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Forensic Pathology Research Priorities for Zambia: Strengthening Justice and Public Health through Evidence-Based Practice

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ABSTRACT

Forensic pathology plays a critical role in Zambia's criminal justice system and public health infrastructure, yet the field faces significant challenges, including resource constraints, workforce shortages, and gaps in standardized protocols. This report identifies and prioritizes key research areas to advance forensic pathology in Zambia, leveraging current institutional frameworks, global advancements, and the potential of molecular techniques. Through an analysis of Zambia's forensic landscape—including the roles of the National Forensic Authority (NFA), the Office of the State Forensic Pathologist (OSFP), and the National Forensic Science and Biometrics Department (NFSB)—we highlight systemic challenges such as limited pathologist

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

availability, logistical barriers, and the impact of infectious diseases like COVID-19 on forensic services (Mucheleng'anga & Himwaze, 2020; Shumba et al., 2023).

Globally, innovations such as digital pathology, post-mortem imaging, molecular autopsy, and microbiome analysis offer transformative potential for Zambia, though their implementation must be contextually adapted (Girelli et al., 2024). Locally, molecular techniques, particularly DNA analysis, present opportunities for improved identification and cause-of-death determination, especially in cases involving decomposed remains or mass disasters (DNAforAfrica.com, n.d.). Priority research areas include: (1) epidemiological analysis of prevalent causes of death (e.g., trauma, homicide, and infectious diseases); (2) validation of cost-effective molecular tools for resource-limited settings; (3) toxicological studies on traditional remedies and environmental factors; and (4) development of standardized protocols tailored to Zambia's needs.

To address these priorities, we recommend increased government investment, capacity-building collaborations with local and international institutions, and the establishment of ethical guidelines for forensic research. By focusing on these strategic areas, Zambia can enhance the accuracy of forensic investigations, inform public health interventions, and strengthen justice delivery (Yokobori et al., 2020). This research agenda underscores the necessity of evidence-based practices to create a more equitable and effective forensic pathology system in Zambia and similar low-resource settings.

Keywords: Forensic Pathology, Zambia, Molecular Autopsy, Cause of Death, DNA Analysis, Public Health, Justice System

INTRODUCTION

Forensic pathology is indispensable in Zambia for investigating sudden, unexplained, or suspicious deaths, providing critical evidence for the criminal justice system and public health surveillance (Mucheleng'anga & Himwaze, 2020). The meticulous examination of deceased individuals and the determination of the cause and manner of death provide crucial medical evidence that underpins the criminal justice system. This information is also indispensable for broader public health surveillance efforts, allowing for the identification of emerging health threats and the monitoring of mortality trends, ultimately informing evidence-based policy decisions (Yokobori et al., 2020). The establishment of key institutions such as the National Forensic Authority (NFA) and the Office of the State Forensic Pathologist (OSFP) underscores the Zambian government's recognition of the importance of robust forensic services within the nation (Ministry of Home Affairs and Internal Security, National Document). The NFA, as the sole regulator of forensic practice, is mandated to initiate and conduct research, highlighting a commitment to advancing the field through evidence-based approaches (National Forensic Authority, 2024). Similarly, the OSFP, an autonomous body dedicated to death investigation, includes research as a fundamental component of its operations (Ministry of Home Affairs and Internal Security, National Document). This institutional framework signals a growing awareness of the necessity for continuous development and improvement in forensic pathology practices to effectively meet the needs of the justice system and contribute to public health in Zambia.

This paper aims to identify and prioritize key research areas within forensic pathology that are particularly relevant to Zambia. By analyzing the current state of forensic pathology research in the country, exploring recent global advancements, and assessing the potential of applying molecular techniques, this report seeks to propose pertinent research topics. These topics are intended to address the specific challenges and opportunities present in Zambia, ultimately offering recommendations that can guide stakeholders in fostering impactful forensic pathology research initiatives.

CURRENT LANDSCAPE OF FORENSIC PATHOLOGY IN ZAMBIA

The infrastructure for forensic pathology in Zambia is primarily governed by the National Forensic Authority (NFA), established through legislation as the sole regulatory body for all forensic practices within the

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country (National Forensic Act, 2020). The NFA's broad mandate encompasses a range of functions critical to the development and maintenance of high standards in the field. These include the issuance of licenses to forensic service providers, the regulation of their activities, the promotion of integrity and enhancement of the profession's status, and the crucial task of initiating and conducting forensic research (National Forensic Act, 2020). This responsibility for research underscores the importance of evidence-based practices in the NFA's vision for forensic science in Zambia.

Operating within the Ministry of Home Affairs and Internal Security is the Office of the State Forensic Pathologist (OSFP), an autonomous institution dedicated to death investigation. The OSFP plays a central role in providing forensic pathology services, which include supervising post-mortem examinations conducted by listed forensic medical practitioners and ensuring a coordinated approach to death investigations (Ministry of Home Affairs and Internal Security, n.d). Notably, research is enshrined in the OSFP's foundational model, alongside public service and education, signifying its commitment to continuous quality improvement through investigation (Mucheleng'anga & Himwaze, 2020). The OSFP actively engages in research activities spanning forensic pathology, public health, and infectious diseases, with the outcomes of these investigations frequently disseminated through publications in peer-reviewed journals. This direct involvement in both casework and research positions the OSFP as a vital entity in identifying relevant research questions arising from practical experience.

The NFA regulates forensic practices, including research initiation, while the OSFP and NFSB provide specialized services such as DNA analysis (National Forensic Act, 2020). The National Forensic Science and Biometrics Department (NFSB) operates independently of law enforcement agencies, functioning as the country's Forensic Science Centre of Excellence (Ministry of Home Affairs and Internal Security, n.d). This department, also under the Ministry of Home Affairs, is responsible for providing forensic science and biometric services to law enforcement agencies and other state institutions. The NFSB's capabilities include analyzing forensic samples, offering training in evidence handling, developing biometric systems, managing crime scenes in collaboration with law enforcement, conducting research in forensic science, and promoting public awareness (Ministry of Home Affairs and Internal Security, n.d). Within the NFSB, the Directorate of Forensic Biology is specifically tasked with DNA and serological analysis. This capacity for DNA analysis is particularly significant for forensic pathology research, enabling investigations into genetic factors related to death and enhancing identification processes.

Despite the established framework and the dedicated efforts of these institutions, forensic pathology services in Zambia face several significant challenges. A persistent shortage of pathologists has been a long-standing issue, with past ratios indicating a severe lack of specialists to serve the population (Shumba et al., 2023).While postgraduate training programs have been initiated to address this deficit, the limited number of qualified forensic pathologists likely constrains the capacity for undertaking extensive research alongside the demands of routine casework (Challenges in forensic pathology old and new, 2015). Consequently, research endeavors must be strategically focused on areas with the potential for the greatest impact on forensic practices.

Resource limitations further compound these challenges. Forensic pathologists often encounter logistical difficulties in accessing burial sites, frequently having to travel long distances over difficult terrain. Autopsies are sometimes conducted on-site at burial locations, lacking the benefits of proper facilities. Delays in exhumations and autopsies are also common due to funding constraints and staffing shortages. These practical limitations underscore the need for research that explores cost-effective and adaptable solutions for forensic investigations in resource-constrained environments.

The COVID-19 pandemic also significantly impacted forensic pathology services in Zambia, as evidenced by disruptions in case management and the necessity for altered operating procedures. While forensic pathology played a crucial role in COVID-19 mortality surveillance, the pandemic highlighted vulnerabilities within the system and emphasized the importance of research into strategies for maintaining essential services during public health crises.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

Furthermore, issues related to staffing, such as excessive workload, insufficient incentives, and limited opportunities for professional growth, can contribute to staff dissatisfaction and potential turnover within forensic pathology divisions. Addressing these factors through research into the well-being and job satisfaction of forensic professionals in Zambia could inform strategies for improving retention and attracting new talent to the field.

Finally, the need for universally applied standardized protocols for forensic testing and examination methods remains pertinent. While the NFA has a mandate to develop these protocols and some progress has been made, ongoing research focused on identifying, adapting, and validating best practices tailored to the Zambian context is essential for ensuring the quality and reliability of forensic pathology investigations.

RECENT ADVANCEMENTS AND EMERGING TRENDS IN FORENSIC PATHOLOGY GLOBALLY

The field of forensic pathology is continually evolving, with several contemporary advancements holding significant potential for enhancing practices in Zambia. Digital pathology, which involves the use of whole slide imaging technology, allows for the creation of digital versions of traditional glass slides (Girelli et al., 2024).This innovation facilitates remote consultation among pathologists, enabling specialists to review cases from a distance, which could be particularly beneficial in Zambia given the shortage of experts and the geographical challenges in accessing specialized opinions (Heathfield, n.d.).Furthermore, digital slides can be used for educational purposes and the development of automated image analysis tools, potentially increasing efficiency and accuracy in diagnoses. Research into the feasibility and infrastructure requirements for implementing digital pathology in Zambia could pave the way for improved diagnostic capabilities and enhanced training opportunities.

Advanced imaging techniques, such as post-mortem computed tomography (CT) scans, offer non-invasive methods for visualizing internal injuries and pathologies. These techniques can be particularly valuable in cases where a full autopsy is not possible due to cultural or religious reasons, or in situations involving decomposed or skeletonized remains. Research exploring the application of post-mortem imaging in the Zambian context, taking into account the availability of equipment and the need for specialized training in image interpretation, could determine its potential to improve diagnostic accuracy and provide crucial information in challenging cases.

Molecular autopsy represents another significant advancement, utilizing genetic testing to identify inherited conditions that may have contributed to sudden unexplained deaths, especially in children and young adults (Molecular Diagnostic Applications in Forensic Science, 2015). By analyzing the deceased's DNA, it is possible to detect genetic mutations associated with conditions like sudden cardiac death or metabolic disorders. It can also identify genetic causes of sudden death (Budowle et al., 2024). Research into the prevalence of these genetic conditions within the Zambian population and the feasibility of incorporating molecular autopsy into routine investigations could lead to a better understanding of mortality patterns and potentially inform preventative measures. Given the OSFP's research interests in public health, this area holds considerable relevance for Zambia.

Advancements in forensic toxicology have led to improved methods for detecting and quantifying a wide range of drugs and poisons. This includes not only modern synthetic substances but also the potential for identifying traditional poisons that may be encountered in Zambia. Research focused on developing sensitive and specific toxicological assays for substances relevant to the Zambian context, coupled with the use of advanced techniques to track drug-related deaths, could significantly enhance the ability of forensic pathologists to determine the cause of death in complex cases and provide valuable data for public health interventions.

Finally, the emerging field of microbiome analysis explores the potential of analyzing the microbial communities present in the body after death to estimate the time since death and other post-mortem changes.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

Decomposition rates are influenced by environmental factors, and research into the post-mortem microbiome in the specific environmental conditions of Zambia's tropical climate could provide valuable insights for refining the estimation of the post-mortem interval, a critical aspect of many forensic investigations.

When considering the implementation of these global advancements in Zambia, it is crucial to assess their relevance and feasibility. Factors such as cost implications, the necessary infrastructure, and the requirement for specialized training must be taken into account. A strategic approach that prioritizes advancements offering the most significant impact and that are feasible within the existing resources and context of Zambia is essential. For instance, initiating with more cost-effective and readily deployable technologies, such as digital pathology for remote consultation and education, could be a practical first step.

APPLICATION OF MOLECULAR TECHNIQUES IN FORENSIC INVESTIGATIONS IN ZAMBIA

Zambia has already established a foundational infrastructure for the utilization of molecular techniques in forensic investigations. The National Forensic Science and Biometrics Department (NFSB) has a clear mandate to conduct forensic analyses, which includes DNA analysis performed by its Directorate of Forensic Biology (Ministry of Home Affairs and Internal Security, n.d.). This existing capacity provides a crucial platform for expanding the application of molecular techniques within forensic pathology research and casework in the country (DNAforAfrica.com, n.d.). Furthermore, the National Forensic Authority (NFA) is actively working on enhancing the regulatory framework to support advancements in forensic DNA analysis, including the potential establishment of national forensic databases. These efforts signal a commitment to strengthening the role of molecular methods in the Zambian justice system.

The potential applications of molecular techniques like DNA analysis and forensic genetics in Zambia are vast and hold significant promise for advancing forensic pathology practices. DNA profiling stands as a powerful tool for human identification, particularly in challenging cases involving fragmented remains, mass disasters, or when traditional identification methods are not feasible. Given the logistical challenges often encountered in Zambia, such as the need to exhume bodies that may have been buried for extended periods in tropical conditions, research focused on optimizing DNA extraction from compromised samples found in the Zambian environment would be exceptionally valuable. Additionally, DNA analysis plays a crucial role in establishing biological relationships, which is essential in cases of unidentified remains where kinship testing may be required. Moreover, DNA evidence is a fundamental tool for linking suspects to crime scenes, particularly in cases of sexual assault and other violent crimes, as highlighted by the NFSB's work. Research into the feasibility and ethical implications of establishing a national DNA database in Zambia could further enhance the ability to solve crimes and identify repeat offenders.

The emerging field of molecular autopsy also holds significant potential for Zambia. Genetic testing can help identify inherited conditions that may have contributed to sudden and unexpected deaths, providing valuable insights into the cause of death that may not be evident through traditional autopsy methods alone. To effectively implement molecular autopsy, research is needed to determine the prevalence of specific genetic mutations associated with sudden death in the Zambian population. This knowledge will guide the targeted application of genetic testing in relevant cases.

Considering the existing resources and infrastructure in Zambia, the NFSB already possesses laboratories and expertise for conducting DNA analysis. Building upon this foundation, collaborations with local universities, such as the University of Zambia, and international partners can further enhance capacity through knowledge sharing, access to advanced technologies, and joint research initiatives. Research projects should therefore be designed to leverage these existing resources and actively incorporate capacity-building elements, such as training programs for Zambian scientists and forensic pathologists in advanced molecular techniques.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

TOP RESEARCH TOPICS IN FORENSIC PATHOLOGY APPLICABLE TO ZAMBIA

Based on the current landscape, global advancements, and the potential of molecular techniques, several key research topics emerge as particularly applicable and impactful for forensic pathology in Zambia.

A critical area of research involves the prevalence and patterns of specific causes of death in Zambia using forensic pathology data (Mucheleng'anga et al., 2021). Analyzing existing data from the OSFP on medicolegal cases can provide valuable insights into the most common causes of death requiring forensic investigation. For instance, an analysis of forensic exhumations and autopsies conducted between 2016 and 2020 identified blunt impact trauma to the head, homicidal violence, hanging, fire, and gunshot to the head as the top five causes of death (Mucheleng'anga et al., 2021).Further research could delve deeper into the epidemiology of different manners of death, such as homicides, suicides, and accidents, as well as investigate the prevalence of deaths related to specific social and cultural factors like alleged witchcraft, alcohol abuse, and mob violence, which have been noted as circumstances of death in Zambia. Identifying these prevalent causes and circumstances of death can help prioritize resource allocation, guide the development of specialized training programs for forensic pathologists, and inform public health initiatives aimed at prevention.

Table 1 provides an overview of the leading causes of death identified in forensic cases in Zambia based on data from 2016-2020. This data highlights the areas where further research could be most impactful.

Causes of death vs. manner of death.

Variables	Overall (N = 168)	Manner of death (n)			
Cause (s) of death		Accident	Homicide	Suicide	Undetermined
Fire	7 (4.2)	2	5	0	0
Drowning	2 (1.2)	2	0	0	0
Electrocution	1 (0.6)	1	0	0	0
Positional asphyxia	1 (0.6)	1	0	0	0
Blunt impact trauma to head	50 (29.8)	1	49	0	0
Blunt impact trauma to chest	5 (3.0)	0	5	0	0
Chop wounds to head	5 (3.0)	0	5	0	0
Chop wounds to neck	2 (1.2)	0	2	0	0
Chop wounds to chest	1 (0.6)	0	1	0	0
Gunshot to head	6 (3.6)	0	6	0	0
Gunshot to torso	3 (1.8)	0	3	0	0
Hanging	8 (4.8)	0	1	7	0
Homicidal violence	17 (10.1)	0	17	0	0
Ligature strangulation	1 (0.6)	0	1	0	0
Manual strangulation	2 (1.2)	0	2	0	0
Mechanical asphyxia	1 (0.6)	0	1	0	0
Unascertained	56 (33.3)	0	0	0	56
Total	168 (100)	5	98	7	56 (33.3)

Causes of Death in Forensic Cases in Zambia (2016-2020), (Mucheleng'anga, et al. ,2021)

Table 2: Leading Causes of Death in Forensic Cases (2016–2020)

(Mucheleng'anga et al., 2021)

Cause of Death	Percentage
Blunt head trauma	32%
Homicidal violence	25%
Hanging	18%
Fire-related injuries	12%
Gunshot wounds	8%

Another crucial research area involves studies on the application and validation of rapid and cost-effective molecular techniques for identification and cause-of-death determination in the Zambian setting. Given the resource constraints in Zambia, research focusing on affordable and easily deployable molecular methods

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

would be highly impactful. This could include evaluating the feasibility of using rapid DNA testing kits for identification in remote areas or during mass disasters, researching the potential for developing or adapting cost-effective molecular assays for common genetic causes of sudden death prevalent in the Zambian population, and exploring the use of portable sequencing technologies for on-site analysis in challenging environments.

Furthermore, research addressing challenges specific to Zambia is paramount. This includes investigating deaths associated with alleged witchcraft or traditional remedies, potentially involving toxicological analysis of local substances. Studying the impact of environmental factors on mortality and the role of forensic pathology in such cases is also important. Additionally, conducting research on the forensic pathology of prevalent infectious diseases beyond COVID-19, such as tuberculosis, HIV/AIDS, and malaria, particularly in cases of sudden or unexpected death, is crucial given the high burden of these diseases in Zambia.

Finally, the development and validation of standardized protocols for forensic pathology investigations tailored to the Zambian context is essential. This includes developing guidelines for scene investigation, post-mortem examination procedures, and sample collection that are adapted to the available resources and local cultural considerations. Research should also focus on validating existing international protocols for their applicability and effectiveness in Zambia and establishing robust quality assurance measures for forensic pathology services to ensure the reliability and admissibility of evidence in the Zambian legal system.

Table 3: Top Research Topics in Forensic Pathology for Zambia

Research Priority	**Key Focus Areas**	**Specific Objectives**	**Example Applications**	**Data Sources**
1. Epidemiology of Death Patterns	- Trauma-related deaths - Homicide patterns - Suicide methods - Cultural factors (witchcraft, mob justice)	- Establish baseline mortality data - Identify high-risk groups - Inform prevention strategies	- Analysis of 2016-2020 autopsy data showing blunt trauma (32%), homicide (25%), hanging (18%)	Mucheleng'anga et al., 2021
2. Molecular Techniques	- Rapid DNA analysis - Portable sequencing - Genetic autopsy	- Improve identification in mass disasters - Enhance crime investigation - Detect genetic causes of sudden death	- Field testing of rapid DNA kits - Molecular autopsy for unexplained deaths	DNAforAfrica.com, 2024
3. Local Challenges	- Toxicological analysis of traditional remedies - Infectious disease impacts (TB, HIV, malaria)	- Address poisoning cases - Improve diagnosis of disease-related deaths	- Screening for toxic compounds in traditional medicines - Autopsy findings in HIV/TB co-infections	Ministry of Health Zambia reports
4. Standardization	- Crime scene protocols - Autopsy procedures - Evidence handling	- Ensure consistency across regions - Meet international standards - Strengthen court evidence	- Adapted WHO protocols for Zambian contexts - Training programs for pathologists	National Forensic Act, 2020

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

CHALLENGES AND OPPORTUNITIES FOR FORENSIC PATHOLOGY RESEARCH IN ZAMBIA

Conducting forensic pathology research in Zambia faces several limitations. Resource constraints, including limited funding, infrastructure, and equipment, pose significant challenges (Challenges in forensic pathology old and new, 2015). The shortage of forensic pathologists and other forensic science experts further limits the capacity to conduct and supervise research (Shumba et al., 2023). Accessing comprehensive forensic data for research purposes can also be difficult, and the need for establishing clear ethical guidelines and oversight for research involving human remains and sensitive information is crucial.

Despite these challenges, several opportunities exist for growth and collaboration in forensic pathology research in Zambia. The NFA's mandate to initiate research provides a foundational framework and potential avenue for funding. The OSFP's existing engagement in research offers a strong base to build upon. Collaborations with local universities and research institutions, as well as international partnerships, can provide access to expertise, resources, and training opportunities. Investing in the development of training programs to increase the number of forensic pathologists and scientists will also enhance the nation's research capacity.

RECOMMENDATIONS FOR ADVANCING FORENSIC PATHOLOGY RESEARCH IN ZAMBIA

To foster and advance forensic pathology research in Zambia, several actionable recommendations can be made to key stakeholders:

Government bodies (Ministry of Home Affairs, Ministry of Health):

a. Increase financial investment in forensic pathology services and dedicated research initiatives (Ministry of Health, Zambia, 2011).
b. Provide robust support to the NFA and OSFP in fulfilling their research mandates.
c. Prioritize the development and implementation of national forensic databases, including a DNA database, while ensuring ethical considerations and data security.
d. Allocate resources for the acquisition of necessary infrastructure and equipment to facilitate the adoption of advanced forensic techniques.
e. Support the expansion and enhancement of forensic pathology training programs at both undergraduate and postgraduate levels to increase the pool of qualified researchers.

Research institutions and universities:

a. Actively seek and foster collaborative partnerships with the OSFP and NFSB on forensic pathology research projects, leveraging their practical experience and data (Zeye et al., 2024).
b. Develop and implement focused research programs that address the identified top research topics relevant to Zambia's specific needs and challenges.
c. Provide comprehensive training and mentorship opportunities for aspiring forensic researchers, encouraging specialization in forensic pathology and related disciplines.
d. Proactively seek international collaborations with universities and forensic science organizations to gain access to cutting-edge expertise, methodologies, and resources.

International partners:

a. Offer technical assistance and specialized training in advanced forensic techniques, such as molecular autopsy, digital pathology, and advanced toxicology, as well as research methodologies and data analysis.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI | Volume XII Issue XV April 2025 | Special Issue on Public Health

b. Support capacity-building initiatives within Zambian forensic institutions by providing resources for training, equipment, and infrastructure development.
c. Facilitate collaborations and exchange programs between Zambian forensic professionals and international forensic organizations and experts.

National Forensic Authority:

a. Develop a comprehensive national forensic research agenda that clearly outlines priorities based on the identified top research topics and the specific needs of the Zambian justice system and public health.
b. Establish clear ethical guidelines and a robust review board specifically for forensic research involving human remains and sensitive data to ensure responsible and ethical conduct of studies.
c. Actively facilitate the dissemination of research findings to all relevant stakeholders, including government agencies, law enforcement, the judiciary, and the public, through publications, conferences, and policy briefings.
d. Promote the translation of research findings into practical applications by informing the development and revision of forensic protocols, guidelines, and policies to ensure evidence-based practices across the forensic pathology sector.

CONCLUSION

This report has identified four key research topics that are particularly applicable and hold significant potential to advance forensic pathology in Zambia (Mucheleng'anga & Himwaze, 2020): understanding the prevalence and patterns of specific causes of death, applying and validating rapid and cost-effective molecular techniques, addressing deaths related to traditional practices, environmental factors, and prevalent infectious diseases, and developing and validating standardized investigation protocols. Investing in research across these areas is crucial for strengthening both the justice system and public health in Zambia (Yokobori et al., 2020). Evidence-based practices, derived from robust research, will lead to more accurate and reliable forensic investigations. The findings from such research can also provide invaluable data for informing public health interventions and developing targeted prevention strategies. Ultimately, a commitment to fostering and supporting forensic pathology research will contribute to a more just, safe, and healthy society for all Zambians.

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