



Research Article

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

Issaka Tiembré^{1,2*}, Coulibaly Adama³, Teché Sopi Mathilde², Djoman Christiane^{1,2}, Taha Raymond⁴, John Tra⁵ and Dagnan N Cho Simplicé¹

¹Felix Houphouët Boigny University, Ivory Coast

²National Institute of Public Hygiene, Abidjan, Ivory Coast

³National Institute of Public Hygiene, Adzopé, Ivory Coast

⁴MIRAH Sassandra regional office

⁵Kweni Inc, Maryland, USA

*Corresponding author: Tiembré Issaka, Institut National de l'Hygiène Publique, BP V 14 Abidjan, Côte d'Ivoire.

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Abstract

Since 2008, Côte d'Ivoire has classified rabies as a notifiable disease and one of the five priority zoonoses in 2017. Following an assessment of the burden of the disease and the prioritization of rabies, we drew an integrated national rabies control plan. Despite the activities implemented, the disease has persisted. In this context, we set ourselves the research question of what model, adapted to the characteristics of rabies, could be recommended, based on the determinants of mortality, to accelerate progress towards its elimination in Côte d'Ivoire. We propose an integrated rabies control model adapted to the characteristics of the disease. We conducted a mixed cross-sectional study from January to September 2023. Data were collected by interview, document review, and narrative review of all published work on rabies in Côte d'Ivoire from 2018 to 2023. The situational analysis was first carried out using the SWOT tool, which enabled us to define the strengths, weaknesses, opportunities, and threats of rabies control in Côte d'Ivoire. Then, using data from the articles, we constructed a problem tree of human rabies deaths in Côte d'Ivoire. Finally, we used this problem tree as a basis for building an integrated model of rabies management in Côte d'Ivoire. The study was conducted by following the ethical rules (administrative authorization, informed consent, confidentiality) in force in Côte d'Ivoire.

The main challenges identified in the fight against rabies in Côte d'Ivoire were the low level of animal vaccination, a lack of knowledge about the disease, and the lack of access to PEP. The problem tree highlighted the factors associated with mortality, based essentially on the low vaccination coverage of dogs and the poor knowledge of the disease, which leads to low uptake and non-adherence to PEP. A Model to accelerate progress towards the elimination of rabies in Côte d'Ivoire incorporating interventions that, if implemented, could improve uptake and compliance with PEP as a complement to increasing vaccination coverage in dogs. This model includes a combination of several methods, the main pillars of which are improving geographical and financial accessibility, increasing knowledge, and getting people to take ownership of the fight against rabies. Pending control of the reservoir and vector of the disease, the integrated model of rabies control should be systematically implemented, based on PEP before any exposure to rabies, raising public awareness and improving access to PEP.

Keywords: Problem tree, Integrated model, Rabies control, Côte d'Ivoire

Introduction

Rabies is a viral disease that almost invariably progresses to death as soon as the first signs appear (WHO, 2018). It is ranked 10th among fatal infectious diseases and remains one of the most

severe diseases transmissible to humans [1]. Dogs are the main reservoir animal species in the world, accounting for around 99% of human deaths. According to the WHO (2018), this zoonosis af-



fects more than 150 countries worldwide and is estimated to cause more than 59,000 deaths annually. It could be responsible for more than a million deaths in the 67 endemic countries between 2020 and 2035 if nothing is done [2,3]. Rabies is most prevalent in Asia and Africa, where more than 95% of cases are recorded [1]. The animal responsible for transmitting the disease to humans in these two continents is still the dog in almost 99% of cases, and more than 40% of the victims of this zoonosis are under 15 years of age [1]. In Côte d'Ivoire, rabies is endemic, and the national epidemiological surveillance system regularly reports deaths linked to the disease [4]. Since 2008, the country has classified rabies as a notifiable disease and one of the five priority zoonoses in 2017 [5,6]. In 2015, an initiative was taken to eliminate dog-transmitted rabies by 2030 [7]. An integrated national rabies control plan was implemented after Côte d'Ivoire joined this initiative. In the local context of Côte d'Ivoire and most African countries, rabies was a neglected tropical disease characterized by a scarcity of resources for control. The execution of this plan has led to an intensification of joint activities: communication, dog vaccination, capacity-building for agents in both sectors, investigation, and response organized according to the "one Health" concept, in addition to post-exposure prophylaxis.

Even though rabies is a notifiable disease in both humans and animals, and there is an integrated national Programme to combat this zoonosis, the number of deaths from rabies transmitted by dogs continues to persist and is tending to increase. This situation takes us further away from the significant indicator - "No human deaths due to rabies for 24 months"-required for a country to be internationally recognized as having eliminated rabies as a public health problem [7]. In this context, we asked ourselves the following question: What model, adapted to the characteristics of rabies, could be recommended based on mortality determinants to accelerate progress towards eliminating rabies in Côte d'Ivoire? We put forward the following hypothesis: an integrated model adapted to the characteristics of rabies based on the determinants of this zoonosis could enable it to be eliminated by 2030 in Côte d'Ivoire. The objectives were to:

Carry out a situational analysis of rabies control activities in Côte d'Ivoire.

Develop a problem tree for human rabies deaths in Côte d'Ivoire.

Propose an integrated control model to improve rabies control in Côte d'Ivoire.

Material and Method

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 program 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.

Type and Period of Study

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

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.

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, supplemented by investigation and response reports on cases of death from human rabies.

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."

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.

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 ethical approval by the National Life and Health Sciences Ethics Committee (CNESVS).

Results

Main Documents Consulted

The documentary review used the following documents.

Annual activity reports of the National Institute of Public Hygiene from 2000 to September 2023.

The National Integrated Rabies Control Programme for Côte d'Ivoire (2018-2023).

Records of people exposed to rabies and treated, including.

Veterinary surveillance records.

World Rabies Day reports.

Records of people who have died of human rabies (Excel database).

Investigation and response reports on human rabies deaths from 2000 to September 2023 (Table 1).

Table 1: Characteristics of the articles included in the systematic review.

Journals	Authors	Titles	Years	Links
Black African medicine	Selly-Essis, A. M., Guina, F. G., Yao, B. A., & Lath, E. A.	The prevalence of rabies virus excretion in the saliva of rabid stray-dogs in the Ivory Coast.	2000	Médecine d'Afrique Noire 47(12), 512-515
Tropical medicine	Tiembré I, Benié J, Ekra D, Douba A, Kouamé B, Dagnan S, Tagliante-Saracino J.	Compliance with veterinary surveillance at the Abidjan rabies center	2008	Med Trop2008; 68 : 514-518
Public health	Issaka Tiembré, Diloma Marie Brigitte Aka-Kone, Yao Eugène Konan, Joseph Bénié Bi Vroh, Kouadio Daniel, et al.	Compliance with rabies vaccination in people exposed to rabies in Abidjan (Côte d'Ivoire).	2009	https://doi.org/10.3917/spub.096.0595
Vaccine	Dodet, B. Vaccine, 27(37), 5027-5032.	The fight against rabies in Africa: From recognition to action.	2009	https://doi.org/10.1016/j.vaccine.2009.06.030
Medicine and infectious diseases	Tiembré a, S. Dagnan a, A. Douba a, E.V. Adjogoua b, H.Bourhy c, L. Dacheux c, L. Kouassi d, M. Dosso b, P. Odehouri-Koudou a	Epidemiological surveillance of human rabies in the context of a canine rabies endemic in Côte d'Ivoire.	2010	https://doi.org/10.1016/j.medmal.2010.01.008
Public health	Issaka Tiembré (1), Joseph Vroh Benié Bi (1), Simplicite N'Cho Dagnan (1), Daniel Kouadio Ekra (1), Sonia Zebe (2), Janine Tagliante-Saracino (3)	Epidemiological profile of people exposed to rabies in Abidjan, Côte d'Ivoire	2011	DOI 10.3917/spub.114.0279
Tropical Medicine and Health	Ouattara, S. I., Cissé, H., Kouakou, G., Kolia-Diafouka, P., Doumbia, A., Yokoué, A. D., ... & Bissagnené, E. (2	Human rabies in Abidjan (Côte d'Ivoire): new observations.	2012	Médecine et Sante' Tropicales 2012 ; 22 : 157-161
Bulletin society exotic pathology	I. Tiembre · J. Benie · H. Attoh-Touré · P. Zengbe-Acray · S.M. Tetchi · D. Kpebo · A.P. Lezou · S. Dagnan	Post-exposure prophylaxis drop-outs at the Abidjan Rabies Centre, Côte d'Ivoire	2013	DOI 10.1007/s13149-013-0312-y
Public health	Issaka Tiembré, Joseph Bénié Bi Vroh, Damus Paquin Kouassi, Harvey Attoh-Touré, Kouadio Daniel Ekra, Aly Diane, N'cho Simplicite Dagnan, Janine Tagliante-Saracino	Knowledge, attitudes and practices of heads of household in the commune of Abobo (Abidjan, Côte d'Ivoire) with regard to rabies, in 2008.	2014	https://doi.org/10.3917/spub.144.0547
Malian Journal of Infectiology and Microbiology	Coulibaly M'bégna1, Kouassi Damus Paquin1,2 Yao Gnissan Henri auguste1,2, Kouame Arsène Deby1, Konan N'Guessan1, Soumahoro Sory Ibrahim1,2; Attoh-Toure Harvey.3, Tiembre Issaka	Determinants of the abandonment of post-exposure rabies prophylaxis at the Bouaké Rabies Center, Côte d'Ivoire	2017	https://doi.org/10.53597/remim.v0i10.956
PLoS Negl Trop Dis	Issaka Tiembré, Anaïs Broban, Joseph Bénié, Mathilde Tetchi, Sophie Druelles, Maïna L'Azou	Human rabies in Côte d'Ivoire 2014-2016: Results following reinforcements to rabies surveillance.	2018	https://doi.org/10.1371/journal.pntd.0006649
PLoS Negl Trop Dis	Anaïs Broban, Mathurin C, Tejiokem, Issaka Tiembre, Sophie Druelles, Maïna L'Azou*	Bolstering human rabies surveillance in Africa is crucial to eliminating canine-mediated rabies	2018	https://doi.org/10.1371/journal.pntd.0006367
Tropical Medicine and Health	B.Y.G. Zamina , I. Tiembré , H. Attoh-Touré, K.E. N'Guessan, S.M. Tetchi , B.V.J. Benié.	Factors associated with the abandonment of post-exposure prophylaxis at the Abidjan rabies centre, Côte d'Ivoire.	2018	10.1684/mst.2018.0796
Public health	Bi Yourou Guillaume Zamina, Issaka Tiembre, Konan N'Guessan, Harvey Attoh-Touré, Sopi Mathilde Tetchi, Bi Vroh Joseph Benié	Improving compliance with post-exposure prophylaxis through the use of mobile phones, Côte d'Ivoire	2018	DOI10.3917/spub.185.0545

Journal of epidemiology and public health	B.Y.G. Zamina, I. Tiembre, K. N'Guessan, T.A.S.R. N'Krumah, H. Attoh-Toure', S.M. Tetchi, J. Benie'.	Influence of the knowledge of patients consulting the Treichville rabies centre, Côte d'Ivoire, on compliance with post-exposure prophylaxis.	2019	https://doi.org/10.1016/j.respe.2019.01.118
Pan African Medical Journal,	Kallo, V., Tetchi, M., Boka, M., Dagnogo, K., Mbaruku, G., Ndour, P., ... & Bonfoh, B.	The one health approach creates progress towards elimination of rabies in Côte d'Ivoire	2019	
Open Res Africa,	Amalaman, D. M., Kallo, V., Heitz-Tokpa, K., Ndour, A. N., Gouvela, N. J., Kone, I., & Bonfoh, B.	Social factors hindering canine rabies vaccination in Bouake, Côte d'Ivoire.	2019	(https://doi.org/10.21955/aasopenres.1114900.1)
Vaccine	N. Sreenivasan 1, A. Li 2, M. Shiferaw 1, C.H. Tran 1, R. Wallace 1, J. Blanton 1, L. Knopf 3, B. Abe-la-Ridder 3, T. Hyde 1, U.R. Siddiqi, S, et all.	Overview of rabies post-exposure prophylaxis access, procurement and distribution in selected countries in Asia and Africa, 2017–2018	2019	https://doi.org/10.1016/j.vaccine.2019.04.024
Acta Tropica	Mathilde Sopi Tetchi, 'Begnani Coulibaly, Vessaly Kallo, Gnamien Sylvain Traoré, Tiembré Issakaa, Benié Bi Vroh Joseph, et all.	Risk factors for rabies in Côte d'Ivoire	2020	https://doi.org/10.1016/j.actatropica.2020.105711
Acta Tropica	Mathilde Tetchi, M'Begnani Coulibaly, Vessaly Kallo, Gnamien-Sylvain Traoré, Tiembré Issakaa, Benié Joseph, Felix Gerber f, Monique Lechenne, Jakob Zinsstag, Bassirou Bonfoh.	The Thai Red Cross protocol experience in Côte d'Ivoire.	2020	https://doi.org/10.1016/j.actatropica.2020.105710
Advances in Infectious Diseases	Bi Yourou Guillaume Zamina1, Assikohon Pulchérie Gouzile1, Martial Bama1, Ellélé Aimé Yapi1, Youssouf Diabate1, Tetchi Sopi Malthide1, Tiembré Issiaka	Involvement of Healthcare Staff from First Contact Health Establishments in the Elimination of Human Rabies in the Health Districts of Ferkessedougou and Kong in Ivory Coast, 2020	2020	https://doi.org/10.4236/aid.2022.124059
Acta tropica	Gerber, F., Tetchi, M., Kallo, V., Léchenne, M., Hattendorf, J., Bonfoh, B., & Zinsstag, J. (2020)., 211, 105629.	RABIES IMMUNOGLOBULIN: Brief history and recent experiences in Côte d'Ivoire.	2020	https://doi.org/10.1016/j.actatropica.2020.105629
Acta tropica	Léchenne, M., Traore, A., Hattendorf, J., Kallo, V., Oussiguere, A., Tetchi, M., ... & Zinsstag, J. (2021). Acta tropica, 215, 105808.	Increasing rabies data availability: The example of a One Health research project in Chad, Côte d'Ivoire and Mali.	2021	https://doi.org/10.1016/j.actatropica.2020.105808
World	Soumahoro, S. I., Kouassi, D. P., Kouame, A. D., Yeo, S., Irika, O., Yao, G. H. A., & Tetchi, S. M.	Pilot Study for Introduction of Thai Red Cross Protocol in Rabies Post-exposure Prophylaxis: Case of Regional Public Hygiene Office of Bouake, Ivory Coast).	2021	World, 6(4), 199-203
OJEPi	Issaka Tiembre , Tetchi Sopi Malthide , Akani Bangama , Christiane Djoman , Joseph Benié Bi	Analysis of epidemiological investigations and responses to human rabies deaths in Côte d'Ivoire, 2021	2023	https://doi.org/10.4236/ojepi.2023.133016
Vaccine	Issaka Tiembre, Christiane Djoman, Tetchi Sopi Malthide, Acho Albertine, Joseph Benié Bi .	Feasibility and benefits of a Pre-exposure vaccination campaign against human rabies in students under 15 years of age: Experience of four (4) health districts in Côte d'Ivoire.	2023	DOI: 10.35248/2157-7560.23.14.521

Situational Analysis of Rabies Control Activities in Côte d'Ivoire: The strengths, weaknesses, opportunities, and threats are presented in the table below Table.

The results of the SWOT analysis of rabies control activities in Côte d'Ivoire are shown in Table 2.

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

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

The Problem Tree of Human Rabies Deaths Transmitted by Dogs and the Integrated Rabies Control Model in Côte d'Ivoire:

The Problem Tree of Dog-Transmitted Human Rabies Deaths: According to Figure 1, the problem tree for dog rabies deaths in Côte d'Ivoire, there are three leading causes of dog rabies deaths(Figure 1).

- a. **Low Vaccination Coverage of Dogs:** The low vaccination coverage of dogs (10%) is mainly due to ignorance on the part of dog owners, the cost of the vaccine, and cultural factors.

- b. **Lack of Preexposure Prophylaxis:** The cost of vaccination and the lack of policy and guidelines for implementing rabies vaccination are responsible for the lack of pre-show prophylaxis.
- c. **Difficulties after Exposure:** The main difficulties encountered after exposure are poor compliance with veterinary surveillance, failure to use PEP, inadequate care, and the absence of a policy and guidelines for implementing rabies vaccination(Figure 2).

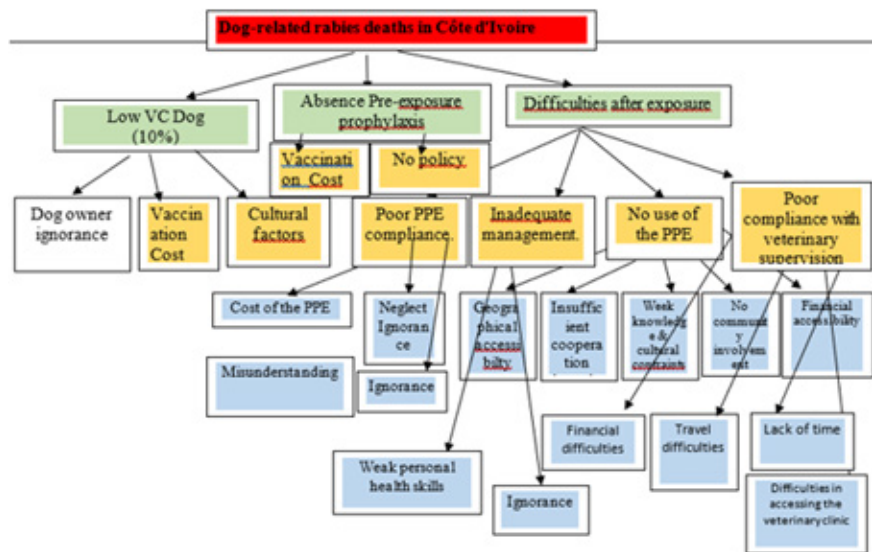


Figure 1: Problem tree of human rabies deaths transmitted by dogs in Côte d'Ivoire.

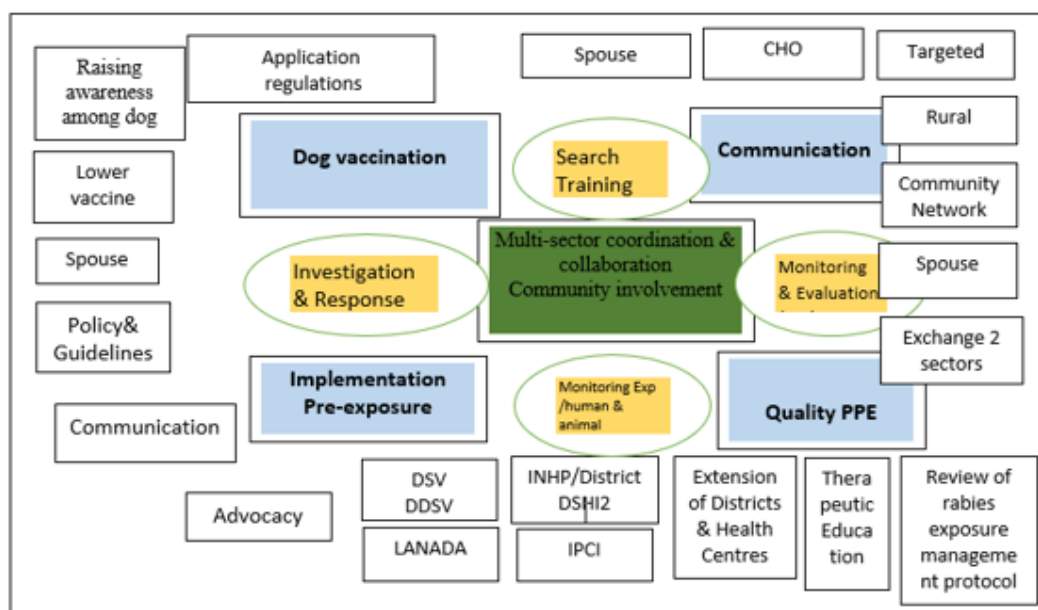


Figure 2: Integrated rabies control model in Côte d'Ivoire.

Integrated Rabies Control Model in Côte d'Ivoire: In Figure 2, the integrated rabies control model is based on:

- a. **Adoption of the Reduced WHO Protocol:** Use of the WHO's reduced protocol should be generalized immediately, as intradermal administration of rabies vaccine reduces costs and saves on doses.
- b. **Extending the Offer of PEP to all District Public Health Centers:** The extension of the PEP offer to all health districts in Côte d'Ivoire should be advocated. In the health districts, the availability of PEP should be ensured in the

health centers. This supply extension is necessary to bring PEP services closer to people at risk and ensure that PEP is used and adhered to. In addition, improving geographical accessibility must go hand in hand with capacity-building and the effective involvement of health workers in first-contact health establishments in the care of people exposed to rabies.

- c. **Implementation of PrEP Vaccination:** It will make it possible to protect children for whom specific exposures go undetected or where parents or guardians refuse to care for them.

- d. **Stepping up Animal Vaccination:** Intensified pets and dogs' vaccination should achieve coverage of at least 70% over five years to control the canine reservoir.
- e. **Multisectoral Coordination and Collaboration**
- f. **Community Participation**

Discussion

Situational Analysis and Problem Tree

The situational analysis of rabies control and the decision tree for human rabies deaths show that the main determinants of the persistence of human rabies deaths in Côte d'Ivoire are people's low level of knowledge about behavior towards their pets, particularly dogs, and the lack of recourse to PEP after exposure to rabies. The low vaccination coverage among dogs and viral circulation exacerbates this situation. After exposure to rabies, the low uptake of PEP can be explained by ignorance of rabies and cultural constraints. However, two other factors linked to the healthcare system have also been highlighted: geographical and financial inaccessibility. Salomao, in 2014 in Mozambique, found the following factors to be significantly associated with the occurrence of cases of human rabies: age < 15 years ($p=0.05$), bite by a stray dog ($p=0.002$), deep wound ($p=0.02$), head bite ($p=0.001$), bite by a non-immune dog ($p=0.01$), lack of use of soap and water ($p=0.001$) and lack of post-exposure prophylaxis ($p=0.01$) Salomão, *et al.*, People's behavior towards dogs originates in their relationship with the dog that is used, without reference to the responsibility associated with it. From this point of view, the animals are not vaccinated, and the cost of vaccines is also a hindrance, as is the failure to apply current regulations on the possession and movement of animals. Compliance with veterinary supervision is deficient, reinforcing that animal owners are not responsible.

One of the most critical factors in human rabies deaths transmitted by dogs in Côte d'Ivoire is the cost of vaccination. The direct cost of PEP is still high in Côte d'Ivoire (between 32,000F and 40,000F CFA); this cost does not consider the indirect cost of transport and time spent traveling to treatment centers. These financial factors act as a brake not only on uptake but also on compliance with PEP. In Burkina Faso, a dose of VAR costs 7,500 CFA francs, yet five doses are needed for full immunization or 37,500 CFA francs for post-exposure treatment in the event of a suspected bite [8]. In Cambodia, the cost of full PPE against rabies has been estimated at between 50% and 100% of a Cambodian farmer's monthly salary [9]. A study in rural Tanzania showed that for a complete cycle of PEP excluding IGVs, a rural Tanzanian patient would have to pay more than USD 100 after a 5-dose regimen. In addition, there are inequalities, such as travel costs for rural patients more than double those of urban patients [10]. In addition, this study highlighted inequalities such as travel costs for rural patients more than double those for patients in urban areas [10].

Geographical inaccessibility to PEP is also a significant factor

in the non-use of PEP. In Burkina Faso, the anti-rabies vaccine is not available in all regions of the country, and there are only two anti-rabies treatment centers in the two major cities (Ouagadougou and Bobo Dioulasso) for the whole country [8]. In Cambodia, Baron (2022) showed a significant negative association between travel time to the Pasteur Institute of Cambodia (PIC) and Post-Exposure Prophylaxis compliance: a one-hour increase in travel time between patients' homes and IPC PEP centers leads to a 70% to 80% reduction in PEP compliance [11]. In Côte d'Ivoire, apart from the 30 INHP branches and the 30 health districts with Rabies Vaccination Units (UNIVAR), patients in other localities are obliged to travel long distances, losing hours or even days of their professional activities, which for some are their only source of income. Under these conditions, the use of and compliance with PEP is neglected. We, therefore, need to decentralize and increase the number of centers providing care for people exposed to rabies and continue public awareness campaigns to change the behavior of animal owners, especially dogs [8].

The Integrated Rabies Control Model in Côte d'Ivoire

Rabies control is based on the vaccination of dogs to interrupt transmission of the virus to humans and vaccination of humans, either in the form of preexposure prophylaxis (PrEP), using the vaccine alone, or Post-Exposure Prophylaxis (PEP), using the vaccine alone or in combination with Rabies Immune Globulin (RIG), depending on the category of exposure. Preexposure prophylaxis eliminates the need to administer rabies immunoglobulin after exposure to an animal (bite, scratch, lick). It helps protect people when rabies immunoglobulin is not always available in all rabies-endemic countries. This preexposure prophylaxis ensures protection, even when exposure goes unnoticed or is not followed by a request for treatment, particularly in children.

The main determinants of rabies mortality in Côte d'Ivoire are low levels of knowledge and cultural constraints, which influence the low uptake of PEP and compliance with PEP. Several strategies have been implemented in the fight against rabies in Côte d'Ivoire. The recommended model is based essentially on the Eco health approach and is adapted to the characteristics of rabies in Côte d'Ivoire. By identifying community participation as the basis for all interventions, the Eco health approach has enabled communities to achieve autonomy and take control of the fight against rabies by themselves and for themselves. The Eco health approach involves bringing together scientists, decision-makers, and community members to improve human health by finding solutions through how people interact with their environment. It recognizes the interdependence of human, animal, and ecosystem health [12]. It is highly participatory, which means that citizens and their representatives are part of the entire research process, from defining the issue to implementing the collectively chosen solution. To eliminate rabies by 2025, set by the Global Alliance for Rabies Control (GARC), we will need to go beyond veterinary and human medicine and include biology, cultural sciences, sociology, and geography [13].

Audrey Simon used this Eco health research approach to solve the problems associated with dogs in Kuujuaq, thanks to her work near and the involvement of local collaborators. This approach helped overcome several shortcomings, including a lack of trust, communication difficulties, an incomplete picture of needs, particularly those of the community, and the resulting lack of commitment. Thanks to the bonds of trust established, the participation of Kuujuaq's residents made it easier to define priority needs and identify effective and sustainable solutions that the community will support with a high degree of acceptability [14].

In this model, multisectoral coordination and collaboration at national, regional, and departmental levels, combined with community participation, are the central elements around which four essential pillars revolve. Collaboration and coordination are among the regional measures advocated by WAHO to deal with priority zoonotic diseases as part of the "one health" approach [15]. Prominent among the strategies implemented are those aimed at improving people's knowledge of the disease and improving financial and geographical accessibility to PEP. To improve people's knowledge of the disease, numerous communication and awareness-raising activities are carried out ad hoc during the World Rabies Control Days initiated in Côte d'Ivoire in 2008, and other ad hoc activities in schools or targeting pupils and teachers. Despite these activities, deaths are still caused by failure to use PEP after exposure. We therefore advocate the Eco health approach, one of the essential pillars of which is community participation. We must involve communities and ensure they take absolute ownership of the fight against rabies. The influence of knowledge about rabies on compliance with PEP means that we can insist on communication to increase knowledge about rabies and the use of PEP.

When intradermal vaccine administration is used for post-exposure prophylaxis, it reduces the number of vaccine vials used by at least 25% compared with the intramuscular route. As the number of patients attending health centers increases, the intradermal route is becoming increasingly cost-effective, reducing the number of vaccine vials by up to 85%. Furthermore, according to Chulasugandha (2006), the cost of post-exposure prophylaxis for a severely exposed child varies from \$28.75 to \$125.00. Preexposure vaccination is only \$2.00 to \$7.25, with an additional cost of \$18.00 to \$23.50 if the post-exposure booster vaccination is required later. Lower costs have been estimated using the WHO-approved reduced-dose intradermal vaccination schedule. Developing countries where rabies is endemic should consider including healthcare costs and better protocols in their annual budget [16].

Implementing this protocol could considerably reduce the cost of PEP by 80%, making it accessible to all populations, especially low-income people. However, this affordability should be put into perspective for category III exposures, where the use of rabies immunoglobulin is required. In legal and regulatory terms, the Côte d'Ivoire National Committee of Independent Experts on Vaccines and Immunization (CNEIVCI) has authorized the use of intrader-

mal vaccines for pre-and post-exposure prophylaxis in Côte d'Ivoire [17]. Similarly, the Cabinet of the Ministry of Health, Public Hygiene, and Universal Health Coverage has authorized its implementation at a national level. Finally, a feasibility study on using the WHO protocol in conjunction with awareness-raising campaigns carried out in Bouake and San Pedro showed a high level of acceptance and increased compliance with rabies PEP.

Apart from affordability, neglect was the main reason people at risk who accepted the Thai Red Cross schedule dropped out. Introducing free rabies PEP through the Thai Red Cross protocol met with public acceptance. This experiment has been crowned with success, with improved compliance with the PEP, which means that people are safely protected against rabies. Therapeutic education for patients receiving PEP is a prerequisite for getting people to adhere to full PEP. As far as geographical accessibility is concerned, we recommend extending PEP services to all health districts in Côte d'Ivoire. In the health districts, the availability of PEP should be ensured in all General Hospitals. This supply extension is necessary to ensure the use of and compliance with PEP. In terms of geographical accessibility, extending care to all the country's health districts and within the districts of the health centers is essential to bring PEP services closer to those at risk. In addition, improving geographical accessibility must go hand in hand with capacity building and the effective involvement of health workers from first-contact health facilities in caring for people exposed to rabies.

Implementing high-quality PEP that is geographically and financially accessible is the key to combating rabies mortality. Implementing preexposure vaccination will make it possible to protect children for whom specific exposures go undetected or where parents or guardians refuse to have them treated. In addition, in the case of category III exposures, it can compensate for the absence of rabies immunoglobulin. The feasibility study carried out shows good acceptability and, above all, good compliance with preexposure prophylaxis protocols. What is more, this preexposure vaccination is more effective than PEP. According to Chulasugandha, *et al.*, the cost of post-exposure prophylaxis for a severely exposed child is from \$28.75 to \$125.00. Preexposure vaccination is only \$2.00 to \$7.25, with an additional cost of \$18.00 to \$23.50 if the post-exposure booster vaccination is required later. These lower costs have been estimated using the WHO-approved reduced-dose intradermal vaccination schedule.

Budgetary constraints in developing countries where rabies is endemic must consider healthcare costs and the best care protocols to implement [16]. Based on the recommendations of the Côte d'Ivoire National Committee of Independent Experts on Vaccination and Vaccines (CNEICI) [17], the cabinet's authorization and the results of feasibility studies carried out in Bouake and San-Pedro, the WHO's intradermal protocol will be used more widely at all sites where people at risk are treated. These studies show that free rabies vaccine used intradermally can considerably increase the use of and compliance with PEP in Côte d'Ivoire. In addition,

this implementation could compensate for the lack of rabies immunoglobulin for category III exposures. The feasibility study showed that the preexposure prophylaxis protocols were well accepted and adhered to.

Canine mass vaccination campaigns can interrupt canine-to-dog transmission of the virus, on which the incidence of canine rabies depends considerably. Vaccination coverage of at least 70% should completely stop canine-to-canine transmission. According to Anyiam, *et al.* a mass vaccination campaign against canine rabies provided free of charge, repeated once or twice, and covering the whole of Chad each time is a feasible and cost-effective way of eliminating rabies nationwide [18]. These strategies are supported by multisectoral coordination and collaboration, epidemiological surveillance, awareness raising, and communication to achieve sustainable behavior change.

All the activities recommended in the model will have to be backed up by support activities, in particular:

- a) Epidemiological surveillance, including investigation and response.
- b) Community involvement by CHWs.
- c) Monitoring and evaluation of activities.

In short, it will be necessary to combine several interventions. If implemented together, all these interventions could improve uptake and compliance with PEP, pending control of canine rabies through vaccination coverage of at least 70%, and enable the country to eliminate dog-transmitted human rabies by 2030. The implementation of this model could face the following challenges: insufficient financial resources to fund the activities set out in the model, challenges relating to collaboration between health workers in the animal and human health sectors, and ownership of the fight by the population. However, the political will demonstrated by the country's adherence to the initiative to eliminate dog-transmitted rabies by 2030 and the adoption of the integrated plan for rabies control in Côte d'Ivoire could make it possible to overcome these challenges.

Conclusion

Numerous risk factors persist low knowledge about the disease, the lack of systematic use of PEP, poor compliance with PEP, and, above all, low vaccination coverage in dogs, the main reservoir of the disease in Côte d'Ivoire. The proposed integrated pest management model is adapted to the characteristics of the disease in Côte d'Ivoire. These activities need to be implemented in a coordinated and integrated manner. Pending control of the germ reservoir, PEP should be systematically implemented in the event of any exposure to rabies. Under these conditions, it is essential to raise awareness among the population, with their full participation, and make PEP more widely available to reduce costs and improve access to PEP.

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Conflicts of Interests

None.

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