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Research Article

Assessment of the National Veterinary Laboratory System Capacity for the Detection of Infectious Threats to Global Health Security in Benin

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Abstract

Introduction: The International Health Regulations 2005 require countries to establish laboratory systems for rapid and safe confirmation of public health emergencies including zoonoses.

Objectives: This study assessed the national veterinary laboratory system capacity for the confirmation of infectious threats to global health security in Benin.

Method: The study was descriptive, cross-sectional and evaluative. The non-probability sampling method with selection of the two existing veterinary laboratories were used. Two questionnaires, one observation grid and the Food and Agriculture Organization laboratory mapping tool-core were used. The system capacity was rated good if each laboratory met at least 80% of the assessed criteria. Otherwise, the capacity was rated insufficient.

Results: The national veterinary laboratory system capacity in Benin was insufficient. Bohicon laboratory satisfied 27.2% of assessed criteria; With the laboratory mapping tool-core, Parakou laboratory had an average indicator of 50.7%. Laboratory collaboration and networking was the best performing domain with 66.7%. Only basic supplies category reached 80%. Laboratory budget, sample accession and availaible technology had the lowest scores. The veterinary laboratory system is facing shortage of staffs. Avian influenza virus is confirmed by the two laboratories; *Bacillus anthracis* and rift valley fever virus are only confirmed by Parakou laboratory. Ebola and Lassa fever are not confirmed. There is no collaboration between the laboratories in the country.

Conclusion: The veterinary laboratories are not able to ensure timely detection of zoonoses and inform health system for preparedness. The development and implementation of the veterinary laboratory system improvement plan is essential for the global health security in Benin.

Introduction

Veterinary Laboratories (VL) are an essential component of Global Health Security (GHS). They are vital for the detection of zoonotic diseases, in food safety, and in the production and development of vaccines and therapeutic strategies for both humans and animals [1]. Their role and importance are growing in response to the increasing of emerging and reemerging infectious and zoonotic diseases [2]. In line with the importance of the VL, the eighth International Health Regulations (IHR) 2005 core capacity requires Member States to establish functional laboratory systems and networks for the detection of GHS threats [3-5]. This requirement became more important since the largest Ebola epidemic in West Africa and the adoption of the Global Health Security Agenda (GHSA) [6]. One of the objectives of the zoonoses action package of the GHSA is to strengthen and maintain the human resources and technical capacities of animal, human and wildlife health services to support zoonotic diseases prevention, detection, and response activities. These services include a functional veterinary laboratory system (VLS) that supports syndromic surveillance. Since the Ebola outbreak in West Africa in 2014, the GHSA has been committed to strengthening laboratory capacity in infrastructures, equipment, and skilled personnel across sectors, sustainable national biosafety, biosecurity, and especially laboratory systems in Africa [7]. In link with this commitment, the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (OIE) and other partners are supporting countries to identify gaps in VLS, to plan and implement corrective measures [8]. Challenges linked to VL are of several types. The panoply of emerging and re-emerging diseases is great. Many existing animal pathogens likely remain unidentified. Several African VL are lacking key capacities [7,8] in front of the growing zoonotic threats. Zoonotic infectious threats in Benin, as revealed by the mapping of health and zoonotic risks in 2017, include Avian Influenza Virus (AIV), *Bacillus anthracis*, rabies virus and hemorrhagic fever viruses namely Rift Valley Fever Virus (RVFV), Lassa Fever Virus (LFV), Ebola Virus (EV) [9]. Benin Republic is also threatened by zoonoses reported in neighbouring countries. In 2016, human epidemic of Rift Valley Fever (RVF) was reported in Niger [10]. RVF was also reported in animals in Nigeria in 2011 [11]. The VLS in Benin must have laboratory capacities to safely confirm these threats. VL must also support early detection of zoonoses evolving in animals and provide alert to health system for preparedness and effective response [12]. Benin has a functional VLS. But, the minimum packages of VL activities are not yet defined. The existing VL are organizing the confirmation of pathogens in animals and are contributing, as they can, to strengthen GHS. Very few specific evaluations of VL in Benin were conducted in the recent years. This included the performance of veterinary services review in 2018 and the assessment of the biosafety and biosecurity in the reference VL of Parakou [13]. However, no comprehensive and holistic evaluation of the VLS capacity in contributing to the

GHS was carried out to our knowledge. To fill this gap, the present study aims to assess the capacities of the national VLS to detect infectious threats to global health security in Benin.

Materials and Methods

Study design

This was a descriptive, cross-sectional and evaluative study. The non-probability sampling method was used. All the two existing laboratories were selected.

Settings

The study took place in Benin, in the Zou and the Borgou departments. The country has 12 departments and shares borders with Burkina Faso, Niger, Nigeria and Togo Republics. The country has a veterinary syndromic epidemiological surveillance system for animal diseases supported by a laboratory confirmation.

Participants

The study population was the VLS of Benin. The targets were the VL involved in the laboratory confirmation of infectious threats. Benin's national VLS is composed of two public sector laboratories. The Veterinary Diagnostic and Serosurveillance Laboratory (LADISERO), a biosafety level 2 laboratory, is established in Parakou, in the Borgou department in the northern part of the country. Majority of livestock farming stakeholders are located in this northen part of the country. LADISERO is closed to Boukombe township, an area of anthrax-infected fields where cattle anthrax is regularly reported [14]. LADISERO is the most equipped laboratory in the country and acts as the national reference laboratory. The second laboratory, less equipped, is the VL of Bohicon (Labovet) in the Zou department in the central part of the country.

Data collection and sources

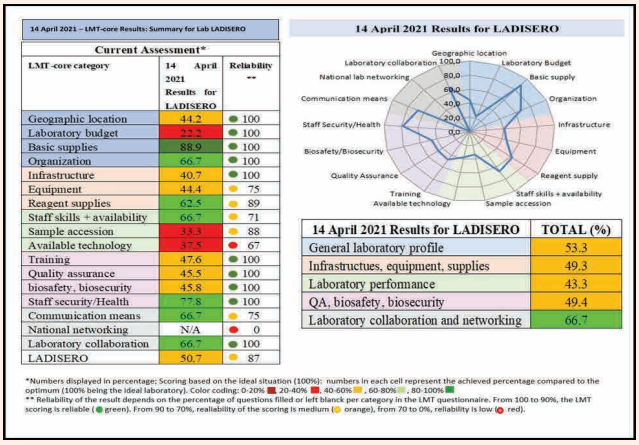
Two questionnaires, one observation grid and the FAO Laboratory Mapping Tool-core (LMT- core) [15] were used to collect data from 15 January to 20 April 2021. In each laboratory, the manager and the staff members present on the day of the investigation were included. Collection techniques included individual interview, group discussion, document exploitation and observation. The first questionnaire was used to collect information from laboratory team leads on management aspects of VL in terms of inputs, process and outputs. The second questionnaire was used to collect information from VL workers on their individual and specific profile, competence and on their appreciation of the management of the VL. The observation grid was used to confirm the availability of tools and materials; and to assess the VL working environment. The three above mentioned collection tools were used in the two VL. The FAO LMT-core was used to evaluate LADISERO. The questions in the LMT-core tool were administrated to the laboratory team during a group discussion. The consensual responses of the team were inserted in the tool. Responses were later validated by the remaining collection techniques. Data collection was carried out by a team of biotechnologists after a two-day training followed by pre-testing of the tools. The evaluation of LADISERO using FAO LMT-core was carried out by a team composed of one epidemiologist and one veterinarian who had more than 5 years of experience in VL management. The process was supervised by one professor in bacteriology-virology and two public health professors.

Variables

The outcome variable in this study was the VL capacity to confirm infectious agents to GHS. In the study, capacity was defined as the ability of VL to confirm targeted zoonotic infectious threats independently of the confirmation techniques (serology test versus Polymerase Chain Reaction (PCR) by example); with respect to biorisk management and quality management principles. The capacity assessment included three steps. The assessment of Labovet capacity, the assessment of LADISERO capacity and the assessment of the overall VLS capacity. The operational aspects of the variables in Labovet focused on eleven criteria covering four domains (Table 1). Each criterion was rated one (1) if the criterion was satisfied and zero (0) when the criterion was not satisfied. The VL was assessed as having good capacity if at least 80% of the criteria were met. Otherwise, the capacity was deemed insufficient. In LADISERO, the FAO's LMT-core was used for operational aspects. This tool defines 17 categories of criteria covering five domains (Figure 1). The LMT-core has overall 108 questions ranged from 1 to 12 per category. Each question was rated from 1 to 4 based on the level of achievement in the laboratory. The highest level of compliance and activity received a score of 4, and the most basic level was rated 1. The tool defines for each question conditions that correspond for 1, 2, 3 or 4 during rating process [15]. The LMT-core has features that automatically generate the score obtained by the laboratory for each category and domain as well as the overall average indicator of the laboratory. The capacity of LADISERO was rated good if the laboratory had an overall average indicator of at least 80%. If the score was less than 80%, the capacity was judged insufficient. The capacity of the national VLS was rated good if Labovet met at least 80% of the assessment criteria and if LADISERO had an overall average indicator of at least 80%. Otherwise, the capacity was deemed insufficient.

Table 1: Results of the assessment of Labovet capacity for the confirmation of infectious threats to global health security, Benin, April 2021.

Domain	Criteria	Criteria met
Capacity to confirm priority diseases	Confirmation of AIV either autonomously or through a reference VL present in the country	Yes
	Confirmation of RVFV either autonomously or through a reference VL present in the country	No
	Confirmation of *Bacillus anthracis* either autonomously or through a reference VL present in the country	No
Specimen collection, packaging and transport	At least one worker trained on specimen collection, packaging and transport	Yes
	SOP on specimen collection, packaging and transport available	Yes
	At least one worker trained on the use of personal protective equipment	No
Biorisk management	SOP on biorisk management available	No
	SOP on management of infectious waste available	No
	Report on the VL biorisk assessment available	No
Quality management	Internal quality management mechanism for at least one test exist	No
	external quality assessment mechanism for at least one test exist	No



14 April 2021 – LMT-core Results: Summary for Lab LADISERO

Current Assessment*		
LMT-core category	14 April 2021 Results for LADISERO	Reliability **
Geographic location	44.2	100
Laboratory budget	22.2	100
Basic supplies	88.9	100
Organization	66.7	100
Infrastructure	40.7	100
Equipment	44.4	75
Reagent supplies	62.5	89
Staff skills + availability	66.7	71
Sample accession	33.3	88
Available technology	37.5	67
Training	47.6	100
Quality assurance	45.5	100
biosafety, biosecurity	45.8	100
Staff security/Health	77.8	100
Communication means	66.7	75
National networking	N/A	0
Laboratory collaboration	66.7	100
LADISERO	50.7	87

14 April 2021 Results for LADISERO	TOTAL (%)
General laboratory profile	53.3
Infrastructues, equipment, supplies	49.3
Laboratory performance	43.3
QA, biosafety, biosecurity	49.4
Laboratory collaboration and networking	66.7

*Numbers displayed in percentage; Scoring based on the ideal situation (100%): numbers in each cell represent the achieved percentage compared to the optimum (100% being the ideal laboratory). Color coding: 0-20% , 20-40% , 40-60% , 60-80% , 80-100%
** Reliability of the result depends on the percentage of questions filled or left blanck per category in the LMT questionnaire. From 100 to 90%, the LMT scoring is reliable (green). From 90 to 70%, reallability of the scoring is medium (orange), from 70 to 0%, reliability is low (red).

Figure 1: Results of the assessment of the Parakou veterinary laboratory capacity using the FAO laboratory mapping tool-core, Benin, April 2021.

Bias

Training, followed by tool pre-testing, was provided to investigators before the survey. The declaration of surveyed people was cross-checked with document exploitation and working environment observation findings.

Statistical methods

The results of the field surveys were analyzed using Stata-14 software. The FAO LMT-core had Excel features that generated automatically figures on the performance

of the laboratory.

Results

Characteristics of the veterinary laboratory resources

Seventeen workers were reported in the two laboratories. Nine were involved in screening and diagnostic confirmation of zoonoses. Based on the workload, their number was considered adequate by managers in Labovet while it was judged insufficient in LADISERO. Of them, only one (1) has received basic academic training in biomedical analysis. The remaining includes two veterinarians, three licensees (baccalaureate+3), two engineers (baccalaureate+4) and one baccalaureate-level in animal production. They received "on the job" training through continuous training or internship in foreign VL. Two technicians were able to confirm *Bacillus anthracis*, six for AIV and five for RVFV. The two VL did not have mechanisms for increasing the number of staff in case of emergencies. There was no continuous training plan in the two VL; the Regional Disease Surveillance System Strengthening project team conducted one supervision in each VL in the twelve months before the survey. The recommendations were only implemented in LADISERO. On other hand, the structures, equipment and materials for collecting and transporting samples were considered adequate in both laboratories by managers. However, reagents and consumables were not adequate. Zoonotic disease case definitions were not available, but notification forms and results sheets were available; LADISERO had a database.

Confirmation capabilities

Table 2 summarizes the ability of the two VL to confirm key pathogens targeted by the study. For AIV, the test is performed on tracheal and cloacal swabs in the two VL. The specimens are stored in refrigerators or cold boxes (during transport) between 4 and 8 degrees Celsius. For the shipment of positive swabs to the reference laboratory, the specimens are stored in Buffer Phosphate Saline liquid. LADISERO performs RVF confirmation on blood; and anthrax on organs and soil samples. Internally, the two VL were not collaborating for sample confirmation. However, Labovet had collaboration mechanisms with foreign VL for the confirmation of anthrax and avian influenza. The two VL were not yet part of international networks for confirmation of LFV and EV.

Table 2: Confirmation capacity and techniques for targeted infectious threats by national VL, Benin, April 2021.

Infectious Threats	Labovet		LADISERO	
	Confirmation	Technique	Confirmation	Technique
AIV	Yes[1]	Serology test	Yes	Serology, PCR
RVFV	No[2]	N/A[3]	Yes	PCR
Bacillus anthracis	No	N/A	Yes	PCR, bacteriology test
LFV	No	N/A	No	N/A
EV	No	N/A	No	N/A

[1]Yes: The veterinary laboratory can biologically confirm the infectious threats.
[2]No: The veterinary laboratory cannot biologically confirm the infectious threats.
[3]N/A: Not applicable.

Evaluation of bohicon VL confirmation capacities of infectious zoonotic threats

Table 1 presents the results of the assessment in Labovet. Out of the 11 criteria evaluated, the VL satisfied to three criteria. The VL satisfied then to 27.2 % of assessed criteria. The rate of satisfied criteria was lower than 80%; then, the capacity of Labovet was insufficient.

Evaluation of the LADISERO

The evaluation of LADISERO with the FAO LMT-core tool gave an overall score of 50.7% (Figure 1) with an overall reliability level of 87%. Then, the confirmation capacity of LADISERO was insufficient. By domain, general laboratory profile obtained a score of 53.3%. Infrastructures, equipment and reagents obtained a score of 49.3%. Laboratory performance had a score of 43.3%; quality assurance, biosafety/biosecurity had a score of 49.4%; laboratory collaboration and networking had a score of 66.7%. Overall, among the 17 categories assessed, only the basic supply category of the general laboratory profile domain had a score above 80% (Figure 1). On other hand, laboratory budget had the lowest score (22.2%). Scores of two categories of laboratory performance domain were also below 40%. These were sample accession (33.3%); and available technology (37.5%). Six categories had a performance between 40% and 50% while six others had a performance between 60% and 80%. The national laboratory networking category was not assessed because the available VL are not networked.

Overall confirmatory capacity of the national veterinary laboratory system

The capacity of Labovet was insufficient (27.2%). Similarly, the capacity of LADISERO, the reference laboratory, was also insufficient (50.7%). Then, the overall capacity of the veterinary laboratory system in Benin was insufficient.

Discussion

The objectives assigned to the study were achieved. The capacities of the national VLS were assessed. The inclusion of all the existing laboratories provided a complete view on the status of VL capacities in the country. The declarative nature of the responses may appear as weakness, but the variability and combination of the data collection techniques enabled verifications and triangulations that reassure about the objectivity of the data collected. The selection of the all existing laboratories enable the generalization of findings to the national VLS.

Human resources

The VLS in Benin is facing shortage of human resources. Very few technicians are working in the veterinarian public sector in the country [16,17]. In addition, a large proportion of them did not receive formal training in laboratory analysis. This situation is not in accordance with FAO orientations; for this organization, auxiliary staffs (animal health assistants, laboratory technicians and meat inspectors) must have formal training as well as practical experience [18]. The confirmatory skills implemented were acquired through on-the-job training or short-term internships in sub-regional laboratories. This is in accordance with findings of Loveland et al. [19] in Massachusetts. This author raised that as consequence of a shortfall in the available trained labor pool, research operations are forced to hire employees with less than the needed skills and try to fill the training gap themselves [19]. However, Benin has academic institutions in charge of formal training in biomedical analysis since decades with a huge number of trained people. But, VL sector seems to not be motivating for this trained workforce. Most of them prefer working in the human health sector. An anthropological study is needed to understand this disinterest to VL activities. However, the scarcity of VL with just two laboratories available in the country does not facilitate frequent demands of veterinary laboratory confirmation tests with as consequence low workloads which could have demotivated these actors. On other hand, the absence of clear career pathways for biologists could also be improved substantially. In fact, few veterinarians and animal production technicians are working in the public sector in the country. In this context, continuous training mechanisms should be strengthened. But the two laboratories have no plan in place to strengthen the capacity of their workforce while the epidemiological profile is in regular mutation. This is accordance with findings raised by FAO who stated that postgraduate training and continuing professional development have been neglected in some countries [18]. This situation limits the competence of available workforce in confirming main pathogens with by example, just two technicians able to confirm anthrax in the country.

LADISERO capacities

The overall performance of LADISERO in confirming infectious zoonotic threats was insufficient. The laboratory obtained an overall average indicator of 50.7%, below the expected threshold of 80%. This insufficient performance was mainly induced by the fact that all assessed domains had low average scores, ranged from 43.3% for laboratory performance to 66.7% for laboratory collaboration and networking. There was no domain that reached the 80% threshold; moreover, only one domain was shown to have a performance between 60% and 80%. LADISERO therefore needs major efforts to do in strengthening its confirmation capacities. But although insufficient, the overall average indicator of LADISERO was higher than the results found in 11 VL in Nigeria. Indeed, in their study, Adebowale and colleagues found an average score ranged between 9.7% in one VL in Oyo State to 39.7% in one other VL in Ogun State [7]. The analysis by category revealed that even for the categories in which LADISERO had the lowest performance, its result was often better than some Nigerian laboratories results. In terms of budget by example, LADISERO was more efficient than three Nigerian VL. Similarly, for the sample accession, LADISERO was more efficient than seven Nigerian laboratories; and for the available technology, LADISERO was more efficient than 10

of the 11 Nigerian laboratories. LADISERO reached 80% threshold for basic supply category. This guarantees the continuity of confirmation services, the safety of equipment and relatively, the workforce well-being. This performance was not reported in any of the 11 Nigerian VL assessed; moreover, there was no Nigerian laboratory that reached 80% for this category. LADISERO performs better in the categories of training, quality assurance, biosafety/biosecurity, staff security/health and laboratory collaboration and networking than the VL evaluated in Nigeria. However, all the VL in Nigeria did not have reference laboratory status as LADISERO. This can explain the relatively better performance of LADISERO. This performance, although better, was lower than the level required for an effective contribution to GHS. Efforts in the laboratory's quality approach should be strengthened in line with the recommendations of the World Organization for Animal Health [7,20,21]. Biorisk measures especially biosecurity must be strengthened [1,13,22]. The VL sector requires large-scale correctives interventions to ensure that its performance will appropriately prevent zoonotic threats in humans. Overall, the problems encountered by LADISERO seem to be common to different VL in the sub-region with different levels of acuity. The relatively good performance reported in LADISERO could be explained by the reduced number of VL in Benin; This enables the concentration of partners support to this laboratory. But in general, the insufficient budget has negative impact on the laboratory's capacity to recruit adequate numbers of qualified workforce and to expand its technical platform towards ability to detect in animal the main zoonotic threats identified during the mapping of veterinary risks.

Capacity of the national veterinary laboratory system

The performance of the national VLS was insufficient. This can be explained by the insufficient level of capacity in the two VL available in the country. Labovet was only able to confirm AIV among the targeted pathogens. There was no VL that has ability to confirm Lassa and Ebola either autonomously or through reference VL. Insufficiencies in biorisk and quality management programs were reported in the two VL. Also, the two VL were missing key equipment; this is more worrying in Labovet which seems to be in decline. Coupled with the workforce issues, these weaknesses can deeply compromise the continuity of VL confirmation activities and even the quality of tests performed [23]. The lack of collaboration and networking of national VL can also explains the insufficient performance of the system. In fact, existence of resilient laboratory networks has been shown to facilitate the pooling of resources and the achievement of objectives [1,24]. But, the two laboratories were not collaborating. Each VL managers prefer interaction with international VL instead of using competences and resources available in the country. This limits the speed of results release and can delay alerts and preparedness. These operational weaknesses in zoonoses confirmation, associated with the insufficient geographical coverage in VL, the weak collaboration between VL; and the absence of data exchange between VL and health sector will not enable the GHS system to effectively implement zoonotic diseases prevention measures especially in health sector. As of now, the veterinary sector is not able to effectively detect zoonotic diseases while they are evolving in animals. In this context, the national public health system in Benin will always be surprised by the occurrence of zoonotic diseases within humans with the obvious risk of late detection, high morbidity and high case fatality rate. The zoonotic public health events can then spread from Benin to other countries in African region and negatively impact the global health security. Such cross-border spread was reported in 2017 during Lassa fever epidemic [25]. The Government must significantly increase institutional, technical and logistical supports to the national VLS through the adequate recruitment of competent workforce, provision of enough operation budget, expansion of technical platforms, improvement of geographical accessibility to VL and adequate legislation. Managers in charge of VLS must improve the organization and management of services, the collaboration and networking; they must, strengthen collaboration with other sectors in line with the 'One Health' approach, and put in place mechanisms for functional information sharing with the health and environmental sectors [24,25].

Conclusion

The capacities of the national VLS in Benin have a lot of areas of improvement. The diagnostic capacities of VL are reduced to few pathogens. The system does not have confirmation capacity for major pathogens reported in the risk mapping. Despite organizational and structural weaknesses, the system has assets that can serve as a basis for the strengthening of its capacity to effectively contribute to GHS in Benin. The development and implementation of VL capacities strengthening plan for health security and the improvement of the "One Health Approach" are urgent in the current health context characterized by the emergence and re-emergence of zoonotic pathogens.

Author Contribution

Conceptualization: Sodjinou VD; Data curation: Sodjinou VD; Formal analysis: Sodjinou VD; Funding acquisition: Sodjinou VD; Investigation: Achade AGA, Sodjinou VD; Methodology: Sodjinou VD; Project administration: Sodjinou VD; Resources: Sodjinou VD; Software: Sodjinou VD; Supervision: Ayelo AP, Affolabi D, Ouendo EMD; Validation: Ouendo EMD; Visualization: Sodjinou VD; Writing - original draft: Sodjinou VD; Writing - review & editing: Achade AGA, Ayelo AP, Affolabi D, Ouendo EMD.

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