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Calibration of Medical Equipment and Quality Health Care Delivery: A Case of Hospitals in Sunyani Municipality

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Abstract

This study examines the impact of medical equipment calibration practices on the delivery of quality healthcare in Sunyani Municipality, encompassing existing procedures, the influence on healthcare quality and costs, and the challenges faced. A quantitative research approach has been utilized for this study. A sample of 394 staff members from the Bono Regional Coordinating Council, Sunyani Municipal Education Directorate, and Sunyani Municipal Assembly was selected using a simple random technique. A structured questionnaire served as the primary data collection instrument. Confirmatory Factor Analysis and Structural Equation Modelling, employing Partial Least Squares methodology, were employed for the data analysis. The findings of this study indicate that rigorous adherence to calibration schedules, coupled with robust quality control measures and ongoing training, is essential for achieving healthcare excellence in municipalities. Furthermore, the study established a significant positive correlation between proper calibration practices and increased healthcare quality, with long-term cost savings being a notable benefit. Despite these positive outcomes, healthcare institutions face challenges such as the lack of standardized protocols and financial constraints, which hinder the effective implementation of these practices. Therefore, this study calls for targeted strategies to enhance awareness and promote technological advancements, paving the way for innovative and quality healthcare in Sunyani Municipality. Future research could delve deeper into these critical aspects, fostering a healthcare system that embodies precision and innovation.

Keywords: Calibration Practices, Quality Healthcare, Healthcare System, Confirmatory Factor Analysis, Partial Least Squares

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Introduction

In the global healthcare landscape, the calibration of medical equipment is crucial for quality healthcare delivery (Nielsen & Sahay, 2022). This process ensures the accuracy and reliability of medical devices, facilitating precise diagnoses, effective treatments, and patient safety (Sivakumar et al., 2020; Al Awadh, 2022). As medical technology advances, the calibration process becomes increasingly significant, with global healthcare institutions emphasizing its importance (Gupta & Sarode, 2017). Proper calibration not only enhances patient safety but also adheres to international standards, contributing to accurate diagnosis, reduced healthcare costs, and increased patient trust (Godwin, 2023; Chow et al., 2023). Despite challenges such as the evolution of sophisticated equipment and associated costs, the importance of calibration in healthcare is undeniable (American College of Clinical Engineering, 2017).

Medical equipment calibration is crucial for accurate healthcare delivery, impacting diagnostic accuracy and patient safety (Sony et al., 2022; Pedersini, 2022). Empirical studies highlight its role in enhancing nursing care, influencing healthcare-seeking behaviors, and improving cost-effectiveness (Moyimane & Kekana, 2017; Rao et al., 2021; Chen et al., 2014; Kikutani, 2023; Kaur et al., 2018; Zare et al., 2023). Accurate calibration reduces diagnostic errors, enhances efficiency (Phuong et al., 2019), and can lead to significant financial savings through reduced equipment downtime (Jansen et al., 2018). It also facilitates precise diagnostics and personalized treatment plans, leading to better patient outcomes and cost savings (Loh et al., 2016). However, challenges exist, including lack of awareness among healthcare professionals (Belhouideg, 2020), equipment diversity (Selvaraj, 2019; Gong et al., 2019), financial constraints (Walsh et al., 2017; Hinrichs-Krapels et al., 2022), and inconsistent standards (Kawalec et al., 2021). To mitigate these, standardized protocols, comprehensive training programs, and investment in specialized expertise are recommended (Kawalec et al., 2021; Garzotto et al., 2020; Wiyor et al., 2019).

In Ghana, particularly in the Sunyani Municipality, the provision of quality healthcare and calibration of medical equipment are critical. The government has initiated various programs to improve healthcare delivery, focusing on infrastructure, medical equipment, and trained personnel (Oluwole et al., 2022). However, specific evidence regarding the importance of calibration in Sunyani is limited, indicating a need for further research. The Sunyani Municipality faces unique challenges in calibrating medical equipment, such as limited resources and technological constraints (Adam & Nwaogwugwu, 2020). Calibration practices must adapt to technological advancements to maintain healthcare quality and efficacy. The integration of advanced technologies is essential, highlighting the need for ongoing research in equipment calibration.

Studies worldwide emphasize the relationship between healthcare quality, equipment calibration, and patient satisfaction (Savitz, 2016; Karkee et al., 2014). In the United States, accurate calibration of medical equipment is crucial for quality healthcare delivery, leading to precise diagnoses and reduced medical errors, which also contribute to cost savings and efficient resource allocation while maintaining regulatory compliance and patient trust (Zamzam et al., 2021). These studies highlight the need to adapt calibration practices to technological advancements, emphasizing its critical importance in enhancing patient outcomes, optimizing healthcare costs, and upholding regulatory standards.

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Research in Africa, particularly in Kenya, Nigeria, and Malawi, underscores the vital role of adequate resources and infrastructure in quality healthcare delivery (Machira & Palamuleni, 2018; Oluwole et al., 2022; Adam & Nwaogwugwu, 2020). Properly calibrated medical equipment, alongside resource availability, is essential for effective healthcare delivery. Studies emphasize well-trained personnel and proper infrastructure as key factors, revealing the interplay between resource availability, equipment calibration, and healthcare quality, which is crucial for African healthcare systems.

Despite Ghana's ongoing efforts to improve healthcare services, specific research on the impact of equipment calibration on patient care is scarce, highlighting a research gap (Ganle et al., 2014). The government's initiatives focus on broader system improvements, yet detailed exploration of equipment calibration's role in quality healthcare delivery is lacking. Comprehensive studies on calibration's implications for patient outcomes, cost-effectiveness, and regulatory compliance are needed to inform evidence-based practices tailored to Ghana's context.

This paper addresses this research gap by focusing on the impact of medical equipment calibration on quality healthcare delivery within Sunyani Municipality, Ghana. It aims to provide insights that inform evidence-based strategies and policies tailored to the local healthcare landscape, enhancing healthcare quality in the region. The next sections will delve into the research methodology, present the results obtained and provide discussions of the findings based on related literature and practice.

Methods

In this particular investigation, quantitative approach was chosen due to the need for numerical data and the goal of extrapolating findings to the total human population (Ivankova & Wingo, 2018). In this study, the explanatory that uses a case study design was chosen to analyze a scenario and provide an explanation for existing correlations between variables (Zayed & Yaseen, 2020). The case study design enables the researchers to do an in-depth analysis of the variables under study by subjecting them to detailed analysis. the population was made of the core staff in the various hospitals in Sunyani Municipality. From Table 1, the total number of employees included in the population is 13

Table 1: Number of Staff in the Selected Public Sector Institutions

Name of Institution	Total Staff
Regional Hospital, Sunyani	793
Sunyani Municipal Hospital	303
SDA Hospital	189
Owusu Memorial Hospital	78
Cross Care Hospital	71
Healthlane Hospital	56
UENR Hospital	75
STU Hospital	69
Green Hill Hospital	51
Total	1685

Source: Field Data (2023)

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The researchers used established sample size formulas to determine the optimal number of participants for the investigation. Sample size is calculated from the following parameters: a population size of 1685, an error term of 0.05, or 5%, and the proportion of missing data: The sample size was determined by a mathematical formula given by Miller and Brewer (2003) as

$$n = \frac{N}{1+e^2}$$

Where n = Sample size
N= Population= 1685
e= Error term =0.05

$$n = \frac{1685}{1+ 1685(0.0025)}$$

$$n= \frac{1685}{5.2}$$

n= 324

The study expanded its initial sample size from 324 to 410 participants to enhance the robustness of its findings.

A random sampling technique was employed, allowing for unbiased selection of staff from three public sector institutions. Data was collected using questionnaires, which offered uniformity, consistency, and anonymity (Neelankavil, 2019; Groves et al., 2018). These questionnaires consisted of closed-ended questions based on a Likert scale, divided into five sections addressing demographics, calibration practices, quality healthcare delivery, healthcare costs, and challenges in calibration. Data analysis was conducted using IBM SPSS (version 26) and SmartPLS (version 3.3.3), employing descriptive and inferential statistics to analyse the relationships between the study's variables.

Results

In the initial phase of the study, a total of 410 questionnaires were distributed, with a remarkable return rate of 96%, equating to 394 completed questionnaires. This high response rate is indicative of a successful data collection strategy and enhances the reliability of the study (Al Khalaf et al., 2022). Despite a 4% return of incomplete questionnaires, the usable response rate remains at a commendable 96%, suggesting a robust dataset for analysis (Rasool et al., 2019).

Background Information of Respondents

The demographic data reveals an almost equal distribution of male and female healthcare personnel, with a slight female predominance, reflecting global trends in the healthcare sector (Al Khalaf et al., 2022). The workforce is predominantly youthful, with the majority aged between 21-40 years. Most personnel are relatively new to the field, with 43% having up to 5 years of service, indicating a dynamic workforce. The majority hold diploma certifications, with postgraduate qualifications being the least represented, suggesting potential for further educational advancement. Nurses and midwives constitute a significant portion of the workforce, with a noted need for increased doctor recruitment. The general department houses the largest number of staff, indicating a comprehensive healthcare system catering to diverse medical needs.

Table 2: Profile of Respondents

Variable	Characteristics	Frequency	Percent
Sex	Male	191	49
	Female	203	52
	Total	394	100
Age	21-30	198	50
	31-40	168	43
	41-50	28	7
	Total	394	100

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Table 2: Profile of Respondents (cont.)

Variable	Characteristics	Frequency	Percent
Years of Employment	Up to 5	169	43
	6-10	112	28
	11-16	85	22
	Above 16	28	7
	Total	394	100
Education	Certificate	108	27
	Diploma	171	43
	Bachelor	90	23
	Postgraduate	25	6
	Total	394	100
Occupation	Nurse	140	36
	Midwife	113	29
	Medical Doctor	29	7
	Technician	112	28
	Total	394	100
Department	General	95	24
	Maternity	57	15
	Laboratory	56	14
	X-Ray	53	13
	Emergency	49	12
	Optometry	42	11
	Dental	24	7
	ENT	18	5
	Total	394	100

Source: Field Data, 2023

Measurement Model Assessment

The study employed Partial Least Square-Structural Equation Modeling (PLS-SEM) considering key assumptions including multicollinearity, item loadings, construct reliability and validity, convergent validity. These assumptions were tested following the methodology of Henseler et al. (2009) to ensure accurate interpretation of the structural model results and to establish the study's validity and reliability.

Multicollinearity

In the field of statistical analysis, multicollinearity often poses a significant challenge when constructing robust models for complex phenomena such as healthcare delivery quality (Pallant, 2007). This study meticulously examined the Variable Inflation Factor (VIF) values associated with various constructs, including "Cost of Healthcare," "Calibration Practices," and "Quality Healthcare." The VIF values for all constructs were found to be significantly below the critical threshold of 10, indicating a lack of multicollinearity and thus ensuring the reliability of subsequent analyses. Specifically, the "Cost of Healthcare" construct exhibited VIF values ranging from 1.732 to 2.818, while the "Calibration Practices" and "Quality Healthcare" constructs demonstrated similar trends with VIF values well below the threshold. This suggests that the variables within these constructs can be confidently utilized in further analyses without the risk of inter-variable interference.

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Table 3: Multicollinearity amongst Variables

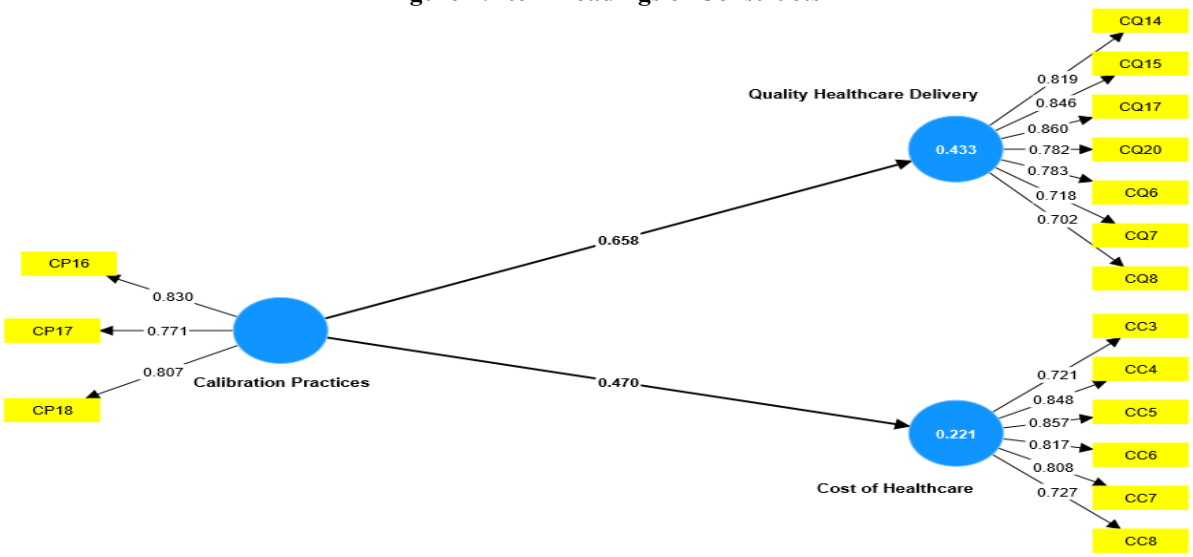
Construct	Label	VIF
Cost of Healthcare	CC3	1.732
	CC4	2.772
	CC5	2.818
	CC6	2.774
	CC7	2.161
	CC8	2.061
Calibration Practices	CP16	1.515
	CP17	1.342
	CP18	1.462
Quality HealthCare	CQ14	2.371
	CQ15	2.676
	CQ17	2.716
	CQ20	1.975
	CQ6	2.065
	CQ7	1.977
	CQ8	1.895

Source: Field Data, 2023

Item Loading

The initial assessment approach involved evaluating indicator loadings for each construct to ensure question reliability and validity. This examination, guided by Henseler et al. (2009), required indicators to have loadings equal to or greater than 0.70, a widely accepted standard. Any components with loadings below this threshold were removed, possibly due to ineffective operationalization within the research domain. Out of 56 indicators, only 16 met the criteria for reliability. Specifically, three out of 21 calibration indicators, seven out of 23 healthcare quality indicators, and six out of 12 healthcare delivery cost indicators were retained. The loadings of the retained items are presented in Figure 1.

Figure 1: Item Loadings of Constructs



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Table 4 presented the factor loading for each indicator included. Thus, the outer loadings below 0.70 were removed from the measurement models since these indicators have less contribution towards these factors.

Table 4: Factor Loadings

Label	Calibration Practices	Cost of Healthcare	Quality Healthcare Delivery
CP16	0.830	-	-
CP17	0.771	-	-
CP18	0.807	-	-
CC3	-	0.721	-
CC4	-	0.848	-
CC5	-	0.857	-
CC6	-	0.817	-
CC7	-	0.808	-
CC8	-	0.727	-
CQ14	-	-	0.819
CQ15	-	-	0.846
CQ17	-	-	0.860
CQ20	-	-	0.782
CQ6	-	-	0.783
CQ7	-	-	0.718
CQ8	-	-	0.702

Source: Field Data, 2023

Internal Consistency Reliability

Table 5 displayed the outcomes of additional evaluation criteria, which encompass construct reliability, construct validity, and convergent validity (average variance extracted).

In this study, we evaluated the internal consistency reliability of the constructs using composite reliability. As suggested by Rossiter (2002), composite reliability is a more suitable indicator of internal consistency compared to Cronbach's alpha. The results presented in Table 5 demonstrate that the latent variables under investigation in this study display a strong level of reliability, as indicated by their loadings exceeding the 0.7 threshold established by Bagozzi and Yi (1988). Notably, the composite reliability score for Quality Healthcare Delivery was the highest, at 0.920, followed by Cost of Healthcare at 0.913, and Calibration Practices at 0.845. These findings imply that the model demonstrates reliability in terms of internal consistency.

Table 5: Assessing Construct Reliability and Validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Calibration Practices	0.725	0.727	0.845	0.645
Cost of Healthcare	0.886	0.897	0.913	0.637
Quality Healthcare Delivery	0.899	0.911	0.920	0.622

Source: Field Data, 2023

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Table 6: Calibration of Medical Equipment Practices

Item	Label	N	Mean	Std. Dev.
Calibration frequency varies based on equipment type and usage.	CP1	394	4.53	0.67
Different equipment types require distinct calibration intervals for accuracy optimization.	CP2	394	4.47	0.80
Compliance with regulatory guidelines influences calibration practices.	CP3	394	4.50	0.78
Skilled and knowledgeable personnel are crucial for accurate calibration procedures.	CP4	394	4.59	0.75
Training and competency development enhance calibration outcomes.	CP5	394	4.62	0.75
Well-trained staff contribute to a culture of quality assurance.	CP6	394	4.63	0.67
Training programmes should be integrated with new equipment purchases.	CP7	394	4.36	0.88
Implementing robust quality control measures helps identify equipment deviations.	CP8	394	4.69	0.73
Quality control safeguards against inaccuracies and enhances patient safety.	CP9	394	4.42	0.81
Regular quality control testing contributes to a culture of quality assurance.	CP10	394	4.63	0.74
Calibration deviations identified through quality control help prevent critical errors.	CP11	394	4.52	0.70
Adhering to established calibration standards is crucial for healthcare institutions.	CP12	394	4.57	0.79
Compliance with industry standards upholds patient safety and reputation.	CP13	394	4.18	0.97
Calibration procedures should align with global regulatory guidelines.	CP14	394	4.26	0.94
Calibration adherence impacts both patient safety and institutional reputation.	CP15	394	4.08	1.08
Calibration records play a pivotal role in troubleshooting and analysis.	CP16	394	4.23	0.87
Documentation ensures compliance with regulatory frameworks.	CP17	394	4.28	0.99
Historical calibration data enables trend analysis and proactive measures.	CP18	394	4.01	1.11
Responsive vendor support mechanisms minimize equipment downtime.	CP19	394	4.09	1.04
Maintenance contracts ensure equipment uptime and operational longevity.	CP20	394	4.28	0.87
Effective maintenance contracts optimize patient safety and clinical outcomes.	CP21	394	4.18	0.79

Source: Field Data (2023)

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Table 7: Quality Healthcare Delivery

Statement	Label	N	Mean	Std. Dev.
The physical appearance of medical equipment in this healthcare facility is well-maintained.	CQ1	394	3.96	1.22
The healthcare facility's decor and furnishings create a comfortable environment for patients.	CQ2	394	3.95	0.89
Medical equipment in this healthcare facility consistently performs accurately and dependably.	CQ3	394	3.82	1.03
I can rely on the medical equipment in this facility to deliver consistent and precise outcomes.	CQ4	394	3.84	1.06
The healthcare staff here deliver services promptly as promised.	CQ5	394	3.92	1.07
The healthcare staff here keep their commitments regarding appointment times and service delivery.	CQ6	394	4.18	0.76
The medical equipment here consistently provides the expected level of performance without fluctuations.	CQ7	394	4.02	0.99
I receive prompt assistance from the healthcare staff when I need it.	CQ8	394	4.04	1.10
The response time of the healthcare staff to patient needs is satisfactory.	CQ9	394	4.12	1.04
The healthcare staff here are willing to listen and provide timely support.	CQ10	394	4.20	0.93
The healthcare staff make an effort to ensure that patients' needs are met promptly.	CQ11	394	4.05	0.91
The healthcare staff are quick to attend to patients' inquiries and requests.	CQ12	394	4.12	0.84
The healthcare staff exhibit a high level of responsiveness to patient needs and concerns.	CQ13	394	4.09	0.87
The healthcare staff inspire trust and confidence in their ability to provide high-quality care.	CQ14	394	4.25	0.94
I feel assured that the healthcare staff here are capable of addressing my medical needs.	CQ15	394	4.12	0.95
The healthcare staff communicate effectively about treatment options and recommendations.	CQ16	394	4.19	0.94
The healthcare staff in this facility provide clear explanations about medical procedures and treatments.	CQ17	394	4.31	0.84
I feel that the healthcare staff here care about my emotional well-being as well as my physical health.	CQ18	394	4.45	0.78
The healthcare staff take the time to listen to patients' concerns and questions.	CQ19	394	4.38	0.81
The healthcare staff make an effort to understand patients' unique circumstances and preferences.	CQ20	394	4.22	0.76
The healthcare staff treat patients with kindness and respect during interactions.	CQ21	394	4.38	0.80
The healthcare staff display a high level of empathy and consideration for patients' feelings.	CQ22	394	4.33	0.79
The healthcare staff in this facility make patients feel valued and understood.	CQ23	394	4.38	0.81

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Table 8: Cost of Quality Healthcare

Item	Label	N	Mean	Std. Dev.
Precise calibration of diagnostic equipment can lead to more reliable and consistent test results.	CC1	394	4.49	0.75
Reducing the need for redundant tests through accurate calibration contributes to cost savings in healthcare.	CC2	394	4.42	0.65
Inaccurate equipment calibration can result in increased consumption of consumables and resources during repeat tests.	CC3	394	4.31	0.77
Legal proceedings due to diagnostic errors attributed to equipment inaccuracy can incur significant financial costs for healthcare institutions.	CC4	394	4.10	0.96
Reputational damage from legal battles over diagnostic errors can impact patient trust and institutional credibility.	CC5	394	4.28	0.81
Rigorous calibration and maintenance schedules are necessary to mitigate potential legal challenges in the healthcare industry.	CC6	394	4.19	0.85
Healthcare institutions have compelling reasons to prioritize equipment accuracy to avoid both legal and financial consequences.	CC7	394	4.16	0.98
Implementing best practices for equipment accuracy can serve as proactive measures to prevent legal and reputational challenges.	CC8	394	4.29	0.97
Effectively utilizing medical equipment is a significant concern for healthcare operations and cost management.	CC9	394	4.37	0.91
Properly calibrated equipment can lead to improved efficiency and resource allocation within healthcare facilities.	CC10	394	4.34	0.92
The establishment of regional maintenance centers can support efficient and sustainable management of medical devices.	CC11	394	4.35	0.99
Mechanization in healthcare projects can lead to time and cost savings, improving overall operational efficiency.	CC12	394	4.36	0.88

Source: Field Data (2023)

Table 9: Challenges in Calibrating Medical Equipment

Item	Label	N	Mean	Std. Dev
Our institution faces challenges in allocating sufficient funds for regular equipment calibration.	CH1	394	4.22	0.91
Limited funding often makes it difficult for us to prioritize equipment calibration.	CH2	394	4.22	0.86
Tight budgets hinder our ability to maintain optimal calibration for high-end medical devices.	CH3	394	4.05	0.93
Diverting funds for equipment calibration affects other important areas such as patient care and staff wages.	CH4	394	4.02	0.90
Lack of skilled personnel results in mis-calibration and compromises the reliability of our devices.	CH5	394	3.55	1.19
Our institution faces challenges in finding knowledgeable personnel for accurate and regular calibration.	CH6	394	3.61	1.24
Operational downtime during calibration can disrupt patient care and lead to delays.	CH7	394	4.10	0.90
Our institution faces challenges in minimizing operational downtime while ensuring accurate calibration.	CH8	394	4.08	0.91
We encounter difficulties in adhering to calibration standards that vary based on regions or institutions.	CH9	394	3.71	1.09

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Table 9: Challenges in Calibrating Medical Equipment (cont.)

Item	Label	N	Mean	Std. Dev
Lack of consistent calibration guidelines leads to variations in equipment performance within our institution.	CH10	394	3.89	1.14
The absence of defined calibration benchmarks creates uncertainties for our healthcare providers.	CH11	394	3.87	1.22
We face challenges in executing multiple conflicting calibration standards across different jurisdictions.	CH12	394	3.77	1.15
Outdated or incomplete calibration standards make it challenging to ensure accurate calibration.	CH13	394	3.91	1.13
Inconsistent guidelines for calibration hinder our efforts to maintain reliable equipment performance.	CH14	394	3.95	1.02
Our institution faces challenges in advocating for the priority of equipment calibration due to lack of immediate tangible benefits.	CH15	394	4.23	1.03
We strive to create a culture where calibration is seen as essential and routine among all staff members.	CH16	394	4.34	0.89
The diverse equipment in our institution poses challenges in maintaining consistent calibration schedules.	CH17	394	4.19	0.81
Managing calibration requirements becomes complex, especially with new equipment additions.	CH18	394	4.41	0.77
Inconsistent calibration schedules sometimes lead to wasteful over-calibration or risky under-calibration.	CH19	394	4.29	0.78

Source: Field Data (2023)

Calibration Practices Employed by Healthcare Institutions

Confirmatory factor analysis was utilized to ascertain the calibration of medical equipment, employing the Partial Least analytical methodology. The evaluation was carried out utilizing many foundational assumptions, such as the consideration of multicollinearity, as well as the reliability and validity of the measurement models, namely the outer models. The evaluation process encompassed the assessment of the reliability of individual items through outer loadings, the internal consistency reliability using measures such as Cronbach's alpha and Composite Reliability.

Multicollinearity

The multicollinearity analysis, using the variable inflation factor (VIF), reveals low multicollinearity among the constructs of Documentation and Record-Keeping, Frequency of Calibration, Quality Control, Adherence to Standards, Training and Competency, and Vendor Support and Maintenance Contracts, as presented in Table 19. The VIF values for these constructs, ranging from 1.189 to 3.881, fall well below the cautionary threshold of 10, indicating a high degree of reliability and uniqueness among the variables. This suggests that these constructs can be confidently used in the confirmatory factor analysis without concerns of redundancy or inflation of variances. However, the Quality Control construct shows slightly higher VIF values for labels QC3 and QC5, suggesting a need for further scrutiny. Overall, the low presence of multicollinearity in the data set supports the development of robust PLS-SEM models.

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Table 10: Multicollinearity of Calibration Practices

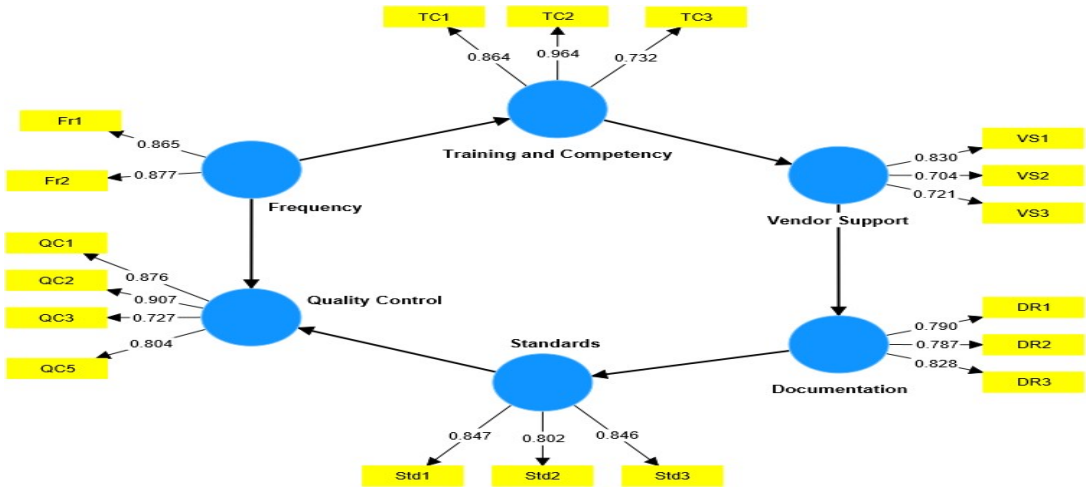
Construct	Label	VIF
Documentation and Record-Keeping	DR1	1.515
	DR2	1.342
	DR3	1.462
Frequency of Calibration	Fr1	1.366
	Fr2	1.366
Quality Control	QC1	1.902
	QC2	2.569
	QC3	3.881
	QC5	4.134
Adherence to Standards	Std1	1.898
	Std2	1.475
	Std3	1.668
Training and Competency	TC1	1.642
	TC3	1.642
Vendor Support and Maintenance Contracts	VS1	1.273
	VS2	1.189
	VS3	1.246

Source: Field Data, 2023

Item Loading

The primary assessment method involved evaluating indicator loadings for each construct to determine item loadings, with the aim of assessing the quality of indicators measuring each construct within the study's context (Henseler et al., 2009). The model eliminated elements with loadings below the threshold of 0.7, a commonly accepted guideline for good quality. This process resulted in the exclusion of 3 out of 21 indicators used to assess the latent variables, as they failed to meet the reliability standards. The remaining indicators, including 2 out of 3 for frequency of calibration, 4 out of 5 for quality control, 3 out of 4 for training and competency, and all indicators for adherence to standards, documentation and record keeping, and vendor support and maintenance contracts, were retained. The loadings for the retained items are presented in Figure 2

Figure 2: Indicator Loadings for Calibration Practices



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Factor Loadings

Table 11 delineates the factor loadings of various items on their respective constructs, such as Documentation, Frequency, and Quality Control, among others. These loadings are crucial in determining the degree to which each item reflects its underlying construct. A factor loading of 0.7 or above is generally deemed significant, indicating a strong correlation between the item and its construct (Zhang et al., 2018). For instance, the Documentation and Record Keeping construct is well-represented by items DR1, DR2, and DR3, with loadings of 0.791, 0.787, and 0.827, respectively. Similarly, the Frequency of Calibration construct is well-represented by items Fr1 and Fr2, with loadings of 0.879 and 0.863, respectively. The Quality Control construct exhibits a wider range of loadings, from 0.728 to 0.907, while the Adherence to Standards construct shows robust loadings, ranging from 0.802 to 0.847. The Training and Competency construct is well-represented by items TC1 and TC3, with loadings of 0.904 and 0.899, respectively. Lastly, the Vendor Support and Maintenance Contract construct displays varied loadings, from 0.683 to 0.829.

Table 11: Factor Loadings

	Documentation and Record-Keeping	Frequency of Calibration	Quality Control	Adherence to Standards	Training and Competency	Vendor Support and Maintenance Contracts
DR1	0.791	-	-	-	-	-
DR2	0.787	-	-	-	-	-
DR3	0.827	-	-	-	-	-
Fr1	-	0.879	-	-	-	-
Fr2	-	0.863	-	-	-	-
QC1	-	-	0.876	-	-	-
QC2	-	-	0.907	-	-	-
QC3	-	-	0.728	-	-	-
QC5	-	-	0.804	-	-	-
Std1	-	-	-	0.847	-	-
Std2	-	-	-	0.802	-	-
Std3	-	-	-	0.846	-	-
TC1	-	-	-	-	0.904	-
TC3	-	-	-	-	0.899	-
VS1	-	-	-	-	-	0.829
VS2	-	-	-	-	-	0.683
VS3	-	-	-	-	-	0.742

Source: Field Data, 2023

Assessing Internal Consistency Reliability of Constructs

Table 12 presents the results of the assessment criteria, including construct reliability, validity, and convergent validity (average variance extracted). The Documentation and Record-Keeping construct demonstrates satisfactory internal consistency reliability (Cronbach's alpha of 0.725) and good convergent validity (AVE score of 0.643). The Frequency of Calibration construct, despite a slightly lower Cronbach's alpha (0.682), shows promising reliability and strong convergent validity (AVE score of 0.759). The Quality Control construct exhibits excellent reliability (Cronbach's alpha of 0.875) and healthy convergent validity (AVE score of 0.692). The Adherence to Standards construct also shows strong reliability (Cronbach's alpha of 0.779) and good convergent validity (AVE score of 0.692). The

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Training and Competency construct displays strong reliability (Cronbach's alpha of 0.769) and excellent convergent validity (AVE score of 0.813). Lastly, the Vendor Support and Maintenance construct, despite a lower Cronbach's alpha (0.623), maintains acceptable reliability and satisfactory convergent validity (AVE score of 0.568).

Table 12: Assessing Internal Consistency Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Documentation and Record Keeping	0.725	0.731	0.844	0.643
Frequency of Calibration	0.682	0.684	0.863	0.759
Quality Control	0.875	0.957	0.899	0.692
Adherence to Standards	0.779	0.785	0.871	0.692
Training and Competency	0.769	0.770	0.897	0.813
Vendor Support and Maintenance Contract	0.623	0.651	0.797	0.568

Source: Field Data, 2023

Multicollinearity

The "Lack of Awareness" construct, denoted by labels Aw3 and Aw4, exhibits Variance Inflation Factor (VIF) values of 1.715, significantly below the threshold of 10, indicating minimal interrelation between the variables and providing a solid foundation for further analysis (Pallant, 2007). Similarly, the "Inconsistent Calibration Standards" construct, represented by variables Cs2 to Cs6, displays VIF values ranging from 1.902 to 2.962, suggesting low multicollinearity and the importance of enhancing calibration standards. The "Equipment Diversity" construct, marked by labels Ed3 to Ed5, also shows low multicollinearity, emphasizing the need to consider equipment diversity in calibration protocols. The "Finance" construct, with variables Fin1 to Fin4, presents low multicollinearity, highlighting the distinct influence of financial factors on the calibration process. Lastly, the "Specialised Expertise" construct, represented by Se5 and Se6, exhibits low multicollinearity, underscoring the importance of specialized expertise in the calibration process.

Table 13: Multicollinearity of Challenges Faced in the Calibration of Medical Equipment

Construct	Label	VIF
Lack of Awareness	Aw3	1.715
	Aw4	1.715
Inconsistent Calibration Standards	Cs2	2.962
	Cs3	2.241
	Cs4	2.694
	Cs5	1.977
	Cs6	1.902
Equipment Diversity	Ed3	1.403
	Ed4	2.034
	Ed5	1.704
Finance	Fin1	2.059
	Fin2	2.563
	Fin3	2.101
	Fin4	1.944

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Table 13: Multicollinearity of Challenges Faced in the Calibration of Medical Equipment (cont.)

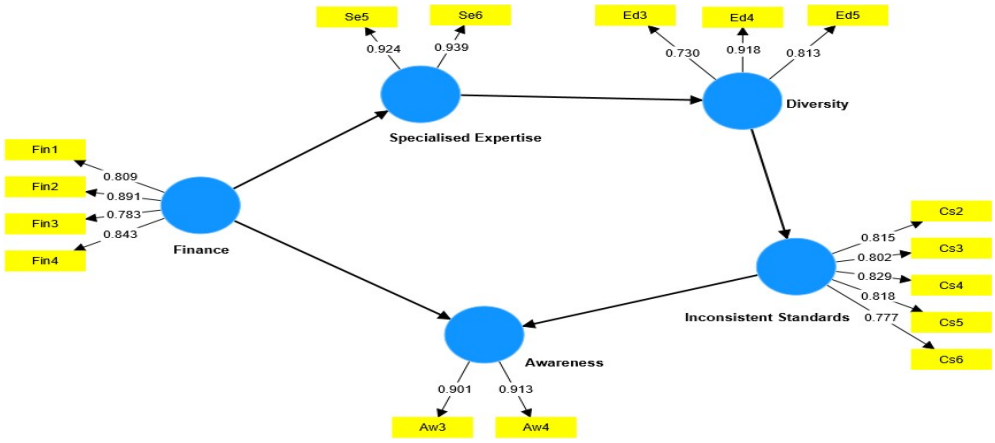
Construct	Label	VIF
Specialised Expertise	Se5	2.182
	Se6	2.182

Source: Field Data, 2023

Item Loading

The primary method of assessment entailed the evaluation of indicator loadings for each construct, with the purpose of determining the item loadings. The assessment of the indicators that measure each construct within the context of the study was carried out by utilizing item loadings to ascertain their level of quality. Henseler et al. (2009) propose that a construct can be deemed to possess good quality if its constituent elements demonstrate loadings equal to or greater than 0.70, in accordance with the commonly accepted guideline. As a result, the model undertook a process of eliminating elements for each construct that displayed loadings below the threshold of 0.7. One potential rationale for this result is that the items obtained from literary sources may not have adequately operationalized the construct being studied within the specific research field.

Out of the total of 16 indicators employed to assess the latent variables, a subset of 1 indicator was deemed unsuitable for inclusion as they failed to meet the established standards for indicator reliability. With the exception of inconsistent standards whose 1 indictor out of 6 was removed all the indicators of the other variables were maintained. The indicator loadings for the items that were retained are displayed in Figure 3.



Source: Field data, 2023

Factor Loadings

Table 14 delineates the values associated with various constructs - lack of awareness, equipment diversity, finance, inconsistent standards, and specialised expertise - each representing distinct challenges in the calibration of medical equipment. The "Awareness" construct, comprising elements Aw3 and Aw4 with values of 0.901 and 0.913 respectively, suggests these elements are significant indicators of the level of awareness in calibration procedures. The "Equipment Diversity" construct, encompassing elements Ed3, Ed4, and Ed5 with values of 0.730, 0.918, and 0.813 respectively, indicates these elements as potential markers of diversity challenges in calibration. The "Finance" construct, with elements Fin1 to Fin4 and values between 0.783 and 0.891, demonstrates a notable correlation with financial aspects of the calibration process. Lastly, the "Inconsistent Standards" construct, with elements Cs2 to Cs6 and values around 0.8, underscores these elements as substantial markers of challenges posed by inconsistent standards in the calibration sector.

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Table 14: Factor Loadings

	Lack of Awareness	Equipment Diversity	Finance	Inconsistent Standards	Specialized Expertise
Aw3	0.901	-	-	-	-
Aw4	0.913	-	-	-	-
Ed3	-	0.730	-	-	-
Ed4	-	0.918	-	-	-
Ed5	-	0.813	-	-	-
Fin1	-	-	0.809	-	-
Fin2	-	-	0.891	-	-
Fin3	-	-	0.783	-	-
Fin4	-	-	0.843	-	-
Cs2	-	-	-	0.815	-
Cs3	-	-	-	0.802	-
Cs4	-	-	-	0.829	-
Cs5	-	-	-	0.818	-
Cs6	-	-	-	0.777	-
Se5	-	-	-	-	0.924
Se6	-	-	-	-	0.939

Source: Field Data, 2023

Assessing Internal Consistency Reliability of Constructs

Table 15 presents the internal consistency reliability of various constructs, including "Lack of Awareness," "Equipment Diversity," "Finance," "Inconsistent Standards," and "Specialized Expertise," using statistical parameters such as Cronbach's Alpha, Composite Reliability (rho_a and rho_c), and Average Variance Extracted (AVE). The "Lack of Awareness" construct demonstrates satisfactory internal consistency and convergent validity, with a Cronbach's Alpha of 0.785, Composite Reliability of 0.787 (rho_a) and 0.903 (rho_c), and an AVE of 0.823. The "Equipment Diversity" construct reveals similar reliability with a Cronbach's Alpha of 0.764, Composite Reliability of 0.835 (rho_a) and 0.863 (rho_c), and an AVE of 0.679. The "Finance" construct exhibits strong reliability, with a Cronbach's Alpha of 0.855, Composite Reliability of 0.909 (rho_a) and 0.900 (rho_c), and an AVE of 0.693. The "Inconsistent Standards" construct shows robust reliability, with a Cronbach's Alpha of 0.870, Composite Reliability of 0.884 (rho_a) and 0.904 (rho_c), and an AVE of 0.654. Lastly, the "Specialised Expertise" construct displays remarkable reliability and convergent validity, with a Cronbach's Alpha of 0.848, Composite Reliability of 0.855 (rho_a) and 0.929 (rho_c), and an AVE of 0.868.

Table 15: Assessing Internal Consistency Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Lack of Awareness	0.785	0.787	0.903	0.823
Equipment Diversity	0.764	0.835	0.863	0.679
Finance	0.855	0.909	0.900	0.693
Inconsistent Standards	0.870	0.884	0.904	0.654
Specialised Expertise	0.848	0.855	0.929	0.868

Source: Field Data, 2023

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DISCUSSIONS

Calibration of Medical Equipment Practices

Table 6 demonstrates a strong consensus among respondents regarding the significance of skilled personnel and comprehensive quality control measures in improving calibration practices, as indicated by high mean values and low standard deviations. However, perceptions vary on the importance of historical calibration data, adherence to global guidelines, and the impact of calibration adherence on institutional reputation, as shown by mean values around 4.0 and higher standard deviations. This variation may indicate evolving perspectives or gaps in current practices that warrant further exploration. Additionally, areas related to documentation and vendor support mechanisms show a divergence in viewpoints, suggesting a need for further consensus-building in these areas (Table 6).

The critical constructs identified underscore the importance of accuracy and reliability in healthcare settings. Studies such as Vahedi et al. (2018) highlight the significant impact of educational interventions on improving documentation standards, a key aspect of these constructs. This underscores the role of continuous professional development in enhancing medical documentation. Hodgson et al. (2017) emphasize the need for ongoing technological improvements, particularly in electronic health record documentation, which aligns with the broader construct of stringent quality control measures. Saleh et al. (2023) propose an innovative approach to vendor selection, correlating with the strategic importance of robust vendor support, a central construct. Their multi-criteria decision-making platform optimizes medical equipment acquisition, ensuring selection of vendors who meet rigorous criteria. Guergov (2022) underscores the importance of adherence to established standards and protocols within the Internet of Medical Things (IoMT), reinforcing the need for stringent standards to ensure quality and safety in healthcare services. Collectively, these studies substantiate the constructs, outlining a path for institutions to optimize calibration practices, thereby enhancing healthcare precision and reliability. This suggests a move towards a systematic, technology-driven, and education-centered approach to improve healthcare delivery, emphasizing the importance of collaboration between vendors, healthcare professionals, and technology.

Quality Healthcare Delivery

The data indicates a moderate level of satisfaction concerning the physical aspects of the healthcare facility, including medical equipment maintenance and decor, with mean values below 4 and a moderately high standard deviation, suggesting room for improvement and diverse evaluations (mean values range from 3.82 to 3.96). Similarly, the reliability and performance consistency of medical equipment also demonstrate a trend of moderate satisfaction with a broad range of opinions (mean values range from 3.8-4.02). However, service delivery and staff responsiveness aspects show a positive trend with mean values ranging from 4.04 to 4.45 and lower standard deviations, indicating a stronger consensus on the quality of service. The staff's communication efficiency and understanding of patients' unique circumstances also receive positive feedback, with mean values exceeding 4.2 and lower standard deviations. Overall, the data suggests a high standard of patient care, particularly in terms of staff responsiveness and empathy.

This discussion emphasizes the crucial role of accurate medical equipment calibration in enhancing healthcare delivery quality, as supported by empirical literature and research findings. A positive correlation exists between precise medical equipment calibration and improved healthcare quality within Sunyani Municipality's healthcare institutions (Moyimane & Kekana, 2017; Rao et al., 2021; Chen et al., 2014).

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Studies highlight the detrimental effects of inadequate medical equipment in rural hospitals, the influence of well-calibrated equipment on healthcare-seeking behaviors, and the role of calibration in improving medical imaging equipment's diagnostic accuracy (Moyimane & Kekana, 2017; Rao et al., 2021; Chen et al., 2014). Further, research underscores the cost-effectiveness and increased healthcare provider satisfaction achievable through regular and precise calibration of medical equipment (Johnson et al., 2023; Kaur et al., 2018). The importance of well-calibrated equipment in telemedicine, ensuring accurate data transmission and facilitating quality remote healthcare, particularly in underserved areas, is also highlighted (Wang et al., 2018). Lastly, in critical settings like ICUs, appropriately calibrated medical equipment can directly contribute to improved patient outcomes, leading to shorter hospital stays and fewer complications (Garcia et al. Zare et al., 2023).

In conclusion, the empirical evidence robustly supports the findings, emphasizing the critical role of accurately calibrated medical equipment in enhancing various aspects of healthcare delivery quality. The benefits range from improved patient safety to reduced healthcare costs and effective telemedicine, underscoring the need for focused attention and investment in this critical area to foster a healthcare environment where quality and excellence are paramount.

Cost of Quality Healthcare

Table 8 data underscores the significant recognition of the financial and operational implications of quality healthcare, with a particular emphasis on the role of precise equipment calibration. The high mean values, approximately 4.49 and 4.42, reflect a strong consensus among respondents on the importance of accurate calibration for achieving reliable results and reducing unnecessary healthcare costs. The low standard deviations (0.75 and 0.65 respectively) suggest a general agreement among respondents. The data also reveals an understanding of the potential consequences of inaccurate calibration, including increased resource utilization, legal consequences, and reputational damage, with mean values ranging from 4.10 to 4.31. The need for rigorous calibration and maintenance schedules is also highlighted, with mean values for these aspects around 4.19 and 4.16. The data further emphasizes the importance of proactive measures to avoid legal and reputational challenges and enhance operational efficiency, with mean values ranging from 4.29 to 4.37.

The objective of this study was to assess the beneficial effects of accurate medical equipment calibration on the cost-effectiveness of healthcare delivery in the Sunyani Municipality, with a focus on the second hypothesis. The empirical literature reviewed supports the significant positive impact of meticulous calibration practices on reducing healthcare delivery costs. Phuong et al. (2019) emphasized that precise calibration of medical equipment reduces diagnostic errors, thereby decreasing costs associated with incorrect diagnoses and treatments. Jansen et al. (2018) highlighted a direct correlation between reduced equipment downtime and precise calibration practices, suggesting that well-maintained and calibrated equipment experience fewer malfunctions, thus saving significant financial resources. Loh et al. (2016) identified the role of accurately calibrated equipment in facilitating precise diagnostics and personalized treatment plans, which not only speeds up the recovery process but also reduces hospital stays, thereby saving on associated costs. Liu et al. (2021) recommended the formulation of stringent policies governing medical equipment calibration as a pragmatic approach to curbing escalating healthcare costs. Bachynsky (2019) foresaw a promising trajectory for the sector with sustained

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investments in innovative calibration technologies, which can potentially lead to a reduction in operational costs and an enhancement in patient outcomes. In conclusion, the findings validate the significant positive impact of precise calibration practices on healthcare cost reduction, thus validating the second hypothesis of the study. This comprehensive exploration underscores the pivotal role of calibration in fostering an economically sustainable healthcare ecosystem in the Sunyani Municipality.

Challenges in Calibrating Medical Equipment

Table 9 data elucidates the challenges faced by a healthcare institution in calibrating medical equipment, focusing on budgetary constraints, skilled personnel availability, and adherence to diverse calibration standards. The financial challenges, as indicated by mean values between 4.02 and 4.22 and standard deviations between 0.86 and 0.93, are perceived to significantly impact other areas such as patient care and staff wages. The data also reveals a moderate consensus on the shortage of skilled personnel affecting calibration reliability, with mean values around 3.55 and 3.61 and higher standard deviations (1.19 and 1.24), suggesting varied opinions. Operational downtime due to calibration processes is seen as disruptive, with a mean value of 4.10 and a standard deviation of 0.90. The institution also appears to struggle with calibration standards and guidelines, as indicated by mean values between 3.71 and 3.95 and standard deviations between 1.02 and 1.22. However, there is a strong consensus on the importance of a culture that values regular calibration and the complexity of managing calibration requirements, especially with new equipment.

The research underscores the significant challenges in medical equipment calibration, including a lack of awareness, equipment diversity, inconsistent standards, financial constraints, and the need for specialized expertise (Belhouideg, 2020; Selvaraj, 2019; Kawalec et al., 2021; Walsh et al., 2017; Garzotto et al., 2020). The knowledge gaps among healthcare professionals can compromise diagnostic accuracy and treatment methodologies, necessitating continuous education programs (Shimada et al., 2018). The diversity of equipment adds complexity to calibration protocols, escalating costs and resource requirements, and calls for unified calibration standards (Gong et al., 2019; Romakin and Mohammadnezhad, 2019). Inconsistent calibration standards directly impact patient safety and treatment efficacy, emphasizing the need for standardized procedures, specialized knowledge, and traceability (Martins et al., 2020; Azami et al., 2021). Financial constraints pose multifaceted challenges, from high calibration costs to disruptive effects of equipment downtime, necessitating comprehensive maintenance management programs and collaborative cost-sharing approaches (Walsh et al., 2017; Hinrichs-Krapels et al., 2022; Zamzam et al., 2021; Bell et al., 2020). Lastly, the need for specialized expertise in calibration is critical to ensure patient safety, requiring investment in training and educational programs (Garzotto et al., 2020; Wiyor et al., 2019).

Conclusions and Recommendation

This study underscores the significant role of precise calibration practices in enhancing healthcare delivery within the Sunyani Municipality. These practices, embedded in regular calibration schedules, quality control measures, and adherence to calibration standards, are pivotal in elevating healthcare standards. Through continuous training and development programs, healthcare professionals are equipped to manage the diversity of modern medical equipment, enhancing precision and accuracy in healthcare delivery. Collaborations with vendors through maintenance contracts have proven instrumental in maintaining the quality and performance of medical

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equipment, thereby fostering superior healthcare delivery.

Moreover, the study affirms that proper calibration procedures not only enhance healthcare quality but also serve as a pivotal factor in reducing long-term healthcare costs. By minimizing the incidence of misdiagnoses and unnecessary repeat tests, these practices foster cost-efficiency and safeguard resources. However, challenges persist, including limited awareness about calibration procedures among medical staff, inadequate training avenues, and financial constraints hindering the acquisition of advanced calibration technology.

Recommendations to foster enhanced calibration practices include standardization of calibration protocols, enhanced training and development programs, investment in advanced calibration tools and technologies, collaborative engagements with vendors, awareness and sensitization programs, research and development initiatives, development of specialized units, and governmental support and policy intervention. By implementing these recommendations, it is anticipated that healthcare institutions within the Sunyani Municipality will be better positioned to offer quality healthcare services characterized by precision, reliability, and efficiency.

Future research should explore how the integration of emerging technologies such as Artificial Intelligence (AI) and Internet of Things (IoT) can revolutionize medical equipment calibration practices. Additionally, future research should delve into creating structured and dynamic training programs that foster a workforce adept at handling and maintaining modern medical equipment proficiently.

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