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Rabies mortality and morbidity associated with animal bites in Africa: a case for integrated rabies disease surveillance, prevention and control: a scoping review

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ABSTRACT

Objective The objective of this scoping review was to map the current situation and available evidence and gaps on rabies morbidity, mortality, integrated rabies surveillance programmes, and existing prevention and control strategies in Africa.

Methods We conducted a systematic scoping review following the Joanna Briggs methodology and Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews checklist. Medline, Embase, CINAHL (EBSCOHost), Scopus, Web of Science and rabies web conferences were used to search for peer-reviewed publications between January 1946 and May 2020. Two researchers reviewed the studies and extracted data based on author (year) and region, study design and data collection duration, participants/comparators, interventions, control conditions/exposures and outcomes (rabies mortality and morbidity) and key findings/gaps/challenges. The results were reported narratively using Arksey and O'Malley's methodological framework.

Results Electronic search yielded 2775 records, of which 43 studies were included. A total of 543 714 bite victims were censored through the included studies. Most of the victims were less than 15 years of age. The studies included rabies morbidity (21) and mortality (15) fluctuating in space and time across Africa depending on countries' rabies prevention and control practices (16). Others were surveillance (nine studies); surveillance and prevention (five studies); management and control (seven studies); and surveillance, prevention and control (six studies). We found challenges in rabies reporting, existing dog vaccination programmes and post-exposure prophylaxis availability or compliance.

Conclusion This study found challenges for dog rabies control and elimination in Africa and the need for a policy to drive the goal of zero dog-transmitted rabies to humans by 2030.

Strengths and limitations of this study

- We conducted an extensive search of published and grey literature to identify studies to include in the scoping review.
- Pulling together data from both published and grey literature from the Ministries of Health gave us an opportunity to understand the breadth of rabies epidemiology and how surveillance, prevention and control would be a critical tool in implementing effective control of rabies across Africa.
- We conducted screening of identified articles and extraction of data in duplicate.
- We reported the results narratively as it was not possible to combine data from different studies conducted using different study designs and different population groups.

BACKGROUND

The natural history of rabies disease in Africa is not well known, but it is well accepted that the disease must have been present in northern Africa for hundreds of years, particularly as an urban dog disease and was also associated with cycles in the Middle East.[1] European colonisation influenced the spread of dog rabies in Western and Central Africa.[2] In many sub-Saharan African countries, rabies has become epizootic only in the 19th and

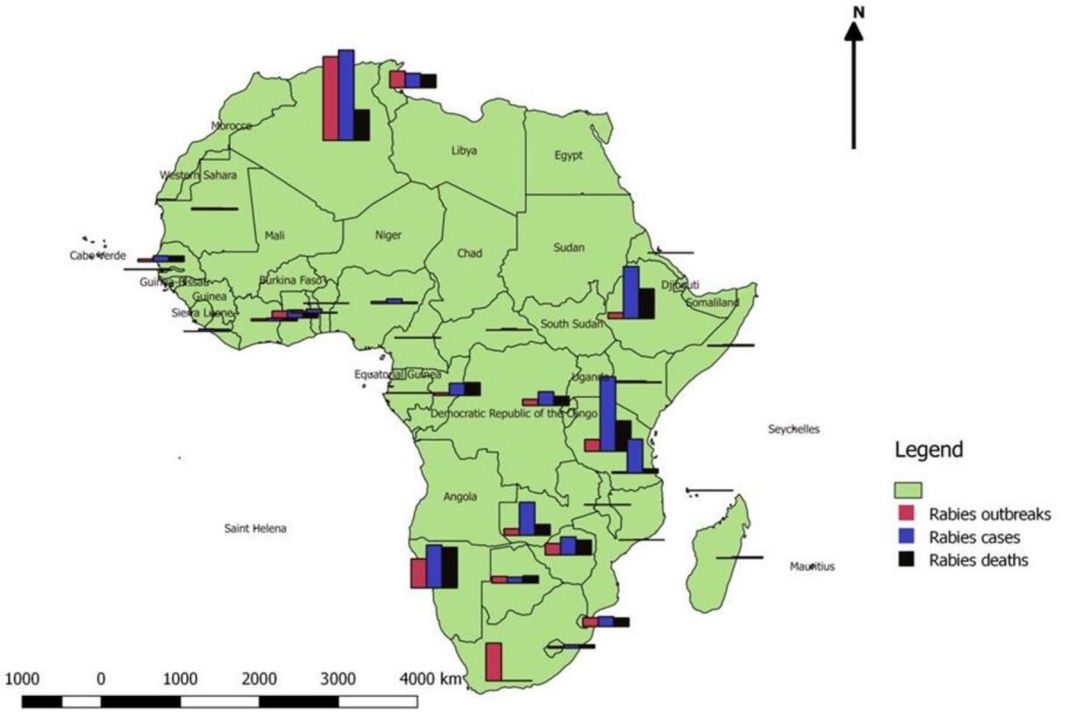

Figure 1 Human rabies distribution in 32 African countries (2011).

20th centuries involving domestic dogs and free-ranging wildlife species.[1–3]

More than 59 000 people die of rabies worldwide every year,[4 5] 99% of them in African and Asian countries where dog rabies is endemic.[4 6–10] Due to the lack of laboratory confirmation, sporadic epidemiological surveillance and unreported clinical cases in developing countries, current mortality estimates almost certainly under-represent the true incidence of human rabies deaths.[4 8–10] Rabies is responsible for an estimated 21 000–25 000 deaths annually in Africa.[4 11 12] Figure 1 shows a map illustrating rabies distribution in 32 African countries considering rabies outbreaks in animals, cases and deaths in humans.[13] In 2011, a total of 33 African countries reported 1607 outbreaks of rabies, 2779 cases and 1524 deaths.[13] Data show that rabies accounts for 7.2% of all animal disease outbreaks reported, making it the disease with the highest number of outbreak reports in Africa in 2011.[13] Algeria, Namibia, Eswatini (former Swaziland), Tunisia, Uganda, Zambia and Zimbabwe reported high morbidity and mortality with 563 cases (33.9% deaths), 269 cases (94% deaths), 62 cases (88.7% deaths), 91 cases (90% deaths), 466 cases (40.9%), 207 cases (32.8% deaths) and 114 cases (80.7% deaths), respectively.[13]

Dog rabies predominates throughout most of Africa; the domestic dog is the principal reservoir host as well as the most important source of infection for people.[14] In addition, there are many other lyssaviruses (also referred to as rabies-related viruses) reported from African countries. Most of these rabies-related viruses have been associated with obscure hosts including specific bat species and shrews, partly attributable to the difficulty in biosurveillance of these viruses. RABV, however, spreads in terrestrial mammalian hosts in Africa and has not been associated with bat infections as it is the case in the Americas. While all mammals (domestic and wild) are susceptible to RABV infection, some are able to retain those virus variants adapted to their species while others are only reported as dead-end hosts.[15] Rabies has been reported in both domesticated species and wildlife. These are sometimes diagnosed with rabies virus infection in Zambia, South Africa, Ethiopia, Kenya, Tanzania, Zimbabwe and Egypt.[15–21]

Most reported cases of rabies in wild carnivorous species included yellow mongoose (*Cynictis penicillata*) and bat-eared fox (*Otocyon megalotis*)[22] as well as critically endangered wild dogs (*Lycaon pictus*).[19 23–25] In Ethiopia, rabies outbreaks were described in the endangered Ethiopian wolf (*Canis simensis*) population.[26 27] In 2014 and 2015, RABV infection was also observed in two wild dogs and a spotted hyaena (*Crocuta crocuta*) in the Madikwe Game Reserve, North West Province of South Africa, in Ethiopia and in Nigeria,[21 25 28] monkeys and jackals (*C. adustus* and *C. mesomelas*).[16 17 20 21] The review of 20 studies across Africa has revealed that bite victims account for 91.9% (48 092 dog bites), cat bite for 2.9%, jackal bite for 0.8% and 4.41% for others (monkey, donkey, horse, rat, pig, rabbit, Honey badger, kudu, goat, cattle, eland and hyaena).[29–48]

Mass vaccination of dogs as a key component of national rabies elimination programmes has been successful in eliminating dog-transmitted rabies in Europe, North and Latin America, and Japan.[49–51] By far, the most significant public health threat comes from RABV, and over 99% of all globally reported human cases are caused by exposure to unvaccinated dogs infected with canine RABV variant, mostly in Asia and Africa.[52]

In most of Africa, and specifically Western and Central African countries, notification of rabies disease is not mandatory, so epidemiological data are scarce.[53] Human rabies could be prevented by the immediate administration of post-exposure prophylaxis (PEP) following exposure to rabid animals.[5 45] However, people in low-income countries often do not receive these life-saving treatments because either PEP treatment is costly and not readily available, or because of lack of rabies awareness, people might not go to hospital for treatment.[5 9 54] The lack of effective educational outreach at community level had led to gaps in knowledge as to the best way to avoid animal bites and administer first aid following bites or other potential rabies exposures.[55] A recent study has shown considerable in-country variability in the availability of rabies vaccines and immunoglobulin vaccine supply system, administration route (intramuscular (IM) vs subcutaneous (SC), cost of vaccine and rabies immunoglobulin (RIG). In a global survey conducted in rabies-endemic countries, 49 of the 54 African countries were rated as moderate to high risk for human rabies, while 16 of the 23 countries that responded to the survey had inadequate surveillance systems.[12 56]

One major barrier is the difficulty of consistently achieving the required coverage of 70% of the dog population across the hard-to-reach landscapes that characterise much of sub-Saharan Africa.[57–59] Reviewing dog vaccination coverage in African countries, only South Africa, Tanzania, Algeria, Morocco and Egypt had the dog vaccination coverage of 63%, 37.24%, 23.7%, 25% and 23.7%, respectively.[60 61] In all other African countries, dog vaccination coverage was below 18% with further below 5% in some cases.[60] The analysis of the above data and the consideration of the framework for the elimination of dog rabies suggested by Wallace *et al* and others stipulated the existing coverage of dog rabies vaccination, that was directly associated with the number of years it would take to achieve rabies elimination.[62] Theoretically, Global Dog Rabies Elimination Route consisting of a 13-year time frame would be an ample time for even the least developed rabies prevention systems to achieve elimination by 2030 if completely committed to this achievement.[62] This system divided countries into three categories: (1) phase I—preparation (dog vaccination >18%), (2) phase II—vaccination of dogs (dog vaccination: <18% and >70%) and (3) phase III—70% continued vaccination of dogs. African countries have been categorised into phase I, II and III but with no data on dog vaccination.[63] The available data indicate that most African countries were still at the preparation phase since 'zero rabies by 2020' was initiated 5 years ago. Although the feasibility of reaching 70% dog vaccination coverage has been shown through pilot projects in a wide range of settings, African countries still struggle to achieve a 70% yearly dog vaccination rate.[10 14] In Africa, dog mass vaccination systems have demonstrated some effectiveness as a proof of principle in countries such as South Africa,[49–64] Tanzania,[49 65–67] Malawi[49 68] and Chad.[54 69–71]

Inadequate education for veterinarians and physicians, insufficient resources for proper confirmatory diagnosis and risk assessment, and the lack of effective communication channels between Ministries of Health and Agriculture frequently have led to failures of prophylactic intervention, even in regions where vaccines and immunoglobulins were available.[55] A recent study conducted in Africa and Asia revealed that RIGs were found to be less available than the vaccine, with access restricted in almost two-thirds of the countries surveyed.[72] Eleven (11) African countries had comprehensive access to RIG. Of the seven countries with broad access to vaccines, six of them had a national rabies prevention programme or policy. Two of the countries had only a monitoring programme/strategy in place.[72] This is worrisome as it exposes a huge absence of surveillance and prevention policies in most African countries. The absence of a robust monitoring process is mostly attributed to the lack of rabies in national communicable disease plans and reporting systems at national level in Africa.[73] Therefore, widespread under-reporting is likely to occur in many affected countries due to lack of health information, civil registration and vital statistical systems, and inaccessibility of clinical care and diagnostic confirmation[73] as symptoms of the disease may be non-specific and similar to other encephalitic infections. Even where data exist in Africa, the lack of communication and exchange of data between the animal and human health sectors also hinders the collection, storage and reporting of coherent data to international databases.[73] The WHO meeting in Geneva in 2018 on 'Moving Progress towards Rabies Elimination' pointed out that political engagement is a key factor with governments providing leadership role in the coordination of elimination strategies.[12] The global collection of data on deaths from any neglected disease is a huge challenge, and early attempts to collate data for human deaths from canine rabies were no exception.[74] Due to the lack of regular reporting of rabies cases to the WHO from many member states, the RabNet Database was closed down in 2011.[75] Therefore, rabies is not reportable in many African countries, which restricts data collection by structured surveillance systems.[73] One Health evolved from the recognition that an interdisciplinary approach is required to understand complex health problems, and that the health of humans and animals is inextricably linked.[76] Rabies requires a comprehensive, strategic, and targeted control and prevention approach with collaboration from human, animal, and environmental health disciplines at local, national, and global levels to achieve more effective control.[77] In fact, most of African countries lack a One Health approach to prevent human rabies deaths.[78]

The WHO, the World Organization for Animal Health (OIE), the Food and Agriculture Organization and the Global Alliance for Rabies Control (GARC) have developed a strategic global plan to end canine-mediated rabies by 2030.[7 12 79] This initiative provides a concerted approach to the prevention of rabies, combined with the strengthening of human and veterinary health systems.

These would enable reaching out to the most underserved communities in the world by engaging, encouraging and supporting all countries to lead and improve elimination efforts.[73] This scoping review was therefore designed to map the evidence on rabies morbidity, mortality, integrated rabies surveillance, prevention and control in African countries. Its objectives were: (1) to assess the extent of available research on the morbidity and mortality of rabies due to animal bites conducted in Africa; (2) to identify research gaps in the literature on the impact of rabies in Africa so as to effectively plan public health intervention; (3) to ascertain the current level of rabies disease surveillance, prevention and control that exists in African countries; (4) to assess the published adverse events and complications associated with human rabies vaccination in African countries; (5) to assess the different types of vaccines used and the effectiveness of locally produced and imported vaccines in treating rabies in different parts of Africa; and (6) to assess rabies morbidity and mortality associated with dogs and contact with a suspect animal in humans.

METHODOLOGY

Study design

This paper used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews checklist[80] and the Joanna Briggs Institute guidelines[81] as a norm for reporting scoping reviews. The analysis was conducted in accordance with the structure suggested by Arksey and O'Malley,[82] further developed by Tricco *et al*.[83]

Eligibility criteria

The search was conducted from 1 January 1946 until 30 May 2020. A PICO (Population/Interventions/Comparisons/Outcomes) search framework was set, where P (humans infected with rabies in African countries), I (integrated rabies disease surveillance, prevention and control), C (little or no integrated rabies disease surveillance, prevention and control) and O (reduced human morbidity and mortality of rabies associated with animal bites) were chosen. The included studies are described in online supplemental table 1.

Electronic search

We conducted a systematic search of the electronic databases Medline (OVID), Embase (OVID), CINAHL (EBSCOHost), Scopus (Elsevier), Web of Science and web conferences (*rabiesalliance.org*, *www.who-rabies-bulletin.org* and *https://www.oie.int/*). The search techniques were limited to English. The main search strategy was listed in online supplemental material 1. EndNote V.X9 reference manager was used to remove duplicates. JLT reviewed all the papers identified by title in order to pick those that were potentially appropriate, with a clear bias towards retention. The abstracts of all the studies chosen on the basis of their titles were independently reviewed by two reviewers (PN and JLT) and any variations were preserved in the study.

Data charting process

For all studies selected at the abstract level, data were extracted and plotted in the table, covering author (year) and region, study design and data collection duration, participants/comparators, interventions and control conditions/exposures, outcomes (rabies mortality and morbidity), and key findings/gaps/challenges. The final decision to include studies was taken on the basis of this data extraction and whether it met the inclusion/exclusion requirements, based on an independent review by two authors (PN and JLT) and a discussion of any differences; the third author (RT) was available for consultation if consensus could not be reached. Our inclusion criteria were the following: rabies occurrence or mortality rates, all ages included, only studies performed in Africa, studies in which at least one intervention included monitoring, prevention and control of rabies, and only quantitative studies.

A data extraction sheet has been developed and used to extract data from included papers. The data collection sheet included: author, region, year, study design, level of evidence, sample size description, interventions or exposures, results, and key findings/gaps/challenges. Two reviewers (PN and JLT) worked separately at all levels of the study. The results were then compared and any variations were addressed and resolved by PN and JLT. The third author (RT), who also summarised the findings, was consulted when a discrepancy could not be resolved. The evaluation of the probability of bias, the methodological standard of the included studies, was not assessed due to the scoping review of the study.[82]

Data items

Seven items were listed in the data collection chart table. We included the first author, the year of publication of the study and the country (item 1), study design and period of data collection (item 2), the sample size, mean or median age, and gender (item 3). The intervention and control conditions/exposures included surveillance, prevention and control of rabies and any other form of intervention used in human rabies (item 4). The number or rate of human rabies morbidity included annually or during the study period (item 5). Human rabies mortality recorded the death or mortality rate annually or during the study period (item 6). Main findings/gaps/challenges included other outcomes such as data gaps found, available research evidence as well as PEP or vaccine adverse events (item 7).

Critical appraisal of individual sources of evidence

The methodological quality of included studies was not evaluated due to the scoping nature of the review.[83]

Synthesis of results

Studies were summarised based on author (year) and country, study designs, participants and comparator,

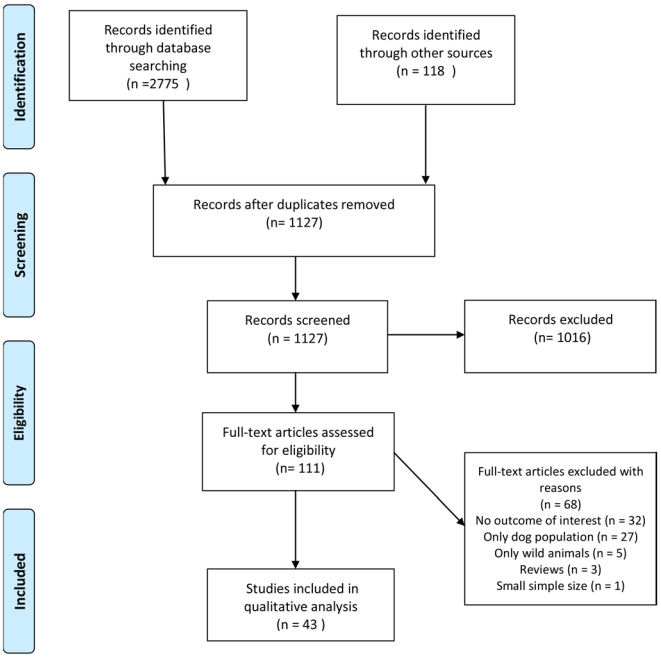

Figure 2 Flow diagram of human rabies mortality and morbidity associated with animal bites in Africa.

interventions and control conditions/exposures, key outcomes, gaps, findings and challenges. Interventions were subdivided into rabies prevention, surveillance, control and management. Where data were not clearly provided to compute morbidity and mortality rates, we reported the results narratively, as recommended in scoping reviews methodological framework.[82]

RESULTS

Study selection

The searches from the five electronic databases hit a total of 2775 records (Medline: 696, Embase: 952, CINAHL: 289, Scopus: 431 and Web of Science: 407) that led to a total of 1127 titles and abstracts that were screened after the removal of duplicates. We retained 111 of these based on their title and abstract screening. The full-text screening's stage led to 43 potential articles relevant to our scoping review. The scoping review flow chart was described in figure 2.

Study characteristics

The review reported only quantitative studies on rabies surveillance, prevention and control. Thirty-two quantitative studies were retrospective cohort with 8 months to 14 years of study duration,[21 29–31 33 34 36 38–46 48 84–98] three studies were mixed designs (retrospective and cross-sectional study),[47 99 100] three were prospective cohort studies,[32 35 101] two were cross-sectional studies,[102 103] one was case–control,[37] one was clinical trial[104] and a randomised control trial.[105]

We grouped the included studies into five categories based on rabies interventions, namely (1) prevention and control, (2) surveillance, (3) surveillance and prevention, (4) treatment and control, and (5) surveillance, prevention and control. Figure 3 shows the distribution of studies according to the intervention in 19 African countries. We also summarised all studies included in the final analyses in online supplemental table 1 which included seven parts in line with the specified framework for data synthesis: (1) rabies morbidity, (2) rabies

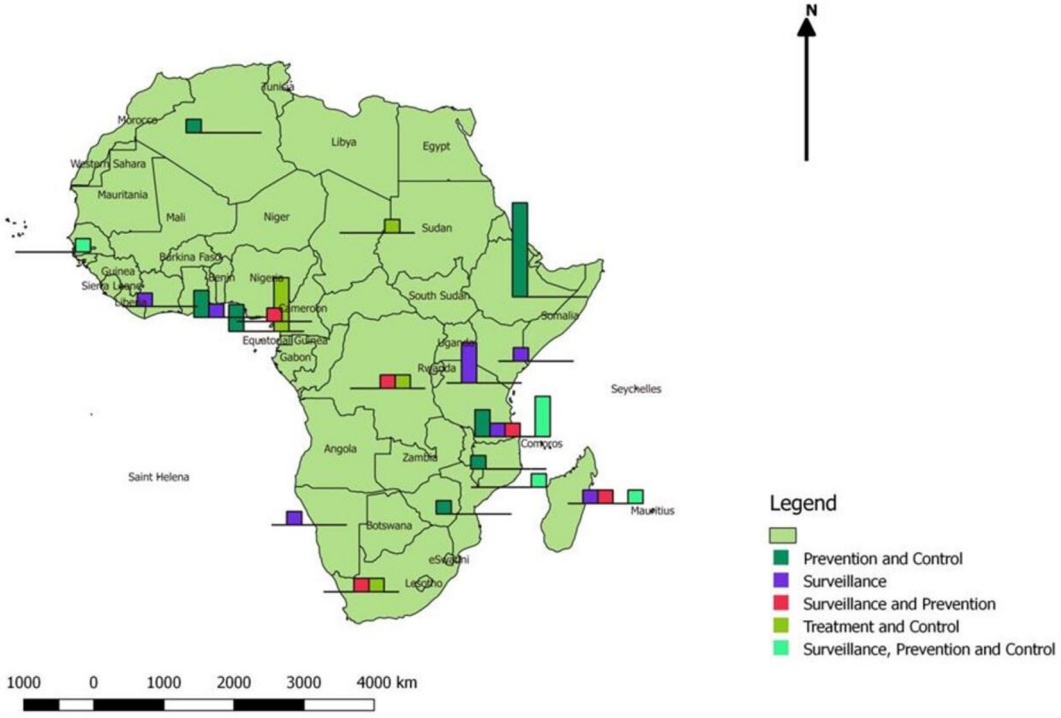

Figure 3 Distribution of 43 studies in African countries.

mortality, (3) interventions for rabies control, (4) rabies disease surveillance, prevention and control, (5) available research evidence, (6) research gaps identified, and (7) adverse events and complications associated with rabies vaccination.

Patient characteristics

A total of 543 714 bite victims were recorded in included studies. Age-specific and sex-specific distribution revealed that the most fatal cases belonged to age groups 0–14 years.[29 33 35 38 43 45 46 48 84 91 92 94 96 100 102] Other studies identified rabies victims of 15 years and above.[30 38 39 42 46 84 95 96 100 103] The median age was 18 years in most of the studies and ranged from 1 to 95 years. Most of the children were males.[45 46 94 96] However, another study has indicated that females have more animal-related bites than males.[29] Young children are at higher risk of contracting rabies in the absence of PEP and wound care due to the location of the bites they incur.[102] Based on the extent and depth of injury, 1567 victims were recorded. Extent and depth of injury was classified as broken skin (11.1%), scratch (9.25%), superficial (loss of epidermis only) (36.38%), deep (27.31%) and simple (affect only one tissue) (12.38%).[29 31 101 103] Further, 10 006 bites were described in regard to the site of exposure among which included the head/neck/face (5.08%), leg/feet (61.06%), arm/hand (23.23%), buttocks/trunk (10.32 %) or multiple (0.31%).[29–33 42 47 93 95 99 102]

Individuals suspected to have rabies were clinically managed by the chief doctor paediatricians and nurses.[32 36 37 40 84 94 99 103] The main treatments were wound management, antibiotics, and prophylaxis against tetanus and rabies. Nine studies reported wound management as part of PEP.[32 37 40 47 93–96] Reports were collected in hospitals, treatment and health centres, health clinics and pharmacies.[103]

Study outcomes

Rabies morbidity

Twenty-one studies reported human rabies morbidity in Africa (table 1).[30 34–39 41 43 46 48 84 86 88–92 97 99–101 103] Among them, five studies were undertaken in Tanzania, the first study estimated an average annual incidence per 100 000 bites of 37.1, 11.3 and 33.5 in the human population districts of Ulanga (193 280 inhabitants), Kilombero (321 611 inhabitants) and Serengeti (176 057 inhabitants), respectively.[89] The second study found that the incidence of bite patients seeking PEP declined substantially (>50%) from 2011 to 2015.[90] The third study estimated an annual incidence of ~58 cases per 100 000,[41] the fourth study reported a mean incidence of 74 bites considered at risk of rabies transmission per 100 000 persons per year,[97] and the last study conducted in Tanzania revealed an average of 75.6 and 19.3 probable rabies exposures per 100 000 persons per year.[99] Three studies conducted in Ghana reported 54 dog bite victims bitten by rabies-positive dogs within 3 years,[84] 13 cases of human rabies in a 6-year retrospective records review[38] and an annual incidence of rabies cases of 172 per 100 000 people.[48] Four studies reported rabies morbidity in Ethiopia. Yizengaw *et al* reported a high incidence rate of rabies exposure during spring (360, 39%) and summer (244, 26.4%) seasons and a total of 924 human rabies exposure cases received the anti-rabies PEP from September 2015 to August 2017.[100] The incidence of human rabies exposure was reported to be 40 per 100 000 persons in Ethiopia,[33] annual estimated rabies incidence of 2.33 cases per 100 000 in humans,[101] and the incidence of human rabies exposure cases calculated per 100 000 persons was 35.8, 63.0, 89.8 and 73.1 in 2012, 2013, 2014 and 2015, respectively.[93] A study conducted in Zimbabwe found among rabies suspect, 42 (73.7%) were positive.[39] In Madagascar, 9 of the 11 suspected human cases tested from 2005 to 2010 with a laboratory-confirmed rabies.[86] In Uganda, a total of 208 720 patients with animal bite injuries were treated at health facilities across the country.[88] Ivory Coast reported 50 cases of human rabies with annual incidence of 0.06–0.08 per 100 000.[35] The incidence of human injuries caused by animal bites was 289 per 100 000 persons with the highest incidence reported at 302 per 100 000 and lowest at 121 per 100 000 persons in Kenya.[38] Another study undertaken in Malawi reported 14 paediatric rabies cases during the study period.[92] A 6-year retrospective study revealed 31 positive cases of human rabies in Madagascar.[46] In Democratic Republic of Congo (DRC), a 5-year retrospective study found 29 positive to rabies in a total of 5053 dog bites recorded in the veterinary clinics,[34] and Frey *et al* estimated an annual incidence of bites from suspected rabid animals of 12.9/100 000 and an incidence of 0.7 human rabies deaths/100 000 in Chad.[103] Namibia reported above 16 cases per year from 2011 until 2015 with a maximum of 23 cases observed in 2015 with an incidence of 1.0 and 2.4 per 100 000 inhabitants and per year on average.[43]

Rabies mortality

Sixteen studies reported rabies-related mortality in Africa (table 2).[21 31 37 40 42 44 45 85 87–89 98 99 101–103] Ethiopia reported three studies among which 320 people, diagnosed clinically, died of rabies in a 5-year retrospective study conducted in the national level,[21] 386 human rabies fatalities were reported in an 8-year retrospective study with an annual range of 35–58 deaths in Addis Ababa and outside of Addis Ababa.[45] There were also 32 cases of human rabies recorded from which 3 people ended with fatality in North Gondar administrative zone.[101] Four studies assessed rabies mortality in Tanzania from which Ulanga, Kilombero and Serengeti districts reported human rabies mortality rates of 2.4, 0.8 and 1.4/100 000 per year, respectively.[89] Sixteen human deaths (1291 bite victims) due to rabies were reported within the Integrated Bite Case Management Study across 20 districts in 4 regions in Southern, Central and Northern Tanzania.[98] Other studies reported 28 deaths from suspected rabies cases during the 5-year period in the two districts, an average of 1.5/100 000 per year in

Table 1 Mapping human rabies morbidity rate

Country (region, district and town)	Human rabies morbidity rate	Study duration
Chad (N'Djamena)	An annual incidence of bites from suspected rabid animals of 12.9/100 000[103]	7 months, September 2008–April 2009[103]
Democratic Republic of Congo (Kinshasa)	29 positive to rabies in 5053 dog bites recorded in the veterinary clinics[34]	5 years, 2009–2013[34]
Ethiopia (national level; Ababa and outside of Addis Ababa; North Gondar administrative zone)	A total of 924 human rabies reported.[101] The incidence of human rabies exposure was reported to be 40 per 100 000 people in Ethiopia[33]; annual estimated rabies incidence of 2.33 cases per 100 000 in humans[101]; the incidence of human rabies exposure cases calculated per 100 000 people was 35.8, 63.0, 89.8 and 73.1 every year[91]	1 year, January 2016–31 December 2016; 2 years, 2015–2017; 3 years, 2012–2015; 11 months, April 2009–March 2010[33 91 100 101]
Ghana (Techiman municipality; eastern region of Ghana)	54 dog bite victims bitten by rabies-positive dogs[84]; 13 cases of human[38]; an annual incidence of rabies cases of 172 per a population of 100 000[48]	4 years, 2009–2012; 6 years, 2011–2016; 2 years, 2013–2015[38 48 84]
Ivory Coast (national level)	Annual incidence of 0.06–0.08 per 100 000[35]	3 years, 2014–2016[35]
Kenya (Machakos and Kitui counties in lower eastern region; Kisumu county in Lake Victoria basin; Nandi county in Central Rift Valley and Kilifi coastal region)	Human injuries caused by animal bites, incidence of 289 per 100 000 persons[30]	6 years, 2011–2016[30]
Madagascar (national level)	9 of the 11 suspected human cases tested with a laboratory-confirmed rabies[86] 31 positive cases of human rabies reported[46]	6 years, 2006–2011; 6 years, 2005–2010[46 86]
Malawi (Blantyre)	14 paediatric rabies cases reported[92]	6 years, 2012–2017[92]
Namibia (Kavango)	An incidence of 1.0 and 2.4 per 100 000 inhabitants and per year on average[43]	7 years, 2011–2017[43]
Tanzania (Mwanza region; Tabora; Shinyanga; Mara; Ulanga; Kilombero; Serengeti; Dodoma region; Ngorongoro districts in northern Tanzania and in the 11 districts in southern Tanzania)	Average annual incidence per 100 000 bites of 37.1, 11.3 and 33.5 in human population[89] An incidence of bite patients seeking PEP declined substantially (>50%)[95] An annual incidence of 58 cases per 100 000[41] Mean incidence of 74 bites considered at risk of rabies transmission per 100 000 persons per year[97] An average of 75.6 and 19.3 probable rabies exposures per 100 000 persons per year[99]	5 years, 2002–2006; 4 years, 2002–2006; January 2011–January 2013; 7 years, 2008–2014; 2002–2017; 2011–2017; 2011–2016[41 89 90 97 99]
Uganda (national level)	208 720 patients with animal bite injuries treated across the country[88]	14 years, 2001–2015[88]
Zimbabwe (national level)	Among rabies suspect, 42 (73.7%) were positive[39]	11 years, 1992–2003[39]

PEP, post-exposure prophylaxis.

Serengeti and 2.3/100 000 in Ngorongoro.[44] Fourteen (14) among 1005 bite victims died showing clinical signs of rabies within 5 years.[99] Three (3) studies identified rabies mortality in Uganda. Among them, there were 592 (95% CI 345 to 920) deaths,[102] where one dose of PEP was sufficient for protection following a rabid animal bite. Another research estimated a total of 371 deaths of rabies with a cumulative total of 117 085 rabies cases in 9 years[87] and a 14-year retrospective study revealed a total of 486 suspected human rabies deaths among 208 720 patients with animal bite injuries treated at health facilities across the country.[88] A study undertaken in Moramanga district (Madagascar) recorded an annual incidence of 42–110 rabies exposures and 1–3 deaths per 100 000 persons.[31] An estimated seven rabies deaths (95% CI 4 to 10 deaths) per year was recorded in N'Djamena (Chad).[101] A study conducted in Algeria excluding Sahara region found an annual average of 20.6 human rabies deaths.[90] A total of 14 cases of fatal rabies with 12 deaths were reported in Maputo city, which is the capital of Mozambique.[37] An average annualised rabies attack rate of 136 rabies cases per 100 000 dog bite injuries (7 of 5139) with 6 of 7 deaths were reported in South Africa.[42] There were patients with serious rabies manifestations and the case fatality rate of 100% in a study conducted in Kinshasa (DRC).[40]

Rabies disease surveillance, prevention and control

Rabies prevention and control

The review summarised rabies prevention and control based on rabies exposure status, PEP, dog vaccination and seasonality. Among 36 741 bite victims recorded in studies reporting PEP[29 41 45 84 91 92 97] the PEP was initiated based on WHO grade of exposure.[106] We found 505 bites in grade 1 (8.78%), 2050 in grade 2 (35.63%) and 3199 in grade 3 (55.59%).[32 33 42 95 96] The overall PEP course among bite victims varied between 24% and 99%.[29 84]

Table 2 Mapping human rabies mortality rate

Country (region, district and town)	Morbidity rate	Study duration
Algeria (national level excluding Sahara region)	An annual average of 20.6 human rabies deaths[85]	13 years, 2006–2018[85]
Chad (N'Djamena)	An estimated 7 rabies deaths (95% CI 4 to 10 deaths) per year[103]	8 months, September 2008–April 2009[103]
Democratic Republic of Congo (Kinshasa)	Case fatality rate of 100%[40]	8 months, December 2008–July 2009[40]
Ethiopia (national level, Ababa and outside of Addis Ababa, North Gondar administrative zone)	320 people died of rabies in 5 years[21] 386 human rabies fatalities were reported with annual range of 35–58 deaths[45] 32 cases in human rabies recorded[101]	5 years, 1997–2001, 8 years, 2001–2009; 11 months, April 2009–March 2010; 1 year, January 2016–31 December 2016; 2 years, 2015–2017; 3 years, 2012–2015; 11 months, April 2009–March 2010[21 33 45 91 100 101]
Madagascar (Moramanga district)	An annual incidence of 42–110 rabies exposures and 1–3 deaths per 100 000 persons[31]	1 year, 2016–2017[31]
Mozambique (Maputo city)	A total of 14 cases of fatal rabies with 12 deaths[34]	3 months, April–July 2014[34]
South Africa (Uthungulu District of Kwazulu-Natal province)	An average annualised rabies attack rate of 136 rabies cases per 100 000 dog bite injuries (7 of 5139) with 6 of 7[42]	3 years, 2008–2010[42]
Tanzania (Ulanga, Kilombero and Serengeti districts; 20 districts in 4 regions in Southern, Central and Northern Tanzania; Serengeti and Ngorongoro)	Human rabies mortality rates of 2.4; 0.8 and 1.4/100 000 per year, respectively[89] 16 human deaths (1291 bite victims) due to rabies were reported[99] 28 deaths from suspected rabies cases during the 5-year period in the two districts, an average of 1.5/100 000 per year and 2.3/100 000[44] 14 among 1005 bite victims died showing clinical signs of rabies within 5 years[99]	5 years, 2002–2006; 3 years, 2006–2008; 2002–2017; 2011–2017; 2011–2016[44 89 99]
Uganda (national level; 10 districts)	592 (95% CI 345 to 920) deaths[102] An estimated total of 371 deaths of rabies with a cumulative total of 117 085 rabies cases in 9 years[87] A total of 486 suspected human rabies deaths among 208 720 patients in 14 years[88]	8 years, 2001–2009; 14 years, 2001–2015; 3 months[87 88 102]

We reported 2652 bites victims in studies reporting PEP and mass dog vaccination.[33 38 39 85 100] Dog vaccination coverage varied from 14.1% to 68.78%.[33 85] In Ethiopia and Zimbabwe, the dog vaccination decreased significantly across the study and also the health status of most dogs involved in biting was unknown.[39 100] Rabies prevention and control also depended on the seasonality. In Ethiopia, two studies reported season-wise rabies exposure. The first study reported rabies exposure during spring (360 of 924, 39%) and summer (244 of 924, 26.4%) seasons.[100] The second study that found the highest human rabies exposures were reported in spring (April–June) followed by winter (January–March), while the lowest distribution of human rabies exposure was recorded in autumn (October–December).[33] In Nigeria, Osaghae reported the prevalence of dog bite was highest, 41 of 81 (50.6%), during the hot season (April–June) and low, 14 of 81 (17.3%), during the wet season (July–October).[93] Another study conducted in Nigeria recorded the highest number of dog bites with two peaks in April and October 2008.[47] However, the number of dog bite cases was lowest. For all years, the numbers of dog bite cases recorded were lowest at the beginning of the year and dog bites increased during the last 3 months (October–December) of the year 2006.[47] Animal-to-human rabies transmission was highest during the dry months of July–November in Zimbabwe.[39] In DRC, a study found there was no seasonal difference observed for rabies occurrence either for clinical cases or confirmed cases throughout the study period.[34] In Tanzania, each year, the majority of rabies cases were recorded during the period June–October.[41] In the dry season, significantly fewer rabies-positive cases were reported than in the rainy season in Namibia.[43] In Chad, more rabies records per month were collected during the hot, dry season months (March and April), than during the dry season months (September–February).[103] In Senegal, dog bite victims were higher in dry season (November–May) than rainy season (June–October).[32] Besides, bite victims in rural areas took longer, on average, to receive PEP than those

in urban areas.[89 97 100] Probable human rabies cases were higher in rural than urban areas.[33 35]

Rabies surveillance, prevention and control

The findings revealed that 39 802 bite victims were recorded in rabies surveillance and prevention interventions. The studies included laboratory, database and network surveillance.[34 36 42 46 90] The rabies prevention included PEP and dog vaccination. Laboratory surveillance has improved rabies diagnosis,[34 36 42 46 90] and database and network surveillance improved mortality and morbidity records[35 42 90] and allowed better estimates of the true rabies burden.[36] Furthermore, compliance with PEP regimens was significantly higher, rating from 83.7% to 93% in two studies.[42 90] In contrast, dog vaccination remained low (10%–12.6%).[36 46]

We found five studies including rabies disease surveillance, prevention and control.[31 32 37 44 98 99] Among them, three studies[32 37 44] have reported significantly improved rabies morbidity and mortality and also PEP uptake. The PEP uptake was 71% and it dramatically reduced the risk of developing rabies.[39] Another study did not report any death with high number of patients receiving PEP.[32]

A combined strategy of mass dog vaccination, enhanced surveillance, and expanded access to PEP reduced the annual incidence of rabies exposures and deaths annually in Madagascar.[31] Strict measures such as vaccination of dogs in the neighbourhoods where human rabies cases had occurred, mass vaccination campaign of dogs, participation of private veterinary clinics in animal vaccination, collection of stray dogs in selected neighbourhoods, and community education regarding prevention and control measures had drastically reduced rabies cases in humans to 14 during the study period in Mozambique.[37]

Post-exposure management

We found seven studies on rabies management and control. Among them, six studies addressed wound management and PEP.[40 47 93–95 103] Wound severity was graded as follows: 0=no apparent injury seen, 1=skin scratch with no bleeding, 2=minor wound with some bleeding, 3=deep or multiple injuries.[95] The reported severity of the wound was classified as deep wound, lacerated wound, superficial wound or scratch.[103] The severity of the injury was determined using the WHO dog bite injury grading system.[106] Soap, water, wound dressing, tetanus prophylaxis, anti-rabies vaccination, intravenous fluids, diazepam and antibiotics were also part of the management. The overall review reported 5754 bites managed according to the WHO dog bite injury grading system, 3199 (55.59%) were grade 3; 2050 (35.63%) were grade 2 and 505 (8.78%) were grade 1. In 52 cases (7%), the grade of the bite was not recorded.[30 31 40 93 97]

Available research evidence on human rabies

Rabies cases in various committees emphasise the need for active surveillance by following up of people bitten by animals and mass dog vaccinations to alleviate the zoonotic threat of the virus.[87] Strengthening rabies surveillance, controlling rabies in dogs, proper post-exposure management, increasing the awareness of the community and ensuring availability of PEP at lower health facilities are the best approaches of eliminating rabies.[88 92 101] Other studies have demonstrated that reinforcement of rabies surveillance system can improve rabies reporting, which ultimately allows for better estimates of the true rabies burden in the countries.[34 36 42 90] Compliance with PEP regimens was significantly higher for patients following the implementation of automated reminders in comparison with patients attending normal clinics.[42 90] Other studies concluded that preventing dog bites would most effectively reduce bite injuries by improving public health education among children below 15 years.[42] Public health education is also enhanced by encouraging early PEP initiation and completion, development and implementation of responsible dog ownership, animal behaviour educational programmes as well as improving human and veterinary health linkages.[30 42] Evidence also showed that no rabies victim in Mozambique received full post-exposure vaccination and the factors significantly associated with human rabies were: age <15 years (p=0.05), bite by stray dog (p=0.002), deep wound (p=0.02), bite in the head (p=0.001), bite by unimmunised dog (p=0.01), no use of soap and water (p=0.001), and no PEP (p=0.01).[39] Studies have shown that all the rabies vaccines including suckling mouse brain virus (SMBV), fetal bovine kidney virus (FBKV), purified chicken embryo cell rabies vaccine, purified vero cell rabies vaccine, sheep brain anti-rabies vaccine, human diploid-cell vaccine and purified equine RIG were efficacious. However, the WHO and OIE contraindicated SMBV and FBKV in both animals and humans.[29 31 32 36 45 46 102 104 105] Furthermore, a clinical trial with a purified chicken embryo cell rabies vaccine dose used intramuscularly every 2 years generated ineffective immune response to rabies virus[104] as the Zagreb protocol (two intradermal injections of 0.1 mL at two sites, deltoids and/or thighs, on days 0, 3, 7 and 28) was not applied. Even though a randomised control trial showed antibody response 26.7% of SMBV recipients and 28.6% of FBKV recipients within a week, both SMBV and FBKV were equally efficacious and well tolerated,[105] however those vaccines are contraindicated by the WHO because of its association with neurological adverse reactions (severe allergic encephalomyelitis). Furthermore, these vaccines are inferior to modern vaccine in terms of potency and immunogenicity.[107] Table 3 describes the available research evidence on human rabies in Africa.

Adverse events and complications associated with rabies vaccination

Adverse events and complications associated with rabies vaccination were reported based on SMBV, FBKV, purified chicken embryo cell rabies vaccine, purified vero cell rabies vaccine, sheep brain anti-rabies vaccine, human diploid-cell vaccine and purified equine RIG. All the four-dose or Zagreb regimen was reported in all the RIGs.[108]

Table 3 Mapping human rabies evidence identified in Africa

Evidence map	Studies	Impacts/outcomes
Strengthening rabies surveillance	35 36 42 87 88 90 92 101	Reinforcement of rabies surveillance system that can improve rabies reporting and increase the awareness of the community, and ensuring availability of PEP at lower health facilities are the best approaches of eliminating rabies.
Automated short message service (SMS) reminders and telephone contacts	42 44 90 98 99	Compliance with PEP regimens was significantly higher for patients following the implementation of automated SMS reminders and telephone contacts.
Public health education (PEP initiation and completion, responsible dog ownership, behaviour educational programmes and veterinary health linkages)	30 42 47 88 92 101	Lack of enforcement of regulations for licensing of dogs and rabies vaccination increased human rabies morbidity and mortality.
Accurate rabies diagnostic	31 35 36 38 39 46 86 99	The diagnosis of dog bite and rabies was clinical and laboratory based. This improved accurate rabies cases reporting.
Mass dog vaccination	39 85 92	Even though the 70% coverage was not achieved, there was an inverse relationship between dog vaccination coverage and dog rabies cases during the study period.
SMBV, FBKV, purified chicken embryo cell rabies vaccine, purified vero cell rabies vaccine, sheep brain anti-rabies vaccine, human diploid-cell vaccine and purified equine rabies immunoglobulin (RIG) (Zagreb protocol)	29 31 32 35 46 102 104 105	Studies have shown that all the rabies vaccines and RIG were efficacious and well tolerated. However, the WHO contraindicated SMBV and FBKV.
Effective rabies control and management	36 42 85 92	PEP, mass dog vaccination and WHO dog bite injury grading system
Integrated bites case management/rabies disease surveillance, prevention and control	31 32 37 44 98 99	Studies have shown the importance of coordinated surveillance, prevention and control in the eradication of rabies.

FBKV, fetal bovine kidney virus; PEP, post-exposure prophylaxis; SMBV, suckling mouse brain virus.

Among the studies reporting rabies vaccination, only one study using a purified vero cell rabies vaccine at day 0 (two doses), day 7 (one dose) and day 21 (one dose) study found that adverse events occurred in 6% of the patients with two doses and after the third dose, 3% developed adverse events. However, most of the adverse events were minor and associated with headache, fever and pain at the injection site that occurred simultaneously on the same day of the vaccine injection.[32] Other studies did not report any adverse events and complications associated with rabies vaccination.[29 31 36 45 46 102 104 105]

Research gaps identified

In this review, we identified 66.67% African countries reporting poor rabies diagnostic capacity, 50% reported the lack of coordinated surveillance, 50% showed the lack of PEP course completion, 22.22% had insufficient rabies control and 77.78% had low dog vaccination coverage. Insufficient knowledge and practice on rabies prevention was also identified as a gap. However, we did not find enough studies to evaluate this gap in Africa (table 4).

The recorded data available so far have shown the underestimation of rabies diagnosis, PEP and fatal human cases, and could be attributed to poor diagnostic capacity and the absence of national rabies surveillance system. In African countries, rabies diagnostic is mostly clinical.[21 30 32–34 37 40 42 43 45 48 87–89 92–94 97 102 103] Among 11 studies, including human rabies surveillance, only 4 reported adequate and successful surveillance,[35 36 42 90] 12 studies reported lack of accurate data or non-existing surveillance data[30 34 37 42 43 46 48 86–88 102 103] (table 4). Other studies reported that dog bite victims did not complete the post-exposure anti-human rabies vaccine course and were not likely to receive PEP[31 32 35 41 42 44 84 89 94 97 99] (table 4). The exposure victims considered to be at risk of rabies either did not receive any PEP or did not receive all PEP vaccinations due to unavailability, shortage, cost barriers, insufficient knowledge about prompt PEP, category 1 exposure injury or misadvice.[36 40 42 44 47 48 95 98 99] A study has reported that the lack of PEP was the cause of 100% fatality rate in DRC.[40] There was significant difference between rural and urban exposure cases in respect of the time of arrival to the hospital, and living in rural areas was statistically associated with loss to follow-up after the first dose.[34 47 97 100] There was also high human rabies exposure rate in children and in the rural community.[31 34 97 100] Insufficient knowledge about rabies' dangers and prevention, particularly prompt PEP, as well as wound management, was the main cause of rabies deaths.[44] A higher proportion of human rabies exposures was caused by unprovoked dogs and of these, the majority were unvaccinated.[33 47] Dog vaccination remains an urgent intervention gap. Among 18 studies conducted

Table 4 Mapping research gaps and strengths in Africa

African countries	Mapping research gaps and strengths in Africa					
	Diagnostic capacity	Coordinated surveillance	Lack of PEP course completion/PEP unavailable	Inefficient control	Insufficient knowledge and practice on rabies prevention	Low dog vaccination coverage (<70%)
Algeria	N/A	N/A	N/A	√[90]	N/A	X[90]
Cameroon	√[36]	√[36]	X[36]	√[36]	N/A	X[36]
Chad	X[108]	X[108]	X[108]	X[108]	N/A	X[108]
Democratic Republic of Congo	X[34 40]	X[34]	X[34 40]	X[34 42]	N/A	X[42]
Ethiopia	X[21 33 45]	N/A	X[91]	X[33 91 101]	X[101]	X[33 91 101]
Ghana	X[48]	X[48]	X[48 84]	X[38 48 84]	N/A	X[38 84]
Ivory Coast	√[35]	√[35]	X[35]	X[35]	N/A	X[35]
Kenya	X[30]	X[30]	X[30]	X[30]	N/A	N/A
Madagascar	√[31 46 86]	X[46 86]	X[31 46]	X[31 46 86]	N/A	X[31 46]
Malawi	X[92]	√[92]	√[92]	√[92]	N/A	N/A
Mozambique	X[37]	X[37]	X[37]	X[37]	N/A	X[37]
Namibia	X[43]	X[43]	N/A	X[43]	N/A	N/A
Nigeria	X[93 94]	N/A	X[47 93–95]	X[47 93–95]	N/A	X[47]
Senegal	X[32]	√[32]	X[32]	X[32]	√[32]	X[32]
Tanzania	X[90 97]	√[89 97]	X[41 44 89 97 99]	X[41 44 89 97 99]	X[44]	N/A
Uganda	X[87 88 102]	X[87 88 102]	X[102]	X[87 88 102]	N/A	X[87 102]
South Africa	√[42]	√[42]	X[42 96]	√[42]	N/A	N/A
Zimbabwe	√[39]	√[39]	N/A	X[39]	N/A	X[39]

PEP, post-exposure prophylaxis.

in 9 countries, none of them reported the target of 70% of dog vaccination (table 4). The highest dog vaccination rate was reported in Algeria (67.3%)[85] and the lowest in Madagascar (10%).[46]

DISCUSSION

This is to our knowledge the first scoping review synthesising publicly available data on rabies in Africa and weighing such data in support of the global goal of 'zero human rabies deaths by 2030'. The purpose of this scoping analysis was to provide a summary of evidence on rabies morbidity, mortality, integrated rabies surveillance, prevention and control in Africa. Overall, studies have shown that African countries face a range of problems based on rabies surveillance, prevention and control that have negative effects on rabies mortality and morbidity. Reviewing rabies morbidity and mortality rates across Africa, data obtained fluctuated largely over time and space in various countries, as well as in different regions or districts across the same area. While some countries may have shown significant improvement in rabies morbidity and mortality data, the morbidity and mortality rates in Africa generally remain high. Included studies showed no standardisation in reporting human rabies outcomes, human rabies morbidity and mortality rates were reported in terms of annual incidence and number of infected human rabies and deaths related to rabies. Moreover, small-scale studies may not reflect the national or regional human rabies morbidity and mortality rates. Therefore, it was difficult to have an accurate picture per country and assess human rabies situation between African countries.

These are the consequences of a lack of laboratory rabies confirmation, epidemiological surveillance, inadequate mass dog vaccination and PEP policy, and unreported clinical cases in African countries. Lack of monitoring data on rabies or low data quality is problematic, resulting in rabies being poorly addressed in most African countries. Results have also shown that of the 11 countries in which rabies surveillance has been applied, only 4 studies reported that surveillance decreased rabies morbidity and mortality.[35 36 42 90] Comparing old and new data (before and after the 'zero rabies by 2030' target), rabies diagnosis and surveillance have not improved in most of the African countries. As a result, well-structured rabies surveillance enhanced the reporting of morbidity and mortality and also has a visible impact on rabies elimination strategy in Africa. While strategies have been subdivided into surveillance, prevention, control and management of rabies (see table of included studies), only three studies have shown the efficacy of the combination of surveillance, prevention and control of rabies.[32 37 44]

However, passive surveillance has shown its limitations in rabies elimination because cases are reported clinically with or without laboratory-based strategies, inducing inaccurate diagnostic tools, scarcity of laboratory confirmation and poor reporting system.[30 43 46 87 88 102] This is why both passive and active surveillance are preferable to strengthen rabies monitoring and reporting in African countries.[109] Strengthening rabies surveillance is also the foundation of the provision of actionable data for efficient management of wildlife diseases.[110] Besides, the review has shown that strengthening surveillance, prevention and management of rabies has shown good evidence in three separate studies.[32 37 44] Coordination of surveillance, prevention and control of rabies can play an important role in the eradication of rabies in Africa. It is worth noting that specific awareness of when and where the disease occurs is essential to the formulation of prevention, control and elimination strategies.[110]

As seen above, the implementation of different rabies interventions at national level has never reached African countries. It is vital that African countries achieve the 2030 target of eliminating human rabies by providing readily accessible and affordable PEP in all countries in the continent where rabies infection is endemic. The exposed victims considered to be at risk of rabies either did not receive any PEP or did not receive complete PEP vaccinations due to unavailability, shortage, cost barriers, insufficient knowledge about prompt PEP or misadvice.[36 40 44 48 95 98 99] This could be emulated from Thailand, which has significantly reduced human deaths from rabies to fewer than 10 cases per year by educating the public and health workers and delivering PEP free of charge across the country before mass dog vaccination achieved the minimum 70% coverage.[111 112] When provided correctly and in a timely manner, rabies PEP is almost 100% effective in the prevention of the disease.[72 113] The findings of the review revealed that the dog bite victims found to be at risk of rabies either did not receive PEP or did not receive all the PEP vaccines due to unavailability, shortages, cost barriers, long distance travel to the hospital or misadvice.[31 32 35 36 40 41 44 48 84 89 94 95 97–99] It is important to remember that PEP, combined with other treatments such as soap, water, wound dressing, antibiotics, tetanus prophylaxis and anti-rabies vaccination, has been shown to be beneficial for dog bite victims. Two studies have shown that compliance with PEP regimens was substantially higher for patients who did not receive PEP after automated reminders.[42 90] Taken together, our results point to a suboptimal system requiring specific improvements to achieve prompt provision of rabies PEP for persons exposed to rabies.[112]

Statistical modelling studies show that the annual vaccination of 70% of the canine population would induce adequate herd immunity to effectively eradicate canine rabies and subsequent human exposure.[10 44] The lowest and highest reviewed dog vaccination rates were 10% and 67.3%, respectively,[10 46] and no reliable data on dog vaccination were reported in most of the studies. This is because many campaigns, if conducted, struggle to achieve a 70% vaccination rate.[10 14] This is due to husbandry practices, rabies knowledge, geographical area/location and the ages of dogs.[114] Evidence has shown the dog mass vaccination systems have demonstrated some effectiveness in reducing human rabies morbidity and mortality in countries such as KwaZulu-Natal, South Africa,[49 65] Serengeti, Tanzania,[49 66 68] Malawi[44 69] and Chad.[70 71] However, the Tanzanian study has shown that, if vaccine coverage was not sustained, rabies infection would resurface extremely quickly.[34] Despite effective monitoring of rabies at the Tanzania study site from 1998 to 2001, vaccine coverage decreased from 2001 to 2003 resulting in a new rabies outbreak, with human exposures increasing by six times in 2003 relative to previous years.[44] Further, free mass dog vaccination intervention has proven to increase dog vaccination coverage. Government and stakeholders should work actively to provide a free sustainable dog vaccination.

Besides, the evidence has also illustrated the effectiveness of other strategies, such as mobile phone touch tracing strategies, new rabies vaccines, integrated bite case management and wound management, which were correlated with PEP and/or mass dog vaccination. Africa is yet to recognise rabies as an immediate public health problem; this may be due to a lack of awareness of the burden of disease and inadequate surveillance. Policies should be put in place to raise awareness of rabies at grassroots level and coordination between the appropriate agencies for improvements of the policies.[47 54]

The World Animal Health Information System is a well-established global animal disease reporting system that reproduces the data submitted by countries to the OIE, but is also constrained by the under-reporting problems inherent in national reporting systems.[115 116] The need for regional One Health-oriented reporting network has therefore become apparent.[117 118] The development of rabies-specific regional bulletins has been extremely effective in the Pan-American Health Organization field.[117] The database such as the New Latin American Rabies Surveillance System should be applicable in Africa.

Indeed, the elimination of rabies is not feasible without African cooperation. No single country will retain rabies-free status unless it is brought under control in neighbouring countries.[113] Regionally organised efforts are required to eradicate human rabies, taking into account country-specific needs and sociocultural acceptability.[113] Canine rabies-endemic regions have formed international rabies networks based on the successful Meeting of Rabies Program Directors of the Americas (REDIPRA) model which enables them to create a unified and directed approach towards elimination within their regions.[119] REDIPRA meetings can be considered a model for coordination and governance in the world.[7 118 119] In Africa, the Pan-African Rabies Control Network (PARACON) was formed under the secretariat of GARC, as an Africa-focused advisory and networking initiative.[119] It was established in order to unify all sub-Saharan African countries and any related rabies networks in a One Health

approach towards rabies control and elimination.[119] The PARACON facilitates the development and implementation of national rabies elimination strategies, with a focus on sustainability through governmental support.[119] However, the probability of meeting the 2030 goal without African and international solidarity is low, as more than two-thirds of countries are in the low-level human development community.[120] Leading countries should serve as role models, sharing their knowledge and skills so that no nation is left behind. African unification with international support will enable the common goal of zero human rabies deaths to be achieved by 2030.[120] Therefore, regional network support, channel and pool efforts and support-monitoring platforms will help make much progress.[121] Partnerships are important to the achievement of an objective and the last mile is going to be the most demanding.[121] In addition, contact and collaboration between human health and veterinary systems is also critical for the follow-up of both human and animal cases.[122] Data collected on alleged cases of human rabies, human exposures and rabid animals must be constantly reviewed and effectively disseminated.[122] Communication between the various national levels of healthcare administration is a crucial means of disseminating outcomes.[122] Finally, stakeholders need to be engaged in the long term to ensure that surveillance is effective.[122] Knowing that the Global Strategic Plan is catalytic and not intended to replace the strategies and commitments of individual countries,[121] African countries should emphasise gaps, challenges, barriers and evidence applicable to the various districts, countries and regions as indicated in this present study. One Health interventions are provided by approaches to the prevention of human rabies deaths.[123] In African countries, the Ministries of Health, Animal Resources, Natural Resources, Environment and Tourism are in charge of implementing the canine and human rabies programmes in accordance with local, national and international bodies.

Human rabies is 100% preventable through two complementary measures: first, PEP, which involves administration of RIG and a multidose course of rabies vaccination to people bitten by suspected rabid animals; second, mass vaccination of animal reservoirs (primarily domestic dogs, the reservoir in the vast majority of human cases), which reduces the risk of human exposure and can ultimately result in rabies virus elimination.[123]

New rabies control tests and technologies that have been developed, such as oral rabies vaccine (ORV), may be considered as an additional tool for the canine rabies control and elimination. ORV is effective, for instance, in skunks, red foxes and raccoons.[124] ORV has been demonstrated to be effective for the oral immunisation of foxes, some of them being competitors for long baits year consumption. Switzerland eradicated wild rabies since 1985.[122] However, strategies to eliminate human rabies in Africa should adapt the REDIPRA model in African context, which emphasises that people exposed to rabies have timely access to quality immunobiologicals, that appropriate levels of vaccination coverage in dogs in highly enzootic areas are maintained, that national rabies plans are strengthened and that systematic implementation is ensured, that the surveillance system for human rabies transmitted by dogs is strengthened and that systematic implementation is ensured, and that training and the development of a laboratory quality control system, particularly in highly enzootic areas, strengthen education, communication and advocacy in enzootic areas, to ensure the continuous political support that is necessary, develop and adopt a guide that delineates the requirements for declaring countries or areas free of human rabies transmitted by dogs.[119]

CONCLUSION

This comprehensive scoping review is of crucial importance in assessing various pieces of evidence of human rabies morbidity, mortality, monitoring, prevention and management. Rabies control strategies and case effects and available studies established to address various gaps are also important in the management of rabies in Africa. The analysis included past, existing and future viewpoints that are important for African countries to achieve zero rabies transmitted by dogs to humans by 2030. The findings of 43 studies included 32 quantitative retrospective studies, 3 mixed designs (retrospective and cross-sectional studies), 3 prospective cohort studies, 2 cross-sectional studies, 1 case–control, 1 clinical trial and 1 randomised control study. Mapping the outcomes, the review included rabies morbidity (21 studies), mortality (15 studies), rabies prevention and control (16 studies), surveillance (9 studies), surveillance and prevention (5 studies), management and control (7 studies), surveillance, prevention and control (6 studies), strong research evidence (14 studies), rabies vaccination or PEP adverse events (4 studies), and research gaps (41 studies).

Evidence has shown that human rabies morbidity and mortality remain high compared with rabies globally, and human rabies morbidity and mortality fluctuate in time and space across different African countries. In order to better understand this, the review has shown that monitoring, prevention and control of rabies are inadequate and insufficient in most African countries. This is attributable to a variety of gaps and challenges across African countries. In addition, this study found insufficient and ineffective surveillance of rabies, unavailability of PEP, high cost, lack of information on prevention of rabies, and poor or non-existent data on dog vaccination. However, few studies have shown a thorough design of rabies measures such as enhanced surveillance of rabies, regulation of rabies in dogs, proper post-exposure treatment, improved community awareness and availability of PEP in all rural areas, use of cell phone intervention to enhance surveillance of rabies, prevention and control of enhanced rabies morbidity, and more. In addition, African countries can learn about different community-based obstacles that can interfere with surveillance, prevention

and control of rabies disease. This is important to point out that no single country will preserve rabies-free status unless it is brought under control in neighbouring countries.[119] That is why African countries should build a forum for rabies that may be significant to exchange data and experience on rabies. Finally, African countries can also look at futuristic rabies innovations such as ORV.

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REFERENCES

1 Nel LH. Discrepancies in data reporting for rabies, Africa. *Emerg Infect Dis* 2013;19:529–33.
2 Talbi C, Holmes EC, de Benedictis P, *et al*. Evolutionary history and dynamics of dog rabies virus in Western and central Africa. *J Gen Virol* 2009;90:783–91.
3 Nel LH, Rupprecht CE. Emergence of lyssaviruses in the Old World: the case of Africa. In: *Wildlife and emerging zoonotic diseases: the biology, circumstances and consequences of cross-species transmission*. . Springer, 2007: 315. 161–93.
4 Hampson K, Coudeville L, Lembo T, *et al*. Estimating the global burden of endemic canine rabies. *PLoS Negl Trop Dis* 2015;9:e0003709.
5 Desa G, Birasa D, Deneke Y, *et al*. Assessment of knowledge, attitude and practice (KAP) of community toward rabies in Medawelabu district, bale zone, Ethiopia. *Int J Res Granthaalayah* 2020;8:29–42.
6 Cleaveland S, Lankester F, Townsend S, *et al*. Rabies control and elimination: a test case for one health. *Vet Rec* 2014;175:188–93.
7 World Health Organization. Rabies: rationale for investing in the global elimination of dog-mediated human rabies, 2015. Available: https://apps.who.int/iris/handle/10665/185195
8 Fooks AR, Banyard AC, Horton DL, *et al*. Current status of rabies and prospects for elimination. *Lancet* 2014;384:1389–99.
9 Knobel DL, Cleaveland S, Coleman PG, *et al*. Re-evaluating the burden of rabies in Africa and Asia. *Bull World Health Organ* 2005;83:360–8.
10 Lavan RP, King AIM, Sutton DJ, *et al*. Rationale and support for a one health program for canine vaccination as the most cost-effective means of controlling zoonotic rabies in endemic settings. *Vaccine* 2017;35:1668–74.
11 Dodet B, Tejiokem MC, Aguemon A-R, *et al*. Human rabies deaths in Africa: breaking the cycle of indifference. *Int Health* 2015;7:4–6.
12 Adesina MA, Olufadewa II, OgaH YI, *et al*. Incidence and mortality from a neglected tropical disease (rabies) in 28 African countries. *Folia Vet* 2020;64:46–51.
13 Interafrican Bureau for Animal Resources. Rabies distribution, 2013. Available: https://www.au-ibar.org/rabies#Distribution_Map_for_Africa
14 Cleaveland S. Epidemiology and control of rabies: the growing problem of rabies in Africa. *Trans R Soc Trop Med Hyg* 1998;92:131–4.
15 Knobel D, Conan A. Dog ecology and rabies control in Africa world small animal veterinary association world Congress proceedings. *Age* 2014;4:23.
16 Röttcher D, Sawchuk AM. Wildlife rabies in Zambia. *J Wildl Dis* 1978;14:513–7.
17 Botros BA, Salib AW, Mellick PW, *et al*. Antigenic variation of wild and vaccine rabies strains of Egypt. *J Med Virol* 1988;24:153–9.
18 Burrows R. Rabies in African wild dogs of Tanzania. *J Wildl Dis* 1994;30:297–9.
19 Kat PW, Alexander KA, Smith JS, *et al*. Rabies and African wild dogs in Kenya. *Proc Biol Sci* 1995;262:229–33.
20 Foggin CM. The epidemiological significance of jackal rabies in Zimbabwe. In: *Rabies in the tropics*. Springer, 1985: 399–405.
21 Tefera G, Yimer E, Geyid A. Endemic existence of rabies in Ethiopia. *Ethiop Med J* 2002;40:163–10.
22 Nel LH, Sabeta CT, von Teichman B, *et al*. Mongoose rabies in southern Africa: a re-evaluation based on molecular epidemiology. *Virus Res* 2005;109:165–73.

23 Woodroffe R, Prager KC, Munson L, *et al*. Contact with domestic dogs increases pathogen exposure in endangered African wild dogs (Lycaon pictus). *PLoS One* 2012;7:e30099.
24 Scheepers JL, Venzke KAE. Attempts to reintroduce African wild dogs Lycaon pictus into Etosha National Park, Namibia. *S Afr J Wildlife Res* 1995;25:138–40.
25 Sabeta C, Ngoepe EC. Controlling dog rabies in Africa: successes, failures and prospects for the future. *Rev Sci Tech* 2018;37:439–49.
26 Johnson N, Mansfield KL, Marston DA, *et al*. A new outbreak of rabies in rare Ethiopian wolves (canis simensis). *Arch Virol* 2010;155:1175–7.
27 Marino J, Sillero-Zubiri C, Deressa A, *et al*. Rabies and distemper outbreaks in smallest Ethiopian wolf population. *Emerg Infect Dis* 2017;23:2102–4.
28 Tomori O. Wild life rabies in Nigeria: experimental infection and transmission studies with the shrew (Crocidura sp.). *Ann Trop Med Parasitol* 1980;74:151–6.
29 Ramos JM, Melendez N, Reyes F, *et al*. Epidemiology of animal bites and other potential rabies exposures and anti-rabies vaccine utilization in a rural area in southern Ethiopia. *Ann Agric Environ Med* 2015;22:76–9.
30 Ngugi JN, Maza AK, Omolo OJ, *et al*. Epidemiology and surveillance of human animal-bite injuries and rabies post-exposure prophylaxis, in selected counties in Kenya, 2011-2016. *BMC Public Health* 2018;18:996.
31 Rajeev M, Edosoa G, Hanitriniaina C, *et al*. Healthcare utilization, provisioning of post-exposure prophylaxis, and estimation of human rabies burden in Madagascar. *Vaccine* 2019;37 Suppl 1:A35–44.
32 Diallo MK, Diallo AO, Dicko A, *et al*. Human rabies post exposure prophylaxis at the Pasteur Institute of Dakar, Senegal: trends and risk factors. *BMC Infect Dis* 2019;19:321.
33 Gebru G, Romha G, Asefa A, *et al*. Risk factors and spatio-temporal patterns of human rabies exposure in northwestern Tigray, Ethiopia. *Ann Glob Health* 2019;85:119.
34 Twabela AT, Mweene AS, Masumu JM, *et al*. Overview of animal rabies in Kinshasa Province in the Democratic Republic of Congo. *PLoS One* 2016;11:e0150403.
35 Tiembré I, Broban A, Bénié J, *et al*. Human rabies in Côte d'Ivoire 2014-2016: results following reinforcements to rabies surveillance. *PLoS Negl Trop Dis* 2018;12:e0006649.
36 Sofeu CL, Broban A, Njifou Njimah A, *et al*. Improving systematic rabies surveillance in Cameroon: a pilot initiative and results for 2014-2016. *PLoS Negl Trop Dis* 2018;12:e0006597.
37 Salomão C, Nacima A, Cuamba L, *et al*. Epidemiology, clinical features and risk factors for human rabies and animal bites during an outbreak of rabies in Maputo and Matola cities, Mozambique, 2014: implications for public health interventions for rabies control. *PLoS Negl Trop Dis* 2017;11:e0005787.
38 Punguyire DT, Osei-Tutu A, Aleser EV, *et al*. Level and pattern of human rabies and dog bites in Techiman Municipality in the middle belt of Ghana: a six year retrospective records review. *Pan Afr Med J* 2017;28:281.
39 Pfukenyi DM, Pawandiwa D, Makaya PV, *et al*. A retrospective study of wildlife rabies in Zimbabwe, between 1992 and 2003. *Trop Anim Health Prod* 2009;41:565–72.
40 Muyila DI, Aloni MN, Lose-Ekanga MJ, *et al*. Human rabies: a descriptive observation of 21 children in Kinshasa, the Democratic Republic of Congo. *Pathog Glob Health* 2014;108:317–22.
41 Mazigo HD, Okumu FO, Kweka EJ, *et al*. Retrospective analysis of suspected rabies cases reported at bugando referral Hospital, mwanza, Tanzania. *J Glob Infect Dis* 2010;2:216.
42 Kubheka V, Govender P, Margot B, *et al*. Dog bites and human rabies in the Uthungulu district of KwaZulu-Natal Province, 2008–2010: a review of surveillance data. *South African J Epidemiol Infect* 2013;28:33–40.
43 Hikufe EH, Freuling CM, Athingo R, *et al*. Ecology and epidemiology of rabies in humans, domestic animals and wildlife in Namibia, 2011-2017. *PLoS Negl Trop Dis* 2019;13:e0007355.
44 Hampson K, Dobson A, Kaare M, *et al*. Rabies exposures, post-exposure prophylaxis and deaths in a region of endemic canine rabies. *PLoS Negl Trop Dis* 2008;2:e339.
45 Deressa A, Ali A, Bayene M, *et al*. The status of rabies in Ethiopia: a retrospective record review. *Ethiop J Health Dev* 2010;24:127–32.
46 Andriamandimby S, Héraud J-M, Ramiandrasoa R, *et al*. Surveillance and control of rabies in La reunion, Mayotte, and Madagascar. *Vet Res* 2013;44:77–9.
47 Alabi O, Nguku P, Chukwukere S, *et al*. Profile of dog bite victims in Jos plateau state, Nigeria: a review of dog bite records (2006-2008). *Pan Afr Med J* 2014;18 Suppl 1:12.
48 Adomako B-Y, Baiden F, Sackey S, *et al*. Dog bites and rabies in the eastern region of Ghana in 2013–2015: a call for a One-Health approach. *J Trop Med* 2018;2018:1–5.
49 Athingo R, Tenzin T, Shilongo A, *et al*. Fighting Dog-Mediated rabies in Namibia-Implementation of a rabies elimination program in the Northern communal areas. *Trop Med Infect Dis* 2020;5. doi:10.3390/tropicalmed5010012. [Epub ahead of print: 17 Jan 2020].
50 Muller T, Demetriou P, Moynagh J, *et al*. *Rabies elimination in Europe: a success story. in: in rabies control: towards sustainable prevention at the source, compendium of the OIE, global conf. on rabies control, Incheon-Seoul, 7-9 September*. , 2011: 2012, 31–44.
51 Velasco-Villa A, Escobar LE, Sanchez A, *et al*. Successful strategies implemented towards the elimination of canine rabies in the Western hemisphere. *Antiviral Res* 2017;143:1–12.
52 World Health Organization. Who expert consultation on rabies: second report, 2013. Available: https://apps.who.int/iris/handle/10665/85346
53 Dodet B, Africa Rabies Bureau (AfroREB). The fight against rabies in Africa: from recognition to action. *Vaccine* 2009;27:5027–32.
54 Kayali U, Mindekem R, Yémadji N, *et al*. Coverage of pilot parenteral vaccination campaign against canine rabies in N'Djaména, Chad. *Bull World Health Organ* 2003;81:739–44.
55 Franka R, Smith TG, Dyer JL, *et al*. Current and future tools for global canine rabies elimination. *Antiviral Res* 2013;100:220–5.
56 Zemanová S, Korytár Ľ., Benkő Z, *et al*. Ecological factors of transmission, persistence and circulation of pathogens in bat populations. *Folia Vet* 2019;63:32–40.
57 Hampson K, Dushoff J, Cleaveland S, *et al*. Transmission dynamics and prospects for the elimination of canine rabies. *PLoS Biol* 2009;7:e1000053.
58 Minyoo AB, Steinmetz M, Czupryna A, *et al*. Incentives increase participation in mass dog rabies vaccination clinics and methods of coverage estimation are assessed to be accurate. *PLoS Negl Trop Dis* 2015;9:e0004221.
59 Lankester F, Davis A, Kinung'hi S, *et al*. An integrated health delivery platform, targeting soil-transmitted helminths (STh) and canine mediated human rabies, results in cost savings and increased breadth of treatment for STh in remote communities in Tanzania. *BMC Public Health* 2019;19:1398.
60 Global Alliance for Rabies Control. Recent research November 2017, 2017. Available: https://rabiesalliance.org/resource/recent-research-november-2017
61 MEEREB. Rabies diagnostic and epidemiological data,, 2018. Available: https://www.fondation-merieux.org/wp-content/uploads/2017/11/4th-meereb-2018-florence-cliquet.pdf
62 Wallace RM, Mehal J, Nakazawa Y, *et al*. The impact of poverty on dog ownership and access to canine rabies vaccination: results from a knowledge, attitudes and practices survey, Uganda 2013. *Infect Dis Poverty* 2017;6:97.
63 Jibat T, Hogeveen H, Mourits MCM. Review on dog rabies vaccination coverage in Africa: a question of dog accessibility or cost recovery? *PLoS Negl Trop Dis* 2015;9:e0003447.
64 Shwiff SA, Hatch B, Anderson A, *et al*. Towards canine rabies elimination in KwaZulu-Natal, South Africa: assessment of health economic data. *Transbound Emerg Dis* 2016;63:408–15.
65 Cleaveland S, Kaare M, Tiringa P, *et al*. A dog rabies vaccination campaign in rural Africa: impact on the incidence of dog rabies and human dog-bite injuries. *Vaccine* 2003;21:1965–73.
66 Kaare M, Lembo T, Hampson K, *et al*. Rabies control in rural Africa: evaluating strategies for effective domestic dog vaccination. *Vaccine* 2009;27:152–60.
67 Hatch B, Anderson A, Sambo M, *et al*. Towards canine rabies elimination in south-eastern Tanzania: assessment of health economic data. *Transbound Emerg Dis* 2017;64:951–8.
68 Gibson AD, Handel IG, Shervell K, *et al*. The vaccination of 35,000 dogs in 20 working days using combined static point and door-to-door methods in Blantyre, Malawi. *PLoS Negl Trop Dis* 2016;10:e0004824.
69 Léchenne M, Oussiguere A, Naissengar K, *et al*. Operational performance and analysis of two rabies vaccination campaigns in N'Djamena, Chad. *Vaccine* 2016;34:571–7.
70 Anyiam F, Léchenne M, Mindekem R. Cost estimate of canine rabies elimination by parenteral mass vaccination in Chad, 2017. Available: https://edoc.unibas.ch/57353/1/Lechenne_thesis_edoc%20version.pdf
71 Zinsstag J, Lechenne M, Laager M, *et al*. Vaccination of dogs in an African City interrupts rabies transmission and reduces human exposure. *Sci Transl Med* 2017;9:eaaf6984.
72 Sreenivasan N, Li A, Shiferaw M, *et al*. Overview of rabies post-exposure prophylaxis access, procurement and distribution in

selected countries in Asia and Africa, 2017-2018. *Vaccine* 2019;37 Suppl 1:A6–13.
73 World Health Organization. 2016: the beginning of the end of rabies? 2016. Available: https://www.who.int/rabies/resources/tlgh_rabies_oct_2016/en/
74 Bögel K, Motschwiller E. Incidence of rabies and post-exposure treatment in developing countries. *Bull World Health Organ* 1986;64:883.
75 Taylor LH, Knopf L. Partners for rabies prevention. surveillance of human rabies by National authorities-a global survey. *Zoonoses Public Health* 2015;62:543–52.
76 Kamani TM, Kazwala R, Mfinanga S, *et al*. One health: a concept led by Africa, with global benefits. *Vet Rec* 2015;176:496–7.
77 Acharya KP, Acharya N, Phuyal S, *et al*. One-health approach: a best possible way to control rabies. *One Health* 2020;10:100161.
78 Otu A, Effa E, Meseko C, *et al*. Africa needs to prioritize one health approaches that focus on the environment, animal health and human health. *Nat Med* 2021;27:943–6.
79 Jarvis S. Aiming for elimination of dog-mediated human rabies cases by 2030. *Vet Rec* 2016;178:86–7.
80 Tricco AC, Lillie E, Zarin W, *et al*. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;169:467–73.
81 Peters MDJ, Godfrey CM, Khalil H, *et al*. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc* 2015;13:141–6.
82 Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol* 2005;8:19–32.
83 Tricco AC, Lillie E, Zarin W, *et al*. A scoping review on the conduct and reporting of scoping reviews. *BMC Med Res Methodol* 2016;16:15.
84 Edward FD, Osei-Tutu A, Gbeddy K, *et al*. A retrospective study of rabies cases at Techiman municipal, Ghana, 2009 – 2012. *Int J Infect Dis* 2014;21:179.
85 Kardjadj M, Yahiaoui F, Ben-Mahdi M-H. Incidence of human dog-mediated zoonoses and demographic characteristics/vaccination coverage of the domestic dog population in Algeria. *Rev Sci Tech* 2019;38:809-821.
86 Reynes J-M, Andriamandimby SF, Razafitrimo GM, *et al*. Laboratory surveillance of rabies in humans, domestic animals, and bats in Madagascar from 2005 to 2010. *Adv Prev Med* 2011;2011:6
87 Nyakarahuka L, Tweheyo R. Occurrence and mortality rates from rabies in Uganda, 2001-2009. *Int J Infect Dis* 2012;16:e458.
88 Masiira B, Makumbi I, Matovu JKB, *et al*. Long term trends and spatial distribution of animal bite injuries and deaths due to human rabies infection in Uganda, 2001-2015. *PLoS One* 2018;13:e0198568.
89 Sambo M, Cleaveland S, Ferguson H, *et al*. The burden of rabies in Tanzania and its impact on local communities. *PLoS Negl Trop Dis* 2013;7:e2510.
90 Mtema Z, Changalucha J, Cleaveland S, *et al*. Mobile phones as surveillance tools: implementing and evaluating a large-scale intersectoral surveillance system for rabies in Tanzania. *PLoS Med* 2016;13:e1002002.
91 Teklu GG, Hailu TG, Eshetu GR. High incidence of human rabies exposure in northwestern tigray, Ethiopia: a four-year retrospective study. *PLoS Negl Trop Dis* 2017;11:e0005271.
92 Zimmer BL, Gamble L, Foster R, *et al*. Assessment of the impact on paediatric rabies at Queen Elizabeth central Hospital, Blantyre, Malawi, following a mass canine rabies vaccination programme. *Int J Infect Dis* 2019;79:64.
93 Osaghae DO. Animal and human bites in children. *West Afr J Med* 2011;30:421–4.
94 Ogundare EO, Olatunya OS, Oluwayemi IO, *et al*. Pattern and outcome of dog bite injuries among children in Ado-Ekiti, Southwest Nigeria. *Pan Afr Med J* 2017;27:81.
95 Abubakar SA, Bakari AG. Incidence of dog bite injuries and clinical rabies in a tertiary health care institution: a 10-year retrospective study. *Ann Afr Med* 2012;11:108–11.
96 Kent SJW, Naicker B, Wood DR. Demographics and management of dog bite victims at a level two hospital in KwaZulu-Natal. *S Afr Med J* 2012;102:845–7.
97 De Nardo P, Gentilotti E, Vairo F, *et al*. A retrospective evaluation of bites at risk of rabies transmission across 7 years: the need to improve surveillance and reporting systems for rabies elimination. *PLoS One* 2018;13:e0197996.
98 Lushasi K, Steenson R, Bernard J, *et al*. One health in practice: using integrated bite case management to increase detection of rabid animals in Tanzania. *Frontiers in Public health* 2020;8:13.
99 Changalucha J, Steenson R, Grieve E, *et al*. The need to improve access to rabies post-exposure vaccines: lessons from Tanzania. *Vaccine* 2019;37:A45–53.
100 Yizengaw E, Getahun T, Mulu W, *et al*. Incidence of human rabies virus exposure in northwestern Amhara, Ethiopia. *BMC Infect Dis* 2018;18:1–7.
101 Jemberu WT, Molla W, Almaw G, *et al*. Incidence of rabies in humans and domestic animals and people's awareness in North Gondar zone, Ethiopia. *PLoS Negl Trop Dis* 2013;7:e2216.
102 Fèvre EM, Kaboyo RW, Persson V, *et al*. The epidemiology of animal bite injuries in Uganda and projections of the burden of rabies. *Trop Med Int Health* 2005;10:790–8.
103 Frey J, Mindekem R, Kessely H, *et al*. Survey of animal bite injuries and their management for an estimate of human rabies deaths in N'Djaména, Chad. *Trop Med Int Health* 2013;18:1555–62.
104 Olugasa BO, Odeniyi AO, Adeogun AO, *et al*. Antibody levels against rabies among occupationally exposed individuals in a Nigerian university. *Vet Ital* 2010;46:21–8.
105 Harry TO, Adeiga A, Anyiwo CE, *et al*. Anti-rabies treatment of dog-bite victims in Lagos, Nigeria: trial of suckling mouse brain and fetal bovine kidney cell rabies vaccines. *Vaccine* 1984;2:257–60.
106 World Health Organization Technical Report Series. Who expert consultation on rabies, 2005. Available: https://apps.who.int/iris/bitstream/handle/10665/85346/9789240690943_eng.pdf?sequence=1
107 World Health Organization. Who expert consultation on Rabies-World health. Available: https://apps.who.int/iris/bitstream/handle/10665/85346/9789241209823_eng.pdf?sequence=1
108 Ren J, Yao L, Sun J, *et al*. Zagreb regimen, an abbreviated intramuscular schedule for rabies vaccination. *Clin Vaccine Immunol* 2015;22:1–5.
109 Banyard AC, Horton DL, Freuling C, *et al*. Control and prevention of canine rabies: the need for building laboratory-based surveillance capacity. *Antiviral Res* 2013;98:357–64.
110 Kirby JD, Chipman RB, Nelson KM, *et al*. Enhanced rabies surveillance to support effective oral rabies vaccination of raccoons in the eastern United States. *Trop Med Infect Dis* 2017;2:34.
111 Wilde H, Ghai S, Hemachudha T. Rabies: still a silent killer targeting the poor. *Vaccine* 2017;35:2293–4.
112 Wambura G, Mwatondo A, Muturi M, *et al*. Rabies vaccine and immunoglobulin supply and logistics: challenges and opportunities for rabies elimination in Kenya. *Vaccine* 2019;37 Suppl 1:A28–34.
113 World Health Organization. *WHO expert consultation on rabies: third report. 1012 edition*. World Health Organization, 2018.
114 Hergert M, le Roux K, Nel LH. Risk factors associated with nonvaccination rabies status of dogs in KwaZulu-Natal, South Africa. *Vet Med* 2016;7:75–83.
115 Taylor LH, Hampson K, Fahrion A, *et al*. Difficulties in estimating the human burden of canine rabies. *Acta Trop* 2017;165:133–40.
116 Scott TP, Coetzer A, Fahrion AS, *et al*. Addressing the disconnect between the estimated, reported, and true rabies data: the development of a regional African rabies Bulletin. *Front Vet Sci* 2017;4:18.
117 Scott TP, Coetzer A, de Balogh K, *et al*. The Pan-African rabies control network (PARACON): a unified approach to eliminating canine rabies in Africa. *Antiviral Res* 2015;124:93–100.
118 Gongal G, Wright AE. Human rabies in the who Southeast Asia region: forward steps for elimination. *Adv Prev Med* 2011;2011:1–5.
119 Vigilato MAN, Molina-Flores B, Del Rio Vilas VJ, *et al*. Canine rabies elimination: governance principles. *Rev Sci Tech* 2018;37:707–9.
120 Mbilo C, Coetzer A, Bonfoh B, *et al*. Dog rabies control in West and central Africa: a review. *Acta Trop* 2021;224:105459.
121 World Health Organization. Driving progress towards rabies elimination, 2019. Available: file:///C:/Users/Staff/Downloads/WHO-CDS-NTD-NZD-2019.04-eng.pdf
122 Broban A, Tejiokem MC, Tiembré I, *et al*. Bolstering human rabies surveillance in Africa is crucial to eliminating canine-mediated rabies. *PLoS Negl Trop Dis* 2018;12:e0006367.
123 Cleaveland S, Sharp J, Abela-Ridder B, *et al*. One health contributions towards more effective and equitable approaches to health in low- and middle-income countries. *Philos Trans R Soc Lond B Biol Sci* 2017;372:20160168.
124 Tataryn J, Buck PA. The Canadian rabies management plan: an integrated approach to the coordination of rabies activities in Canada. *Can Commun Dis Rep* 2016;42:135–6.

Supplementary Table 1: Extracting and charting data table

Author(year) and country	Study designs	Participants/Comparators	Interventions and Control conditions/Exposures	Outcomes	Key findings/Gaps/Challenges
Rabies prevention and control					
Harry 1984 Nigeria	Randomized control trial	136 patients aged three to 74 years.	Controlled treatment of dog-bite victims with suckling mouse brain (SMBV) versus fetal bovine kidney (FBKV) rabies vaccines.	By day 7, 26.7% of SMBV recipients and 28.6% of FBKV recipients showed antibody response These percentages increased to 95.1 and 81.1, respectively, by day 14, and by day 20 (for SMBV recipients) or day 30 (FBKV recipients) the	We have concluded that both vaccines are equally efficacious and well tolerated.

				response was 100%. Titres dropped by day 90, but in no case to below 1 EU ml^{-1}	
Tefera 2002 Ethiopia	5-year retrospecti ve study	15,940 people dog bite victims	post exposure anti-rabies prophylaxis treatment	320 people were reported to have died of rabies.	The result supports the hypothesis that there is a lack of appropriate reporting system on prevalence of rabies and its impact on humans.
Deressa 2010 Ethiopia	8-year retrospecti ve study	17,204 people received post exposure treatment	Post Exposure Prophylaxis 5% suspension of phenolized sheep brain tissue.	The fatal human cases were 386 humans with annual range of 35 to 58. The age and sex specific distribution showed that the most fatal cases were 42% from the age-group 0-14 category.	PEP against rabies varies from 35.96% to 64.4% across the study. The recorded data showed the underestimate of rabies diagnosis, post exposure prophylaxis and fatal human cases, which could be attributed due to the

				According to this record 66.66% of deaths were males and 33.33% were females.	absence of national rabies surveillance system.
Olugasa 2010 Nigeria	Clinical trial	Of these 70 healthy individuals, 29 (41.4%) consisting of 15 zoological garden workers (75.0%), 13 veterinarians (65.0%) and 1 veterinary student (3.3%)	A purified chicken-embryo cell rabies vaccine One dose (1 ml of ≥2.5 IU/ml vaccine potency) was administered intramuscularly every two years immune to rabies virus (antibody titre >0.5 equivalent units per ml), while 41 (58.6%) were not immune.	Overall, antibody levels increased from 1-5 years to 10-30 years on the job.	Almost all those who had spent at least 10 years on the job had higher levels of rabies vaccination compliance and were immune.
Mazigo 2010 Tanzania	A 5-year retrospecti ve study	A total of 767 bite injuries inflicted by rabies-suspected animals were reported.	Adherence to post-exposure prophylaxis (PEP) regimen	mean annual incidence of ~58 cases per 100,000 (52.5% males, 47.5% females)	Only 28% of the victims completed the vaccination regime.

Jemberu 2013 Ethiopia	Cross-sectional and year prospective cohort study	120 selected dog owners 5 traditional healers in North Gondar zone, Ethiopia.	clinical observation A questionnaire on rabies people's knowledge and practices	Annual estimated rabies incidence of 2.33 cases per 100,000 in humans. During the follow up period, a total of 32 in humans were recorded from which 3 humans ended with fatality.	Vaccination of dogs, proper post exposure management, and increasing the awareness of the community are suggested to reduce the disease burden.
Edward 2014 Ghana	3-year retrospective study	546 dog-bite victims were reported; 295 (54%) were children < 15 years, 169 (31%) were between 15-59 years and 82 (13%) were above 60 years.	Post-exposure prophylaxis	54 dog-bite victims bitten by rabies-positive dogs were reported.	24% of dog-bite victims did not complete the post exposure anti human rabies vaccine course and were not likely to be postexposure prophylaxis.
Ramos 2015 Ethiopia	A retrospective, registry-based study	A total of 683 persons (51.1% females, 73% children) with animal-related bites.	All the patients received an anti-rabies nervous-tissue vaccine.	No important complications were reported.	99% of whom completed the vaccination course.

Kardjadj 2019 Algeria	A 13- year retrospecti ve study	Annual average of PEP cases: 96,203 people	post-exposure prophylaxis and dog vaccination	Annual average of 20.6 human rabies deaths	Overall dog rabies vaccination coverage rate of 68.78%.
Pfukenyi 2009 Zimbabwe	A retrospecti ve study	A total of 57 rabies-suspect human samples were examined and the 15–19-year age group had the highest number of cases.	Dog vaccination coverage	Among rabies-suspect, 42 (73.7%) were positive.	During the study period, there was an inverse relationship between dog vaccination coverage and dog rabies cases. Dog vaccination coverage decreased across the study from 100% to 50%.
Punguyire 2017 Ghana	6-year retrospecti ve records review	680 dog victims, the median age of rabies victims was 30 (range 3-80 years).	Post-exposure prophylaxis of rabies Dog rabies vaccination	13 cases of human rabies were recorded.	Less than 35% of the suspected rabies dogs that bit people over the period were vaccinated. About 20% of the offending dogs had unknown vaccination status.
Teklu 2017 Ethiopia	Four-year Retrospect ive Study	In total, 2180 human rabies exposure cases were registered and followed for their PEP. the greatest exposed age	Prior to PEP administration for humans. Dog vaccination	The incidence of human rabies exposure cases calculated per 100,000 populations was 35.8, 63.0, 89.8	The total annually allocated PEP to the region, nearly 60% was utilized.

		group was >=15 years in all the study years		and 73.1 in 2012, 2013, 2014 and 2015, respectively.	Data on the coverage of preventive dog vaccination and demography were not evident in the study area.
De Nardo 2018 Tanzania	6-year retrospecti ve study	14,624 patients attended the clinics because of animal's bites. Eighty-three per cent (12,098) individuals came from Dodoma Region.	The adherence to post-exposure prophylaxis (PEP)	Mean incidence of 74 bites considered at risk of rabies transmission per 100,000 persons per year.	Overall, 46.0% of the total number of individuals exposed to potentially rabid animals completed the PEP course, while 6.5% (698) did not receive any dose. Living in rural area was statistically associated with loss to follow up after the first dose ($p<0.001$) or after the second dose ($p<0.001$) Females were more likely to be lost after the first dose ($p = 0.006$).
Yizengaw 2018 Ethiopia	2-year retrospecti ve cross-sectional study	A total of 924 human rabies exposure cases received the anti-rabies post-exposure prophylaxis. Of these, males accounted 55.2%	Anti-rabies post exposure prophylaxis	High incidence rate of rabies exposure was reported during spring (339%) and	There was significant difference between rural and urban exposure cases ($p = 0.001$) in respect to the time of arrival to the hospital. There was high

		and the median age was 18 years (ranges: 1–80 years).	A structured data collection questionnaire	summer (26.4%) seasons.	human rabies exposure rate in children and in the rural community. The health status of most dogs (67.3%) involved in biting was unknown (they were stray dogs) and 28.8% were sick: develop the signs of rabid animal within ten days follow up.
Gebru 2019 Ethiopia	One-year retrospecti ve study	368 human rabies exposure cases. Age group of 5 to 14 years old.	Recommendation to start PEP immediately after exposure, depending on the type of exposure. Dog vaccination 14.1%	Incidence of human rabies exposure was 40 per 100,000 populations.	A higher proportion of human rabies exposures was caused by unprovoked dogs (96.5%; 95% CI, 94.0–98.0), and of these, the majority were unvaccinated (85.9%; 95% CI, 81.9–89.1).
Zimmer 2019 Malawi	6-year Retrospect ive study	Children victims of dog bite. The average age was seven years (range 3–11).	Pre and post a comprehensive canine vaccine campaign	14 paediatric rabies cases were found during the study period. More males than females were affected (males: 10	The study shows the importance of eliminating human rabies through canine rabies vaccination.

				(71%); females: 4 (29%)).	
Rabies surveillance					
Fevre 2005 Uganda	Cross-sectional study	A total of 517 patients were interviewed in 10 randomly selected districts in Uganda in the 3 months of the study.	Passive surveillance Survey of dog bite injuries and rabies post-exposure treatment activities in treatment centres supplied with rabies vaccine.	Death in absence of post-exposure prophylaxis (PET), 592 (95% CI 345–920) deaths One dose of PET is sufficient for protection following a rabid animal bite, 20 (95% CI 5–50) deaths annually. Complete course of PET is required for protection following a rabid animal bite, up to 210 (95% CI 115–359) deaths would occur, as 41% of patients did not	Most patients are bitten by dogs, and that a considerable proportion of these are young children, who are at greater risk of developing rabies in the absence of treatment due to the location of the bites they receive. Active animal bite surveillance studies are required to improve our mortality estimates and determine the true burden of rabies in the Ugandan population

				complete their course of PET.	
Reynes 2011 Madagascar	6-year retrospective study	11 human samples were tested for rabies.	Laboratory Surveillance of domestic or tame wild terrestrial mammal and dog brains tested.	Nine of the 11 suspected human cases tested were laboratory confirmed for rabies.	Rabies remains endemic in Madagascar. this study has found the lack of epidemiological data in Madagascar
Nyakarahuka 2012 Uganda	9-year retrospective study	Cumulative total of 117,085 rabies cases were reported in 9 years.	Surveillance reports from all the districts.	A total of 371 deaths of rabies were recorded.	Findings emphasize the need for active surveillance; follow up of people bitten by animals and mass dog vaccinations to alleviate this zoonotic threat**.**
Sambo 2013 Tanzania	Cross-sectional study	Human population (district) Ulanga: 193280 Kilombero: 321611 Serengeti: 176057 The ages of suspect bite victims ranged from 1 to	Extensive investigative interviews were used to estimate the incidence of human deaths and bite exposures.	Average annual incidence/ 100,000 Bites: 37.1;11.3 and 33.5 respectively Death: 2.4; 0.8 and 1.4 respectively	Ninety-four percent (391/415) of these suspects bite victims reported to health facilities for PEP.

		90 years. The majority of suspect bite victims (51%) were children less than 15 years of age.			
Adomako 2018 Ghana	3-year retrospecti ve study	Overall, 4821 dog victims' bites. Most of the cases were in children aged below 10 years.	The health and veterinary services on issues related to surveillance and data quality.	Annual incidence of rabies cases of 172 per a population of 100,000.	In the 82% of cases where data was available, no postexposure prophylaxis (PEP) was administered. The fatality rate was 100%. The study found gross disparities in the number of reported events and overall impression of underreporting.
Masiira 2018 Uganda	A 14-year retrospecti ve review	A total of 208,720 patients with animal bite injuries were treated at health facilities across the country. Up to 81% were patients >=5 years of age and 19% (n = 9,102) were below 5 years of age.	Epidemiological surveillance data .	A total of 486 suspected human rabies deaths were reported.	Strengthening rabies surveillance, controlling rabies in dogs and ensuring availability of post exposure prophylaxis at lower health facilities are the best approach of eliminating rabies.

Tiembre 2018 Ivory Coast	A 2-year descriptive prospective observational study	2968 weekly reports, all were received by the NIPH Anti-rabies Center. Almost one-half of the human rabies cases were in children <=15 years old.	Human rabies surveillance system in those 28 NIPH local units, with specific goals of improving the infrastructure, training, communication, and government involvement.	50 cases of human rabies (15±18 cases/year; annual incidence = 0.06−0.08per 100,000) and more than 30,000 animal exposures (annual incidence = 41.8−48.0 per 100,000).	The study is the result of enhancing human rabies surveillance in Ivory Coast None of cases had received PEP. Post-exposure prophylaxis with rabies vaccine was administered to all animal exposure victims presenting at the NIPH local units; only about 57% completed the full immunization schedule.
Ngugi 2018 Kenya	5-year retrospective study	Among 7307 records analyzed, 7201 (98.6%) had age recorded. The median age was 22 years	Surveillance of PEP was given, and number of PEP doses administered.	Human animal-bite injuries incidence was 289 per 100,000 persons with the highest incidence reported at 302 per 100,000 and lowest at 121 per 100,000 persons.	The study concluded preventing dog bites would most effectively reduce bite injuries by improving public health education among children below 15 years, encouraging early PEP initiation and completion, development and implementation of responsible dog ownership and animal behaviour, educational programmes as well as improving human

					and veterinary health linkages.
Hikufe 2019 Namibia	6-year retrospecti ve study	Of the total number of 113 cases, the majority (67%) were children and teenagers below 16 years of age, peaking at 5–9 years.	Human rabies surveillance data were retrieved from the epidemiological database of the Ministry of Health. Surveillance in animals is based on the reporting of all suspected cases.	Rabies cases have been above 16 cases per year from 2011 until 2015 with a maximum of 23 cases observed in 2015. Incidence: 1.0 and 2.4 per 100,000 inhabitants and per year on average.	Kavango, the region with the highest human rabies incidence was also the region with the lowest animal rabies surveillance intensity.
Rabies surveillance and prevention					
Andriamandi mby 2013 La Reunion, Mayotte, and Madagascar	6-year Retrospect ive study	24 946 patients visited the ARMC at the IPM, of which 97.2% (n = 24 299) received PEP. Males represented 54.3% (n = 13 556) of the cases and ranged in age from one to 97 years (median	Laboratory surveillance of rabies Post-exposure prophylaxis of rabies	31 positive cases of human rabies	None of these patients received PEP except for one who started PEP late, 10 days after the suspected bite.

		= 18 years). Children under 15 years old represented 40.5% (n = 10 107) of the consultants.			Dog vaccination coverage in Madagascar was 10%
Kubheka 2013 South Africa	3-year retrospecti ve study	2 601 patients who were offered rabies PEP. The median age of the people bitten by dogs during the two years was 20 years (with a range from 1- 92 years). The majority (61.3%) were aged 5-29 years old.	human rabies surveillance database the uptake of the rabies PEP and patients telephone contact.	An average annualized rabies attack rate of 136 rabies cases per 100 000 dog-bite injuries (7/5 139). 6/7 died	83.7% [95% confidence interval (CI): 82.4-85.2] completed the PEP treatment.
Sofeu 2018 Cameroon	A one year retrospecti ve study	A total of 1,402 animal exposures were reported in the West region of Cameroon.	The surveillance network consisted of local, regional, and national health and veterinary authorities. PEP and immunizations received prior to the current exposure; and the wound treatment were recorded.	Overall incidence rate of 6.1 exposures per 100,000 people. One was confirmed positive for rabies	Overall, at least 421 (60%) of the exposure victims considered to be at risk of rabies either did not receive any PEP or did not receive all PEP vaccinations. Only 12.6% (117/925) of dogs were reported to have been vaccinated and only 14.4% of the animal exposure cases were

					followed-up with a visit by a veterinarian No adverse events to PEP were reported.
Mtema 2016 Tanzania	A 5-year retrospecti ve study	Reports recorded bite patients seeking PEP (14,565 records, 49%), detailing visits of approximately 5,800 patients.	Automated SMS (short message service, commonly known as a "text" message) reminders to patients due for further PEP doses. Mass dog vaccinations Mobile Phones as Surveillance Tools	Human rabies cases (42 reported) reflected issues with PEP supply. Incidence of bite patients seeking PEP declined substantially (>50%)	Compliance with PEP regimens was significantly higher for patients following the implementation of automated reminders in comparison to patients attending clinics prior 7% of patients failed to obtain PEP.
Twabela 2016 DRC	A 5-year retrospecti ve study	A total of 5,053 attacks were recorded in the veterinary clinics.	Laboratory surveillance PEP and immunizations	29 were found positive to rabies.	Rabies cases were three times higher in peri-urban zone than in urban zone. It was observed that among the 5,053 attacks registered, 83 (1.6%) animals were killed and 15 (0.3%) disappeared just after attack

					without a follow-up or a veterinary observation.
Post exposure management					
Osaghae 2011 Nigeria	A twelve-year retrospective study	105 episodes of human and animal bites Recorded. Comparators: N/A	Wound Management Twenty (%) domestic dogs were vaccinated while 11(%) and six (%) were not vaccinated and without known vaccination status respectively.	A 10-year-old girl had rabies and died on the second day of admission.	The anti-rabies vaccine was not administered to the children bitten by the vaccinated animals.
Alabi 2014 Nigeria	3-year retrospective study and cross-sectional study	Only 195 (50.9%) of the 383 bite victims linked to a positive dog specimen could be traced. About three quarters (141 (73%)) of the victims were aged <16 years.	A review of detailed profiles of dog bite victims managed in the clinics.	54% of the victims took complete PEP. For those who did not complete PEP, 93% of the biting dogs were not vaccinated.	It has shown lack of enforcement of regulations for licensing of dogs and rabies vaccination.

Muyila 2014 DRC	A 8-month retrospecti ve study	21 cases were observed, rather three cases per month. There were 12 boys (57.1%) and 9 girls (42.9%). Biting animal was found to be dog in all cases (100%).	(9.5%) had their wounds treated and received an anti-rabies vaccine (ARV) after the bite incident. Two (9.5%) patients received rabies immunoglobulin (RIG).	100% of patients showed furious rabies manifestations The case-fatality rate was 100%.	The study revealed the dogs were not immunized for rabies.
Frey 2013 Chad	Cross-sectional study	Of 86 people exposed to a suspected rabid animal. The median age was 18 years, with a range between. 2 months and 79 years.	Post-exposure vaccination and wound cleaned.	Estimated annual incidence of bites from suspected rabid animals of 12.9/100 000 and an incidence of 0.7 human rabies deaths/ 100 000, resulting in 7 estimated deaths (95% confidence interval 4–10 deaths) per year.	50% received post-exposure vaccination and a further 8% had their wound cleaned.
Ogundare 2017 Nigeria	A retrospecti ve study	In all, 84 cases of dog bite injuries were managed constituting 0.89% of the total consultations. Most of	Treatments received in the hospital ranged from washing the bite site with soap and water, to suturing of	Six (7.1%) of cases had rabies and died.	Although seventy-eight (92.9%) of the victims had post-exposure prophylaxis (PEP) with anti-rabies vaccine, only 45 (53.6%) of

		the victims were aged 6-12 years (60.7%) and majority (71.4%) was boys.	lacerations and wound dressing, analgesics, tetanus prophylaxis, anti-rabies vaccination (ARV), intravenous fluids and diazepam administration as well as antibiotics administration.		them were managed successfully and subsequently discharged after ensuring adequate wound healing and completion of the vaccination regimen. Thirty-three (39.3%) were lost to follow up.
Abubakar 2012 Nigeria	A 10-year retrospecti ve study	81victims of dog bite injuries. The majority, 45 (55.6%), were children less than 18 years while 36 (44.4%) were adults.	Wound care PEP and the Immunization schedule	Two cases of clinical rabies were seen during the study period.	Prevalence of dog bite was highest, 41 (50.6%), during the hot season (April–June) and low, 14 (17.3%), during the wet season (July–October). None of the victims was previously immunized against rabies.
Kent 2012 South Africa	A 4-year retrospecti ve study	A total of 821 patients complaining of dog bite. Male children aged 6 - 10 years are most likely to present with dog bites.	Advice only Wound management Give vaccine Give anti-rabies immunoglobulin	Of the 821 bites, 642 (78%) were grade 3; 84 (10%) were grade 2; and 43 (5%) were grade 1. In 52 cases (7%), grade of bite was not recorded. Treatment with	Males present more frequently than females, and young males (ages 6 - 10) are most likely to present. This trend reverses after the age of 40 years, when females are more likely to present than males. We also showed that 99%

				rabies vaccine was started in 90% of cases of grade 1 bites, 97% of grade 2 bites and 99% of grade 3 bites. Immunoglobulin was administered for 53% of grade 1 bites, 84% of grade 2 bites and 82% of grade 3 bites.	of grade 3 bite patients are treated with rabies vaccine, but the rate of treatment with immunoglobulin is lower (82%).
Rabies Diseases Surveillance, Prevention and Control					
Lushasi 2020 Tanzania	Multi-center retrospecti ve study	1,291 victims' bite. The study was undertaken across 20 districts in 4 regions in Southern, Central, and Northern Tanzania.	Integrated Bite Case Management (IBCM). We trained government staff to implement IBCM, comprising risk assessments of bite patients by health	Only 63 of these bite patients were referred to other facilities for PEP with 43 assessed as being suspect rabies exposures. Sixteen human deaths due to	Throughout the study regions, PEP was unavailable for 74 bite patients (5.7%) upon presentation to a health facility, during the period of IBCM implementation.

			workers, investigations by livestock field officers to diagnose rabid animals, and use of a mobile phone application to support integration.	rabies were reported within the IBCM study districts. Overall bite patient presentations corresponded to an incidence of 17.4 bites per 100,000 persons per annum.	
Changalucha 2019 Tanzania	5-year retrospecti ve and cross-sectional study	About 36% of patient presentations at health facilities were due to bites from probable rabid dogs (1,878/5,162 patients that sought care) as assessed through contact tracing, with the remainder from healthy animals or animals with unknown status.	Mobile phone-based surveillance records PEP was supplied free-of-charge to hospitals and selected outlying facilities in each district and training was provided to over 300 health workers in use of the updated Thai Red	We detected an average of 75.6 and 19.3 probable rabies exposures per 100,000 persons per year. Of 1005 individuals identified during contact tracing who received late and/or incomplete postexposure vaccination, 14 died showing	Upon seeking care, a further 15% of probable rabies exposed persons did not obtain PEP due to shortages, cost barriers or mis advice. Of those that initiated PEP, 46% did not complete the course. Decentralized and free PEP increased the probability that patients received PEP and reduced delays in initiating PEP.

			Cross ID regimen (5-dose Essen IM regimen). Qualitative interviews with stakeholders at different levels within the health system to characterize the logistics associated with PEP provision.	clinical signs of rabies.	
Rajeev 2019 Madagascar	One-year retrospective study	1019 patients reported to the anti-rabies medical centers (ARMC).	A combined strategy of mass dog vaccination, enhanced surveillance, and expanded access to PEP.	Annual incidence of 42–110 rabies exposures and 1–3 deaths per 100,000 persons annually. Extrapolating an annual burden of 282–745 human rabies deaths with current PEP provisioning averting 1499–3958 deaths each year.	A high proportion of rabies-exposed persons from Moramanga sought (84%) and completed PEP (90% of those that initiated PEP).

Diallo 2019 Senegal	A prospective cohort study was carried out from April 1,2013 to March 31, 2014,	1036 patients sought a consultation at the Pasteur Institute of Dakar for suspicion of rabies exposure.	Post-exposure prophylaxis implementation (consists of injection of four intramuscular doses of a purified vero cell rabies vaccine). Dog rabies vaccination treatment (local treatment of injuries, antibiotics administration, and previous rabies vaccination), knowledge of rabies and attitudes in respect to animal bite.	No death was reported during the study period. Adverse events were reported after the first two doses by 6% of the patients (42/678) (including 5 patients who also received equine RIG at D0), and after the third dose, by 3% (16/493). Most of them were minor: headache (46.5%), fever (31%) and pain at the injection site (22%), and mostly (74%) occurred on the same day of the vaccine injection (up to 7 days).	Out of the patients receiving PEP, 162 (18%) patients received two doses only at D0, 185 (20.5%) three doses at D0 and D7 and 493 (54.5%) completed the full 4-dose schedule.

Hampson 2008 Tanzania	5-year retrospecti ve study	1080 people were traced and interviewed who had been bitten by animals.	Contact tracing was used to gather data on rabies exposures, post-exposure prophylaxis (PEP) delivered and deaths case reports from livestock offices and community-based surveillance activities.	Twenty-eight deaths from suspected rabies were recorded during the five-year period in the two districts, an average of 1.5/100,000 per year in Serengeti and 2.3 in Ngorongoro	Insufficient knowledge about rabies dangers and prevention, particularly prompt PEP, but also wound management, was the main cause of rabies deaths. Received PEP: 685 (71%) Attended hospital: 971 (85%) PEP dramatically reduced the risk of developing rabies (OR 17.33, 95% CI 6.39–60.83).
Salomão 2017 Mozambique	A case control study	819 cases of animal bites were registered, of which 64.6% (529/819) were from Maputo City. Same neighborhood close to the human rabies victim's house were used as controls (case: control ratio of 1:4).	Affixing posters in health units regarding treatment of animal bites and post-exposure prophylaxis. Delivery of additional quantities of anti-rabies vaccine to the Prophylaxis.	A total of 14 cases of fatal rabies, among them 12 died.	No rabies victim received full post-exposure vaccination Factors significantly associated with human rabies were age <15 years (p = 0.05), bite by stray dog (p = 0.002), deep wound (p = 0.02), bite in the head (p = 0.001), bite by

			Decentralization of post-exposure prophylaxis. Vaccination of dogs in the neighborhoods where human rabies cases had occurred. Mass vaccination campaign of dogs. Participation of private veterinary clinics in animal vaccination. Collection of stray dogs in selected neighborhoods. Community education regarding prevention and control measures.		unimmunized dog (p = 0.01), no use of soap and water (p = 0.001), and no post-exposure prophylaxis (p = 0.01).

Supplementary material 1

Search Strategy:

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) <1946 to May 25, 2020>

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1 exp rabies/ or exp Rabies virus/ or rabies.mp.

2 africa*.mp. or exp Africa/

3 (Algeria or Angola or Benin or Botswana or Burkina Faso or Burundi or Cameroon or Cape Verde or "Central African republic" or Chad or Comoros or Congo or "Democratic Republic of Congo" or DRC or Djibouti or Equatorial guinea or Egypt or Eritrea or Ethiopia or Gabon or Gambia or Ghana or Guinea or Bissau or Ivory coast or "“Cote d ivoire" or Jamahiriya or Kenya or Lesotho or Liberia or Libya or Madagascar or Malawi or Mali or Mauritania or Mauritius or Mayotte or Morocco or Mozambique or Namibia or Niger or Nigeria or Principe or Reunion or Rhodesia or Rwanda or "Sao Tome" or Senegal or Seychelles or "Sierra Leone" or Somalia or "South Africa" or "St Helena" or Sudan or Swaziland or Tanzania or Togo or Tunisia or Uganda or Zaire or Zambia or Zimbabwe or "Central Africa" or "West Africa" or "East Africa" or "Southern Africa" or South Africa).mp.

4 2 or 3

5 1 and 4

6 mortality/ or mortality.mp.

7 fatality.mp.

8 morbidity.mp. or Morbidity/

9 surveillance.mp. or Population Surveillance/

10 (vaccine or vaccines).mp. or Vaccination/

11 6 or 7 or 8 or 9 or 10

12 Rabies Vaccines/

13 5 and 11

14 4 and 12

15 13 or 14

16 limit 15 to english language