2021 (n = 1,027, a decrease of 9.4%) and then expanding substantially in 2022 (n = 2,201, an increase of 114%). Shelter B showed more moderate but consistent annual growth from 341 intakes in 2018 to 550 in 2020. Shelter D followed a non-monotonic pattern, declining from 249 in 2018 to 129 in 2019 (a decrease of 48.2%) before increasing to 216 in 2020 (an increase of 67.4%).

After accounting for shelter-level differences, there was no significant time trend in the proportion of non-live outcomes across the study period (OR = 0.99 per year, 95% CI: 0.95 to 1.04; p = 0.45), indicating that the case-fatality composition within each shelter remained stable from year to year. Shelter B had a significantly higher probability of a non-live outcome relative to Shelter A (OR = 1.69, 95% CI: 1.41 to 2.03; $p < 0.001$), while Shelter C and Shelter D did not differ significantly from Shelter A (Shelter C: OR = 1.10, p = 0.05; Shelter D: OR = 0.98, p = 0.87).

Table 3. Annual intake and outcome count by participating animal shelter. Intakes were summarized by year of admission. Live outcomes include released, adopted, fostered, and permanent resident animals, whereas non-live outcomes comprise death and euthanasia.

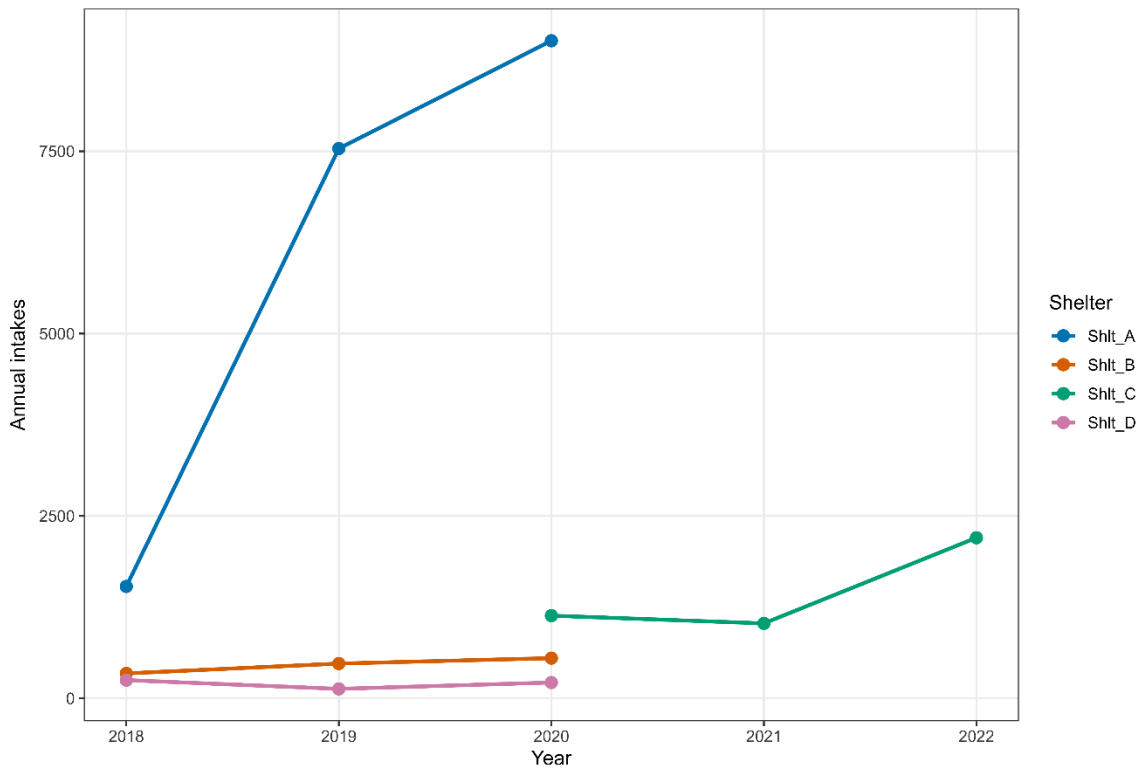
shelter	Year of entry	N	% change	Live outcomes	Non-live outcomes
Shlt_A	2018	1533	NA	887	646
Shlt_A	2019	7537	391.65	4228	3307
Shlt_A	2020	9015	19.61	4835	4160
Shlt_B	2018	341	NA	14	71
Shlt_B	2019	476	39.59	81	102
Shlt_B	2020	550	15.55	111	111
Shlt_C	2020	1133	NA	569	564

Shlt_C	2021	1027	-9.36	463	564
Shlt_C	2022	2201	114.31	1199	819
Shlt_D	2018	249	NA	35	35
Shlt_D	2019	129	-48.19	48	33
Shlt_D	2020	216	67.44	58	45

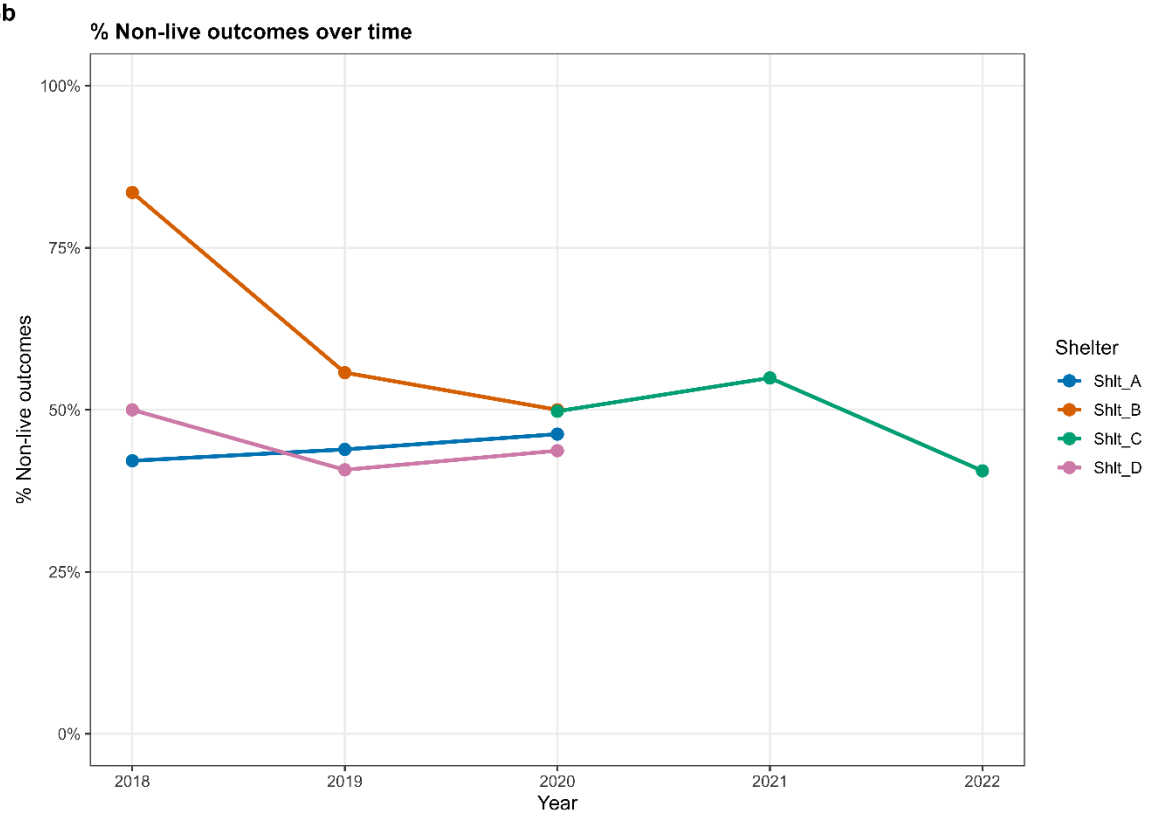
366

367 Figure 3. Graph showing temporal trends in A) annual intakes over 3 years and B) non-live
368 proportions over 3 years in four animal shelters. Most shelters showed increase in intakes over the
369 years but no particular trend in non-live outcomes were evident.

3a



3b



370

371 Length of Stay

Length of stay data were available for 21,630 records from Shelter A, Shelter C, and Shelter D; Shelter B was excluded entirely due to the absence of exit date data. A total of 4,224 dogs (19.5%) had LOS = 0, representing same-day admissions and discharges. Among the 17,406 dogs with LOS greater than zero, the distribution was severely right-skewed (skewness = 12.83; minimum = 1 day; first quartile = 2 days; median = 8 days; third quartile = 22 days; mean = 18.79 days; maximum = 1,377 days), with 35 records exceeding 365 days and likely representing dogs assigned to permanent in-shelter residency. Descriptive details of LOS by dominant body system affected across the different shelters are provided in Table 4 and Figure 4a.

Table 4. Descriptive statistics for length of stay (LOS) of dogs admitted with different dominant body-system conditions across the participating shelters. For each shelter and dominant body system, the table presents the number of admissions (*n*), the percentage of same-day cases (LOS = 0 days), median LOS, first and third quartiles (Q1 and Q3), maximum LOS, and mean LOS (days). These descriptive statistics illustrate differences in hospitalization duration among body-system categories and highlight variation in case management and discharge patterns across shelters.

shelter	Dominant body system	n	% zero	median	q1	q3	Max LOS	Mean LOS
Shlt_A	NEURO	720	33.8	1	0	9	236	8.9
Shlt_A	MUSCULO	5798	20.6	3	1	15	1377	14.8
Shlt_A	ONCO	246	16.3	9.5	2	23.75	365	20.6
Shlt_A	DERM	5556	15.5	8	1	24	1017	18.5
Shlt_A	GASTRO	2886	14.9	3	1	10	828	9.5
Shlt_A	RESP	190	7.4	9	3	17.75	122	14
Shlt_A	REPRO	114	17.5	4	1	22.5	148	14.7
Shlt_A	OPHTHALMO	130	11.5	9	2	16.75	124	14.8
Shlt_A	SYSTEMIC	930	23.2	2	1	8.75	219	9.3
Shlt_A	WELFARE	918	10.1	9	3.25	15	382	15.1

Shlt_A	BEHAV	24	25	7	0.75	23.75	63	16.7
Shlt_C	NEURO	105	78.1	0	0	0	34	1.6
Shlt_C	MUSCULO	859	27.2	4	0	17	376	13.8
Shlt_C	ONCO	272	15.1	16.5	5	31.25	295	23.9
Shlt_C	DERM	864	17.9	12	2	25	421	21.2
Shlt_C	GASTRO	208	43.8	1	0	6.25	372	11
Shlt_C	RESP	15	66.7	0	0	3.5	20	2.8
Shlt_C	REPRO	3	33.3	27	13.5	35	43	23.3
Shlt_C	OPHTHALMO	66	15.2	14.5	5.25	23	107	17.5
Shlt_C	SYSTEMIC	215	34.9	1	0	8.5	141	7.2
Shlt_C	WELFARE	1272	30.2	3	0	14	765	13.4
Shlt_D	NEURO	55	12.7	15	2	34	179	31.6
Shlt_D	MUSCULO	74	1.4	21	7.25	36.75	255	30
Shlt_D	ONCO	39	0	24	18.5	39	1057	59.8
Shlt_D	DERM	25	0	19	11	37	128	28.2
Shlt_D	GASTRO	9	0	6	3	44	579	136.4
Shlt_D	RESP	2	0	4	3.5	4.5	5	4
Shlt_D	REPRO	3	0	19	13	52.5	86	37.3
Shlt_D	OPHTHALMO	1	0	1293	1293	1293	1293	1293
Shlt_D	SYSTEMIC	6	0	14	4.5	22.75	43	16.5
Shlt_D	WELFARE	24	8.3	8	4.5	37	494	61.8
Shlt_D	BEHAV	1	0	25	25	25	25	25

The probability of a same-day exit differed significantly across dominant body systems in a binomial GLMM hurdle model (n = 21,630; Table 5, Figure 4b). Relative to the Dermatological reference category, Neurological cases had by far the highest odds of same-day exit (OR = 3.56, 95% CI: 3.05 to 4.16; BH-adjusted $p < 0.001$), followed by Systemic presentations (OR = 1.75, 95% CI: 1.51 to

2.03; $p < 0.001$) and Musculoskeletal cases (OR = 1.46, 95% CI: 1.34 to 1.60; $p < 0.001$). Gastrointestinal cases also showed modestly elevated same-day exit odds (OR = 1.14, 95% CI: 1.01 to 1.28; $p = 0.032$). Oncological cases were significantly less likely than Dermatological cases to be same-day exits (OR = 0.741, 95% CI: 0.58 to 0.95; $p = 0.019$). Respiratory, Reproductive, Ophthalmological, Welfare context, and Behavioural presentations did not differ significantly from the Dermatological reference after BH correction.

Table 5. Mixed hurdle model for same day exit across different dominant body systems adjusted for shelter variation. Neurological cases, which include cases of rabies and late-stage distemper, have the highest odds, suggesting that dogs suffering from such symptoms are either admitted too late or are euthanised or suffer non-live outcomes leading to same day exit.

Term	OR	Std. Error	Statistic	Adjusted p value
(Intercept)	0.12	0.07	-3.50	<0.01
NEURO	3.56	0.28	16.07	<0.01
MUSCULO	1.46	0.07	8.32	<0.01
ONCO	0.74	0.09	-2.35	0.04
GASTRO	1.14	0.07	2.14	0.06
RESP	0.74	0.16	-1.38	0.18
REPRO	1.26	0.31	0.95	0.34
OPHTHALMO	0.67	0.15	-1.84	0.10
SYSTEMIC	1.75	0.13	7.34	<0.01
WELFARE	1.10	0.07	1.41	0.18
BEHAV	1.95	0.92	1.42	0.18

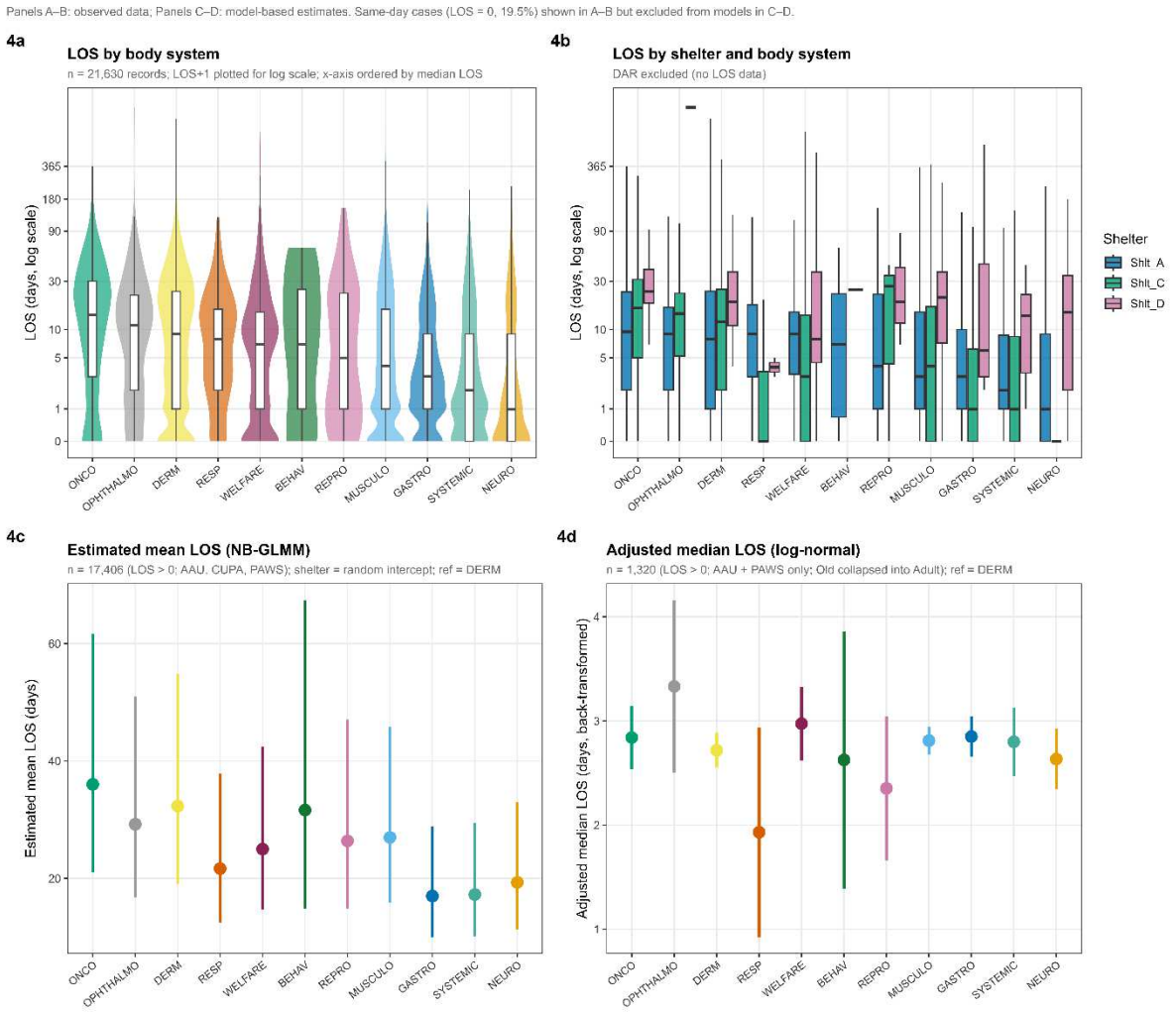
A Kruskal-Wallis test on dogs with LOS greater than zero confirmed highly significant overall differences in LOS across dominant body systems ($\chi^2 = 918.22$, $p < 0.001$). Post-hoc Dunn pairwise comparisons with BH correction identified 37 of 55 possible body system pairs as statistically

different (Supplementary Table S2). A negative binomial GLMM with shelter as a random intercept was fitted to dogs with LOS > 0 from all three contributing shelters (n = 17,406, with Dermatological as the reference category, Figure 4c). Estimated marginal means showed that Oncological cases had the longest model-estimated mean LOS (36.02 days, 95% CI: 21.03 to 61.70), exceeding the Dermatological reference (32.32 days, 95% CI: 19.04 to 54.87) by a rate ratio of 1.11 (95% CI: 0.99 to 1.24; $p = 0.06$). Gastrointestinal presentations had the shortest estimated mean LOS (16.99 days, 95% CI: 9.99 to 28.87; rate ratio vs DERM = 0.526, 95% CI: 0.49 to 0.56; $p < 0.001$), followed closely by Systemic presentations (17.25 days; rate ratio = 0.53, 95% CI: 0.49 to 0.58; $p < 0.001$). Neurological cases also had substantially shorter mean LOS than the reference (19.32 days, 95% CI: 11.29 to 33.05; rate ratio = 0.598, 95% CI: 0.54 to 0.67; $p < 0.001$). Ophthalmological and Behavioural presentations did not differ significantly from the Dermatological reference ($p = 0.29$ and $p = 0.94$ respectively). A sensitivity analysis excluding the 35 records with LOS exceeding 365 days produced directionally consistent results across all body systems, confirming that no finding was materially driven by extreme outliers.

A log-normal linear model fitted to the subset of dogs with both sex and age class recorded from Shelter A and Shelter D (n = 1,320; Shelter B excluded for missing LOS; Shelter C excluded for missing age class, Figure 4d) was statistically significant overall ($F(13, 1306) = 2.299$, $p = 0.005$) but explained only 2.2% of variance in log-transformed LOS (adjusted $R^2 = 0.013$). No body system, sex, or age class predictor reached significance after BH correction. The sole statistically significant predictor was shelter: dogs admitted to Shelter D had an estimated 1.50-fold longer LOS than comparable cases at Shelter A after adjusting for body system, sex, and age (multiplicative factor = 1.50, 95% CI: 1.22 to 1.84; $p < 0.01$).

Figure 4. Panel graph showing A) length of stay (LOS) by intake cause, B) LOS by body system and shelter, C) Shelter adjusted mean LOS in different cause of entry by body systems, and D) sex and age adjusted median LOS by body system across Indian animal shelters. Shelter B was excluded from these analyses as the dates of outcomes were not recorded by the shelter. Length of stay differed substantially among intake causes, with neurological and gastrointestinal cases generally having

shorter stays and dermatological and oncological cases tending to remain in shelters for longer. These patterns were consistent across both observed data and model-based estimates after accounting for shelter and demographic factors.



Survival Analysis

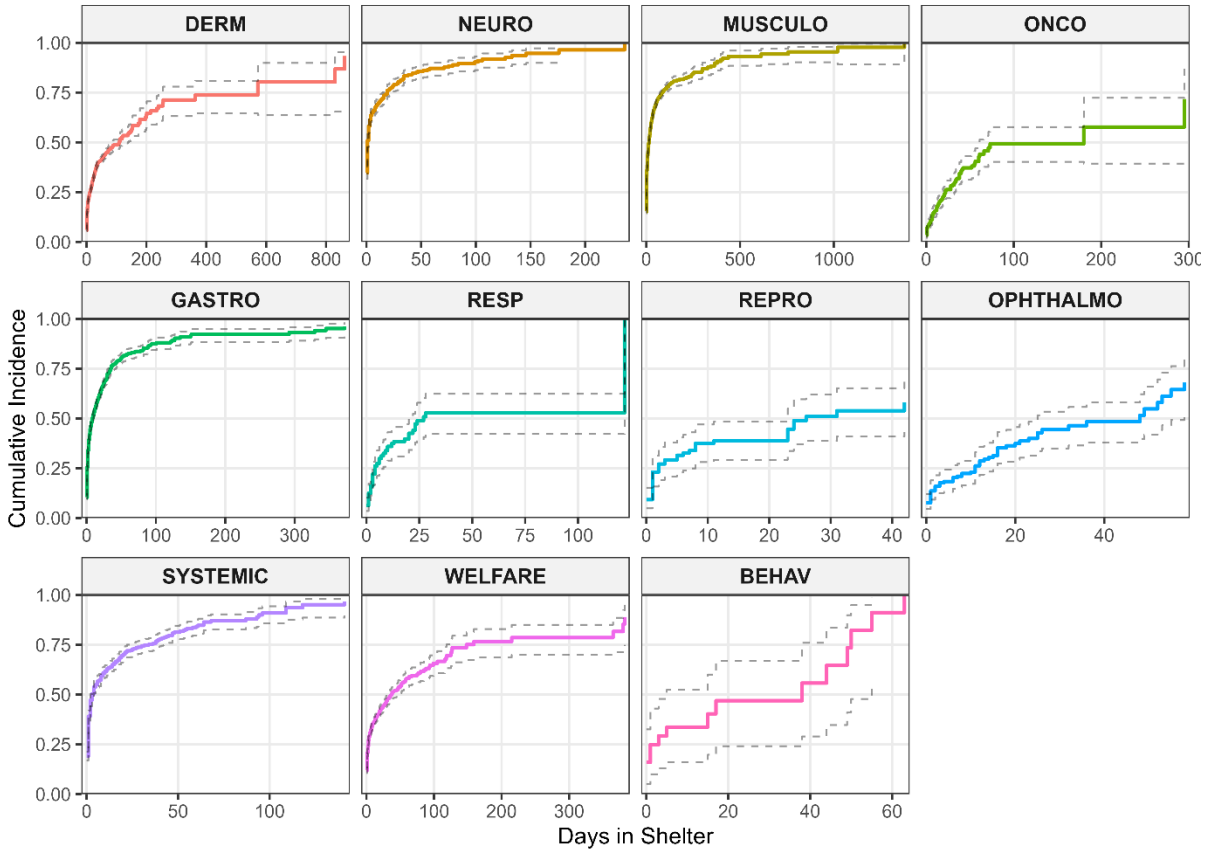
The survival dataset comprised 21,607 dogs with both valid LOS and a resolved outcome: 9,680 events (natural death: n = 9,337; euthanasia: n = 343) and 11,927 right-censored live exits. Body system was strongly associated with time to non-live outcome across the full dataset (log-rank test: χ^2= 1969, p <0.001; Table 6; Figure 5). Median time to reach a 50% cumulative incidence of a non-live outcome varied substantially among dominant body-system categories. Neurological cases reached a 50% cumulative incidence most rapidly (median 1 day; cumulative incidence 95% CI: 0.48-0.54), followed by systemic (3 days; 95% CI: 0.47-0.53), gastrointestinal (8 days; 95% CI: 0.48-0.52)

and musculoskeletal conditions (14 days; 95% CI: 0.49-0.52). Intermediate median times were observed for reproductive (26 days; 95% CI: 0.39-0.62), respiratory (27 days; 95% CI: 0.41-0.60), behavioural (38 days; 95% CI: 0.29-0.76) and ophthalmological conditions (48 days; 95% CI: 0.39-0.62). Dermatological cases had a substantially longer median time to a non-live outcome (109 days; 95% CI: 0.47-0.53), while oncological cases exhibited the longest median time (180 days; 95% CI: 0.39-0.72), indicating a comparatively slower accumulation of non-live outcomes than other body-system categories.

Table 6. Median time (days) to a non-live outcome estimated from cumulative incidence analysis by dominant body system. Median time (days) at which the estimated cumulative incidence of a non-live outcome first reached 50% for each dominant body-system category. Estimates were obtained from cumulative incidence functions with live outcomes treated as censored observations. The lower and upper C.I. values represent the 95% confidence interval for the estimated cumulative incidence at the median event time, rather than confidence intervals for the median time itself.

Body system	Median time	Lower C.I.	Upper C.I.
BEHAV	38	0.29	0.76
DERM	109	0.47	0.53
GASTRO	8	0.48	0.52
MUSCULO	14	0.49	0.52
NEURO	1	0.48	0.54
ONCO	180	0.39	0.72
OPHTHALMO	48	0.39	0.62
REPRO	26	0.39	0.62
RESP	27	0.41	0.60
SYSTEMIC	3	0.47	0.53
WELFARE	37	0.47	0.53

Figure 5. Cumulative incidence curves of non-live outcomes by dominant body system showing the probability of a non-live outcome over time for dogs admitted with different dominant body-system conditions. Shaded dashed lines represent 95% confidence intervals; steeper curves indicate a higher likelihood of non-live outcomes occurring earlier during the shelter stay.



Because sparse body system categories such as Behavioural, Respiratory, Reproductive, and Ophthalmological, had insufficient events for stable estimation in the Cox model, these were grouped into a combined 'Other' category for regression analyses. A mixed-effects Cox model with sex as a covariate and shelter as a random intercept was fitted to records with sex documented (n = 1,613; 706 events; Table 7; Figure 6). The shelter random effect standard deviation was 0.236 (variance = 0.056), confirming meaningful between-shelter clustering in baseline hazard. The proportional hazards assumption was satisfied for all terms (Schoenfeld residuals: $\chi^2 = 3.92$, p = 0.79; sex: $\chi^2 = 0.001$, p = 0.97; global $\chi^2 = 3.94$, p = 0.86). Relative to Dermatological cases, Neurological presentations carried the highest hazard of non-live outcome (HR = 3.15, 95% CI: 2.27 to 4.36; BH-adjusted p < 0.001), followed by Systemic (HR = 2.02, 95% CI: 1.42 to 2.87; p < 0.001), Gastrointestinal (HR = 2.00, 95%

CI: 1.57 to 2.56; p < 0.001), and Musculoskeletal presentations (HR = 1.60, 95% CI: 1.28 to 1.99; p < 0.001). Oncological cases showed a reduced hazard relative to the reference (HR = 0.61, 95% CI: 0.35 to 1.08; BH-adjusted p = 0.117) that did not reach significance after BH correction. Welfare context presentations and sex were not independently associated with survival (Welfare HR = 0.98, p = 0.93; Female vs Male HR = 1.07, p = 0.43).

Figure 6. Graph showing Hazard ratio for non-live outcome based on dominant body system implicated in intakes among free-ranging dogs in animal shelters. Compared with dermatological conditions, dogs admitted with neurological, systemic, gastrointestinal, and musculoskeletal conditions had a significantly higher risk of experiencing a non-live outcome. Female sex and the remaining intake causes were not significantly associated with outcome.

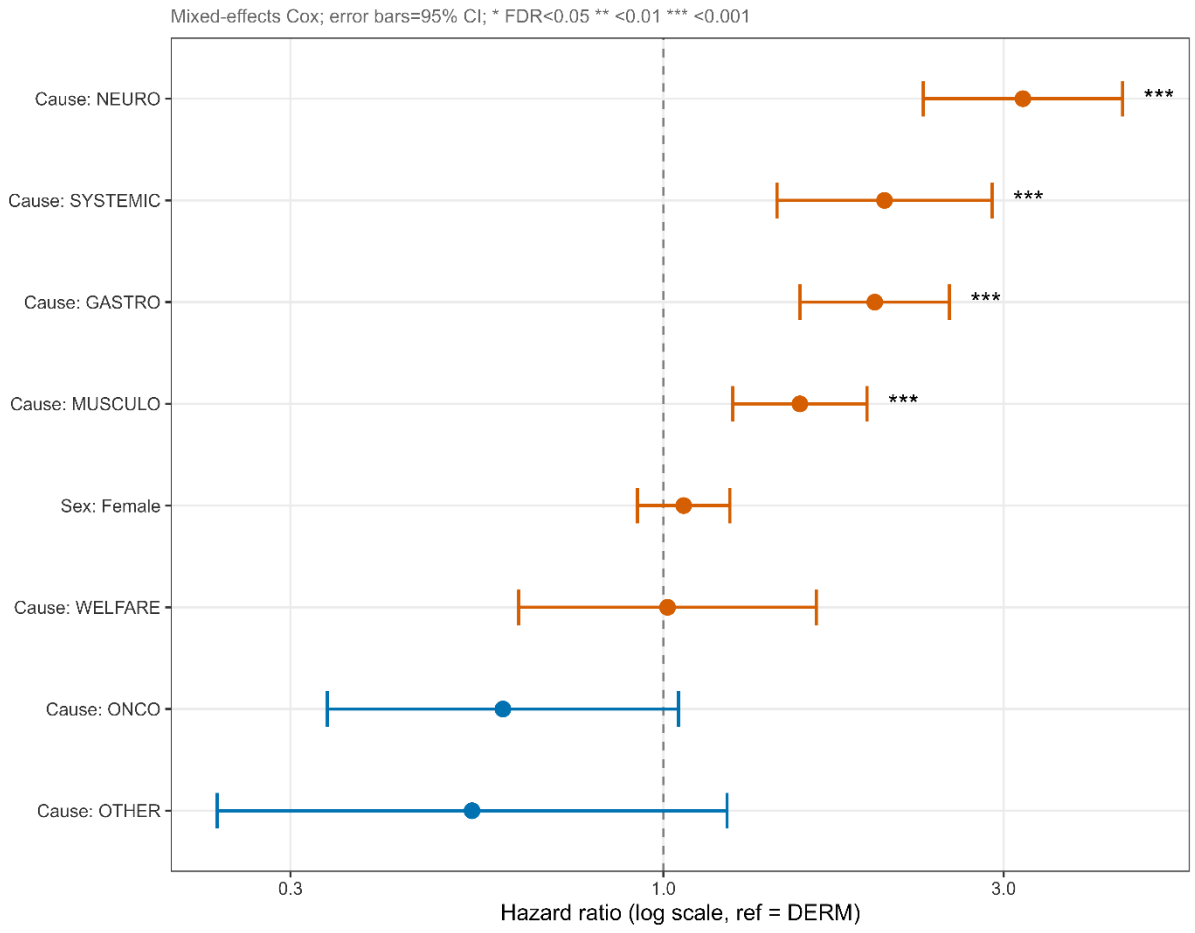


Table 7. Mixed-effects Cox proportional hazards model examining factors associated with time to a non-live outcome in dogs admitted to participating animal shelters. Hazard ratios (HR) with 95%

confidence intervals (CI) are presented for dominant body-system categories and sex. Dermatological conditions (DERM) and male dogs served as the reference categories. Hazard ratios greater than 1 indicate a higher instantaneous risk of experiencing a non-live outcome (death or euthanasia), whereas values less than 1 indicate a lower risk relative to the reference group. P-values were adjusted for multiple comparisons using the Benjamini-Hochberg false discovery rate (FDR) procedure.

Terms	HR	Lower C.I.	Upper C.I.	Adjusted p
GASTRO	2.00	1.57	2.56	<0.01
MUSCULO	1.60	1.28	1.99	<0.01
NEURO	3.15	2.27	4.36	<0.01
ONCO	0.61	0.35	1.08	0.14
OTHER	0.59	0.26	1.35	0.28
SYSTEMIC	2.02	1.42	2.87	<0.01
WELFARE	0.98	0.60	1.60	0.93
sex: Female	1.07	0.92	1.25	0.42

Fine-Gray competing risks regression was applied to the full survival dataset (n = 21,607) to separately estimate sub-distribution hazard ratios for natural death, with shelter included as a fixed covariate. Relative to Dermatological cases, the highest sub-distribution hazard for natural death was carried by Neurological presentations (SHR = 4.02, 95% CI: 3.67 to 4.40; $p < 0.001$), followed by Systemic (SHR = 3.09, 95% CI: 2.85 to 3.36; $p < 0.001$), Gastrointestinal (SHR = 2.50, 95% CI: 2.35 to 2.67; $p < 0.001$), and Musculoskeletal (SHR = 2.13, 95% CI: 2.01 to 2.25; $p < 0.001$) presentations. Behavioural cases also showed a substantially elevated sub-distribution hazard (SHR = 2.36, 95% CI: 1.67 to 3.33; $p < 0.001$). Oncological cases had a significantly lower sub-distribution hazard for natural death relative to the reference (SHR = 0.79, 95% CI: 0.66 to 0.94; $p = 0.006$). Shelter C (SHR = 0.83, 95% CI: 0.78 to 0.88; $p < 0.001$) and Shelter D (SHR = 0.58, 95% CI: 0.49 to 0.70; $p < 0.001$) both showed significantly lower sub-distribution hazards for death relative to Shelter A. The Fine-

Gray model for euthanasia as the competing event of interest was not fitted owing to the small number of euthanasia events (n = 343) and model instability.

Shelter-Level Variation in Survival by Intake Cause

Among the ten body systems with sufficient events across at least two shelters for a formal comparison, three showed statistically significant variation in survival across shelters following BH correction (Table 8). Welfare context presentations showed the strongest heterogeneity (log-rank χ^2 = 156.0, BH-adjusted p <0.001), driven by markedly longer median survival at Shelter A (93 days, 95% CI: 52 days to not estimable) than at other shelters, reflecting the compositional difference in Welfare intakes between organisations: Shelter A's Welfare category was dominated by Animal Birth Control sterilisation admissions, which are discharged rapidly in good health, while the same category at other shelters included higher proportions of cruelty, abandonment, and acute welfare intervention cases with substantially poorer prognoses. Neurological presentations also showed pronounced shelter heterogeneity (log-rank χ^2= 57.5, BH-adjusted p <0.001), with Shelter A recording a median neurological survival of two days (95% CI: 1 to 2 days), most likely reflecting the predominance of rabies-suspect presentations at that shelter. Musculoskeletal cases showed the third significant shelter difference (log-rank χ^2 = 23.7, BH-adjusted p <0.001), with median survival of 13 days at Shelter A (95% CI: 12 to 14 days). By contrast, Dermatological (χ^2= 0.21, BH-adjusted p = 0.901), Gastrointestinal (p = 0.127), Systemic (p = 0.369), Oncological (p = 0.369), Ophthalmological (p = 0.330), Reproductive (p = 0.369), and Respiratory (p = 0.145) presentations did not differ significantly in survival across shelters, indicating a broadly consistent prognosis for these body systems regardless of institutional context.

Table 8. Heterogeneity in outcomes across dominant body systems in different shelters

Body system	χ^2	Adjusted p-value
WELFARE	156.29	<0.001
NEURO	57.48	<0.001

MUSCULO	23.71	<0.001
GASTRO	5.96	0.13
RESP	5.25	0.15
OPHTHALMO	3.24	0.33
ONCO	2.25	0.37
REPRO	2.21	0.37
SYSTEMIC	2.41	0.37
DERM	0.21	0.90

Discussion

This study characterises, for the first time at a multi-site scale, the intake and outcome patterns of free-ranging dogs across Indian animal rescue shelters. Drawing on 24,421 records from four geographically dispersed shelters, the findings demonstrate physical trauma as the primary reason for shelter admission, occurrence of non-live outcomes at a rate substantially higher than published Global North benchmarks, a strikingly poor prognosis in neurological presentations, and difference in underlying drivers of intakes across shelters even when the broad clinical categories appear similar on the surface. Taken together, these results describe a shelter system functioning as a downstream safety net for an upstream population welfare crisis, in the absence of adequate upstream population management, vaccination coverage, and injury prevention infrastructure.

Three findings stand out as the most consequential for both shelter practice and policy. First, the overwhelming dominance of traumatic injury as an intake cause, evident across all four shelters regardless of geography, climate, or urbanisation level, indicates that road traffic accidents, dog fights, and human-inflicted harm are not localised problems but a structural feature of free-ranging dog life in Indian cities generally. Traumatic injury was the primary driver of both ‘Dermatological’ and ‘Musculoskeletal’ presentations across all four shelters, regardless of geographic region. This has direct implications for preventive interventions such as improved road design in high-density dog

population areas, community sensitisation, and expanded CNVR coverage to reduce territorial conflict may plausibly reduce the burden shelters currently absorb reactively.

Second, the data identified neurological presentations as carrying disproportionately poor survival- most plausibly linked to rabies-suspect and canine distemper cases given India's endemic rabies burden (10) underscores that vaccination coverage gaps are not merely a public health statistic but have a direct, measurable signature in shelter mortality data. The same-day exit odds of 3.56 confirm that most dogs presenting with a neurological dominant body system, containing terms explicitly associated with rabies presentation, are euthanised or die on the day of admission. Canine distemper, which shares several neurological signs with late-stage rabies and for which no curative treatment exists, contributes additional cases.

Third, while the participating shelters captured considerable geographic and ecological diversity, they cannot be considered representative of all Indian animal shelters. Shelter populations are shaped by regional disease burden, urbanization, human demographics, animal management practices, admission criteria, and clinical resources. Thus, findings from any individual shelter, or even a small group of shelters, should be interpreted as context-specific rather than nationally representative, a limitation that has been recognized throughout the international shelter medicine literature (31).

Quantitative shelter intake-outcome data from the Global South remain sparse relative to the extensive literature available for North America, Europe, and Australia. Comparison of above metrics with Global North shelter statistics requires considerable interpretive caution, given the structural differences in shelter operating models described earlier in this study. A study in Colorado showed a decrease by 12.4% between 2000-2015 (32). Euthanasia rates reported by Shelter Animals Count and comparable North American registries has fallen from around 24 million in 1970 to 1.5 million dogs in 2016 (33), reflecting a shelter system oriented substantially toward adoption placement and population control euthanasia policies that have declined markedly over the past two decades. Outcome patterns now overwhelmingly prioritize live releases, which include adoption, return-to-owner (RTO), and transfers to partner facilities (34,35). A 2017 census of dog shelters in five U.S. states reported that 45% of dogs were adopted, 19% were reclaimed by their owners, and 18% were

570 transferred, and an average euthanasia rate of 14% for dogs (20). The non-live outcome rates observed
571 in the present study exceed this range substantially, but this difference should not be read as evidence
572 of inferior care. Indian shelters, as described earlier, admit almost exclusively sick or injured animals
573 presenting at an advanced clinical stage, with treatment and release to territory as the default outcome
574 pathway rather than adoption and euthanasia being reserved legally and near-exclusively for
575 confirmed or strongly suspected rabies and cases of medical futility. The intake population is therefore
576 not comparable to the largely healthy owner-surrendered and stray populations that dominate North
577 American shelter intake (32,36,37). Trauma-dominant intake is more informative is in cause-of-entry
578 in Indian shelters, while present in Global North shelter populations, constitutes a much smaller
579 proportion of overall admissions there than in the Indian data presented here, reflecting the much
580 lower background rate of untreated injury among owned and semi-owned dog populations in high-
581 income settings.

582 Need for standardised data collection in India

583 Perhaps the most consequential finding of this study, from a systems perspective rather than a clinical
584 one, is methodological rather than epidemiological. The near-total absence of shared data standards
585 across Indian animal welfare organisations constitutes a fundamental barrier to evidence-based shelter
586 medicine and policy in the country. Constructing the harmonised dataset used in this study required
587 extensive manual reconciliation of incompatible record formats, cause-of-entry vocabularies, and
588 outcome coding schemes across four shelters. This mirrors a challenge that has been explicitly
589 identified in international shelter medicine as a barrier to comparative research and evidence-based
590 policy (31), but the problem is more acute in India given the scale, dispersion, and resource variability
591 of the animal welfare sector. Establishing a shared minimum data specification, when adopted
592 collaboratively across willing organisations, would substantially increase the value of routinely
593 collected shelter data without requiring additional data collection burden on already resource-
594 constrained staff. Digital record-keeping platforms designed specifically for the operational
595 constraints of Indian shelters, potentially building on the classification framework developed in this
596 study, represent one practical pathway toward this goal.

Limitations and future directions

There are several limitations in this study that we would like to acknowledge. First, as mentioned earlier, four shelters, however geographically diverse, cannot be considered representative of India's national shelter landscape, which comprises thousands of registered and unregistered organisations with widely varying capacity, geography, and operational practice. Second, the reliance on shelters with sufficient digital record-keeping infrastructure to participate introduces a selection bias toward better-resourced organisations, potentially underrepresenting the conditions faced by smaller or less formally structured shelters. Third, the retrospective nature of the data meant that cause-of-entry classification depended on the accuracy and consistency of original clinical recording by shelter staff, introducing potential misclassification, particularly for causes recorded as free text rather than through a structured intake form. Classification was based on field triage vocabulary rather than confirmed clinical diagnoses. Non-specific entries such as anorexia and generalised weakness can inflate the apparent frequency of Gastrointestinal and Systemic categories relative to what a structured clinical examination would indicate. Fourth, non-aligned temporal windows across shelters constrained the ability to draw direct cross-shelter comparisons for any given calendar year. Fifth, substantial missingness in sex and age data at certain shelters limited the statistical power available for demographic subgroup analyses.

The variations in intake causes suggest that the intake profile of an Indian animal shelter is not a neutral epidemiological sample of illness and injury in the surrounding dog population, but rather a filtered representation shaped by local road infrastructure, population density, climate, tourism patterns, shelter operational niche, and the diagnostic capacity available to the facility's clinical team, all of which interact in ways that make straightforward cross-shelter comparison of raw category frequencies potentially misleading without contextual adjustment. Thus, future studies incorporating geospatial covariates such as road network density, vehicle count, urbanisation index, and estimated free-ranging dog population size within shelter catchment areas would allow a more systematic disentanglement of these drivers. Furthermore, quantitative evidence of rescue volume, treatment outcomes, and community impact can considerably improve the credibility of shelters when applying

for government grants, corporate social responsibility (CSR) funding, philanthropic donations, and international funding opportunities, as funding agencies increasingly require measurable indicators of impact rather than anecdotal evidence alone.

Conclusion

This study provides one of the first multi-shelter quantitative assessments of dog intake characteristics, clinical presentation, length of stay, and outcomes across multiple animal rescue organizations in India. By characterizing the diversity of cases received by shelters and identifying factors associated with hospitalization duration and non-live outcomes, our findings establish an important evidence base for understanding the operational challenges faced by rescue organizations that primarily serve free-ranging dog populations. The marked differences observed among clinical categories and participating shelters underscore the complexity of shelter medicine and highlight that shelter performance should be interpreted within the context of the case mix and local operational environment rather than through simple outcome metrics alone. As companion animal rescue systems continue to expand throughout the Global South, the routine adoption of standardized electronic record-keeping and data-driven evaluation will become increasingly important for improving clinical decision-making, optimizing resource allocation, and supporting evidence-based animal welfare policy. More broadly, collaborative data sharing among rescue organizations has the potential to transform routine shelter records into a valuable resource for veterinary epidemiology, welfare science, and conservation medicine, enabling researchers, practitioners, and policymakers to work together towards improving the health and welfare of free-ranging dogs and the communities with whom they coexist.

Ethics approval and consent to participate

Ethical approval was not required for this study because it involved retrospective analysis of anonymized shelter records and did not involve any direct interaction with animals or humans. Written permission and informed consent for data sharing were obtained from the managers or authorized representatives of all participating animal shelters prior to data collection.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available because they were obtained under confidential data-sharing agreements with the participating animal shelters but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

RM, AP and AB conceived and designed the study; RM acquired the data, curated the database, performed the statistical analyses, interpreted the results, and drafted the manuscript. All authors read and approved the final manuscript.

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Authors' information (optional)

Not applicable.

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