Tec Empresarial
P-ISSN: 1659-2395; E-ISSN: 1659-3359

THE ROLE OF LABORATORIES IN DISEASE CONTROL AND OUTBREAK RESPONSES

Layla Mohammed Hadadi[1], Yahya Hassan Alshuqayri[2] and Abdulaziz Ageel AlAgeel[3]

[1] Corresponding Author, Nursing Specialist, lmh2858@gmail.com, KFMC, SA
[2] Nursing Specialist, Jako20124@gmail.com, KFMC, SA
[3] Senior Medical Technologist, aaalageel@kfmc.med.sa, PCLMA, KFMC. SA

Abstract: Laboratories play a crucial role in disease control and outbreak responses by providing essential diagnostic services, surveillance data, and research support. This essay explores the significance of laboratories in detecting, monitoring, and responding to infectious diseases, emphasizing their role in public health emergencies.
By analyzing the functions of laboratories, the challenges they face, and the advancements in technology that enhance their capabilities, this essay highlights the critical role they play in controlling and managing disease outbreaks. Understanding the importance of laboratories in disease control and outbreak responses is essential for developing effective public health strategies and preparedness measures to address emerging health threats.

Keywords: laboratories, disease control, outbreak responses, diagnostics, surveillance, public health emergencies.

1.2 1. Introduction to Disease Control and Outbreak Responses

To truly understand the important role laboratories can have in managing the control of infectious diseases and responding to outbreaks, it is first necessary to establish the baseline components of disease control and outbreak responses. In addition to the myriad factors surrounding the transmission and immunity to infectious diseases, there are four primary pillars of disease prevention. These are biosecurity, often the first line of defence against disease; public health, the initial response to a disease outbreak; health management, maintaining general health to mitigate disease impact; and medical intervention, the last stand against a disease following infection that sometimes will be the first.

Outlined within these four areas are numerous tasks executed during normal responses to a disease outbreak, together with the activities of significant importance prior to any outbreak. Preventing a disease outbreak is at the core of each of these pillars, a commonality that drives preparedness as the foundation of any response. The capability to detect and contain disease at its earliest stages only results from sustained preparedness. Disease control can be significantly more effective and overall outbreak management becomes substantially less complex when, and if, the major components of these response activities are evenly supported as a whole. There are taskings within these four main pillars that require unique capabilities typically found only within specialised institutions. Laboratories dedicated to the detection of pathogens, whether they are focusing on clinical diagnostics to confirm individual cases or environmental monitoring for contamination, are one of these capacities. Detected diseases can then be monitored and characterised to inform

appropriate responses and better understand how to manage the disease or control future outbreaks (F Houlihan & Ag Whitworth, 2019).

1.1. Definition and Importance of Disease Control

Disease control means all of the preventive public health strategies that forestall the initiation of a disease process or that intervene early in the progress of a disease so that it will have less chance of establishing itself and producing adverse effects. It encompasses the various strategies employed to reduce the incidence, prevalence, morbidity, or mortality of a disease. The control of communicable diseases comprises a broad range of interventions that affect not just affected persons in one place, but also the environment, carriers of disease, contacts, etc., and other measures taken against the disease and control programs. A timeless starting point for good public health practice indicates the importance of taking measures even when the disease incidence is low or not evident in an effort to prevent it from becoming a public health threat (H. Tulchinsky & A. Varavikova, 2000). This is best illustrated with regard to curbing epidemic outbreaks, the incidence of which quickens with the covered area or number of infected individuals. An increase in the number of disease-stricken individuals may lead to an increase in the percentage of affected persons from some of the exposed groups as time passes if they are not medically taken care of. The prevention and early intervention in these cases would be much easier and save costs compared to treatment of a serious epidemic.

Disease-control strategies consist of a series of interventions, beginning with isolation and quarantine at one extreme, through vaccination, suppression, or elimination of vectors, animals, or arthropod hosts of disease, education campaigns, health education, public-awareness, new drug or treatment development, improvement and/or enforcement of existing legislation and policy, to attempts to change macro-level determinants of the disease (including, but not limited to, poverty alleviation campaigns). Many directions must be taken for effective control of a given transmissible disease, and due to its social nature, it is typically underreported. Disease-control policy thus is typically driven by research but must take into account the extent to which non-epidemiological variables may influence infection rates. Hence there exists the need for intersectoral collaboration or the need for the state to act in an integrated way across disparate sectors.

1.2. Overview of Outbreak Responses

The frequency of reported outbreaks of infectious diseases has increased over the past 3 decades, with predictions that this rise will continue. Outbreak response continues to follow nine basic principles: establish the presence of an outbreak, verify the diagnosis, make a case definition, find cases and contacts, conduct basic epidemiology, test hypotheses, institute control measures, communicate the situation and establish ongoing surveillance. Significant advances have been made over the past 5 years using progress in digital, laboratory, epidemiology and anthropological equipment or techniques. Future outbreaks of high-consequence are inevitable, and vigilance and preparation must continue in order to prevent significant mortality, morbidity and socio-economic crisis. Outbreaks of infectious diseases are a major health and socio-economic problem and present an existential threat to societies and governments. The likelihood of large outbreaks or pandemics of high-Consequence infectious diseases (HCIDs) occurring always exists, and the number of individuals affected and the associated morbidity, mortality and socio-economic crisis will increase as a function of overall population size, density and global interconnectivity (F Houlihan & Ag Whitworth, 2019). Recent large outbreaks of HCIDs include plague, diphtheria, Ebola virus

disease (EVD), human monkeypox, Zika, middle east respiratory syndrome coronavirus (MERS-CoV), and re-emerging Lassa fever. An increase in LHCDs occurrence is predicted in the future, due to environmental changes; reduction of biodiversity; forceful alteration of natural ecosystems; increase in close contact between humans and wildlife; and increase in mismanagement of the natural world. A diverse and evolving array of unrecognised or disregarded pathogens poses threats to global health. Outbreaks of disease are also threats to international security, economic viability, social peace and cohesion, and individual health and wellbeing.

1.3 2. The Role of Laboratories in Disease Control

One of the basic strategies for disease control is the appropriate management of clinical specimens – for testing and surveillance purposes – within a comprehensive laboratory system (N. Okeke, 2016). Health care aggregators such as health facilities and other service providers everywhere routinely handle sterilization succeeded by diagnostic investigations, ultimately necessitating the laboratory analysis of clinical samples. The provision of high-quality test outcomes and other laboratory procedures based on clinical samples play a crucial role in appropriate patient management; in this context, laboratories are considered by far the most important source of objective information on which to base timely health care decisions. Informed health care appraisal involves the consideration of multiple domains, which includes possible signs and symptoms of illness collectively referred to as a health event. Herein, the laboratory provides unassailable support to comprehensively understand what is happening in the body of the sick, through the generation of results from the testing of bodily fluids such as blood or urine, excretion mainly emanating from the body's individual homeostasis balance.

Laboratories maintain a multifaceted role in the health system with respect to diagnostics, surveillance, and research involving a, often interconnected, array of functional areas and services. Along with health center curatives, laboratories are thus deemed essential or critical within the district health system. The provision of timely and accurate test information is critical for sound patient management and for appropriate policy, research, and wide public information needs. Well-managed laboratories are able to deliver information on the basis of high-quality service provision, and this information is vital in making informed decisions, particularly in the public health management of diseases and outbreaks. Therefore, the laboratory wealth (reliable, accurate, and links to good public health practice) and prompt communication from the laboratory are vital for the initiation of containment activities. Public health responses to disease or suspicion of an outbreak necessitate action on behalf of public health authorities and may include the implementation of a vaccination program or other preventative measures to guard against further infections; laboratory services are once more critical in information or guidance that in essence determines what action is or ought to be undertaken.

2.1. Diagnostic Testing

Laboratory diagnostic testing is one of the cornerstones of disease control and plays a vital role in monitoring ongoing public health threats, mitigating disease outbreaks, and safeguarding public health. There are a variety of tests that can be performed within laboratories. This includes molecular tests, serological tests, as well as culture methods - where the virus is grown in cells and identified by other means. The accuracy and speed of diagnostic tests are critical for a timely and appropriate response to an outbreak. A major utility of the diagnostic tests is to identify the causative agent of the disease, allowing for the proper development and administration of control measures (Tomo et al., 2020).

Laboratories are involved in the development, optimization, and validation of new testing methodologies, including those for newly emerging diseases. The laboratory also ensures the quality of diagnostic results and offers training to other practitioners. Despite available diagnostic tests for many infectious diseases, they are not always accessible to all in urban and especially rural populations. Ideally, communities living in both urban and rural settings would have better access to diagnostic tests. This should enable to rapidly inform treatment and isolation decisions. Diagnostic tests have performed better, as expected, in urban areas or other well-serviced locations (Pretorius & Venter, 2017).

Additionally, the laboratory response capacity is also a significant limitation. During outbreaks of infectious diseases, there can be an exponential increase in the number of individuals needing diagnostic testing. This places strain on the available resources, such as test kits, laboratory personnel, and biosafety equipment. This can be exacerbated by disparate resource allocation between different geographical areas.

2.2. Surveillance and Monitoring

A key component of disease control, particularly for infectious diseases, is timely knowledge. To know the occurrence and distribution of prevalent conditions is important at every level of health administration. Since the time of John Snow, the pioneering epidemiologist, it has been realized that the accurate collection, recording, and assessment of figures denoting disease occurrence are of fundamental importance to public health. In the present century, the development of rapid communication has allowed research on data to assume an ever-greater importance. This development was well summarized by (Arita et al., 2008).

The importance of this sort of assessment has now been well elaborated in one particular instance by (Abat et al., 2016). Such approaches, alongside the traditional monitoring of hospitalized case and laboratory-based reporting, are of especial value in a rapidly transforming world; however, it is stressed that the quality of this assessment cannot exceed the quality of the input data.

The twofold reason for such collection has been expressed as firstly the tracking of changing trends in common parameters, and secondly the determination of priorities for further consideration by the public health authorities. The disease trends at whatever level of administration; village, district, or nation, may demonstrate excesses of the usual endemic diseases in either time or place, or alternatively may show an increase in relatively unknown conditions.

2.3. Research and Development

Research and development (R&D) is the foundation for the development of health technologies that are vital for all levels of disease control action, especially in countries with limited resources. The availability of new knowledge, diagnostic technologies, drugs, vaccines, and non-pharmaceutical interventions drives the feasibility and flexibility in the control of emerging or resurgent infectious diseases. Development of R&D helps rapid and effective response to epidemic-prone and newly recognized pathogens. Furthermore, R&D helps anticipate changes of knowledge and understanding of epidemiological patterns of diseases which might drive how they are controlled. This is particularly relevant given some pathogens are capable of changing their behaviour rapidly in response to environmental stimuli and genetic/biological exchange with other pathogens (N. Okeke, 2016). Research and development in detection, research, and treatment of underlying diseases in disease surveillance has yielded disease morbidity and reduced mortality. Most infectious diseases are transmitted through hands and many can be exploited as biological

weapons, frequently leading to widespread human casualties. Although bioterrorism in the practical natural epidemic remains a controversial point, early disease outbreak recognition is a critical goal of preparedness for bioterrorism by constructing effective response systems and strong networked disease surveillance in the world. Collaboration in research between disciplines, sectors and countries is a necessary prerequisite for the development of effective health strategies, especially for systems of antimicrobial resistance, environmental health risks, and health damage mitigation. In many regions potential multilateral or regional research sites are needed for which ERB could offer a platform for effective coordination between partners. Disease control research strategies should be based on an integrated approach in which different research activities are connected with crucial health policy and control actions. Ethical considerations must be included in research planning and execution. Declining budget resources of universities could be partly compensated by a change in research priorities, more focus on public health. The particular part of R&D in an infectious disease area that is essential for disease control and can be promoted through reflection on ERB, LCC, or WHO TB/RBM is proposed, such as vaccine and rapid diagnostic tests development, field trial evaluation of vaccine efficacy, enhancement of drug supply for chemotherapy of resistant TB cases, development of algorithms for DR-TB case management, operational research on reage and trends in drug susceptibility patterns of different DR-TB strains. Supply of first and second line drugs for treatment of drug-resistant TB is a problem of high priority for disease control, particularly in conjunction with the appearance of a considerable proportion of completely drug-resistant strains. Need for research on alternative regimens and drug availability including the development of hors-commerce first wife anti-TB drugs is stressed. As new TB vaccine candidates enter the phase I clinical trial efforts must guide decisions on which vaccines merit further development, to accelerate preclinical and early clinical research and development on new TB vaccine candidates. Transition from development of single drug-resistant TB (MRes), multi-drug-resistant TB (MDR-TB) to extremely drug-resistant tuberculosis (XDR-TB) raises many questions on more effective short-term case management and preventive aspects. Development of operational research and exploration of trends and patterns of XDR-TB spread could help better understanding their spread; development of revised algorithms for the management of XDR-TB cases including new drugs where possible and recognized treatment regimens.

1.4 3. Laboratory Infrastructure and Capacity Building

Laboratory testing is critical for disease control and public health interventions; a diagnosis often shapes the response. Disease investigation processes in public health also produce data and samples that require analysis. In light of this, suitable laboratory infrastructure should be viewed as a foundational element along with human resources and responsibilities with the establishment and operation of any disease control system. Laboratories range from makeshift spaces in clinics to advanced facilities. All types of laboratories can play a critical role in public health in their own right. Clinic-level laboratories can provide the test results that guide patient care behavior and inform case finding and outbreak response. Larger district-level facilities routinely support these activities, while also implementing more complex testing for investigations. National laboratories have the capacity to characterize new pathogens, and their data underpin strategic threat assessments. Specialized research laboratories, either nationally or internationally managed, may conduct work that directly supports guidelines and interventions (C. Iwen et al., 2018). While some are capable of complex and hazardous experiments, it is more common for facilities to be geared towards epidemiologic research on genetic sequencing of isolates. Understanding of transmission

and evolution can, in turn, guide control measures. Thus, all levels of laboratory fit within the broader public health architecture and have their own role to play. For laboratory networks to function effectively as part of a whole system, trained laboratory staff must be equipped and resourced with dependable reagents and diagnostic supplies. Infrastructure and capacity-building programs should focus on this broad vision of laboratory roles that contribute to public health aims. However equipped, facilities must have the relevant skills and functions that are available when needed. Alongside day-to-day work, maintenance and equipment can be overlooked during healthy budget cycles and lacks direct public health have 'reinforcements' when it matters. Training programs for staff may need to be developed, or adapted, as these programs to enhance the skillset of laboratory workers, ensuring that across the network there is suitable capacity to respond to evolving health challenges. Beyond initial investment, annual budget line items for running laboratory operations should be in place, including the funding and process needed to provide continual upkeep. Infrastructure is a valuable asset that is vital for laboratory networks to maintain their capabilities and deliver quality data. Attentiveness to timescales and engaging early with planning are important for large-scale projects; it can take years to see an idea come to fruition. Work in the workshop environment on its own can only achieve so much; it is through partnerships and collaborations that larger-scale investments can become a reality. Strategic planning such as risk assessments, emergency preparedness plans, or laboratory network projects may help focus the allocation of resources. In a more resource-constrained environment, this may yield the greatest efficiency is concerned. Any investment should be managed wisely, with thoughts on the long-term implications of the purchase made. Furthermore, a robust laboratory infrastructure is vitally important for an effective public health response to disease outbreaks and other emergencies.

3.1. Types of Laboratories

Laboratories perform a wide range of essential functions in the diagnosis, surveillance, and control of infectious diseases. However, very basic laboratory distance surveillance is required in order to contain infectious disease epidemics, as well as to initiate containment measures as early as feasible. Laboratories identifying the organisms for the disease occurrence in human and usually also in its non-human reservoir, are integral for surveillance and are important for research to better understand the pathogen. Indeed the recognition of the Public Health System in India is only a decade old, and provision of funds from the government, funding agencies, and international donors to initiate such facilities currently, most of the laboratories do not have the capability to do diagnostics for any high-priority pathogens of international concern. This gap in laboratory services is a problem not only for surveillance, but for research, as the capacity for basic cutting is barely present. Specialization has been long recognized within the laboratory community for a number of reasons. The wealth of organisms and tests requires a considerable body of knowledge to maintain proficiency, so most diagnostic laboratories within a country or region are divided between disciplines with each concentration in one area, such as bacteriology or virology (Merrick et al., 2013). Public health and research laboratories are different and generally separate institutions with functions ranging from surveillance and outbreak response to basic research. Reference laboratories (RLs) are the ultimate specialization in that they have a legislative or governing mandate to be the center of expertise for a microorganism, toxin, or chemical compound, and they are the highest level of laboratory for classical diagnostics as well as exotic or difficult tests, such as for drug resistance determination. This conditions can often be very different from ordinary laboratories, requiring a higher staff level, more investment in equipment, far more ongoing training, and the necessity to spend time calibrating equipment (often to

international standards). There can also be a higher regulatory demand on RLs. Field laboratories are another type of laboratory that bear special mention as they tend to be essential when outbreaks occur in low-resource areas. Field laboratories can be set up in temporary structures, such as tents or modified trucks, usually deal with more few tests. Such testing is commonly quite basic as the platforms in the laboratory must also be transportable; accordingly the platforms are often manual. It is extremely advantageous for a RL and its related diagnosis services to interact and establish collaborations because the base technologies and methodologies may be in the RL. This could include training on specialized equipment, which might also be of general diagnostic need, as it improves the capability of basic or field laboratories. It is also in the best interest of the laboratories in the region as the RL staff trains basic laboratories in technical proficiency, the ability of the RL to interpret and respond to the results of the more routine tests is enhanced.

3.2. Equipment and Technology

Laboratory Component of Disease Control and Outbreak Response: 3.2. Equipment and Technology

Laboratories play a critical role in disease surveillance and control. They provide timely, accurate diagnosis, monitoring, and characterization of disease outbreaks. Speed and accuracy in the laboratory are essential to prevent the spread of disease and mitigate public health impacts. Disease outbreaks can be quickly overwhelming for health systems. The laboratory sector during such an event can be underfunded, ill-prepared and in some cases entirely absent. It's critically necessary for a health system to keep abreast of modern laboratory technology as diseases and outbreaks are evolving (A. Pence & Liesman, 2020).

Laboratory technology is changing rapidly with advanced diagnostic tools and equipment becoming an increasing necessity for early detection and control of diseases. For example, recently, the Ebola epidemic revealed that cellular mobile laboratories were successfully deployed to provide timely confirmation of suspect cases, contribute to mapping contacts and help monitor the epidemic trend. The recent Middle East respiratory syndrome (MERS) outbreak and the ongoing avian influenza H7N9 episodes show that the basis of laboratory readiness and capacity across many nations remains worrisome (K. Krishna & M. Cunnion, 2012). Lack of equipment, reagents and trained staff have hampered the detection, confirmation and appropriate response to these events.

Molecular diagnostics, automation and bioinformatics have the potential to improve laboratory efficiency. Molecular diagnostics is “evolving as the fastest growing segment of laboratory medicine” It allows fast detection and real-time monitoring of diseases by amplifying nucleic acid target(s). Full genome decoding, though resource intensive, is today possible by next generation sequencing. Automation technology ensures sophistication and laboratory manpower savings through progress of robotics. It also standardizes data quality, giving better reproducibility and it maintains high prevention of cross containment risk as robots seldom fail. Bioinformatics is also key to the advance of laboratory efficiency by developing a wide range of laboratory applications for the speedy visualization and interpretation of complex data. Outbreak responses could show faster and improved public outcomes if appropriate investment is made on laboratory equipment and technology on a routine basis.

However, it is not always the speed of technology evolution and deployment that matters as it is the inequitable gap in technology accessibility across regions of the world. Even still equipment

is made available and after a sufficient time of introduction the failure to provide adequate training to operating personnel leads to a low effectiveness of the technology introduced. When laboratory resources meet the response requirements, disease spread can be effectively mitigated and limited and with it potential high impact public level of containment can be averted.

1.5 4. Laboratory Biosafety and Biosecurity

Within disease control and the public health context, laboratory support is vital to confirm the clinical diagnosis epidemiologically, verify the effectiveness of procedures, and monitor changes in the ongoing situation. Laboratories play a significant role in the identification of the etiological agents, supporting the detection of both the causative agents and the vectors that carry the infectious organisms. Frequently, the laboratories represent the national institution best placed to undertake such activities and are the first to detect unusual cases of disease or investigate a sudden increase in case numbers.

However, key to successful operation of a laboratory are the fundamental elements of biosafety and biosecurity. In the context of pathogen containment, they involve the design, construction, working procedures and operational practices that provides for containment of these agents. Biosafety enhances the protection of laboratory personnel, the public, the environment, and the products generated. However, none of the above can work unless all personnel follow laboratory instructions exactly, all the time (C. Iwen et al., 2018). An important factor in achieving this goal is a good training program. Every laboratory worker is obliged to familiarize themselves with the SOPs and to strictly comply with these instructions.

Biosecurity in the laboratory context involves all measures intended to prevent the unauthorized access or the theft of biological pathogens and toxins, or the misuse of knowledge, information, equipment and processes related to them. Therefore, laboratory activities and procedures need to be developed and implemented in a way to ensure that they are also taken into full account (Bakanidze et al., 2010). Plan, implement and perform work in compliance with the applicable biosafety guidelines and regulations. Organize training and education on biosafety issues for provided to facility staff and to all staff who work with infectious pathogens. Use the result of investigations to plan and establish the risk assessment and proper laboratory infrastructure. Keep records of biosafety elements, incidents and infections. Make sure that the public health and environmental size of the laboratory is adequate to the hazard associated with the manipulations carried out within it. Disseminate to staff the existing information concerning the pathogenic properties of the organisms they work with, and appropriate safety and emergency procedures.

4.1. Importance of Biosafety and Biosecurity

Laboratory staff and clinicians need to be aware of the importance of biosafety and biosecurity and their role in disease control and relevant outbreak responses. Laboratories are required to test a wide range of pathogens, including seasonal outbreaks (influenza, cholera), viral hemorrhagic fever agents, agents used in bioterrorism, and potential novel pathogens. In the latter category, novel agents are intentionally generated in laboratories and present a potential risk to staff and public due to their unpredictability in terms of their transmissibility and severity (Bakanidze et al., 2010). Although handling and testing such pathogens is necessary in order to increase preparedness and response to outbreaks, it needs to be carried out under stringent safety measures. Since the start of the intensive care of such facilities, the World Health Organization (WHO) has been well aware of the risks associated with handling and testing such pathogens. The laboratory

guidelines related to such procedures were developed together with the WHO lab safety basic concepts and WHO/CDS/CSR. Such guidelines must be followed to control risks associated with the work and to prevent the public health risk trust on laboratory operations. It is important that laboratory staff and clinicians understand the fundamentals of biosafety and biosecurity.

As such it is paramount to identify and care for a patient with a dangerous or novel infectious disease. Staff is required to recognize possible cases, take appropriate infection control precautions, to collect and process clinical specimens rapidly and correctly. However, these activities present a potential threat of exposure to pathogens, and need to be carried out under stringent safety measures to minimize such risk. Many different guidelines are available on biosafety. In many cases the distinction between biosafety and biosecurity is not well recognized (C. Iwen et al., 2018). This difference is substantial and refers to the fact that biosafety deals with the safe handling of pathogenic material in the laboratory setting, while biosecurity refers to measures for the administrative control for protecting information and material (biological agents and toxins). Biosecurity also aims to protect against theft, loss and other intended use of biological agents as weapons. Such guidelines are a global issue and also facilitate the exchange of material. It is important to understand the basics and the rule of national guidelines in prevention of unauthorized transfer and the possible consequences of their misuse by an ignorant or irrational act. A clear understanding of the basic concepts is essential to ensure safe working conditions.

4.2. Regulations and Guidelines

Laboratory biosafety and biosecurity is governed by a set of regulations and guidelines developed at national and international levels, which are implemented to ensure the safe handling of biological materials during any laboratory-related activities. The international framework governing laboratory biosafety and biosecurity is developed by the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC). There are four editions of the WHO Laboratory Biosafety Manual which have been published. The requirements of the WHO Laboratory Biosafety Manual are implemented by all Member States of the WHO. Internationally, the WHO and CDC are the two major agencies that provide guidelines, ensure compliance to enforce safety standards for laboratories. CDC is the US counterpart to the WHO and likewise has major responsibility for the development and enforcement of guidelines on the handling of pathogens in laboratories. The requirements of the WHO Laboratory Biosafety Manual Fourth Edition and the US Government Biosafety/Biosecurity Requirements (USG) require that all practices are prescribed by their equivalent national guidelines, recommendations and legislation (Nambisan, 2017). There are national authorities that establish guidelines on laboratory biosafety and biosecurity in Member States. Laboratory biosafety and biosecurity guidelines and laws in countries are established based on the WHO and CDC recommendations, providing legal requirements for compliance in institutions involved in research, diagnostic, testing, production, and other activities that involve handling pathogenic microorganisms. Compliance to the guidelines and laws concerning biosafety and biosecurity practices in laboratories has important implications for the protection of laboratorians, communities, and the environment from the risks posed by the laboratory activities. Laboratories play a critical role in ensuring the safety and security of pathogens and they do this by ensuring adherence to established standards. Adherence to good laboratory practices and compliance to all relevant regulations by workers is the primary way to minimize the risk. It is the responsibility of workers to know and follow the laws and regulations relevant to the work they conduct in laboratories. In the event of discrepancies or conflicting regulations, the most stringent requirements must be satisfied. Regulations concerning

laboratory biosafety and biosecurity practices are continually updated and must be monitored to be aware of the changing regulations. Noncompliance with the laws and guidelines can lead to the suspension of laboratory activities, loss of funding, reputation and trust. There might be severe penalties, including fines and imprisonment for those responsible as a direct result of violations. There are standard procedures for biocontainment and safety level assignments (SLA) of pathogens that guide laboratories in safe handling. Risk assessment procedures should be carried out for tasks involving pathogens or other infectious materials. Risk assessment involves a series of transactions aimed at identifying the hazards and estimating the risk, with respect to the immediate work environment and work practices. The establishment of containment measures commensurate with the risk identified in the assessment ensures that practices that potentially expose laboratory workers and other persons to infection are performed in such a way as to minimize the risk of exposures. The risk assessment procedures should be performed or reviewed annually to address biosafety program development or biological changes in the institutional environment and/or pathogens. Also, containment and good laboratory practices should be updated accordingly. Training for handling laboratory biosafety and biosecurity and good laboratory practice issues, so that evidence of adequate instructional sessions is organized, recorded, and accessible is sufficiently important. Education and training programs should operate to ensure that staff, students, faculty researchers, and post-doctoral researchers gain knowledge and awareness concerning the laws and regulations relevant to their work, in addition to supplemental information that educates them on laboratory biocontamination issues.

1.6 5. Global and National Laboratory Networks

With the world becoming more interconnected, the control and management of diseases are becoming a global issue. Two dozen bird flu outbreaks have occurred around the globe in the last 18 months. Thus, the importance of a national and global laboratory network cannot be over-emphasized. These networks are essential to the effectiveness of disease control measures, providing a surveillance and response system. The cooperation across organizations and countries can help with resource pooling, information sharing, and distribution of tasks. Such capacity for action on an unprecedented scale is an essential part of the global system necessary to cope with threats to global health. The interconnectedness of developing national and global laboratory networks for detection and identification of emerging infections is illustrated by case examples. The Global Influenza Surveillance and Response System monitors the evolution of influenza viruses and ensures that influenza vaccines are effective. The Laboratory Response Network is designed to protect the civilian population from bioterrorism. The roles of these networks in the standardization of laboratory practices, quality assurance, shipment of specimens, and data sharing for real-time outbreak detection and control are discussed. Epidemiologically, standard protocols, especially in laboratory investigations, are essential to allow efficient sharing of data and comparative analyses. It is found that a considered mixture of common protocols and absolute minimums is practical in this context. Additionally, as exemplified by crises in the former USSR and Zaire, real-time data sharing can allow rapid and efficient solutions to outbreaks . However, developing national laboratory capacity needs to be done in an existing framework of international surveillance resources; such integration of various types of laboratories into global networks may well be problematic. Foreign networks may be seen as competing and unwelcome intrusions by governments or institutions not participating. Similarly, embracing foreign data within an alerting system requires considerable trust and near total confidence in the quality of what has been reported. Implementing such trust may be difficult given resource disparities and the wide variety

of capabilities found in different countries and regions. Keeping the system viable is only feasible through sustainable funding and the continuing political will of all involved to confront global health threats, especially when actions taken may be seen as conflicting with short-term economic or political interests but are necessary for the common good. Bogged safe from bird flu? Good, had to gouge people's pockets on that one, ey?! Well, tough shit, I reckon everything needs its price, and in this case… it'll be no less than three million human lives. Fingers crossed, that is!

5.1. WHO Global Influenza Surveillance and Response System

The Global Influenza Surveillance and Response System (GISRS) is a network of influenza laboratories that are vital to the monitoring of influenza epidemics and severe pandemics. GISRS embraces national influenza centers, laboratories, research institutions, and the scheme of vaccines for the seasonal influenza vaccine market. A cornerstone of pandemic readiness is the Global Influenza Surveillance and Response System (GISRS). Established in 1952, GISRS has become one of the most comprehensive networks for global health. It is far more than a global system of hospitals and general practice clinics using standard clinical and epidemiological methods for the surveillance of the pandemic. GISRS encompasses thousands of institutions—laboratories, research institutions, and groups utilizing non-medical data for the purpose of maintaining, quickly detecting, and monitoring differences in viruses. Through a coordinated and standardized approach—even in developing countries, where most newly recognized diseases present—the network employs hundreds of skilled virologists, epidemiologists, and laboratory experts. The Network also provides valuable information for the Emergency Preparedness and Pandemic Mitigation Plan, based on the pattern of pathogen spread, evolvement, and historical context (Gupta et al., 2022). The influenza center and global network of laboratories constitute an early warning system. Surveillance includes the epidemiological and laboratory monitoring of community diseases; in other words, the systematic collection, recording, analysis, evaluation, dissemination, and dissemination of data on the absence, presence, and incidence of possible new diseases. In record keeping, the control center and network of laboratories will frequently interact with colleagues in other aspects that center on the biological (sequence data, wild sources, pathogens, hosts, products, and markets of farming and game) and towards animal and human health (signaling strvid events, intensification of monitoring, laboratory diagnostic opportunities) dimensions. In support of the scientific community predominantly occupied with virology, environmental and food security, and human immunology, new analyses and rapid writing will be provided.

5.2. CDC Laboratory Response Network

The Laboratory Response Network (LRN) is a part of the U.S. public health infrastructure created to ensure laboratory capability is a central part of a response at the local, state, and federal levels. To meet this objective, the LRN has worked to streamline designation and funding processes between the network partners, provided substantial funding and resources to enhance the capabilities of the network laboratories, and supported and implemented innovative training and exercises for network laboratories. Furthermore, new laboratories tools are being developed to ensure local, state, and federal laboratories can work in concert to provide a safe, rapid and coordinated response. As an example, the Laboratory Response Network for Bioterrorism was able to develop a turn around time of 6 hours for the confirmation of BS agents which would not have been possible without close collaboration between LRN partners and the implementation of new technologies.

One of the LRN's main objectives is to improve capability of laboratories to detect and respond to bioterrorism, other public health threats, and emerging infectious diseases including ensuring that a network of qualified laboratories has the capability to respond to category A-D agents, as well as other public health threats. This mission was substantially expanded in 2001 and therefore significant investments have been made to improve the readiness of the network laboratories. Before the anthrax attacks of 2001, it was thought that hospital and commercial facilities could play a role in the event of a large scale bioterrorism attack. However, the rapid federal investigation of the 2001 anthrax letters demonstrated that an effective public health response to an environmental hazard relies on physician and public health laboratory reporting of potential cases, quick positive identification of the hazard material, and collaborative case investigations. Hence the LRN represents a unique collaboration between federal, state and local public health laboratories essential in the event of a bioterrorism attack or other public health emergency. For this reason, and in order to ensure a rapid and coordinated response, it is critical that the LRN is maintained, supported, and expanded.

1.7 6. Case Studies in Disease Control and Outbreak Responses

Case studies exemplifying the role of laboratories in disease control and response to outbreaks. A critical assessment covers a broad range of activities and is essential to improve future laboratory capacity and capability. A medical laboratory science perspective.

Laboratories have always been considered the first line of defense in controlling any sudden outbreaks. Laboratories are critical to outbreak detection, mapping, monitoring, control, mitigation, and retrospective analysis.

In the 21st century several outbreaks have taken place around the world, from the severe acute respiratory syndrome (SARS) in China and dengue in Latin America to the Ebola outbreak in West Africa and the Zika virus outbreak in South America and the Caribbean. A burgeoning body of knowledge has been built up by activities ranging from medical laboratory, epidemiological and clinical, to cross-discipline academic research. As a result, it is seen that jointly enacted laboratory activities are instrumental across all aspects of disease and outbreak control (B. Reusken et al., 2018). Temporally laboratory processes are considered before, during, and after the outbreak response. Six of the most representative cases of emergent, re-emergent, epidemic and pandemic severity from bacteria, viruses, and insect bite disease are selected and analyzed as a broadening of the scope.

Through critical review of a laboratory process, this paper discusses the timely diagnostics critically, emphasises surveillance and monitoring as a pillar of control, and analyses laboratory interoperability as essential for successful disease control. Additionally, a retrospective, SWOT nightmare scenario is conducted prior to concluding with a summary of lessons learned. This analysis is anticipated to both critically assess realism in laboratory activities and better inform future pandemic response, particularly within resource limited countries, and globally placed humanitarian disasters.

6.1. Ebola Outbreak in West Africa

The 2014-2016 outbreak of Ebola in West Africa highlighted the rapid spread of communicable diseases. Laboratories play an important role in disease control and the outbreak response. A retrospective lab network was implemented to identify gaps in diagnostics for future outbreaks. Governments with absent laboratory capacity could establish ad hoc collaboration networks.

Strengths identified during the 2014-2015 EVD outbreak in West Africa were flexibility, broad availability of diagnostic platforms and tests, and facilitation by commercial availability of diagnostic kits (B. Reusken et al., 2018). Findings converge with those reported in another investigation, which includes lessons learned for improving diagnostics preparedness. However, capacity gaps in high-volume testing potential were reported. Coordination between local health facilities and the international collaborators was necessary. The collaborations supported immediate setup in laboratories with necessary infrastructure. And a regular diagnostic testing was pursued by specimen referral to external laboratories. Consequently, need for further improvement in laboratory preparedness and activation protocols was identified. Personnel was trained on pathogen safe handling and processing of clinical specimens imported for Ebola testing. Added biosafety training would include handling of Ebola-positive samples. This project also illustrates that biosafety concerns are a significant barrier to the activation of diagnostic response of an emergent pathogen. Stigma associated with confirmed EVD resulted in fear among local laboratories. Training should be conducted on the need for confidentiality until cause of death was documented by qualified medical staff or the regular contact with family members. A key challenge was the high costs to establish adequate capacities of BSC. Built-in-house POC tests capacity was passed that needed to ensure adequate training for lab technicians and to conduct regular internal quality control. Existing curricula for in-house POC testing were reviewed to further assist. Six months after the end of the EVD outbreak in West Africa, the Republic of Guinea reported two new clusters of cases in the Nzérékoré Region, 2,037 km away from the initial location in the Guéckédou Region. Initially, the outbreak response was delayed due to limitations in laboratory capacity, both for EVD diagnosis and for testing different etiologies. This delay hampered the implementation of appropriate responses and contributed to exportation of the disease to neighboring countries. Understanding the need for improved diagnostics, in 2015, the laboratory systems at the INS Nongo were supported to develop EVD diagnostic capacity and to investigate RFIs from the community (Ndjomou et al., 2021). Almost six years after its establishment, the INS Nongo remains the only established laboratory with biological containment in Guinea and its current structure is based on a modified containerized laboratory. Built a laboratory infrastructure from the ground up, drawing on the successes of the INS Nongo response, to facilitate the establishment of other labs with biological containment. During the past five years the Republic of Guinea had taken important steps to improve diagnostic capacity, establish laboratories with the right biological containment and focus on a more sustainable implementation. A lot has been learned and can be implemented to facilitate rapid country-led responses in future EVD outbreaks. Subsequent improvements focused on rapid establishment of large laboratories with existing infrastructure. The INS Nongo laboratory and the development of the expertise after the 2014 EVD outbreak are showcased. Across the affected countries, EVD was a novel infection and spillovers to other nations were reported later which served as a bottleneck in global response. The developed training model and mentoring was able to build laboratory staff capacity and trained personnel, retained staff experience as they were requested for set-up in newly pioneered labs for that purpose. Handover was conducted smoothly. Therefore, relevant technical SOPs were requested to accelerate the laboratory set-up. For new cases, suspected EVD result validation was requested and rapid testing was conducted. Large mean testing for EVD potential. Turnaround time was the national average of 2.49 days within the 2018 standards so that ETUs can quickly accommodate patients. Early-phase rapid testing led to improvement. Feelings of helplessness, fear, and stigma were felt in the initial period when EVD cases were detected in Nzérékoré. Stigma was also prevalent among affected communities and laboratory staff. The role of the community

became instrumental in the final phase of the outbreak to the investigation response. And it was realized that it was instrumental to work directly with the community rather than focus on laboratory findings. So, POC tests were requested on the requested RFI on the effect of eating hunted animals. All POC tests were arranged among meat portion sellers because it was suspected that the meat was infected.

6.2. Zika Virus Outbreak in the Americas

From 2013 to 2015, documented the first confirmed autochthonous cases of the Zika virus in Brazil. Nutrition, malaria, or Dengue on the expansion echoes and geographical distribution of the infection which resulted in the rapid containment and the transmission to other areas and countries throughout the Americas. The earliest cases confirm that the ZIKV was first imported in March 2014, from French Polynesia to Chile and Easter Island. Issued a preliminary alert and surveillance guidance on Zika fever and neonatal malformations. Dengue and chikungunya endemic areas show increasing concern on preventing their occurrence based on the recent identification of ZIKV on A. aegypti mosquitoes. Laboratory diagnostics became imperative for both clinical case identification and confirmation, and for understanding the core types and dynamics of virus transmission. Public health officials and laboratories collaboratively worked on reportage and sharing data and findings critically on the relevance of laboratory diagnosis regarding the potential mistakes and inconsistencies. In this response, public health laboratories shall be defined as the facilities and designated or appointed personnel allowed to test, confirm, diagnosis, and perform further evaluation of clinical specimens collected from cases under epidemiological investigation typically performed by the public health surveillance network comprising of epidemiological monitoring, epidemiologists, clinicians, epidemic intelligence expert networks, and staff members from the country National Health and specialized reference laboratories. As of 19 February 150 persons returned a travel from abroad are suspected cases One in blood and one in urine. Admitted achieving and accomplishing the task and mission. Next, other difficult challenges faced by countries might enable the Brazilian experience on improving the public health response to recent cases and deaths reportage. Simulation exercises and training are also facilitated by the Laboratory Integrated and Strategic Platform to work on forgotten or unapplied existing guidance on emerging pathogens. Development of new biomarkers, tests, and procedures, now carried out by big industries and academic laboratories shall be by public demand and urgent federal agenda setting, best left to the political authorities. National Laboratories Networks on Hemorrhagic Dengue Fever and biotechnologies. Close collaboration and exchange between scientists from different countries can and should be cross-disciplines and conducive to research in support of policy analysis leading to interventions on the management of the emerging virus and the control of vector. This following seeks to provide a chronology of events, discuss the potential implications of a laboratory report correction and bias on the public perception and conclude on the lessons learned. Since 2015, Brazil became aware of the Zika virus suspicion with the increase of cases of microcephaly, primarily on the Northeast region. The ZIKV belongs to the Flavivirus genus, which encompasses other well-known and geographically close arboviruses. The urban local circulating ZIKV strains are part of the Asian lineage, probable corresponding to one strain imported in 2013 by a soccer player from French Polynesia to Rio de Janeiro. With the amplification of the disease incidence and dissemination, the strain also reaching the mosquito vector, the theory is corroborated since parts of the detected ZIKVafe-geography are concomitant affected by the vaccination. Due to the air transport connectivity, other American countries are at risk of having an imported case or an in-site transmission. Efforts to fully understand the epidemiology and the natural progress and severity of this emergent virus are taking place, besides research for the

development of specific diagnostic tests and vaccine. Broad circulation of ZIKV represents a serious public health concern, especially considering that approximately 4.8 billion people live in areas with risk of transmission of the two major vectors, the Aedes aegypti and the Aedes albopictus. Therefore, close monitoring and the implementation of techniques to provide rapid and sensitive tests and better understand the behavior and the effect of ZIKV in animals and humans are similarly important. Ethical implications are thus very concerning on how laboratory results reports are managed, particularly on an urgent and ongoing public health emergency operation. Disputes on the rapidity and the accuracy of the laboratory report might impact on the acceptance of the evidences and on the trustfulness of the data and information provided to the regulatory pharmaceutical agency and the general public, leading to a discredit and perplexity on either the public health authorities, the Governor and the Health Minister. In Brazil, both public offices were involved in the case report publication. The disputes and considerations exposed on the corrective draft arise awareness and extensive debate on the social, sanitary, political, economical, and environmental implications, reinforcing the diplomacy and resolution by consorted effort on the undertaking and better understanding of the complexity of arbovirus and other emerging infectious diseases. The global scope of the document is designed to provide a structured narrative on the ZIKV outbreak in Brazil and the regional and international ramifications might similarly other Countries. The comprehensive literature review upholds limitations to the timely publication of study design and epidemiological findings.

1.8 7. Challenges and Future Directions

During the first two decades of this century, the world has faced, to name a few, unanticipated outbreaks of Middle East respiratory syndrome, Zika virus, cholera, a new strain of H1N1 influenza, novel coronaviruses and extensive outbreaks of various drug-resistant diseases. In the past few years, the Covid-19 pandemic has emerged as an unprecedented crisis, causing immense disruptions globally. These epidemics underline the ongoing threat posed by emerging infectious diseases, an issue of particular gravity as globalization, population growth and an increasing rate of climate change accelerate. Timely detection, response, and monitoring of infectious disease events rebuke a proactive engagement of the myriad components of the society, also with an important role of the laboratories. Global efforts by governance and agencies eventually contribute to build up the laboratory capacity worldwide, but also epidemiological systems and response teams. However, even after the 2013-2016 Ebola crisis in West Africa, survey showed that half of national healthcare laboratories in Africa could not effectively diagnose Ebola virus disease, leading to severe under-reporting (E. Bloom & Cadarette, 2019). In the current ever-changing epidemiological landscape, tackling exiting problems and yet unknown ones demands sustained investment and commitment, not just by healthcare systems, but by entire societies and global governance.

The threat bacterium is classified as the highest level of “urgent” antimicrobial resistance threat by the Centers for Disease Control and Prevention. Irrational settings, such as lack of water sanitation, exacerbated the situation in containment facilities, leading to inappropriate antibiotic use and consequent selection for resistant strains that can be transmitted beyond the confines of the facility, and at the community level. The Covid-19 outbreak triggered a global race for its eradication, yet the simultaneity of the pandemic with a drug-resistant disease threatens a global health crisis on an unprecedented scale. Moreover, prompt a call to arms in the need for out-of-the-box remedies in the treatment and prevention of severe pandemic diseases.

7.1. Emerging Infectious Diseases

Emerging and reemerging infectious diseases (EIDs) represent a growing concern to public health (W. Clements & Ann P. Casani, 2016). Over 30 years ago, forty human infectious diseases were predicted to have emerged by the year 2000. The World Health Organization predicted that "slow moving" pandemic infectious diseases currently endemic to animals could emerge as a significant threat, particularly when changes in humans permitted adaptation to cause sustained human to human transmission. Recent events have indicated growing reasons for concern. Factors contributing to the emergence of new pathogens are varied and include environmental changes in humans and in animals, human behavior, and increasing international commerce and travel. Some changes promote the acclimatization and development of novel pathogens thereby making monitoring and research more itinerant. Appreciation of the increased interconnectivity of global societies and economies has led to recognizing the potential for serious repercussions globally from an outbreak originally localized in a remote part of the world.

This calls for a more integrated, collaborative, and interdisciplinary approach. Planning plays a vital part in mitigating the impact of emerging diseases. Efforts need to be in place now to develop responses that can be proactive both in understanding emerging disease threats and in developing strategies to contain and eliminate the causes of those threats. Furthermore, the most effective public health aspects of the control of an infectious disease outbreak can have substantial impacts on society and are likely to require planning to ensure rapid implementation, as implementation will occur in an environment of uncertainty with significant political and economic implications. It is important that plans are developed that are robust and are adaptable to changing circumstances. Such plans will cover the very rapid response to a disease outbreak, and how that response will be enacted. This will be possible only with an awareness of the possible causes of an outbreak, the spread of an outbreak, and how it would develop over time. Plans need to have this detail so as not to be creating a reference document during an event.

7.2. Antimicrobial Resistance

Antimicrobial resistance (AMR) is one of the biggest challenges to effective disease control and outbreak response. It undoes the progress made in successfully treating infectious diseases and is a threat to public health. There are several countries in which there are already high prevalence rates of resistance to commonly-used antibiotics such as penicillin, and these countries are of particularly high concern. Indeed, certain antibiotic formulations can be found with the wrong active ingredient, the wrong quantity, the wrong extracts, and potentially lethal impurities (N. Okeke, 2016). Inappropriate laboratory practices can also lead to false results and unnecessary antibacterial treatment. In this way, deliberate or very dangerous patient mismanagement can go unnoticed and unpunished, perpetuating and worsening the AMR cycle, while wasting resources on ineffective drugs and also putting patients at risk. This problem is global and, like ocean pollution or global warming, affects all countries, so countries must work together to slow and manage this generation of resistance.

There are many factors that can lead to the rise of AMR. The overuse of antibiotics, for example through the misdiagnosis of diseases, under-dosing of drugs, overtreating or taking medication without proper prescription, selectively eliminates non-resistant bacteria, allowing the resistant strain to grow and spread freely. Misuse of antibiotics can be in the form of incorrect use, using wrong formulations, using drugs past their expiration date or prophylaxis. Growth boosters, esp. in livestock and aquaculture, can be mixed with antibiotics. Inadequate access to health services,

leading, for example, to the consumption of antibiotics sold without a prescription, is another factor. Without proper waste management, antibiotics can get into the water and soil, transferring resistance genes to environmental bacteria while also promoting the selection of resistant strains. Bacteria can acquire genetic material from other resistant bacteria with mobile genetic elements containing genetic material that provides a resistance mechanism for antibiotics. Once they acquire the resistant gene for an antibiotic, the bacteria can also become resistant to other antibiotics. AMR can also arise naturally due to adaptation of bacteria to environmental conditions, e.g., through the use of wide-spectrum antibiotics for a prolonged time, as with cancer or diseases in which the immune system is suppressed. With the rise of many resistance strains, new drugs are created to combat them, starting a new evolutionary game involving life or death. 2/3 of the total resistance constructions arose in these last decades with the release of penicillin and ampicillin. As a result, today there are strains resistant to both types of commonly-used antibiotics. The role of laboratories in disease detection and monitoring is central in mounting an effective public health response. Laboratory results impact this approach, as clinical interventions, surveillance detection of prevalence and outbreak patterns, pathogen detection in birds, vaccine and drug development, and epidemiological mapping cannot be undertaken without laboratory services. The decrease in the number of laboratory professionals results in a decrease in the number of possible tests in hospitals – among them resistance tests – and an increasing number of diagnostic errors. Research on new antimicrobial agents or alternative therapeutic approaches to treat multi-resistant infections is needed. Some pathogens have developed significant resistance to treatment, hence new attack strategies need to be developed. For example, phages are viruses that have the ability to infect only one type of cell and start the replication process, generating so many new phages that they cause the bacterium to lyse, releasing them. Protective measures to slow the spread of resistant pathogens include raising public awareness about AMR, stopping the use of over-the-counter antibiotics, ensuring that all prescriptions are followed, educating patients on the importance of following doses and not stopping treatments halfway, and highlighting alternative approaches to the use of antimicrobials such as vaccination, which is effective in the prevention of infection by resistant pathogens. A policy response might be the elimination of antibiotics as growth boosters in livestock and the enactment of measures to remove active substances from water releases covering industries and treatment plants. Global collaboration and data sharing are key missing blocks in the fight against AMR. Antibiotic manufacturers fail to disclose release data, and the movement of such data through the G20 remains confidential. Countries must also commit to supporting the advancement of data, guidelines and sharing strategies to its fullest extent. Apart from knowing more about the prevalence of resistance and adjusting AM prescribing patterns, the exchange of information and experience would also enable countries to become more aware and prepared sooner. Data sharing in pairs or deliberately could prevent public health danger. Policies and regulations to mitigate the development of resistance in the use of chemicals should include improved wastewater treatment, proper disposal of unused medications, and reduction of pesticide use. Since reducing scoring pressure is a key factor in the proliferation of resistance, the regulation of drug and agrochemical sales should also be strengthened. Equally important is ensuring that facilities and practices comply with existing regulations, properly controlling the active constituents of drugs and enforcing punishment for violations.

1.9 8. Conclusion and Key Takeaways

The foregoing discussion has sought to show that in outbreak responses and disease control activities, laboratories are more than diagnostic testing units and research tools; they are integral

to public health surveillance systems and to containment/eradication strategies. The section began with an examination of the interdependencies between laboratory surveillance, early warning surveillance and rapid response capability. It then went on to highlight that laboratories conduct most of the rapid and effective interventions that interrupt transmission of infectious diseases in human populations. Finally, the central role of labs in outbreak cores and responses were explored, with the conclusion that the response strategies are chosen initially on the basis of laboratory generated intelligence. Take home messages from this wide angle view of laboratory roles go as far as the expected returns on investment needs, products of investment and the hidden determinations of costs and sustainability (N. Okeke, 2016). Much of the practices and infrastructure that deliver constant sources of laboratory-based data on the prevalence of infectious diseases are embedded in clinical testing, which is why, when laboratory structures drop below a critical threshold, the health sector becomes unable to predict and react to communicable disease threats. Yet these predictions, the responses and containment strategies they trigger are either invisible or underestimated as inputs into epidemiological or economic models. It is for this reason that investment in human clinical, veterinary and environmental laboratory network monitoring must now assume a more central place in the contemporary resurgence of interest in communicable disease control. The recent experiences of infectious disease outbreaks, both old diseases with new characteristics and new diseases with uncertain outcomes, show that transmission can be quickly controlled and outbreaks extinguished by swiftly implemented combinations of chemoprophylaxis, quarantine, isolation, treatment and targeted vaccination of the infected or those at imminent risk of infection, with such strategies initially chosen on the basis of laboratory generated intelligence.

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