

Development of an Integrated Rabies Control Model in Côte d'Ivoire

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Abstract Since 2008, Côte d'Ivoire has recognized rabies as a notifiable disease and, in 2017, elevated it to one of the country's top five priority zoonoses. Despite the implementation of various measures and initiatives, the battle against rabies has been an ongoing struggle. This study aims to answer the question: What model, tailored to the unique characteristics of rabies and mortality determinants, can be recommended to expedite the progress towards its elimination in Côte d'Ivoire? The study introduces an integrated rabies control model specifically adapted to the disease's characteristics. The research was conducted through a mixed cross-sectional study spanning from January to September 2023. Data collection involved interviews, document reviews, and a narrative review of all rabies-related publications in Côte d'Ivoire from 2018 to 2023. Ethical guidelines were adhered to, including administrative approval, informed consent, and the preservation of confidentiality. The primary challenges identified in the fight against rabies in Côte d'Ivoire encompassed low dog vaccination rates, limited public awareness about the disease, and inadequate access to Post-Exposure Prophylaxis (PEP). A problem tree analysis elucidated the factors contributing to mortality, with a primary focus on insufficient dog vaccination coverage and inadequate public knowledge, leading to suboptimal PEP utilization. The proposed model to expedite rabies elimination in Côte d'Ivoire comprises a set of interventions designed to enhance PEP utilization while concurrently increasing dog vaccination coverage. Key elements of the model include bolstering geographical and financial accessibility, enhancing public knowledge, and instilling a sense of communal responsibility in the battle against rabies. In the absence of control over the disease's primary reservoir and vector, the integrated model of rabies control promotes the systematic implementation of PEP before any exposure to rabies, combined with extensive public awareness campaigns and improved PEP accessibility.

Keywords: Problem tree, integrated model, rabies control, Côte d'Ivoire

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1. Introduction

Rabies is a devastating viral disease that almost invariably leads to death once the initial symptoms manifest [1]. Among infectious diseases, it ranks as the tenth deadliest and remains one of the most severe diseases that can be transmitted to humans [1]. Dogs stand out as the primary reservoir of the virus globally, responsible for nearly 99% of human deaths. According to the World Health Organization [1], this zoonotic disease affects over 150 countries, resulting in an estimated 59,000 annual deaths. Alarming projections suggest that between 2020 and 2035, it could claim more than a million lives in the 67 endemic countries if no decisive

action is taken [2]. Rabies is most rampant in Asia and Africa, where over 95% of recorded cases occur [1]. Notably, in these two continents, dogs remain the primary carriers of the disease in almost 99% of cases, with more than 40% of the victims being under 15 years of age [1].

In the case of Côte d'Ivoire, rabies is endemic, and the national epidemiological surveillance system regularly reports deaths attributed to the disease [3]. Since 2008, the country has classified rabies as a notifiable disease, and in 2017, it was designated as one of the top five priority zoonoses [4,5]. In 2015, a pivotal initiative was launched with the aim of eliminating dog-transmitted rabies by 2030 [6]. Subsequently, Côte d'Ivoire joined this initiative, leading to the implementation of an integrated national rabies control plan. In the local context of Côte d'Ivoire and many African countries, rabies was considered a

neglected tropical disease, characterized by a shortage of resources for effective control. The execution of this plan has spurred an intensification of collaborative efforts, encompassing communication, dog vaccination, capacity-building for professionals in both health and veterinary sectors, comprehensive investigation, and a response framework organized under the "One Health" concept, in addition to post-exposure prophylaxis.

However, despite rabies being a notifiable disease in both humans and animals, and the presence of an integrated national program to combat this zoonosis, the number of deaths caused by dog-transmitted rabies continues to persist and, alarmingly, is on the rise. This unsettling trend puts us further from the pivotal indicator of "No human deaths due to rabies for 24 months," which is the threshold for international recognition of a country's successful elimination of rabies as a public health concern [6].

In light of this concerning scenario, we pose the following question: "What model, tailored to the unique characteristics of rabies, can be recommended, based on mortality determinants, to expedite progress toward eliminating rabies in Côte d'Ivoire?" Our hypothesis suggests that an integrated model, specifically adapted to the attributes of rabies and grounded in the determinants of this zoonosis, could pave the way for its elimination in Côte d'Ivoire by 2030. Our objectives are as follows:

- Conduct a comprehensive assessment of rabies control efforts in Côte d'Ivoire.
- Develop a problem analysis highlighting the key factors contributing to human rabies deaths in Côte d'Ivoire.
- Propose an integrated control model designed to enhance rabies control in Côte d'Ivoire.

2. Material and Method

2.1. Study Setting

This study was carried out within the rabies control system in Côte d'Ivoire, which consists of 2 components: the national animal health system and the human health system.

The animal health component

There are three (3) levels in its administrative structure: the central level, the intermediate level, and the peripheral level.

- The intermediate level concerns the regions, with 20 Directorates responsible for supervising and coordinating the activities of the Departmental Directorates.

- The peripheral level, representing the departmental diapason, comprises 57 Departmental Directorates, 162 Animal and Fisheries Resources Breeding Stations, and 12 Border Entry and Inspection Stations. There are also 30 private veterinarians with a health mandate to carry out mass vaccination campaigns to combat priority diseases. 13 Groupminds de Défense Sanitaire (GDS) for pigs and 10 for poultry are involved in epidemiological disease surveillance and control. The private veterinary pharmaceutical sector is essential in distributing veterinary medicines and products. Since 2000 (Order n°113 /

MINAGRA/CAB), Côte d'Ivoire has set up the National Animal Disease Epidemiological Monitoring Network through the creation of a national early warning and prevention system for animal diseases thanks to the Pan-African Programme for the Control of Epizootics (PACE). The National Animal Disease Early Warning and Prevention system comprises the Animal Disease Epidemiological Monitoring Network and the National Rapid Intervention and Prevention Technical Unit.

Human health

This is provided by the Ministry of Health, Public Hygiene, and Universal Health Coverage through the INHP and its branches, of which the Rabies Centre is the reference center for the fight against human rabies in Côte d'Ivoire. Its missions are detailed in the following activities:

- Systematic treatment of people exposed to rabies by following current protocols and preexposure vaccination of people at risk;
- Follow-up of people who have been exposed to rabies, using the telephone reminder system for those who have been lost to follow-up to enable them to complete the current vaccination protocol;
- Behavior Change Communication (BCC) on rabies;
- Organizing and coordinating epidemiological surveillance of human rabies throughout the country, in collaboration with the health districts, via four (04) communal branches, twenty (20) regional branches, and six (06) departmental branches.

2.2. Type and Period of Study

We conducted a mixed cross-sectional study from January to September 2023.

2.3. Study Population

The study population consisted of thirty key persons in the field of rabies control in Côte d'Ivoire, both human and veterinary: - At the human level, there were six agents at the reference center, ten agents at the decentralized level of the INHP branches, and six agents at the health district level. - At the veterinary level, we interviewed three resource persons at the central level and three resource persons at the decentralized level.

2.4. Data Collection and Management

Data were collected by interview and document review. - The interviews concerned resource persons. The data essentially concerned the strengths, weaknesses, opportunities, and threats in the fight against rabies and the determinants of deaths from human rabies in Côte d'Ivoire; Each resource person essentially considered the activities in their field, in line with the "one health" concept.

- The document review covered the period from January 2000 to September 2023. and focused mainly on analysis of the annual activity reports of the National Institute of Public Hygiene, the records of people exposed to rabies and treated for it, including veterinary surveillance records, the reports of World Rabies Control Days, and the records of people who died of human

rabies(Excel database), supplemented by investigation, and response reports on cases of death from human rabies, the National Integrated Rabies Control Programme for Côte d'Ivoire (2018-2023)

- The narrative review covered all published works relating to rabies in Côte d'Ivoire over the same period. The works selected included scientific articles, scientific papers on rabies presented at conferences, published conference proceedings, and press interviews on rabies in the world and in Côte d'Ivoire from 2000 to 2023. The search was carried out in the following databases: - Pubmed / Medline ; - Electronic university databases; - Journal websites; - Sci-Hub - Author reprints received from journals.

The Internet search engines used were Google Chrome, Google, and Google Scholar. Free-language searches were preferred, and the keywords used were "rage, Côte d'Ivoire."

2.5. Data Analysis

The extracted information comprising the following variables was grouped, and the study variables were extracted and classified into four themes: - Risk factors for death; - The limits of the interventions implemented; - Situational analysis of the institutional framework for rabies control, highlighting strengths, weaknesses, opportunities, and threats. - The implementation of an integrated rabies control model in Côte d'Ivoire. The situational analysis was first carried out by considering human and animal activities under the "one health" concept and using the SWOT tool (Strengths, Weaknesses, Opportunities, and Threats), which enabled us to define

the strengths, weaknesses, opportunities, and threats of rabies control in Côte d'Ivoire. Then, using the data from the articles, we constructed a problem tree of human rabies deaths in Côte d'Ivoire. Finally, we used this problem tree to build an integrated model for rabies management in Côte d'Ivoire.

2.6. Ethical Considerations

This study complied with all the stages. It received administrative authorization from the management of the INHP. The informed consent of the interviewees was obtained, and the confidentiality of key information was respected by means of codes and by canceling names. It, therefore, did not require an ethical approval by the National Life and Health Sciences Ethics Committee (CNESVS).

3. Results

In Côte d'Ivoire, rabies is primarily an endemic, rural, and predominantly juvenile health concern characterized by a limited understanding of the disease and associated risky behaviors, particularly prevalent in rural areas [8-17]. It is noteworthy that the implemented activities often fail to adequately consider the unique characteristics of this disease [18-27]. However, promising results have emerged from innovative approaches undertaken as part of feasibility studies, offering hope for the potential elimination of rabies in Côte d'Ivoire [28-33].

Table 1. Characteristics of Reviewed Articles and Key Findings

References (Year)	Location	Study population	Main results
[8] 2000	Abidjan	Stray dogs	Saliva is the main factor in the dissemination of the rabies virus, and stray dogs are the main vector in Côte d'Ivoire (99% of cases by bite).
[9] 2014	Abobo,	Householders	Risk behaviors persist, especially in rural areas: immediate washing of lesions with soap and water was ignored by over 96% of heads of household. 20.4% of heads of household felt that nothing should be done after a bite.
[10] 2010	Abidjan	Patients who died of human rabies at CAR	Annual incidence of 0.028 cases per 100,000. Despite the increase in the number of cases observed from 2006 onwards, due to the strengthening of disease surveillance, further progress is still needed to assess the true incidence of rabies in Côte d'Ivoire.
[11] 2011	Abidjan	Subjects exposed to rabies	5 exposures per 10,000 people. The most exposed age groups were 0-9 and 10-19 (22.4% and 29.5% respectively).
[12] 2012	Abidjan, Hospital environment	Files on human rabies fatalities	The rabies cases occurred after bites from stray dogs whose vaccination status was unknown.No pre-exposure prophylaxis had been carried out, and four patients had received incomplete post-exposure prophylaxis.
[13] 2018	National territory	Subjects exposed to rabies and under PPE.	The reinforced system recorded 15 to 18 cases per year (annual incidence of 06 to 0.08 per 100,000) and over 30,000 animal exposures (annual incidence of 41.8 to 48.0 per 100,000).Nearly half of all human rabies cases involved children aged ≤ 15 years.
[14] 2018	National territory	Data	Most surveillance systems in endemic countries, notably Côte d'Ivoire, are weak.
[15] 2020	Bke , San Pedro	Population canine	The dog-to-household ratio has been estimated at one dog per three households (0.33) or one dog per 20 people (0.05).
[16] 2021	Tchad, Côte d'Ivoire Mali	Data	The lack of data collection and documentation, the experience of human health workers and veterinarians, and the weak infrastructural capacity of the veterinary and human health systems in the project countries posed major challenges.
[17] 2020	Bouaké et San Pedro	Subjects exposed to rabies and under PPE.	The main problems identified are the geographical accessibility of rabies control centers, the frequent bites caused by unvaccinated dogs, often category III exposure, and the widespread abandonment of PEP in a context of ignorance.
[18] 2023	National territory	Subjects who died of human rabies	Joint interventions involving human and animal health professionals were rare, and communication about rabies with communities was low (36%).
[19] 2018	Abidjan	Subjects exposed to rabies and under PPE.	- Drop-out rate: 45 to 60%. Main reasons: PPE cost (76%), negligence (28%) - Associated factors: average household income, knowledge of signs of human rabies (Agitation), geographical and financial inaccessibility.

References (Year)	Location	Study population	Main results
[20] 2017	Bouake	Subjects exposed to rabies and under PPE.	54% of exposed subjects had abandoned their treatment. The main reasons for discontinuation were the cost of PEP (76%) and negligence (28%). The main obstacles to compliance with PEP were the remoteness of health care facilities from rural populations and financial inaccessibility.
[21] 2008	Abidjan	Animal owners	Only 31.3% of exposed subjects produced the three veterinary certificates required by law. 37.3% cited financial difficulties; 57 (28.4%) travel difficulties; 20 (9.9%) lack of time.
[22] 2009	Abidjan	Subjects exposed to rabies and under PPE.	PPE compliance was estimated at 53.1%. Exposure outside the city of Abidjan, absence of an income-generating activity, minor exposure, absence of immunization of the incriminated animal, and the fact that the animal was alive after exposure were associated with non-compliance.
[23] 2009	French-speaking Africa	Conference report.	In order to break the cycle of indifference due to under-reporting of rabies, integrated and prolonged rabies control is recommended.
[24] 2019	Abidjan	Subjects exposed to rabies and under PPE.	Subjects who knew about agitation as a sign of human rabies completed the EPP more than those who did not. Subjects who knew about biting as a mode of transmission did less to complete their PEP than those who did not.
[25] 2019	Bouaké	Animal owners	In rural areas, where dogs are kept primarily for hunting, vaccination is perceived as inhibiting the dog's ability to hunt. These shortcomings are obstacles to the widespread use of vaccination against canine rabies.
[26] 2019	Asia and Africa	Data	Although all the countries in our assessment had rabies vaccines available in the public sector to some extent, barriers to access include the high cost of the vaccine for both the government and patients.
[27] 2018	Abidjan	Subjects exposed to rabies and under PPE.	441 subjects (59.3%) who had abandoned their PEP. The choice of protocol influenced compliance with PEP, in that subjects who chose the 5-dose protocol were more likely to abandon their PEP (p 0.001).
[28] 2020	Bouake, San Pedro	Subjects exposed to rabies.	The free rabies vaccine used for identification purposes is one of the best solutions for improving PPE compliance in Côte d'Ivoire.
[29] 2020	Ferkessedougou, Kong	Healthcare Staff from First Contact Health Establishments	Some health workers did not have the necessary knowledge to manage people exposed to rabies. As a result, not all of them were involved in rabies PEP.
[30] 2020	Bouaké, san Pedro	Subjects exposed to rabies..	Better access to active vaccines is effective in reducing rabies deaths, even if access to rabies immunoglobulin remains difficult in developing countries.
[31] 2021	Bouaké, San Pedro	Subjects exposed to rabies.	Free vaccination is not synonymous with acceptance by all populations. But it is an opportunity for many people, especially the poorest.
[32] 2018	Abidjan	Subjects exposed to rabies.	Mobile telephony is a useful tool for educating patients to adhere to post-exposure prophylaxis.
[33] 2023	Abidjan, Agboville	Students under 15 years of age	Vaccine compliance for this campaign was 76.43%. The cost of the vaccines was covered 96% by the National Institute of Public Hygiene (INHP) and 4% by parents.

Table 2. Results of the SWOT analysis of rabies control interventions in Côte d'Ivoire

Strengths	Weaknesses
<p>Rabies communication activities (JMR, response activities, School, GARC training, local rabies committees)</p> <p>Surveillance of human and animal rabies through the animal and human rabies surveillance system</p> <p>Joint investigation and response in the event of detection of human rabies</p> <p>Vaccination of people at risk as part of the PPE offer</p> <p>Routine vaccination of dogs, punctuated by vaccination campaigns</p> <p>Carrying out feasibility studies to guide decision-making (pre-exposure vaccination, intradermal protocol, involvement of CHWs)</p> <p>Multi-sector collaboration in the implementation of activities (Organisation of JMR, Investigations and response)</p> <p>Development of protocols for treating people exposed to rabies</p> <p>Setting up a network of anti-rabies centers throughout the country</p>	<p>Ad hoc communication activities</p> <p>Insufficient collaboration and exchanges</p> <p>Little joint investigation/response</p> <p>Implementation limited to INHP and UNIVAR branches</p> <p>Lack of knowledge of PEP protocols by peripheral health workers</p> <p>Low vaccination coverage of dogs</p> <p>Convincing results of feasibility studies, but scale-up not yet effective</p> <p>Low vaccination coverage of dogs</p> <p>Financial inaccessibility of populations to PEP (high cost of PEP)</p> <p>Geographical inaccessibility of the population to PEP</p> <p>Cultural constraints</p> <p>No policy or guidelines for implementing preventive vaccination against rabies in Côte d'Ivoire</p> <p>Weak collaboration between the 2 sectors</p> <p>Protocols for treating people exposed to rabies not updated</p> <p>Low public awareness of rabies</p> <p>Low community participation in communication activities (lack of ownership)</p>
Opportunities	Threats
<p>Existence of political will</p> <p>Involvement of partners</p> <p>Existence of an integrated rabies control plan;</p> <p>The country has signed up to the initiative to eliminate dog rabies by 2030.</p> <p>Involvement of technical and financial partners in the implementation of national plan activities</p> <p>Integration of Covid 19 vaccination activities</p>	<p>Impact of COVID19 on rabies activities</p> <p>Vaccine supply difficulties</p> <p>Low funding for plan activities</p>

3.1. Situational Analysis of Rabies Control Activities in Côte d'Ivoire

A comprehensive evaluation of the strengths, weaknesses, opportunities, and threats is outlined in Table 2.

3.2. Problem Analysis of Human Rabies Deaths Transmitted by Dogs and the Integrated Rabies Control Model in Côte d'Ivoire

3.2.1. Problem Analysis: Human Rabies Deaths Caused by Dog Transmission

Figure 1 illustrates the problem tree for dog rabies deaths in Côte d'Ivoire, identifying three primary causes:

- Low Vaccination Coverage of Dogs: The limited vaccination coverage of dogs (10%) primarily results from dog owners' lack of awareness, the vaccine's cost, and cultural factors.
- Lack of Pre-exposure Prophylaxis: The absence of pre-exposure prophylaxis can be attributed to the vaccination's cost and the absence of policies and guidelines for rabies vaccination implementation.
- Difficulties After Exposure: Challenges encountered following exposure encompass inadequate compliance with veterinary surveillance, failure to utilize post-exposure prophylaxis (PEP), insufficient care, and the absence of policies and guidelines for rabies vaccination implementation.

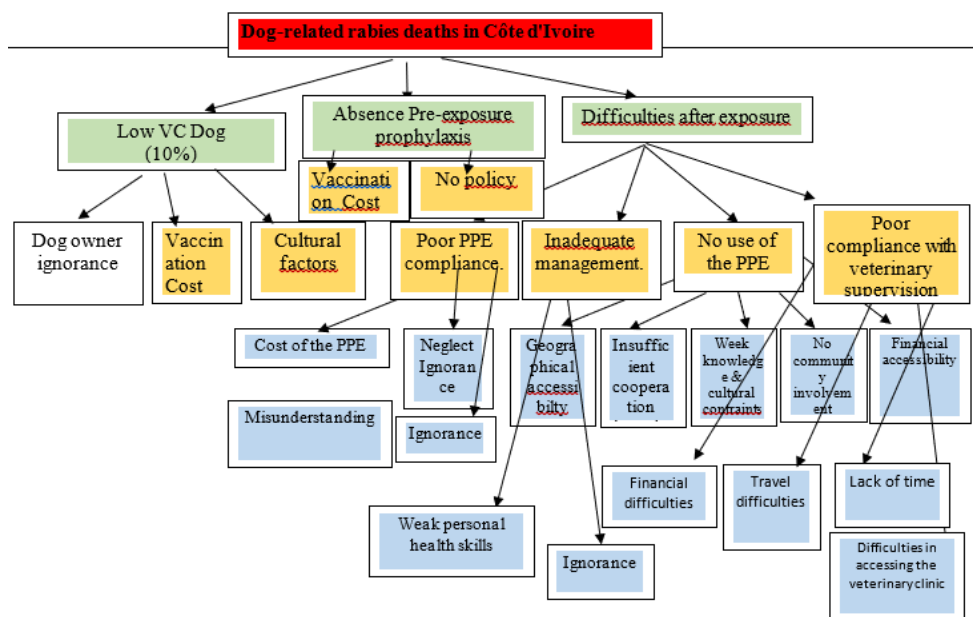


Figure 1. Problem tree of human rabies deaths transmitted by dogs in Côte d'Ivoire

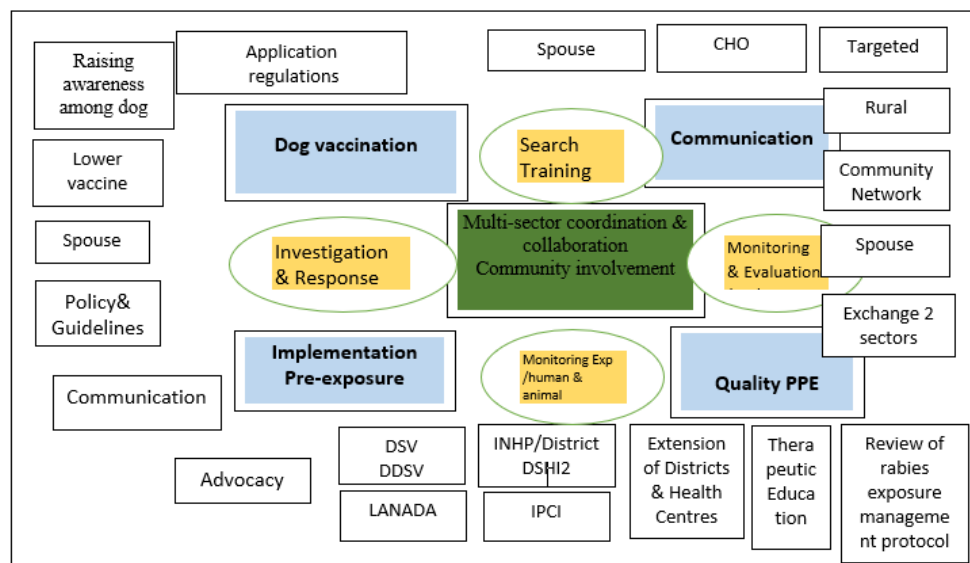


Figure 2. Integrated Rabies Control Model

3.2.2. Integrated Rabies Control Model in Côte d'Ivoire

The integrated rabies control model, as depicted in Figure 2, is founded on two key pillars:

- **Adoption of the WHO's Reduced Protocol:** The immediate and widespread adoption of the World Health Organization's (WHO) reduced protocol for rabies vaccination is central to the model. Utilizing intradermal administration of the rabies vaccine not only reduces costs but also conserves vaccine doses, making it a cost-effective approach.
- **Expansion of Post-Exposure Prophylaxis (PEP) Accessibility to All District Public Health Centers:** The model strongly advocates for the extension of PEP accessibility to all health districts in Côte d'Ivoire. Within these health districts, it is imperative to guarantee the availability of PEP services at local health centers. This extension serves the crucial purpose of bringing PEP services closer to individuals at risk, ensuring their access to and adherence to PEP. Furthermore, the enhancement of geographical accessibility must be complemented by capacity-building initiatives and the active involvement of healthcare personnel in first-contact health establishments, where they can effectively care for individuals exposed to rabies.

Implementation of PrEP Vaccination: The implementation of Pre-Exposure Prophylaxis (PrEP) vaccination is an integral component of the model. This approach serves to protect children in scenarios where specific exposures may go undetected or when parents or guardians decline care for them.

Ramped-Up Animal Vaccination: A crucial element of the model involves the intensified vaccination of pets and dogs. The aim is to achieve a minimum coverage of at least 70% over a span of five years, thus effectively controlling the canine reservoir.

Multisectoral Coordination and Collaboration: Collaboration across various sectors is imperative in the effective implementation of the rabies control model. Multisectoral coordination fosters synergy among different entities, contributing to more comprehensive and well-rounded efforts.

Community Participation: The active involvement of communities is a cornerstone of the model. Community participation not only enhances awareness but also fosters collective responsibility in rabies control efforts, making the approach more effective and sustainable.

4. Discussion

4.1. Situational Analysis and Problem Analysis

In Côte d'Ivoire, rabies presents a distinctive profile marked by its endemic, rural, and predominantly juvenile nature, characterized by a low level of awareness regarding the disease, particularly in rural areas. Various interventions have been initiated as part of the ongoing battle against rabies. The situational analysis of rabies control and the problem tree of human rabies deaths

clearly reveal that these interventions often do not adequately consider the disease's epidemiological characteristics. Indeed, the juvenile and rural aspects of the disease are frequently overlooked in the implemented strategies and actions (refer to Table 1). Within this context, the primary determinants contributing to the persistence of human rabies deaths in Côte d'Ivoire include the public's limited knowledge of how to interact with their pets, especially dogs, and the insufficient utilization of Post-Exposure Prophylaxis (PEP) following exposure to rabies. This challenging situation is further exacerbated by the low vaccination coverage among dogs and the continued circulation of the rabies virus.

The reluctance to seek PEP after rabies exposure can be attributed to a combination of factors, including ignorance of rabies and cultural constraints. Nevertheless, two additional factors associated with the healthcare system have been identified as influential: geographical inaccessibility and financial barriers. Salomao's research in Mozambique in 2014 identified several factors significantly linked to human rabies cases, such as age less than 15 years ($p = 0.05$), dog bites by strays ($p = 0.002$), deep wounds ($p = 0.02$), head bites ($p = 0.001$), bites by non-immunized dogs ($p = 0.01$), lack of access to soap and water ($p = 0.001$), and absence of post-exposure prophylaxis (PEP) ($p = 0.01$) [40].

People's behavior toward dogs largely stems from their relationship with these animals, which often lacks a sense of responsibility. Consequently, many dogs remain unvaccinated, and the cost of vaccines poses a significant barrier, as does the failure to adhere to existing regulations regarding animal ownership and movement. Poor compliance with veterinary oversight underscores the general lack of responsibility among animal owners.

One of the most critical factors contributing to human rabies deaths transmitted by dogs in Côte d'Ivoire is the cost of vaccination. The direct cost of Post-Exposure Prophylaxis (PEP) remains high in Côte d'Ivoire, ranging between 32,000F and 40,000F CFA, without accounting for the indirect costs associated with transportation and time spent traveling to treatment centers. These financial factors not only impede the uptake of PEP but also hinder compliance with its regimen. For comparison, in Burkina Faso, a single dose of the VAR vaccine costs 7,500 CFA francs, and five doses are necessary for complete immunization, totaling 37,500 CFA francs for suspected bite cases requiring post-exposure treatment [41]. In Cambodia, the estimated cost of a full PEP regimen against rabies can consume between 50% and 100% of a Cambodian farmer's monthly income [42]. A study in rural Tanzania revealed that for a full cycle of PEP, excluding indirect costs, a rural Tanzanian patient would have to allocate more than USD 100 after a five-dose regimen. Additionally, disparities exist, with rural patients incurring travel expenses more than twice as high as those of their urban counterparts [7].

This study has drawn attention to disparities, notably the significant differences in travel costs between rural and urban patients, with rural patients incurring more than double the expenses [7]. Geographical inaccessibility to Post-Exposure Prophylaxis (PEP) emerges as a prominent factor affecting its utilization. In Burkina Faso, the anti-rabies vaccine is not universally accessible across the

country, with only two anti-rabies treatment centers located in the major cities of Ouagadougou and Bobo Dioulasso, serving the entire nation [41]. In Cambodia, Baron's research in 2022 revealed a substantial negative association between the time required to travel to the Pasteur Institute of Cambodia (PIC) and compliance with Post-Exposure Prophylaxis (PEP). An increase of one hour in travel time between patients' residences and IPC PEP centers resulted in a 70% to 80% reduction in PEP compliance [34]. In Côte d'Ivoire, aside from the 30 INHP branches and the 30 health districts equipped with Rabies Vaccination Units (UNIVAR), residents in other regions are often forced to travel significant distances, causing them to lose hours or even days of their professional activities, which, for many, represent their sole source of income. In such circumstances, the utilization and adherence to PEP are frequently neglected. Consequently, the decentralization and expansion of care centers for individuals exposed to rabies, coupled with sustained public awareness campaigns aimed at modifying the behavior of animal owners, particularly with respect to dogs, are deemed necessary [41].

4.2. The Integrated Rabies Control Model in Côte d'Ivoire

Rabies control hinges on two key aspects: the vaccination of dogs to disrupt virus transmission to humans and the vaccination of humans. Human vaccination takes two forms—pre-exposure prophylaxis (PrEP), employing the vaccine independently, and post-exposure prophylaxis (PEP), which includes the vaccine alone or in combination with rabies immunoglobulin (RIG), depending on the exposure category. PrEP offers protection and eliminates the need for rabies immunoglobulin administration following animal exposure, making it particularly beneficial in scenarios where exposure goes unnoticed or is not followed by immediate treatment, especially among children.

The primary drivers of rabies-related mortality in Côte d'Ivoire are the population's low awareness levels and cultural constraints, which contribute to the limited adoption of PEP and PEP adherence.

Numerous strategies have been initiated in the fight against rabies in Côte d'Ivoire. The recommended model, primarily rooted in the Ecohealth approach, is meticulously tailored to suit the specific characteristics of rabies in Côte d'Ivoire. By recognizing community involvement as the foundational element of all interventions, the Ecohealth approach empowers communities to attain self-sufficiency and actively engage in the battle against rabies. This approach involves uniting scientists, policymakers, and community members to enhance human health by seeking solutions that harmonize human interactions with the environment. It acknowledges the interdependence of human, animal, and ecosystem health [35]. The Ecohealth approach, characterized by its high degree of participation, ensures that citizens and their representatives are integral to the entire research process, from defining the problem to implementing collectively chosen solutions.

To meet the ambitious goal of eliminating rabies by 2025, as set forth by the Global Alliance for Rabies Control (GARC), a multidisciplinary approach is required,

encompassing veterinary and human medicine, biology, cultural sciences, sociology, and geography [43]. Audrey Simon successfully employed this Ecohealth research approach to address canine-related issues in Kuujuaq, collaborating closely with local partners. This approach effectively surmounted several challenges, such as trust deficits, communication barriers, incomplete understanding of community needs, and a resultant lack of commitment. Establishing trust-based relationships facilitated the engagement of Kuujuaq's residents, simplifying the identification of priority needs and the development of effective, sustainable solutions with a high degree of community acceptance [44].

In this model, multisectoral coordination and collaboration at the national, regional, and departmental levels, together with active community participation, form the central elements around which four vital pillars revolve. Collaboration and coordination align with regional measures recommended by WAHO for addressing priority zoonotic diseases within the "One Health" approach [36].

Notable among the strategies implemented are those geared toward enhancing public knowledge of the disease and improving both financial and geographical access to Post-Exposure Prophylaxis (PEP). To boost public awareness of the disease, a multitude of communication and awareness campaigns are conducted during World Rabies Control Days, initiated in Côte d'Ivoire in 2008, as well as other targeted activities in schools involving students and teachers. Despite these endeavors, some deaths still result from the failure to utilize PEP following exposure. Hence, we advocate for the Ecohealth approach, where community participation is one of the fundamental pillars. Communities must be actively engaged, fostering a sense of ownership in the fight against rabies. Recognizing the influence of knowledge about rabies on PEP compliance, we emphasize communication to enhance understanding about rabies and the importance of using PEP.

The utilization of intradermal vaccine administration for post-exposure prophylaxis can notably reduce the number of vaccine vials required, by at least 25%, in comparison to the intramuscular route. As the number of patients seeking care at health centers increases, the intradermal method becomes progressively cost-effective, potentially reducing the number of vaccine vials needed by up to 85%.

Furthermore, according to Chulasugandha [37] the cost of post-exposure prophylaxis for a severely exposed child varies from \$28.75 to \$125.00. Pre-exposure vaccination is merely \$2.00 to \$7.25, with an additional expense of \$18.00 to \$23.50 if a post-exposure booster vaccination becomes necessary later on. Lower costs can be achieved using the WHO-approved reduced-dose intradermal vaccination schedule. For developing countries where rabies is endemic, it is advisable to incorporate healthcare costs and improved protocols into their annual budgets [37].

Adopting this protocol has the potential to significantly reduce the cost of PEP by up to 80%, rendering it accessible to all populations, particularly those with limited incomes. However, it's essential to consider affordability in the context of category III exposures, which necessitate the use of rabies immunoglobulin. In

terms of legal and regulatory aspects, the Côte d'Ivoire National Committee of Independent Experts on Vaccines and Immunization (CNEIVCI) has granted authorization for the utilization of intradermal vaccines for both pre- and post-exposure prophylaxis in Côte d'Ivoire [38]. Additionally, the Ministry of Health, Public Hygiene, and Universal Health Coverage has given its national-level approval for implementation. Finally, a feasibility study conducted in Bouake and San Pedro on using the WHO protocol, coupled with awareness-raising campaigns, demonstrated a high level of acceptance and increased compliance with rabies PEP.

Beyond affordability, neglect represented the primary reason why individuals at risk who accepted the Thai Red Cross schedule eventually dropped out. The introduction of free rabies PEP following the Thai Red Cross protocol met with public approval and achieved remarkable success, resulting in improved PEP compliance, thereby ensuring the safety of individuals against rabies. Education and counseling for patients receiving PEP are crucial prerequisites for achieving full adherence to the prophylactic regimen.

Regarding geographical accessibility, we strongly recommend extending Post-Exposure Prophylaxis (PEP) services to all health districts in Côte d'Ivoire. Ensuring the availability of PEP within all General Hospitals at the district level is pivotal to ensure PEP use and compliance. Geographical accessibility enhancement involves expanding PEP services across all health districts and within the health centers at the district level. It is essential to bring PEP services closer to individuals at risk. Furthermore, efforts to improve geographical accessibility must be coupled with capacity-building initiatives and the active involvement of health workers from primary healthcare facilities in caring for individuals exposed to rabies.

Implementing high-quality PEP that is both geographically and financially accessible serves as a key strategy in combatting rabies mortality. The introduction of pre-exposure vaccination has the potential to protect children for whom specific exposures may go unnoticed or where parents or guardians refuse treatment. Moreover, in the context of category III exposures, it can serve as a substitute for the absence of rabies immunoglobulin. The feasibility study conducted has demonstrated excellent acceptability and, notably, strong adherence to pre-exposure prophylaxis protocols. Additionally, pre-exposure vaccination is more cost-effective compared to PEP. Based on the recommendations of the Côte d'Ivoire National Committee of Independent Experts on Vaccination and Vaccines (CNEIVCI) [38], as well as cabinet approval and the results of feasibility studies conducted in Bouake and San-Pedro, the wider utilization of the WHO's intradermal protocol is endorsed across all sites where individuals at risk are treated. These studies have indicated that the use of free rabies vaccine via intradermal administration can significantly enhance the utilization of and compliance with PEP in Côte d'Ivoire. Moreover, this implementation can potentially address the shortage of rabies immunoglobulin for category III exposures. The feasibility study has demonstrated high acceptability and adherence to preexposure prophylaxis protocols.

Canine mass vaccination campaigns hold the potential to break the cycle of canine-to-canine transmission of the

virus, significantly impacting the incidence of canine rabies. Achieving a vaccination coverage of at least 70% is key to halting canine-to-canine transmission completely. As per Anyiam et al. [39], a mass vaccination campaign against canine rabies, offered free of charge and repeated once or twice, covering the entire territory of Chad on each occasion, represents a feasible and cost-effective strategy for nationwide rabies elimination [39]. These strategies gain additional support from multisectoral coordination and collaboration, epidemiological surveillance, awareness-raising, and communication, all geared towards achieving sustainable behavioral change.

All the activities recommended within the model must be complemented by supporting activities, including epidemiological surveillance encompassing investigation and response, active community involvement by Community Health Workers (CHWs), and the ongoing monitoring and evaluation of activities.

In essence, a combination of these interventions, when executed in tandem, has the potential to enhance the utilization and compliance with PEP while working towards the control of canine rabies through achieving a vaccination coverage of at least 70%. This integrated approach could enable Côte d'Ivoire to eliminate human rabies transmitted by dogs by 2030.

The implementation of this model may face several challenges, including limited financial resources to fund the activities outlined within the model, challenges related to inter-sectoral collaboration among health workers in the animal and human health sectors, and the necessity for the population to take ownership of the fight against rabies. However, the demonstrated political will by the country in adhering to the initiative to eliminate dog-transmitted rabies by 2030 and the adoption of the integrated plan for rabies control in Côte d'Ivoire offer hope in overcoming these challenges.

5. Conclusion

Côte d'Ivoire continues to grapple with numerous risk factors contributing to the persistence of rabies, including low disease awareness, irregular use of Post-Exposure Prophylaxis (PEP), suboptimal PEP compliance, and notably, insufficient vaccination coverage among dogs, the primary reservoir of the disease in the country. To combat this public health menace effectively, it is imperative to adopt the proposed integrated rabies control model, custom-tailored to the unique characteristics of the disease in Côte d'Ivoire.

These model activities must be executed in a coordinated and cohesive manner, addressing multiple fronts simultaneously. In the absence of comprehensive management of the disease's primary source, rabies Post-Exposure Prophylaxis (PEP) should be systematically applied following any rabies exposure incident. In this context, it is of utmost importance to conduct extensive public awareness campaigns with active community involvement, facilitating the broad availability of PEP, thereby reducing the financial burden and enhancing accessibility.

As Côte d'Ivoire moves towards achieving the elimination of dog-transmitted human rabies by 2030, the implementation of these recommended activities,

bolstered by political commitment and coordinated efforts, is paramount. By addressing the root causes of rabies transmission, enhancing knowledge, promoting PEP utilization, and expanding vaccination coverage, Côte d'Ivoire can make significant strides towards reducing the burden of rabies and ultimately eliminating it as a public health concern. The commitment of the government and the active participation of communities are essential elements for achieving this ambitious goal.

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