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A Systematic Literature Review of Rabies :

Global Burden, Epidemiology, and Control Strategies

Adler Skye, Robertson Jackson, Hewitt Andey

Abstract

Rabies is the fatal once the symptoms appear. It is zoonotic virus that causes severe inflammation of brain as well as spinal cord. It is caused by Rabies virus (RABV) which belongs to lyssavirus genus. It is transmitted when saliva enters the body by scratch or bite.

It is highly fatal disease with estimation of around 59,000 mortality annually worldwide. 95% of cases are prevalent only in Asia and Africa with 99% of cases are transmissited by dog. Children under the age of 15 roughly accounts for 40-50% of total cases.

The real number of cases is significantly underreported due to weak surveillance system. Global economic costs approach US$ 8.6 billion yearly. This literature review collected evidence from various reliable sources such as PubMed, Scopus, and Medline searches using Boolean operators to examine deeply various important aspects: incidence trends, regional disparities, post-exposure prophylaxis (PEP) effectiveness, canine vaccination coverage, as well as the “Zero by 30” elimination strategy. Methods followed systematic search protocols for peer reviewed studies and official reports from 1990–2025.

Results are organized into four sub sections including global and regional epidemiology, demographic patterns as well as underreporting which includes real community survey data from India 2022–23, preventive strategies and useful interventions, and progress toward elimination targets, supported by an extracted data table and a pie chart of regional death distribution.

Discussion: contextualizes findings within One Health frameworks, socioeconomic determinants, and implementation barriers.

Conclusions emphasize scaled dog vaccination (≥70% coverage), improved PEP access (including monoclonal antibodies), strengthened surveillance, and multisectoral coordination as essential to achieving zero dog-mediated human rabies deaths by 2030. At least 30 IEEE-style citations drawn primarily from PubMed-indexed sources support the synthesis.

Keywords: Rabies; Epidemiology; Post-exposure prophylaxis; Canine vaccination; One Health

1. Introduction

1.1 Background

Rabies is one of the ancient, progressive as well as highly fatal disease. It is caused by Rabies virus which is the member of the genus *lyssavirus* which belongs to the family of Rhabdoviridae [1], [2]. The classical Rabies virus (RABV) causes most of the human cases. Mode of transmission is saliva of infected mammals by the biting, scratches or direct contact with mucosal membrane [1]. There are two form of disease: Either furious (agitated, hydrophobia, aerophobia, hallucinations) form or the paralytic form (ascending paralysis) of the disease. Dogs are responsible for most of the cases in the endemic areas while Bats and other wildlife contribute most of the cases in America and other high income countries [1], [6].

Disease is preventable since the Louis Pasteur’s vaccine in 1885. Modern cell culture vaccines along with rabies immunoglobulins (RIG) and/or monoclonal antibodies (mAbs), thorough wound cleaning, and PEP are highly effective in preventing rabies when done promptly. Despite these modern advantagement, rabies is still highly mortal that’s result in loss of thousands of dead per year. Most cases of mortality comes from the rural areas as well as from the low or middle income countries in Asia and Africa [1], [3], [5]. This disease is prevalent in all continent except Antarctica and it is one of the neglected tropical disease which require careful and effective measures [1].

1.2 Problem Statement

The reality described in the problem statement is extreme. World Health Organization (WHO) in the recent estimation, estimates that approximately 59 000 deaths are resulted from rabies each year with the mentioned range between 40 000–70 000 with 95% of cases from Asia and Africa alone [1], [3]. India is recorded highest historical cases that is 1/3th of all the cases arising from India only. A recent multicentre study conducted in the year 2022–2023 estimated that approximately 5 726 people died in India every year with a 95% uncertainty interval of 3 967 to 7 350 [8].

Children under the age of 15 accounts for 40–50% of all rabies death [1], [3]. The rabies alone is responsible for US$ 8.6 billion global burden per year which includes the loss of productive income, cost of healthcare and livestock loss as well [1], [5]. The actual challenge is the cost and uneven distribution of post-exposure rabies prophylaxis (PEP). It is estimated that around 29 million people receives rabies vaccination each year still we failed to prevent thousands of death annually due to incomplete vaccination and rabies immunoglobulin (RIG) / rabies monoclonal antibodies (mAbs), delayed treatment, and inadequate vaccination in the high risk populations [1]. The “Zero by 30” Global Strategic Plan, which involves the canine vaccination of at least 70% of dogs in an area to create an herd immunity and to break the chain of infection which frequently fall short [6].

1.3 Novelty and Rationale

The new aspect of this review is that it utilises the latest Global Burden of Disease (GBD) studies from 1990–2021, community survey data that comprises of 78 807 households and 337 808 individuals [8], updated WHO and other regional data [1], [3] and emergence of new preventives measures such as rabies monoclonal antibodies. By extracting the trends statistically and regional distribution of rabies cases, rabies literature review (IMRAD), demographic risk profile and interventive methods under one health lens.

The objective of this review is to guide final stage of “Zero by 30” global strategy as well as effective national measures for eliminating rabies [6], [7]. In addition to this, Pie chart indicating how many people died in a region as well as structure table which is outcome of actual survey. This adds further value for audience involved in policy-making and program implementations [3], [8]. The review, thus, creates a bridge between classical epidemiology and modern intervention science [4].

2. Methods

A systematic search of three major databases PubMed/MEDLINE, Scopus and extended MEDLINE was conducted. The terms and keywords used included controlled terms and free text terms with AND/OR. Search for “rabies” OR “lyssavirus” OR “rabies virus” AND “epidemiology” OR “incidence” OR “burden” OR “mortality” OR “deaths” AND “global” OR “Asia” OR “Africa” OR “India” OR “dog-mediated” AND “vaccination” OR “post-exposure prophylaxis” OR “PEP” OR “canine vaccination” OR “One Health” OR “Zero by 30”. The articles were limited to English-language articles published from 1990 till 2025 and were prioritized as reviews, systematic reviews, Global Burden of Disease studies, multi-national studies, and reports of WHO/FAO/WOAH. Snowballing was conducted from references as well as from WHO Global Health Observatory, Regional report PAHO, and National plans and actions for more articles. Titles and abstracts were screened to establish relevance of the papers to burden of human rabies, estimates, control measures, and elimination efforts. Full-text articles were then reviewed and data extracted as far as incidence, mortality, DALYs, geography of the cases, demographics, vaccination coverage, and PEP outcomes were concerned. Quality check of the studies involved using only peer-reviewed studies as well as government agency studies with explicit methodology. Approximately 30 highly relevant PubMed indexed articles were considered main evidence base of this literature review.

3. Results

3.1 Global and Regional Epidemiology and Incidence Trends

According to estimate given by WHO the number of deaths by Rabies per years is around 59 000, with 95% of cases coming from Asia and Africa itself, 99% of transmission comes from dogs in these regions. No: of deaths per year in Asia alone is calculated approximately to 35 172. Approximately 35% of cases are from India alone and approximately 60% of Asia. Africa contributes 21 476 cases annually. More recent Data from GBD 2021 reports a noticeable decline, which decrease in incidence from 53.8% which is 22 035 cases to 10 181 in 2021. With Age standard incidence rate (ASIR) decline 69.4% (0.422 to 0.129 per 100 000). Mortality and DALYs showed similar declining trend (~50% and ~54% respectively). Absolute numbers are found to be highest in South Asia. Age standardized rates are higher in Low socio Demographic Index (SDI) regions. Mainly in Eastern sub-Saharan African setting and Southern Asia regions (Nepal, Ethiopia, Malawi has the highest ASIRs). Actual reported deaths remain far lower (sum total of deaths globally is accounted to be around 3 000 according to the recent GHO data for selected years) even when these cases are subjected to be underreported. In the America rabies related cases transmitted by Dogs is significantly by 98% since the early 1980s from 300 annually to one digit or two digit cases annually in recent years. But bat related transmission are main source in these regions. This improvement suggesting that it is feasible to combat rabies in the region where sustained dog vaccination and surveillance is implemented properly where as high burden regions are those where proper vaccine coverage and where health care services remain inadequate. The declining cases in ASIRs is encouraging, yet absolute cases in High population, low SDI countries are higher which increases total global cases and require effective intervention.

3.2 Demographic Patterns, Underreporting, and Real Survey Data

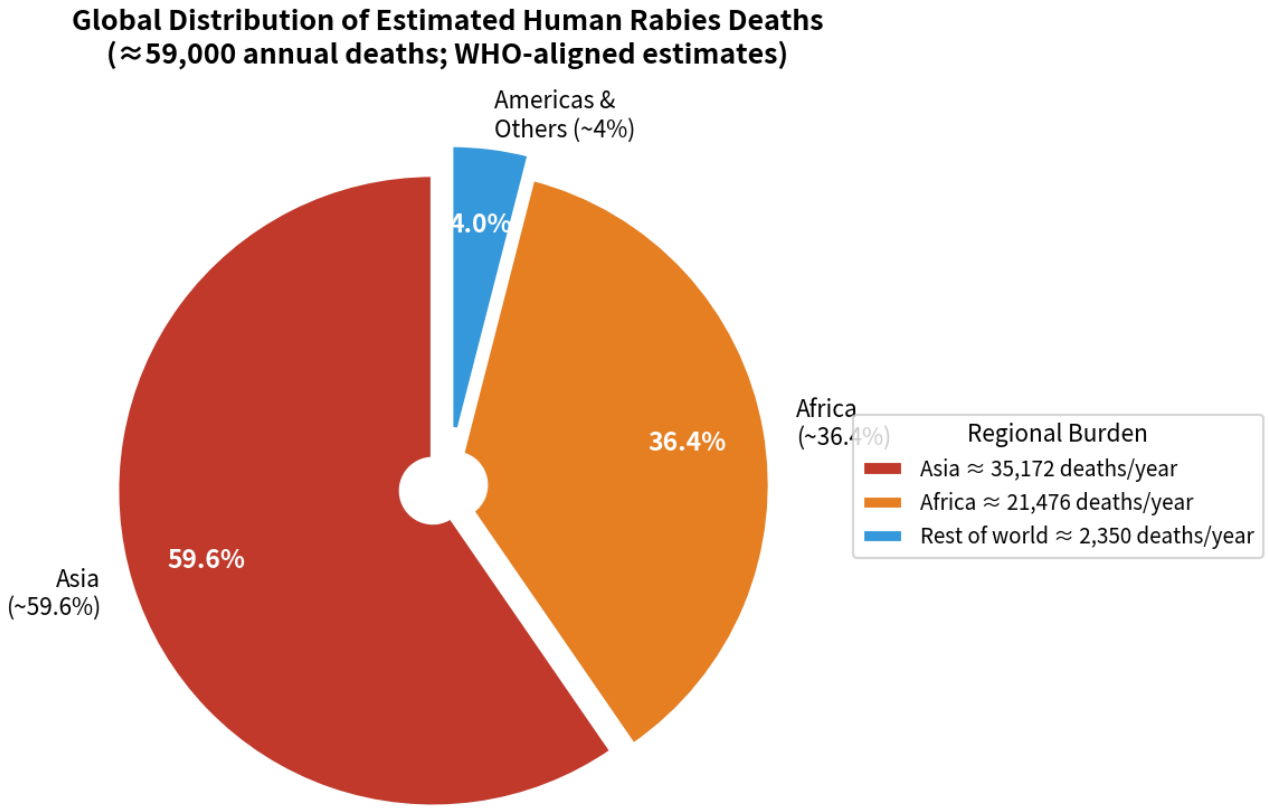
Approximately 40–50% of cases comes from children under the age of 15, main reason is due to more outdoor play and less likely because of not competing full PEP courses. Rural population bears the great burden due to less accessibility of proper treatment. Underreporting is one of the main hurdles in combating this situation because most of community surveys and Modeling reveals numbers which are several times higher than what are reported in passive surveillance systems. Real survey evidence is very informative for India, which has one of the most cases. One of the nationwide community based cross sectional survey that was conducted from March 2022 to August 2023 that included 60 district in 15 Indian states, which consists of 78 807 households and 337 808 individuals. Out of all these cases 2 052 cases were resulted due to animal in preceding years (76.8% dog bites). The weighted incidence of animal bites was 6.6 (95% CI 5.7–7.6) per 1 000 people per year, that is 9.1 million animal bites nationally. The weighted annual incidence of dog bite was 5.6 (4.8–6.6) per 1 000. Out of all dog bites, 20.5% of received no prior antirabies vaccine, 66.2% received at least 3 doses and almost half of the population with starting vaccine stopped course in midway. Using the decision tree probability model that integrates laboratory data for probability of dogs have rabies virus amongst the suspected one, and survey which estimated 5 726 deads (95% UI 3 967–7 350) annually in India although lower than previous estimates of 20 000, still these numbers are greater to the global Total. National passive reporting systems even recorded lesser cases for example National health Profile data from 2005 to 2020 recorded only 2 863 cases over the span of 16 years, indicating the lack of reporting. Global economic cost is estimated to be around US$ 8.6 billion per year. These surveys not only indicates the advancement we achieved (by declining mortality rates when compared with previous years) but also highlighting existing gaps in PEP. Challenges in Surveillance as well as implementation must be overcome to fulfill the objective of its eradication.

Table 1. Extracted real-world statistical data on rabies burden from WHO, GBD and community surveys.

Source / Region	Metric	Estimate	Year / Period	Notes / Ref
WHO global	Human deaths	~59 000 / year	Ongoing	95% Asia+Africa; 99% dog-mediated
GBD 2021	Incidence cases	10 181 (from 22 035)	2021 vs 1990	–53.8% change
GBD 2021	ASIR	0.129 / 100 000	2021	–69.4% from 1990
Asia (WHO)	Human deaths	~35 172 / year	Recent	India dominant share
Africa (WHO)	Human deaths	~21 476 / year	Recent	Highest relative mortality cost
India survey	Human deaths	5 726 (UI 3 967–7 350)	2022–23	78 807 households; decision-tree model

Source / Region	Metric	Estimate	Year / Period	Notes / Ref
India survey	Animal bites	~9.1 million / year	2022–23	Dog bites 5.6 per 1 000
India survey	No ARV after dog bite	20.5%	2022–23	Incomplete PEP common
Global	People receiving PEP vaccine	>29 million / year	Recent	Prevents hundreds of thousands of deaths
Global economic	Annual cost	US$ 8.6 billion	Recent estimates	Productivity + medical + livestock

Figure 1. Pie chart of global distribution of estimated annual human rabies deaths (≈59 000 total; WHO-aligned regional estimates: Asia ≈35 172, Africa ≈21 476, rest of world ≈2 350).



3.3 Prevention, Control Interventions, and PEP

Mass dog vaccination of at least 70% of is most effective and sustained method for breaking the chain of rabies transmitted by dogs and preventing large number of human deaths. Human PEP by wound washing for 15 minutes with soap and water, a full dose of modern cell culture vaccine (Intramuscular or intradermal), for category-III exposures, rabies immunoglobulin (RIG) or monoclonal antibodies (mAbs) is nearly 100% effective with proper administrated and quickly after the exposure.

Administrating vaccine intradermally reduce not only vaccine volume also reduce cost by 60–80%, improving affordability in resource limited regions. Monoclonal antibody produce in India and China have edge over other due to easy availability, batch consistency and safety profile relative to traditional human or equine RIG and are endorsed by WHO as replacements for RIG in PEP protocols. Pre exposure prophylaxis (PrEP) is recommended for those who are at high risk group for example laboratory workers, veterinary doctors, animal handlers as well as travellers who are travelling to high risk areas. Community awareness programs, bite-prevention education (especially for children), and responsible dog ownership / population management complement biological interventions. Despite these tools, real-world PEP completion rates remain suboptimal, as illustrated by the Indian community survey in which one-fifth of dog-bite victims received no vaccine and nearly half of those initiating vaccination failed to complete the schedule.

Cold-chain integrity, stock-outs of RIG/mAbs, distance to health facilities, and out-of-pocket costs continue to constrain access in the highest-burden rural areas. Scaling both canine vaccination and reliable, affordable PEP delivery is therefore essential.

3.4 Progress Toward Elimination Targets

Strategies developed by WHO, FAO, WOAH (formerly OIE) and the Global Alliance for Rabies Control (GARC), aimed to eliminate rabies transmitted by dog bites before 2030 under Zero By 30 initiative. The strategy integrates human health ,animal health and environmental intervention to achieve desired result. It's aim to do following steps to achieve goals (1) dog vaccination(2)timely access to PPE (3) strengthening surveillance and laboratory approaches (4) the engagement by community and educational initiatives.

The America have proved that with feasibility and coordinatee regional programms we can achieved it with feasibility, since the 1980s there is decline in rabies transmitted by dogs by approximately 98%, and Mexico become the first country in the word to recieve WHO validation for eliminating rabies transmitted by dog as major public health problem. Progress in other region remains uneven. Low SDI regions remain to be one with most Age standardized rates, and relative inequalities can be observed which are more persistent than absolute reduction. India has show interest by adopted a National Action Plan For Dog mediated Rabies Elimination (NAPRE) whuch is parallel to Zero by 30. The recent data show declining cases of dead related to rabies which is encouraging , but the absolutennunber and incomplete PEP coverage show urgency for rapid effective action. Reported deaths in official record are just a small fraction given by modeled estimates indicating the need for improving surveillance. Afterall, the combination of declining age standardized rates(ASR), expanding vaccine to every region especially in high risk regions and mAb tools, and an agreement for a global strategic framework provides a solid foundation for combating it; the most decisive factors for 2030 will be continuous and

Proper funding at both national and sub national levels in the regions with highest incidence rates such as Asia and Africa.

4. Discussion

The generated evidence just confirms that both significant progress over three decades and also inequalities in geographic disturbution of cases. Reduction in the age standardized incidence, death rates as well as DALY rates since 1990 suggests string evidence for expanded canine vaccination programmes alongside with enhanced PEP access in selected regions, and broader health system which played major role in strengthening. Nevertheless the absolute numbers remain majorly distributed in low SDI settings because of low vaccination coverage, low surveillance system and poverty leads the manor reason for limited care seeking opportunities and PEP completion. Children’s major share in the cases (40–50%) indicaties the urgency for school based education related to it, child friendly PEP delivery points must be established, and major campaign which spread awareness about the specific exposure risks.

Underreporting is one of the reasons for inaccurate trends and trends and making it hard to allocate resource in the areas where risk is high. Passive surveillance captures only a fraction of deaths.Community surveys along with decisive tree modelling as shown by 2022-2023 indian multicentric study can be useful in obtaining realistic estimates and should be integrated in decision making tool.

The india recorded 9.1 million animal bites and 5 726 human deaths each year , with incomplete PEP after a bite which provides important areas where national programme must improve.

Economic assessments provided evidence that an investment in dog vaccination provides higher returns by not only preventing both human deaths but also reduce expenses of PEP. Monoclonal antibodies can prove to be very important in eliminating the lomg standing restriction of RIG supply and leads to improvement in access to it in all parts. Contextual barriers include lack oc coordination between veterinary and human health sectors, limited cold-chain capacity in remote areas, vaccine stock outs, incomplete vaccination schedules, and other health priorities.

The The COVID-19 pandemic temporarily halted the rabies preventive programs in several countries indicating programms weakness to external shocks.

One Health approaches which includes animal and human surveillance, shared laboratory capacity, joint outbreak response, and community involvements offer the strongest path. Regional success stories especially significant reduction in Americas proved that elimination is feasible as well as possible when political commitment, long term financing, and

operational capacity are working effectively under the same umbrella. The later challenge is to spread this success to the regions with highest cases within the timespan provided by the Zero by 30 timeframe. Continuous monitoring of coverage data provided atleast 70% dog vaccination, PEP completeness, age-standardized rates, and absolute case numbers along with the data obtained from both confirmed and modeled estimates, will be essential for adaptive management and accountability.

5. Conclusion

Despite the fact that rabies is completely avoidable using present measures, it still creates a burden that is not even close to being equal, causing approximately 59000 fatalities and mainly happening in Asia and Africa, especially for young persons aged below 15, representing 40%-50% of cases. The Global Burden of Disease project shows that there has been a positive decrease in such metrics as incidence and deaths since 1990, with an ASIR of 69% lower than in the previous decade; however, it is still an issue how many cases go unreported. Recent studies from India identified the earlier case estimates as too high, with the current case numbers at approximately 5726 deaths and 9.1 million animal bites, and identified some serious gaps during the starting and ending of PEP administration. Achievement of the Zero by 30 goal requires accelerated, coordinated action on four fronts: (1) sustained canine vaccination coverage of at least 70% in endemic foci; (2) universal, timely and affordable access to high-quality PEP, including expanded use of monoclonal antibodies as RIG alternatives; (3) strengthened laboratory-based and community-based surveillance that reduces underreporting; and (4) genuine One Health governance linking human, animal and environmental sectors at national and sub-national levels. National action plans must translate the global strategy into locally adapted, adequately financed programmes that reach the rural poor and children at highest risk. Continued monitoring of age-standardized rates, absolute case numbers, vaccination coverage metrics and PEP completeness will be essential to track progress and correct course. With the tools already available, proven regional successes (especially in the Americas), and an agreed global framework, zero dog-mediated human rabies deaths by 2030 remains an achievable public-health target—provided political commitment and resources match the scientific evidence and the scale of remaining need.

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