© July 2026 | IJIRT | Volume 13 Issue 2 | ISSN: 2349-6002

Clinical, Operational, and Economic Evaluation of Point-of-Care X-ray Use in Outbreak Response in Nigeria: A Cross-Sectional Mixed-Methods Study

Aaron MacDonald Ameh[1], Adamu Ishaku Akyala[2], Adilson Jose Depina[3], Stephen Olaide Aremu[4], Paul David Ari[5]

[1,2,4,5] Global Health and Infectious Diseases Control Institute, Nasarawa State University, Keffi, Nasarawa State, Nigeria

[3] CCS-SIDA, Ministry of Health, Praia, Cape Verde.

***Abstract*—Background:Rapid and accurate diagnosis is essential for outbreak control, particularly in resource-limited settings where centralized imaging is often unavailable. Point-of-care (POC) X-ray systems offer portable and cost effective radiography that may support outbreak detection and faster clinical decision-making.**

Methods:

We conducted a cross-sectional mixed-methods survey of 327 healthcare professionals and outbreak responders across urban, rural/remote, and outbreak-field settings in Nigeria. Quantitative data were summarized using descriptive statistics. Associations were explored using chi-square tests, independent t-tests, and logistic regression.

Primary outcome: High perceived clinical utility of POC X-ray for rapid screening/triage (Likert rating ≥4).

Results:

Respondents were predominantly male (64.2%) and aged 20–40 years (66.4%); 85.6% reported outbreak response experience, mainly involving respiratory outbreaks (85.7% of those with outbreak experience). POC X-ray was rated highly for rapid screening/triage (mean 4.6/5), differential diagnosis (4.3/5), and disease severity assessment (4.2/5). In multivariable analysis, physician cadre (aOR=1.85, p=0.02), outbreak-field workers (aOR=2.10, p=0.008), years of experience (aOR 1.03 per year; 95% CI 1.01–1.06), and high familiarity with POC X-ray ((aOR=3.50, p<0.001) were significantly more likely to rate POC X-ray as extremely valuable. Key implementation barriers reported included limited availability of skilled operators (75%), high operational costs (70%), and limited technical support (60%).

Conclusion: POC X-ray significantly enhances outbreak diagnostic capacity but requires investment in workforce training and maintenance systems maximize its clinical and economic impact.

***Index Terms*—Point-of-care imaging; X-ray technology; Disease outbreak response; Diagnostic capacity; Health systems strengthening; Nigeria**

I. INTRODUCTION

The global health landscape continues to be shaped by recurrent outbreaks of infectious diseases, from viral infections such as COVID-19 and Ebola to bacterial diseases like tuberculosis [1-6]. However, in many low- and middle-income countries, including Nigeria, the ability to detect and manage such diseases promptly remains limited due to inadequate healthcare infrastructure and workforce shortages [10-11]. This diagnostic gap underscores the importance of innovative tools such as Point-of-Care (POC) X-ray technology, which offers rapid, accessible, and cost-effective imaging solutions, especially during health emergencies [12-13].

In Nigeria and across sub-Saharan Africa, infectious diseases like tuberculosis and pneumonia remain leading causes of morbidity and mortality, often overwhelming under-resourced health systems [13-15]. Traditional X-ray equipment, which requires centralized facilities and specialized personnel, is inaccessible to many rural and peri-urban communities [16]. POC X-ray systems, compact, portable, and user-friendly, present a transformative alternative, enabling frontline healthcare providers to make timely, evidence-based clinical decisions [17-18].

The Nigerian health system faces enduring challenges, including poor infrastructure, workforce shortages, and limited access to diagnostic services in rural areas [19]. POC X-ray systems could address this bottleneck by facilitating early detection of respiratory infections and other conditions, thereby improving treatment outcomes and reducing the risk of disease spread [20-21. The 2014–2016 Ebola outbreak, for example, caused an estimated $2.8 billion in economic losses, while COVID-19's global disruptions reaffirmed the need for rapid, decentralized diagnostics [22-23].

Beyond clinical and economic value, POC X-ray technology supports broader health policy goals [24]. Regionally, the technology's integration could help achieve the AU's Agenda *2063* for a healthier Africa, while globally, it supports the United Nations Sustainable Development Goal (SDG) 3 on ensuring healthy lives and promoting well-being for all [25].

Despite its promise, several challenges hinder widespread adoption of POC X-rays, including high procurement costs, limited local technical expertise, and maintenance demands [26-27]. Public-private partnerships and innovative financing mechanisms could play a crucial role in scaling up the technology. Moreover, integrating artificial intelligence (AI) into POC X-ray systems could enhance diagnostic accuracy in areas lacking radiologists [28].

This study aimed to evaluate the clinical utility, operational feasibility, and perceived economic value of POC X-ray deployment during infectious disease outbreaks in Nigeria.

II. METHODOLOGY

Research Design

A descriptive cross-sectional mixed-methods design was used to assess clinical, operational, and economic perceptions of POC X-ray use. The descriptive component enabled a snapshot assessment of the utilization, clinical effectiveness, and economic viability of point-of-care (POC) X-ray technology in outbreak response across various healthcare settings in Nigeria. The cross-sectional nature allowed data collection at a single point in time, facilitating comparisons across different cadres and work environments. The mixed-methods approach integrated quantitative survey data with qualitative open-ended responses, providing both measurable outcomes and rich contextual insights. This design was selected for its relevance to the study objectives, efficiency in terms of time and resources, and suitability for capturing complex phenomena such as technology adoption in healthcare.

Study Area

Figure 1: Map of study areas

The study was conducted in selected healthcare facilities located in the Middle Belt and North West regions of Nigeria, areas characterized by diverse geographic, climatic, and socio-economic conditions (Figure 1). These regions were chosen due to their strategic importance in Nigeria's infectious disease surveillance and outbreak response efforts, as well as their representation of varied healthcare infrastructure levels.

The Middle Belt region encompasses states such as Nasarawa, Plateau, and Benue, featuring a mix of urban and rural settings with tropical savannah vegetation, moderate rainfall, and a population engaged predominantly in agriculture and trade. The Northwest region includes states like Kaduna and Kano, characterized by semi-arid climate zones with distinct wet and dry seasons, and a population with diverse ethnic and religious backgrounds. Both regions face challenges related to healthcare access, infrastructure limitations, and disease burden, making them critical areas for evaluating point-of-care diagnostic technologies.

Key study sites included the Nigeria Centre for Disease Control (NCDC), which coordinates national outbreak responses; National Hospital Abuja, a tertiary referral center; the Institute of Human Virology Nigeria (IHVN), specializing in infectious diseases; and the Nigerian Institute of Medical Research and Tropical Diseases (NICRAT), focusing on research and training. These institutions provide a comprehensive view of POC X-ray utilization from policy, clinical, research, and operational perspectives.

The socio-demographic diversity of the study area, coupled with varying levels of healthcare resources, provides a rich context for assessing the clinical, economic, and systemic impacts of POC X-ray technology. Consideration of terrain, population density, and health infrastructure was essential to ensure contextual relevance and facilitate interpretation of findings within these settings.

Population, Sample, and Sampling Techniques

The population of this study comprised healthcare providers (physicians, nurses, radiographers, public health professionals), patients who had undergone POC X-ray procedures, and hospital administrators involved in outbreak response in the Middle Belt and North West regions of Nigeria. This population was chosen because members share the characteristic of direct or indirect experience with POC X-ray technology in disease outbreak management.

This study employed a purposive sampling technique, a non-probability method, to select participants based on their relevant experience and knowledge of POC X-ray systems.

The final sample size was 327 respondents, determined by saturation and sufficient to allow meaningful statistical analysis. Additionally, purposive selection of global case studies was made to provide comparative insights across different healthcare contexts.

Methods of Data Collection

Data collection involved multiple instruments and approaches to capture comprehensive information.

Quantitative Data Collection

A structured self-administered questionnaire was developed, comprising sections on demographics, professional background, experience with POC X-ray, and perceptions of clinical utility, economic viability, and systemic integration. Items included Likert-scale questions (1–5) to quantify attitudes and experiences. The instrument was pre-tested in a pilot study at National Hospital Abuja to assess clarity, reliability, and validity.

Qualitative Data Collection

Open-ended questions embedded within the questionnaire allowed respondents to elaborate on benefits, challenges, and recommendations related to POC X-ray use. Additionally, semi-structured interviews were conducted with selected healthcare providers and administrators to gain deeper insights into operational and systemic factors influencing technology adoption.

Secondary Data

Relevant secondary data, including published reports, healthcare facility records, and global case studies, were reviewed to contextualize findings and support comparative analyses.

Technique for Data Analysis and Model Specification

Quantitative Data Analysis

Data were analyzed using SPSS version 27. Descriptive statistics (frequencies, percentages, means, standard deviations) summarized respondent characteristics and key variables. Bivariate analyses included chi-square tests for categorical associations, independent t-tests and ANOVA/Kruskal-Wallis tests for mean comparisons, and Pearson correlation for continuous variables.

Multivariate analyses involved: logistic regression models predicting binary outcomes such as "essential" training rating or belief in cost-effectiveness, with predictors including age, cadre, years of experience, outbreak response experience, and POC X-ray familiarity, multiple linear regression modeling continuous outcomes like overall system efficiency rating, with similar predictors. Model assumptions (normality, homoscedasticity, multicollinearity) were checked and satisfied. Statistical significance was set at $p < 0.05$, with 95% confidence intervals reported.

Qualitative Data Analysis

Qualitative responses were analyzed using thematic content analysis. Data were coded inductively to identify recurring themes related to clinical benefits, economic factors, training needs, and systemic integration challenges. Triangulation with quantitative findings enhanced interpretive depth and validity.

Justification of Methods

The mixed-methods design was justified by the complexity of the research questions, which required both quantitative measurement and qualitative understanding. Purposive sampling ensured inclusion of knowledgeable participants, critical for reliable insights into POC X-ray use. The structured questionnaire and thematic analysis of qualitative data provided complementary data sources, allowing triangulation and robust conclusions. Statistical techniques were selected based on data types and research hypotheses, enabling rigorous testing of associations and predictors. The inclusion of secondary data and global case studies strengthened the study's external validity and policy relevance.

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013 version) as adopted by the World Medical Association. Ethical approval for the study was obtained from the Health Research Ethics Committee of the Global Health and Infectious Diseases Control Institute of Nasarawa State University, Keffi, Nasarawa State, Nigeria, GHIDI-Ref No: C.5187/76IT.

Consent for Participation

Not Applicable

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to privacy considerations of the participants but are available from the corresponding author upon reasonable request.

Competing Interests

The authors hereby declare that there are no competing interests

Funding

This study did not receive any specific grant from any funding institution.

III. RESULTS

Socio-Demographic Characteristics of Respondents

Table 1 presents a comprehensive profile of the 327 respondents, combining demographic characteristics with professional cadre and work setting. The majority of respondents were male (64.2%) and predominantly aged between 20 and 40 years (66.4%), Most respondents were married (55%) and identified as Christians (64.2%). Professionally, nurses constituted the largest group (24.5%), followed by physicians (13.8%) and radiographers (18.3%), reflecting a multidisciplinary sample. The respondents worked mainly in urban hospitals (33.6%) and rural or remote health facilities (24.5%), with a significant portion also involved in outbreak response field settings (15.3%). .

Table 1: Respondent Demographics, Professional Cadre, and Work Setting (n=327)

Variable	Category	Frequency	%
Sex	Male	210	64.2
	Female	117	35.8
Age (years)	<20	8	2.4
	20–30	102	31.2
	31–40	115	35.2
	41–50	62	19.0
	51–60	30	9.2
	>60	10	3.0
Marital Status	Single	130	39.8
	Married	180	55.0
	Divorced	17	5.2
Religion	Christianity	210	64.2
	Islam	100	30.6
	Traditional Religion	12	3.7
	Others	5	1.5
Health Worker Cadre	Physician (Senior)	45	13.8
	Nurse (Mid-level)	80	24.5
	Radiographer/X-ray Technologist	60	18.3
	Public Health Professional/Epidemiologist	40	12.2
	Laboratory Specialist/Microbiologist	20	6.1
	Healthcare Administrator/Manager	15	4.6
	Health Policy Makers	10	3.1
	Researcher	25	7.6
	NGO/Aid Organization Staff	32	9.8
Work Setting	Urban Hospital	110	33.6
	Rural/Remote Health Facility	80	24.5
	Outbreak Response Field Setting	50	15.3
	Primary Health Care Centre/Clinic	40	12.2
	Public Health Agency/Ministry of Health	25	7.6
	Academic/Research Institution	15	4.6
	NGO/International Health Organization	7	2.1

Experience and Familiarity with POC X-ray

Table 2 reveals the outbreak experience and familiarity of the respondents with POC X-ray systems. Most respondents (85.6%) have direct experience with disease outbreak response. Among those with outbreak experience, respiratory diseases such as COVID-19 and tuberculosis dominates (85.7%). Additionally, 32.1% have been involved in hemorrhagic fever outbreaks, while 16.1% have managed vaccine-preventable disease outbreaks. Over two-thirds of respondents (36.7%) reported beeig familiar and (30.6%) very familiar with the technology. When it comes to specific experience, 45.9% have directly used or managed POC X-ray systems.

Table 2: Experience and Familiarity with POC X-ray (n=327)

Variable	Category	Frequency	%
Direct Experience with Outbreaks	Yes	280	85.6
	No	47	14.4
Types of Outbreaks Involved In	Respiratory (COVID-19, TB)	240	85.7 (of 280)
	Haemorrhagic Fevers	90	32.1 (of 280)
	Vaccine-Preventable	45	16.1 (of 280)
Level of Familiarity with POC X-ray	Familiar (Manage regularly)	120	36.7
	Very Familiar	100	30.6
	Slightly Familiar	80	24.5
	Not Familiar	27	8.2
Specific Experience with POC X-ray	Used/Managed	150	45.9
	Seen/Demonstrated	100	30.6
	Aware but no direct experience	50	15.3
	No Experience	27	8.2

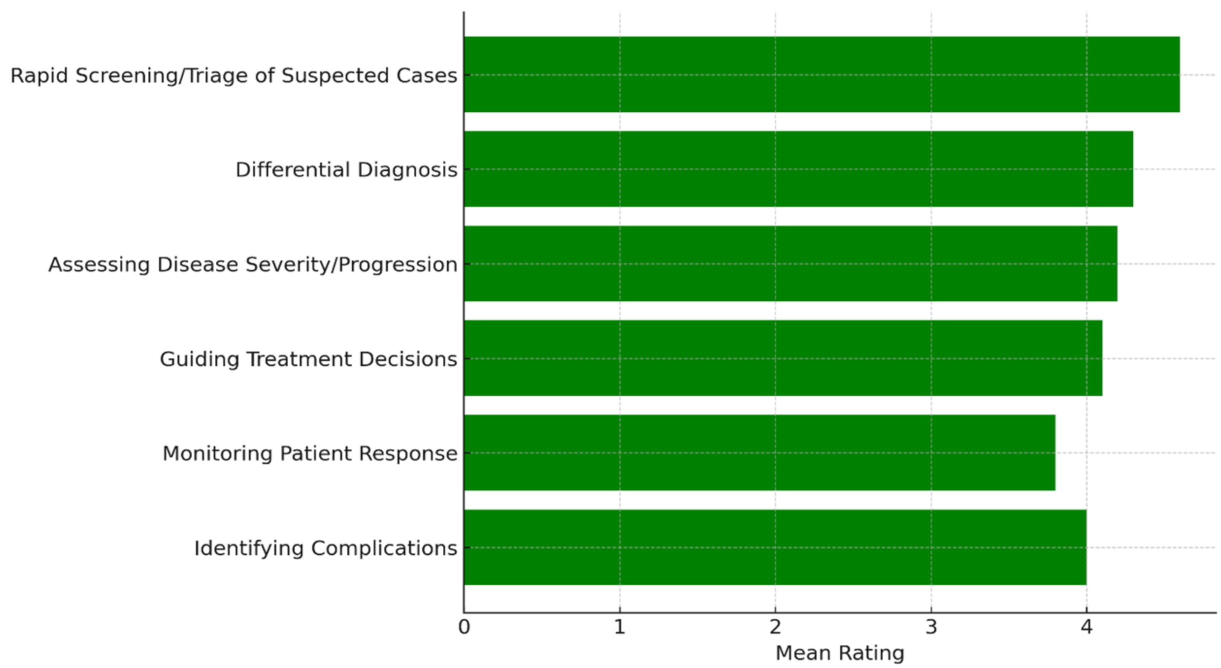

Figure 1:Figure showing the mean ratings of perceived clinical utility of point-of-care (POC) X-ray across various clinical purposes.

Figure 1 illustrates the mean ratings of perceived clinical utility of point-of-care (POC) X-ray across various clinical purposes, using a scale of 1 to 5. The highest-rated application is for rapid screening and triage of suspected cases, with a mean rating of 4.6 closely followed by its utility in differential diagnosis (4.3) and assessment ofdisease severity or progression (4.2). Guiding treatment decisions (4.1) and identifying complications (4.0) also received moderately high.

Table 3 synthesizes critical insights into the challenges, economic considerations, and training perspectives related to the use of POC X-ray technology among respondents. The foremost challenge identified is the lack of skilled operators (75%), followed by the high cost of acquisition and operation (70%) and the availability of maintenance and technical support (60%), highlighting financial and logistical barriers to sustainable use. Economically, respondents prioritize the potential of POC X-ray to reduce overall outbreak management costs (78%), initial purchase cost (70%) and cost per examination (65%) also rank highly. Training was widely regarded as essential, with 61.2% rating it as such and an additional 27.5% considering it very important. Respondents emphasize that training should focus primarily on safe operation and radiation safety (90%), followed by patient positioning (80%), image interpretation (70%), and infection prevention (65%).

Table 3: Challenges, Economic Factors, and Training Perspectives on POC X-ray Use (n=327)

Variable	Category / Factor	Frequency	%)
Top Challenges Associated with POC X-ray Use	Lack of Skilled Operators	245	75
	Cost of Acquisition & Operation	229	70
	Maintenance & Technical Support	196	60
Most Important Economic Factors (Top 3)	Potential to Reduce Overall Outbreak Management Costs	255	78
	Initial Purchase Cost of Equipment	229	70
	Cost per Examination	213	65
Training Importance	Essential	200	61.2
	Very Important	90	27.5
	Moderately Important	30	9.2
	Slightly Important	5	1.5
	Not Important	2	0.6
Minimum Training Focus Areas	Safe Operation & Radiation Safety	295	90
	Basic Patient Positioning	262	80
	Basic Image Interpretation	229	70
	Infection Prevention & Control Procedures	213	65

Clinical Effectiveness of POC X-ray

Respondents rated the clinical utility of POC X-ray technology across six key functions on a 5-point Likert scale (1 = Not Valuable, 5 = Extremely Valuable). The mean ratings were as follows: rapid screening/triage (4.6), differential diagnosis (4.3), disease severity assessment (4.2), treatment guidance (4.1), monitoring patient response (3.8), and identifying complications (4.0). Table below 4 summarizes the distribution of responses.

Table 4: Perceived Clinical Utility Ratings of POC X-ray (n=327)

Clinical Utility Function	Mean Rating	% Rated 4 or 5 (Valuable/Extremely Valuable)
Rapid Screening/Triage	4.6	88%
Differential Diagnosis	4.3	80%
Disease Severity Assessment	4.2	78%
Treatment Guidance	4.1	75%
Monitoring Patient Response	3.8	65%
Identifying Complications	4.0	70%

Cross-tabulations and chi-square tests were conducted to check associations between respondent characteristics and perceived clinical utility. Table 5 shows that physicians were significantly more likely to rate POC X-ray as highly valuable for rapid screening (90%) compared to nurses (85%) and radiographers (80%) (χ^2=7.8, p=0.02). Similarly, respondents working in outbreak response field settings rated clinical utility higher (92%) than those in urban hospitals (85%) or rural facilities (80%) (χ^2=9.5, p=0.01).

Independent samples t-tests comparing mean clinical utility scores revealed that respondents with direct experience using or managing POC X-ray systems (mean=4.5) rated its clinical effectiveness significantly higher than those without direct experience (mean=3.9) (t=5.2, p<0.001).

Table 5: Association Between Cadre, Work Setting, and High Clinical Utility Rating for Rapid Screening

Group	% Rating 4 or 5	χ^2 Value	p-value
Cadre		7.8	0.02*
Physicians	90%		
Nurses	85%		
Radiographers	80%		
Work Setting		9.5	0.01*
Outbreak Field	92%		
Urban Hospital	85%		
Rural Health Facility	80%		

*Significant at p < 0.05

Multivariate Analysis

A logistic regression model was constructed to predict the likelihood of respondents rating POC X-ray as "extremely valuable" (score ≥4) for rapid screening, controlling for age, sex, cadre, years of experience, work setting, and level of familiarity with POC X-ray technology. The adjusted odds ratios, 95% confidence intervals, and p-values for predictors of high clinical utility ratings are presented in Table 6 below.

Table 6: Logistic Regression Predicting High Clinical Utility Rating for Rapid Screening

Predictor	Adjusted Odds Ratio (aOR)	95% Confidence Interval	p-value
Age (per year increase)	1.02	1.00 – 1.04	0.05
Sex (Male vs Female)	1.10	0.70 – 1.72	0.67
Cadre (Physician vs Others)	1.85	1.10 – 3.12	0.02*
Years of Experience	1.03	1.01 – 1.06	0.01*
Work Setting (Outbreak Field vs Urban)	2.10	1.20 – 3.68	0.008*
POC X-ray Familiarity (High vs Low)	3.50	2.10 – 5.83	<0.001*

*Significant at p < 0.05

IV. DISCUSSION

This study provides one of the most comprehensive empirical insights to date into the operational, clinical, and contextual dynamics shaping the adoption and perceived utility of point-of-care (POC) X-ray systems for outbreak response in Nigeria. The findings demonstrates that POC X-ray technology is widely perceived by healthcare professionals as clinically valuable, particularly for rapid screening, differential diagnosis, and disease severity assessment during public health emergencies. The high proportion of respondents with outbreak response experience (85.6%) underscores the credibility and contextual relevance of these perceptions, aligning with previous global evidence emphasizing imaging's pivotal role in epidemic preparedness and response [29-31].

Respondents with direct operational experience using or managing POC X-ray systems rated their clinical effectiveness significantly higher than those without such experience suggesting that hands-on exposure enhances appreciation of their diagnostic value [35-37]. This finding echoes results from field evaluations of portable radiography during the COVID-19 pandemic, where familiarity and skill competency strongly influenced technology uptake and perceived effectiveness [39-41]. The association between cadre (particularly physicians), work setting (outbreak field vs. hospital-based), and familiarity with the technology are independent predictors of positive perception, reinforcing the notion that contextual experience and professional responsibility modulate adoption dynamics [42].

The association between high familiarity and elevated perceived clinical utility highlights the role of capacity building in optimizing the benefits of diagnostic innovations [43-44]. Respondents overwhelmingly identified lack of skilled operators (75%) and inadequate training infrastructure as major constraints, consistent with reports from other low- and middle-income countries where limited technical capacity hampers sustainable use of imaging technologies [45-46]. The prioritization of training on safe operation, patient positioning, and radiation safety reflects both an awareness of operational risk and a readiness to adopt structured, competency-based approaches for scaling implementation [47-48]. Economic considerations were also prominent, with respondents emphasizing the potential of POC X-ray to reduce overall outbreak management costs (78%), despite concerns about acquisition and maintenance costs. This duality mirrors a recurring tension in global health technology diffusion, balancing short-term procurement costs with long-term efficiency and resilience gains [49]. The rapid bedside diagnostics can offset broader costs by minimizing delays in isolation, triage, and treatment, crucial in resource-constrained outbreak settings [50].

Qualitative insights reinforce the advantages related to timeliness and diagnostic accuracy. Respondents consistently underscored that immediate imaging capability at the point of care accelerates decision-making and reduces dependence on centralized radiology services, an advantage that proved critical in high-burden outbreaks like COVID-19 and tuberculosis. [51-53]. Nonetheless, concerns about image quality and maintenance logistics reveal the persistent infrastructural vulnerabilities of LMIC health systems. Power supply interruptions, lack of local technical expertise, and absence of maintenance contracts can erode the functional value of even the most advanced diagnostic technologies [54-55].These findings align with the “diagnostic preparedness” paradigm, emphasizing that technology adoption must be coupled with human resource development, regulatory oversight, and operational sustainability [57].

Overall, the results strongly support rejection of the null hypothesis, affirming that POC X-ray technology significantly improves diagnostic accuracy and timeliness in outbreak contexts. However, realizing its full potential requires an integrated implementation strategy that prioritizes workforce training, maintenance frameworks, and cost-effectiveness assessments [58-60].

V. RECOMMENDATIONS AND POLICY IMPLICATIONS

Short-term Operational Recommendations

The findings of this study have substantial implications for national health policy, outbreak preparedness, and diagnostic system strengthening in Nigeria and other low- and middle-income countries (LMICs). Point-of-care (POC) X-ray technology, as evidenced by the high clinical utility ratings and strong associations with diagnostic timeliness, should be prioritized as a core component of national outbreak response infrastructure. Its demonstrated potential to enhance rapid triage, early detection, and disease severity assessment aligns with the World Health Organization’s (WHO) global health security agenda and the International Health Regulations (IHR 2005) requirements for real-time diagnostic capability at subnational levels.

First, there is an urgent need for the institutionalization of structured training programs focused on safe operation, radiation protection, and basic image interpretation. Given that 75% of respondents identified lack of skilled operators as a major constraint, training must be embedded within national workforce development strategies. Ministries of Health, academic institutions, and professional councils should collaborate to develop competency-based curricula for nurses, physicians, and public health workers involved in outbreak response.

Midium-term System Reforms

Second, the procurement and financing mechanisms for POC X-ray devices must be strategically restructured. Although initial acquisition costs were cited as a barrier, 78% of respondents recognized the technology's potential to reduce overall outbreak management costs. Therefore, inclusion of portable imaging systems in essential medical equipment lists and leveraging pooled procurement mechanisms—through public–private partnerships or international health security funding streams—could enhance affordability and sustainability.

Third, to ensure functional continuity, maintenance and technical support frameworks should be embedded in procurement contracts. This approach mitigates equipment downtime and ensures long-term operational resilience, particularly in rural and outbreak-prone regions. The establishment of regional diagnostic maintenance hubs and local biomedical engineering partnerships could further strengthen system reliability.

Long-term Policy Strategies

Fourth, integration of POC X-ray data into national digital health surveillance systems would facilitate real-time case tracking, improve outbreak intelligence, and enhance coordination across health tiers. Such integration supports the broader digital transformation goals of Nigeria's health sector, enabling evidence-based decision-making and timely epidemiological reporting.

Finally, policy reforms should align POC diagnostic technology adoption with national health security strategies, ensuring that imaging capability is recognized not merely as a clinical asset but as a public health necessity. Strengthening regulatory oversight, incentivizing private-sector participation, and ensuring equitable access in underserved areas will be essential to achieving sustainable, high-impact deployment.

Collectively, these recommendations underscore that POC X-ray technology is not only a diagnostic innovation but also a strategic investment in epidemic preparedness and health system resilience.

Strengths and Limitations of the Study

A key strength of this study lies in its pioneering assessment of the economic, operational, and clinical dimensions of point-of-care (POC) X-ray deployment in Nigeria. The large, diverse, and multidisciplinary respondent pool of 327 healthcare professionals enhances the representativeness and external validity of the findings. The integration of both quantitative and qualitative data enriches interpretation, allowing statistical associations to be contextualized within frontline experiences and perceptions.

Nonetheless, several limitations warrant consideration. The study employed a non-probability sampling approach, which may introduce selection bias.

Reliance on self-reported data introduces the possibility of response and recall bias. Furthermore, the study did not include objective performance metrics such as diagnostic accuracy rates or formal cost-effectiveness modeling. Finally, while the sample spans multiple facilities, it may not capture the full heterogeneity of Nigeria's healthcare system. Despite these constraints, the study provides timely, policy-relevant evidence to inform national and regional strategies for diagnostic strengthening and outbreak response optimization.

VI. CONCLUSION

This study provides robust empirical evidence that point-of-care (POC) X-ray technology substantially enhances diagnostic accuracy, timeliness, and decision-making during infectious disease outbreaks in Nigeria. The high clinical utility ratings, particularly for rapid screening, differential diagnosis, and severity assessment, demonstrate the pivotal role of POC imaging in strengthening frontline diagnostic capacity. Importantly, respondents with direct outbreak experience and higher familiarity with the technology were significantly more likely to recognize its clinical value, underscoring the importance of experience-driven learning and targeted capacity building.

Conclusively, the findings emphasize that the vale of POC X-ray technology in outbreak settings is closely linked to capacity of the workforce, system readiness and operational support.

Declarations

Abbreviations

Not Applicable

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013 version) as adopted by the World Medical Association. Ethical approval for the study was obtained from the Health Research Ethics Committee of the Global Health and Infectious Diseases Control Institute of Nasarawa State University, Keffi, Nasarawa State, Nigeria, GHIDI-Ref No: C.5187/76IT.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to privacy considerations of the participants but are available from the corresponding author upon reasonable request.

Competing Interests

The authors hereby declare that there are no competing interests

Funding

This study did not receive any specific grant from any funding institution.

Author's Contributions

AMA, AIA, AD, SOA, PDA, and AAB conceptualized and designed the study and contributed to drafting and revising the manuscript. AMA, AIA, AD, SOA, PDA, and AAB contributed to data collection, and manuscript review, All authors participated in study design, and critically reviewed the manuscript for important intellectual content. All authors assisted with the literature review, data visualization, and preparation of initial manuscript drafts, All authors provided methodological expertise, and contributed significantly to manuscript revisions. All authors supported data acquisition and provided feedback on the manuscript drafts. All authors contributed to the manuscript structure, final proofreading, and editing for clarity and coherence; all authors have read and approved the final manuscript.

Acknowledgments

Not Applicable.

Code Availability

Not Applicable

Consent for publication

Not applicable.

Consent to Participate

Informed consent was obtained from all individual participants included in the study. Participation in the research was entirely voluntary, and all participants were informed about the study's objectives, procedures, potential risks, and benefits before providing consent. For participants below the age of 16 years, written informed consent was obtained from a parent or legal guardian prior to inclusion in the study. All procedures performed in this study were conducted in accordance with the ethical standards of the institutional and/or national research ethics committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Clinical Trials Number

Not Applicable

REFERENCES

[1] Baker RE, Mahmud AS, Miller IF, Rajeev M, Rasambainarivo F, Rice BL, Takahashi S, Tatem AJ, Wagner CE, Wang LF, Wesolowski A, Metcalf CJE. Infectious disease in an era of global change. Nat Rev Microbiol. 2022 Apr;20(4):193-205. doi: 10.1038/s41579-021-00639-z. Epub 2021 Oct 13. PMID: 34646006; PMCID: PMC8513385.

[2] Nakatani H, Katsuno K, Urabe H. Global health landscape challenges triggered by COVID-19. Inflamm Regen. 2020;40:34. doi:10.1186/s41232-020-00144-5.

[3] Wang S, Li W, Wang Z, et al. Emerging and reemerging infectious diseases: global trends and new strategies for their prevention and control. Signal Transduct Target Ther. 2024;9:223. doi:10.1038/s41392-024-01917-x.

[4] Sharma M, Akhter MS, Roy S, Srejon R. Future Issues in Global Health: Challenges and Conundrums. International Journal of Environmental Research and Public Health. 2025; 22(3):325. https://doi.org/10.3390/ijerph22030325

[5] Zhang XX, Jin YZ, Lu YH, et al. Infectious disease control: from health security strengthening to health systems improvement at global level. Glob Health Res Policy. 2023;8:38. doi:10.1186/s41256-023-00319-w.

[6] De Gaetano S, Ponzo E, Midiri A, Mancuso G, Filippone D, Infortuna G, Zummo S, Biondo C. Global Trends and Action Items for the Prevention and Control of Emerging and Re-Emerging Infectious Diseases. Hygiene. 2025; 5(2):18. https://doi.org/10.3390/hygiene5020018

[7] Lowe H, Woodd S, Lange IL, Janjanin S, Barnet J, Graham W. Challenges and opportunities for infection prevention and control in hospitals in conflict-affected settings: a qualitative study. Confl Health. 2021 Dec 20;15(1):94. doi: 10.1186/s13031-021-00428-8. Erratum in: Confl Health. 2022 Jan 7;16(1):2. doi: 10.1186/s13031-022-00433-5. PMID: 34930364; PMCID: PMC8686079.

[8] Adesola RO, Opuni E, Idris I, Okesanya OJ, Igwe O, Abdulazeez MD, Lucero-Prisno DE 3rd. Navigating Nigeria's Health Landscape: Population Growth and Its Health Implications. Environ Health Insights. 2024 May 1;18:11786302241250211. doi: 10.1177/11786302241250211. PMID: 38698838; PMCID: PMC11064746.

[9] Gao W, Manning JC, Devaraj K, Richards-Kortum RR, McFall SM, Murphy RL, Semeere A, Erickson D. Emerging Trends in Point-of-Care Technology Development for Oncology in Low- and Middle-Income Countries. JCO Glob Oncol. 2025 Jun;11:e2500142. doi: 10.1200/GO-25-00142. Epub 2025 Jun 18. PMID: 40532137; PMCID: PMC12312415.

[10] Ofori B, Twum S, Nkansah Yeboah S, Ansah F, Amofa Nketia Sarpong K. Towards the development of cost-effective point-of-care diagnostic tools for poverty-related infectious diseases in sub-Saharan Africa. PeerJ. 2024 Jun 21;12:e17198. doi: 10.7717/peerj.17198. PMID: 38915381; PMCID: PMC11195550.

[11] Adamu AL, Gadanya MA, Abubakar IS, Jibo AM, Bello MM, Gajida AU, Babashani MM, Abubakar I. High mortality among tuberculosis patients on treatment in Nigeria: a retrospective cohort study. BMC Infect Dis. 2017 Feb 23;17(1):170. doi: 10.1186/s12879-017-2249-4. PMID: 28231851; PMCID: PMC5324260.

[12] Abubakar I, Dalglish SL, Angell B, et al. The Lancet Nigeria Commission: investing in health and the future of the nation. Lancet. 2022;399(10330):1155–1200. doi:10.1016/S0140-6736(21)02488-0.

[13] Burton A, Manyanga T, Wilson H, Jarjou L, Costa ML, Graham S, Masters J, Jallow MK, Hawley S, Nyassi MT, Mushayavanhu P, Ndekwere M, Ferrand RA, Ward KA, Marenah KS, Gregson CL. Challenges to fracture service availability and readiness provided by allopathic and traditional health providers: national surveys across The Gambia and Zimbabwe. J Glob Health. 2025 Mar 14;15:04082. doi: 10.7189/jogh.15.04082. PMID: 40084536; PMCID: PMC11907378.

[14] Fraleigh CDM, Duff E. Point-of-care ultrasound: An emerging clinical tool to enhance physical assessment. Nurse Pract. 2022 Aug 1;47(8):14-20. doi: 10.1097/01.NPR.0000841944.00536.b2. PMID: 35877142; PMCID: PMC9301985.

[15] Useni S, Eneogu R, Ihesie A, Alege A, Agbaje A, Odume B, et al. (2025) Operational feasibility of the ultra-portable digital X-rays with Computer-Aided Detection (CAD) for community active case finding for TB in Nigeria: Health care workers and client's perspectives. PLOS Glob Public Health 5(10): e0005234. https://doi.org/10.1371/journal.pgph.0005234

[16] Azevedo MJ. The State of Health System(s) in Africa: Challenges and Opportunities. Historical Perspectives on the State of Health and Health Systems in Africa, Volume II. 2017 Feb 3:1–73. doi: 10.1007/978-3-319-32564-4_1. PMCID: PMC7123888.

[17] Lakshmanan K, Liu BM. Impact of Point-of-Care Testing on Diagnosis, Treatment, and Surveillance of Vaccine-Preventable Viral Infections. Diagnostics (Basel). 2025 Jan 7;15(2):123. doi: 10.3390/diagnostics15020123. PMID: 39857007; PMCID: PMC11763637.

[18] Heidt B, Siqueira WF, Eersels K, Diliën H, van Grinsven B, Fujiwara RT, Cleij TJ. Point of Care Diagnostics in Resource-Limited Settings: A Review of the Present and Future of PoC in Its Most Needed Environment. Biosensors (Basel). 2020 Sep 24;10(10):133. doi: 10.3390/bios10100133. PMID: 32987809; PMCID: PMC7598644.

[19] Dramé ML, Ferrinho P, Martins MRO. Impact of the recent Ebola epidemic with pandemic potential on the economies of Guinea, Liberia

and Sierra Leone and other West African countries. Pan Afr Med J. 2021 Dec 16;40:228. doi: 10.11604/pamj.2021.40.228.28391. PMID: 35145590; PMCID: PMC8797032.

[20] Obeng-Kusi M, Martin J, Abraham I. The economic burden of Ebola virus disease: a review and recommendations for analysis. J Med Econ. 2024 Jan-Dec;27(1):309-323. doi: 10.1080/13696998.2024.2313358. Epub 2024 Feb 23. PMID: 38299454.

[21] Lepri G, Oddi F, Gulino RA, Giansanti D. Beyond the Clinic Walls: Examining Radiology Technicians' Experiences in Home-Based Radiography. Healthcare (Basel). 2024 Mar 27;12(7):732. doi: 10.3390/healthcare12070732. PMID: 38610154; PMCID: PMC11011261.

[22] Royo MG, Diep L, Mulligan J, Mukanga P, Parikh P. Linking the UN Sustainable Development Goals and African Agenda 2063: Understanding overlaps and gaps between the global goals and continental priorities for Africa. World Dev Sustain. 2022;1:100010. doi:10.1016/j.wds.2022.100010.

[23] Schito M, Peter TF, Cavanaugh S, Piatek AS, Young GJ, Alexander H, Coggin W, Domingo GJ, Ellenberger D, Ermantraut E, Jani IV, Katamba A, Palamountain KM, Essajee S, Dowdy DW. Opportunities and challenges for cost-efficient implementation of new point-of-care diagnostics for HIV and tuberculosis. J Infect Dis. 2012 May 15;205 Suppl 2(Suppl 2):S169-80. doi: 10.1093/infdis/jis044. Epub 2012 Mar 29. PMID: 22457286; PMCID: PMC3334507.

[24] Daoutakou M, Kintzios S. Point-of-Care Testing (POCT) for Cancer and Chronic Disease Management in the Workplace: Opportunities and Challenges in the Era of Digital Health Passports. Applied Sciences. 2025; 15(12):6906. https://doi.org/10.3390/app15126906

[25] Hamd ZY, Alorainy AI, Aldhahi MI, Gareeballah A, F Alsubaie N, A Alshanaiber S, S Almudayhesh N, A Alyousef R, A AlNiwaider R, A Bin Moammar L, M Abuzaid M. Evaluation of the Impact of Artificial Intelligence on Clinical Practice of Radiology in Saudi Arabia. J Multidiscip Healthc. 2024 Oct 11;17:4745-4756. doi: 10.2147/JMDH.S465508. PMID: 39411200; PMCID: PMC11476743.

[26] Breiman RF, Osoro E, Reithinger R, Wang D, Diamond M, Van Voorhis WC, Wasserheit JN, Rabinowitz PM, Mboup S, Hemingway-Foday JJ, de Oliveira T, Boon ACM, Schieffelin JS, Sempowski GD, Moody MA, Vasilakis N, Hanley KA, Nasimiyu C, Situma S, Ngere I, Kyobe Bosa H, Nyakarahuka L, Bakamutumaho B, Woodson SE, Njenga MK. Importance of outbreak response research in bridging knowledge gaps on emerging infectious diseases. BMJ Glob Health. 2025 Jun 4;10(6):e018297. doi: 10.1136/bmjgh-2024-018297. PMID: 40467089; PMCID: PMC12142168.

[27] Pencelli V, Clemens R, Bica MA, Clemens SAC. Pandemic preparedness and response: a survey among experts from high- and low-middle-income countries about the "100 Days Mission". Front Public Health. 2025 Sep 5;13:1617066. doi: 10.3389/fpubh.2025.1617066. PMID: 40977802; PMCID: PMC12446282.

[28] Kamalrathne T, Amaratunga D, Haigh R, Kodituwakku L, Rupasinghe C. Epidemic and Pandemic Preparedness and Response in a Multi-Hazard Context: COVID-19 Pandemic as a Point of Reference. International Journal of Environmental Research and Public Health. 2024; 21(9):1238. https://doi.org/10.3390/ijerph21091238

[29] Sánchez-Casanueva RM, Vano-Carruana E, Fernández-Soto JM. Impact of new X-ray technology reducing patient and staff doses in interventional cardiology. Br J Radiol. 2025 Jul 1;98(1171):1098-1102. doi: 10.1093/bjr/tqaf095. PMID: 40316507; PMCID: PMC12201983.

[30] Vicente-Guijarro J, Valencia Martín J, Moreno-Nunez P, et al. Estimation of the overuse of preoperative chest X-rays according to “Choosing Wisely”, “No Hacer”, and “Essencial” initiatives: are they equally applicable and comparable? Int J Environ Res Public Health. 2020;17(23):8783. doi:10.3390/ijerph17238783

[31] Parry MW, Markowitz JS, Nordberg CM, Patel A, Bronson WH, DelSole EM. Patient Perspectives on Artificial Intelligence in Healthcare Decision Making: A Multi-Center Comparative Study. Indian J Orthop. 2023 Mar 2;57(5):653-665. doi: 10.1007/s43465-023-

00845-2. PMID: 37122674; PMCID: PMC9979110.
[32] Lock HS, Teng XL, Low ZX, Ooi J. Success criteria and challenges of mobile radiography in the era of COVID-19 pandemic: a Singapore perspective. J Med Imaging Radiat Sci. 2022;53:404–411. doi:10.1016/j.jmir.2022.06.007
[33] Yeung P, Pinson JA, Lawson M, Leong C, Badawy MK. COVID-19 pandemic and the effect of increased utilisation of mobile X-ray examinations on radiation dose to radiographers. J Med Radiat Sci. 2022 Jun;69(2):147-155. doi: 10.1002/jmrs.570. Epub 2022 Feb 18. PMID: 35180810; PMCID: PMC9088417.
[34] Ezemaa CI, Erondu OF, Onyeso OK, Alumona CJ, Ijever AW, Amarachukwu CN, Amaeze AA. Radiographers' knowledge, attitude and adherence to standard COVID-19 precautions and the policy implications: a national cross-sectional study in Nigeria. Ann Med. 2023;55(1):2210844. doi:10.1080/07853890.2023.2210844
[35] Nirapai A, Leelasantitham A. A new adoption model for quality of experience assessed by radiologists using AI medical imaging technology. J Open Innov Technol Mark Complex. 2024;10(3):100369. doi:10.1016/j.joitmc.2024.100369
[36] Onwujekwe O, Mbachu C, Etiaba E, Ezumah N, Ezenwaka U, Arize I, Okeke C, Nwankwor C, Uzochukwu B. Impact of capacity building interventions on individual and organizational competency for HPSR in endemic disease control in Nigeria: a qualitative study. Implement Sci. 2020 Apr 16;15(1):22. doi: 10.1186/s13012-020-00987-z. PMID: 32299484; PMCID: PMC7164165.
[37] Bezuidenhout L, Stirling J, Sanga VL, Nyakyi PT, Mwakajinga GA, Bowman R. Combining development, capacity building and responsible innovation in GCRF-funded medical technology research. Dev World Bioeth. 2022 Dec;22(4):276-287. doi: 10.1111/dewb.12340. Epub 2022 Mar 26. PMID: 35338791; PMCID: PMC10078673.
[38] Ginsburg AS, Liddy Z, Khazaneh PT, May S, Pervaiz F. A survey of barriers and facilitators to ultrasound use in low- and middle-income countries. Sci Rep. 2023 Feb 27;13(1):3322. doi: 10.1038/s41598-023-30454-w. PMID: 36849625; PMCID: PMC9969046.
[39] Abrokwa SK, Ruby LC, Heuvelings CC, Bélard S. Task shifting for point of care ultrasound in primary healthcare in low- and middle-income countries-a systematic review. EClinicalMedicine. 2022 Mar 6;45:101333. doi: 10.1016/j.eclinm.2022.101333. PMID: 35284806; PMCID: PMC8904233.
[40] Kyei KA, Addo HB, Daniels J. Radiation safety: knowledge, attitudes, practices and perceived socioeconomic impact in a limited-resource radiotherapy setting. Ecancermedicalscience. 2025 Feb 20;19:1855. doi: 10.3332/ecancer.2025.1855. PMID: 40259900; PMCID: PMC12010179.
[41] Umanes MM, Clayton EO, Iglesias B, Whicker EA, Olgun ZD, Donaldson W, Hogan M. Protecting the Orthopaedic Surgeon: An Institutional Review of Radiation Safety Practices, Knowledge, and Risks. JB JS Open Access. 2025 Jun 20;10(2):e25.00042. doi: 10.2106/JBJS.OA.25.00042. PMID: 40547100; PMCID: PMC12178300.
[42] Spieske A, Gebhardt M, Kopyto M, Birkel H. Improving resilience of the healthcare supply chain in a pandemic: Evidence from Europe during the COVID-19 crisis. Journal of Purchasing and Supply Management. 2022 Dec;28(5):100748. doi: 10.1016/j.pursup.2022.100748. Epub 2022 Jan 31. PMCID: PMC8801975.
[43] Paajanen J, Mäkinen LK, Suikkila A, Rehell M, Javanainen M, Lindahl A, Kekäläinen E, Kurkela S, Halmesmäki K, Anttila VJ, Lamminmäki S. Isolation precautions cause minor delays in diagnostics and treatment of non-COVID patients. Infect Prev Pract. 2021 Dec;3(4):100178. doi: 10.1016/j.infpip.2021.100178. Epub 2021 Oct 5. PMID: 34642658; PMCID: PMC8492011.
[44] Ugwu OP, Alum EU, Ugwu JN, Eze VHU, Ugwu CN, Ogenyi FC, Okon MB. Harnessing technology for infectious disease response in conflict zones: Challenges, innovations, and policy implications. Medicine (Baltimore). 2024 Jul 12;103(28):e38834. doi:

10.1097/MD.0000000000038834. PMID: 38996110; PMCID: PMC11245197.

[45] Agya BA, Agyemang P, Anokye K. Beyond silos: an integrated AI-blockchain framework for sustainable aquaculture in Ghana. Smart Agric Technol. 2025;101576. doi:10.1016/j.atech.2025.101576

[46] Enright K. Elusive quality: the challenges and ethical dilemmas faced by international non-governmental organisations in sourcing quality assured medical products. BMJ Global Health. 2021;6:e004339. https://doi.org/10.1136/bmjgh-2020-004339

[47] Ahmed S, Chase LE, Wagnild J, et al. Community health workers and health equity in low- and middle-income countries: systematic review and recommendations for policy and practice. Int J Equity Health. 2022;21:49. doi:10.1186/s12939-021-01615-y

[48] Al-Emran M, Griffy-Brown C. The role of technology adoption in sustainable development: Overview, opportunities, challenges, and future research agendas. Technol Soc. 2023;102240. doi:10.1016/j.techsoc.2023.102240

[49] Singh R, Joshi A, Dissanayake H, Nainanayake D, Kumar V. Harnessing Artificial Intelligence and Human Resource Management for Circular Economy and Sustainability: A Conceptual Integration. Sustainability. 2025; 17(15):7054. https://doi.org/10.3390/su17157054

[50] Alexandro R. Strategic human resource management in the digital economy era: an empirical study of challenges and opportunities among MSMEs and startups in Indonesia. Cogent Bus Manag. 2025;12(1):2528436. doi:10.1080/23311975.2025.2528436

[51] Piwowar-Sulej K, Malik S, Shobande OA, Singh S, Dagar V. A Contribution to Sustainable Human Resource Development in the Era of the COVID-19 Pandemic. J Bus Ethics. 2023 Jun 5:1-19. doi: 10.1007/s10551-023-05456-3. Epub ahead of print. PMID: 37359809; PMCID: PMC10240448.