

Image Quality Assessment in Chest Radiography According to European Guidelines: A Narrative Review of Its Relevance and Implementation Challenges in Cameroon

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Abstract: Chest radiography remains the cornerstone of diagnostic imaging globally, functioning as a primary triage and diagnostic tool for a diverse array of cardiopulmonary pathologies, particularly tuberculosis and pneumonia. In resource-constrained environments like Cameroon, healthcare systems exhibit an extreme reliance on chest radiography; however, the structural frameworks necessary to optimize image quality and minimize patient radiation dose are frequently inadequate. This narrative review evaluates the clinical relevance and practical implementation of stringent European image quality guidelines specifically the EUR 16260 anatomical criteria and the European Union Directive 2013/59/Euratom within the Cameroonian context. The analysis synthesizes current methods of image quality assessment, encompassing visual grading analysis, reject and repeat audits, standardized exposure indices (IEC 62494-1), and the integration of artificial intelligence tools such as CAD4TB. Translating European standards to Cameroon encounters profound structural barriers, driven primarily by a critical shortage of radiological personnel, with a radiologist density of approximately two per million inhabitants compared to the European average of 127 per million. Additional friction points include the unmonitored transition from analogue to digital radiography, the inconsistent application of Diagnostic Reference Levels (DRLs), and the limited enforcement capacity of the National Radiation Protection Agency (ANRP). Despite these systemic hurdles, strategic opportunities exist to elevate diagnostic standards. Expanding teleradiology networks to support remote facilities, implementing low-cost quality assurance audits, and leveraging artificial intelligence for automated image assessment offer viable solutions to bridge the quality gap. The establishment of localized DRLs and the prioritized training of radiographers and medical physics experts stand as essential prerequisites for achieving sustainable diagnostic excellence and radiation safety in Cameroon. Establishing routine diagnostic reference levels for standard procedures is a universally recommended practice for adhering strictly to the ALARA principle.

Keywords: Chest radiography, image quality, EUR 16260, radiation protection, Cameroon, digital radiography.

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Introduction

A key principle of modern medical imaging is to balance high diagnostic quality with the need to minimise the risks of ionising radiation. Chest radiography is the basic imaging method for diagnosing pulmonary and cardiovascular conditions and remains the most commonly performed radiological examination worldwide (Seibert & Morin, 2011). However, in areas with limited healthcare resources, particularly in Sub-Saharan Africa, healthcare systems depend heavily on chest radiography. The high burden of infectious respiratory diseases, particularly pulmonary tuberculosis (TB) and lower respiratory tract infections, highlights the importance of chest radiography in public health (Bah et al., 2025; World Health Organisation, 2021). Despite its widespread use, maintaining good image quality in chest radiographs remains a major technical clinical challenge. Poor-quality images can reduce diagnostic accuracy, increase the risk of missing subtle abnormalities or lead to false-positive interpretations. In addition, poor imaging quality may require patients to undergo repeat examinations, resulting in unnecessary additional exposure to radiation (Serra et al., 2024; Stephenson-Smith et al., 2021).

Recognising the need for technical standardisation, the Commission of the European Communities published the EUR 16260 guidelines, which established clear and objective anatomical

criteria for assessing the quality of diagnostic radiographic images (Carmichael et al., 1996). These guidelines were later developed further and legally strengthened through the European Union Council Directive 2013/59/Euratom, which emphasizes the principles of radiation protection, justification, and dose optimization (European Union, 2013). The Directive also introduced the use of Diagnostic Reference Levels (DRLs) and highlighted the important role of the Medical Physics Expert (MPE) in clinical practice. Although these frameworks have greatly improved radiation protection and image quality in high-income countries, applying them directly in low- and middle-income countries (LMICs), such as Cameroon, remains challenging due to differences in healthcare resources and infrastructure.

Cameroon faces a major challenge, as there is a high demand for diagnostic imaging due to the high prevalence of respiratory diseases, but radiological infrastructure and resources remain limited. The radiography sector faces shortages of trained medical professionals, an uneven shift from traditional screen-film systems to digital radiography, and a developing regulatory system for radiation safety (Gnowe et al., 2019; RAD-AID, 2023). Therefore, adapting established European image quality guidelines to the Cameroonian healthcare setting is important for improving public health. This review evaluates the clinical relevance and practical application of European image quality guidelines in Cameroon. It examines current methods of assessing image quality, including visual grading analysis, reject and repeat audits, standardised exposure indices, and the use of artificial intelligence tools to improve diagnostic standards in resource-constrained healthcare settings.

Methodology

To conduct a comprehensive narrative review following the Scale for the Assessment of Narrative Review Articles (SANRA) criteria, a structured literature search was carried out using major biomedical databases. PubMed and PubMed Central were the main databases, followed by Scopus and Google Scholar. Official guidelines and regulatory documents were obtained from the World Health Organization (WHO), International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP), and European Commission.

The search used combinations of keywords related to chest radiography, digital radiography, image quality, quality criteria, EUR 16260, visual grading analysis, reject analysis, IEC 62494-1, Cameroon, Sub-Saharan Africa, diagnostic reference levels, and low-resource settings. The search mainly covered publications from 2015 to 2025 to include recent developments in digital radiography, artificial intelligence, and radiation protection. Important earlier publications, including the original 1996 EUR 16260 report and key papers on visual grading methods, were also included to provide historical context (Bäth & Månsson, 2007; Carmichael et al., 1996).

Articles were included if they were peer-reviewed, published in English or French, and focused on radiographic quality assurance, patient radiation dose, or the radiological workforce. Studies focused only on advanced imaging techniques, such as magnetic resonance imaging, or those without reliable dosimetric or epidemiological data were excluded. Priority was given to empirical studies, clinical audits, randomised evaluations,

and official guidelines and legislation to ensure a reliable evidence base.

Chest Radiography in Clinical Practice and Public Health

Chest radiography is a commonly used imaging method for chest examination. It provides a rapid, non-invasive, and cost-effective way to assess the lungs, pleural spaces, and cardiovascular structures. In global health, it is widely used for the screening, diagnosis, and monitoring of pulmonary tuberculosis. The World Health Organisation (WHO) recommends chest radiography as part of systematic screening programs, where it helps identify individuals who require further bacteriological testing (World Health Organisation, 2021).

In Cameroon, there is a high burden of both infectious diseases and non-communicable cardiothoracic diseases. Respiratory infections, particularly tuberculosis (TB), remain an important public health concern. TB management relies heavily on chest radiography for diagnosis, especially with the increasing occurrence of drug-resistant TB. Studies on rifampicin-resistant pulmonary TB in Yaoundé highlight the importance of early and accurate detection to reduce the risk of poor treatment outcomes and mortality (Kuaban et al., 2021). Chest radiography is also useful in monitoring post-tuberculosis lung disease, which may cause long-term health problems and reduce quality of life. However, current national TB guidelines have limited recommendations for the long-term monitoring of comorbidities and post-tuberculosis lung disease, showing the need for standardised radiographic follow-up.

In Cameroon, the National Tuberculosis Control Programme (PNLT) relies on chest radiography to support TB management across different patient groups (Bah et al., 2025). Chest radiography can serve as an important triage tool before expensive molecular testing such as the GeneXpert MTB/RIF assay, helping identify individuals who require further diagnostic testing. In a multicentre study conducted in Cameroon and Nepal, AI-based systems were used to interpret chest radiographs for TB detection. The study found that using these systems could reduce the number of Xpert MTB/RIF tests required by 66% while maintaining a sensitivity of 95% or higher (Qin et al., 2019). This approach may therefore improve the efficiency of TB screening, particularly in settings where diagnostic resources and trained personnel are limited. Chest radiography also remains useful for monitoring complications and treatment outcomes in patients with multidrug-resistant tuberculosis (MDR-TB).

Beyond tuberculosis, chest radiography is also important for diagnosing community-acquired pneumonia, managing chronic obstructive pulmonary disease, and assessing acute conditions such as congestive heart failure and pleural effusion. However, the usefulness of a chest radiograph depends greatly on its technical quality. Problems such as patient movement, inadequate inspiration, or incorrect exposure can make it difficult to detect subtle abnormalities, including early lung infections or miliary TB. Poor-quality images may therefore lead to repeat examinations, increasing radiation exposure and potentially delaying appropriate treatment (Serra et al., 2024). Therefore, public health programs that use chest radiography for screening and diagnosis require effective and standardised image quality assurance protocols.

European Guidelines on Image Quality

In order to standardise radiographic image quality and patient radiation dose across Europe, the Commission of the European Communities (CEC) published the EUR 16260 guidelines (Carmichael et al., 1996). These guidelines moved away from subjective judgments of image quality and introduced clear and measurable criteria based on the visibility of anatomical structures. According to EUR 16260, a radiograph is considered diagnostically acceptable when it clearly shows the anatomical structures needed for clinical interpretation while keeping radiation exposure as low as reasonably achievable (ALARA) (Martin, 2016).

Criteria for Posteroanterior and Lateral Views

For the standard posteroanterior (PA) or anteroposterior (AP) chest radiograph, the EUR 16260 guidelines stipulate precise parameters governing patient positioning, inspiration, beam penetration, and collimation (Figure 1). A compliant image must demonstrate visually sharp reproduction of the pulmonary vascular pattern extending throughout the entire lung field, specifically tracking the peripheral vessels (Doktor et al., 2019). The trachea, proximal bronchi, and the distinct borders of the heart and aorta must be sharply delineated. Adequate patient inspiration is verified by the clear visualization of the

diaphragm and lateral costophrenic angles, typically corresponding to the visualization of at least six anterior ribs above the diaphragm. Optimal X-ray beam penetration ensures that the retrocardiac lung tissue, the mediastinum, and the thoracic spine are visible through the cardiac silhouette. Crucially, the guidelines demand the visualization of high-contrast linear and reticular details as small as 0.3 mm to 0.5 mm in width to guarantee that subtle nodular pathologies are not overlooked. For example, the criteria dictate the visualization of small round details down to 0.7 mm for high contrast, and 2 mm for low contrast structures in the whole lung. Strict collimation to the lung fields is required to minimize unnecessary irradiation of the thyroid and abdomen, which also improves image contrast by reducing scatter radiation.

For lateral projections, the quality criteria focus heavily on geometric alignment. The superimposition of the posterior ribs is required to verify the absence of axial rotation. The sharp reproduction of the sternum and the clear visualization of both posterior costophrenic angles are mandatory. The lateral view requires meticulous adjustment of exposure factors to penetrate the highly attenuating tissues of the shoulder girdle and the heart while maintaining the diagnostic visibility of the lung apices and the retrosternal clear space.

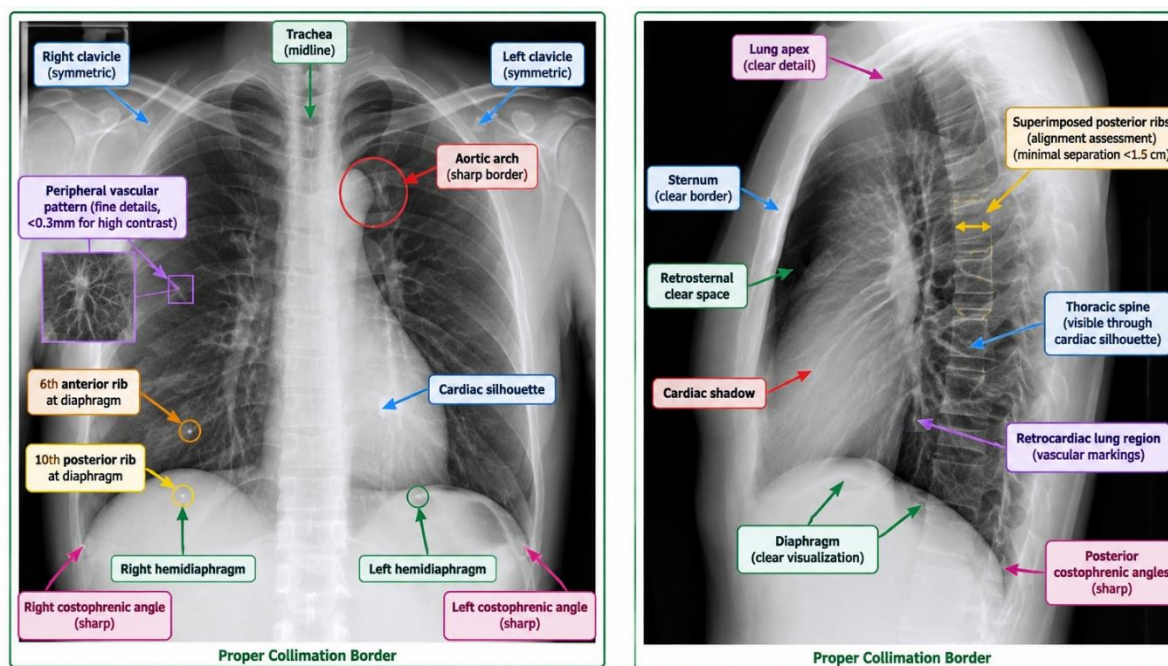


Figure 1: Schematic representation of diagnostic posteroanterior (PA) and lateral chest radiographs illustrating the essential anatomical visibility criteria defined by the EUR 16260 guidelines. (A) The PA projection demonstrates diagnostic acceptability through the sharp reproduction of the trachea, the borders of the heart and aortic arch, the diaphragm, and the lateral costophrenic angles. Adequate inspiration is confirmed by the intersection of the 6th anterior and 10th posterior ribs with the diaphragm. Correct geometric positioning is verified by the symmetric equidistance of the medial clavicles from the midline, while optimal beam penetration is confirmed by the visibility of the thoracic spine, retrocardiac lung tissue, and fine peripheral vascular patterns. (B) The lateral projection verifies correct alignment through the superimposition of the posterior ribs. Essential criteria include clear visualisation of the lung apices, sternal border, retrosternal clear space, diaphragm, and posterior costophrenic

angles, with the thoracic spine adequately penetrated through the cardiac silhouette. Both panels illustrate proper collimation borders used to restrict the exposed area to the necessary anatomical region. Directive 2013/59/Euratom and ALARA Considerations

Legislative Enforcement: Directive 2013/59/Euratom

Building upon the foundational anatomical criteria, the European Union implemented Council Directive 2013/59/Euratom, establishing modernised Basic Safety Standards (BSS) for protection against ionising radiation (European Union, 2013). This legislative directive profoundly disrupted traditional medical imaging operations by legally enforcing the principles of justification and optimisation. It dictates that every medical exposure must demonstrate a net diagnostic benefit to the patient, and that radiation doses must be kept to the absolute minimum necessary to answer the clinical question. Medico-legal analyses of

Directive 2013/59/Euratom emphasize that the directive strictly mandates enhanced patient information protocols and formalized dose reporting in modern practice, binding clinical institutions to rigorous standards of transparency and safety (Karaboue et al., 2024).

A central pillar of the Directive is the mandatory establishment, regular review, and clinical use of Diagnostic Reference Levels (DRLs). DRLs function as an investigational threshold; if a radiological facility consistently exceeds the established national DRL for a standard procedure, it must trigger an immediate clinical audit to identify hardware faults or operator errors. The application of DRLs for the optimization of X-ray imaging, as demonstrated in established healthcare systems like the UK, has proven to be the most effective mechanism for systematically driving down population radiation doses without compromising diagnostic efficacy (Martin, 2016).

Furthermore, the Directive formalises the role of the Medical Physics Expert (MPE), requiring their active and documented involvement in the dose optimisation process, patient dosimetry, and the quality assurance testing of all radiological equipment. The European Commission has provided explicit guidelines defining the MPE's responsibilities, which include analysing complex dosimetric data, advising on the procurement of new radiological equipment, and leading local optimisation committees (European Commission, 2014, Publications Office of the European Union). The European Federation of Organisations for Medical Physics (EFOMP) further delineates how the MPE must act as the primary bridge between clinical radiological practice and the physical sciences to ensure regulatory compliance and patient safety (European Federation of Organisations for Medical Physics, 2014). The core anatomical and technical requirements that align with these European image quality standards are summarised in Table 1.

Table 1: Key European image quality criteria for chest radiography

Criterion	What it means in practice	European standard/source
Inspiration	The radiograph should be taken at full inspiration with suspended respiration. Adequate inspiration is assessed by visualisation of at least six anterior ribs or ten posterior ribs above the diaphragm. The diaphragm and lateral costophrenic angles should be clearly visible, ensuring adequate expansion of the lungs.	EUR 16260 - Carmichael et al. (1996)
Penetration / Exposure	Exposure should be sufficient to demonstrate the thoracic spine through the heart shadow and adequately visualize the retrocardiac lung and mediastinum. Both underexposure and excessive exposure can reduce the visibility of important anatomical structures.	EUR 16260 - Carmichael et al. (1996)
Positioning and Symmetry	The patient should be positioned without significant axial rotation. The medial ends of the clavicles should be approximately equidistant from the spinous processes. Correct positioning reduces anatomical distortion and allows reliable assessment of the thorax.	EUR 16260 - Carmichael et al. (1996)
Pulmonary Vascular Pattern	The pulmonary vascular pattern should be sharply reproduced throughout the lung fields, including the peripheral vessels. Clear visualization of vascular markings indicates adequate image sharpness and contrast.	EUR 16260 - Carmichael et al. (1996)
Anatomical Detail / Spatial Resolution	The image should demonstrate fine anatomical structures with sufficient sharpness. European criteria include visualization of small round details down to approximately 0.7 mm for high-contrast structures and 2 mm for low-contrast structures, together with fine linear and reticular structures.	EUR 16260 - Carmichael et al. (1996)
Tracheobronchial and Mediastinal Structures	The trachea, proximal bronchi, heart borders, aorta, and mediastinum should be clearly visible. Adequate visualization confirms sufficient image quality for assessment of central thoracic structures.	EUR 16260 - Carmichael et al. (1996)
Diaphragm and Costophrenic Angles	The diaphragm and both lateral costophrenic angles should be completely included and clearly demonstrated. This ensures adequate anatomical coverage of the lung bases and helps prevent important abnormalities from being missed.	EUR 16260 - Carmichael et al. (1996)
Motion / Image Sharpness	The examination should be performed with suspended respiration and minimal patient movement. Significant motion can cause blurring	EUR 16260 - Carmichael et al. (1996)

Methods of Image Quality Assessment

Evaluating whether a clinical chest radiograph meets European quality standards requires a structured and systematic

approach. Over time, assessment methods have progressed from subjective visual evaluation to more objective and statistically based grading frameworks.

Visual Grading Analysis

Visual Grading Analysis (VGA) is a statistically established method used to assess the clinical image quality. In VGA, radiologists or experienced radiographers evaluate the visibility of specific anatomical structures according to established criteria, such as EUR 16260 by using an ordinal rating scale. These ratings can be analysed using Visual Grading Characteristics (VGC) analysis, a non-parametric statistical method similar to Receiver Operating Characteristic (ROC) analysis (Bäth & Månsson, 2007). VGC compares the distribution of ratings between a test and a reference condition and calculates the area under the VGC curve (AUC_VGC), which provides a difference to measure between image quality, imaging protocols or image-processing methods.

VGC analysis is increasingly used in radiology image-quality studies because it allows different imaging conditions to compare without exposing patient to the unnecessary variations in radiation dose (Tesselaar et al., 2016). Another approach is Visual Grading Regression (VGR) which uses ordinal logistic regression to analyse visual grading data. It can account for differences between observers and patients, allowing researchers to evaluate factors affecting image quality and assess the potential for radiation-dose reduction (Smedby & Fredrikson, 2014).

Reliability and Observer Variability

The effectiveness of VGA depends largely on observer reliability. Studies of European guidelines have shown varying intra- and inter-observer agreement, depending on the anatomical region and clarity of the criteria. For example, a study using EUR criteria for lumbar spine imaging found that observer training improved agreement, although differences remained in judging “visually sharp reproduction” (Doktor et al., 2019). Comparisons between radiographers and radiologists have also shown that structured training can improve consistency in image-quality assessment. This suggests that experienced radiographers can contribute effectively to quality assurance, particularly where radiologists are limited (Nocum et al., 2023). VGA has also been used to compare low-dose 2D/3D slot scanners with conventional digital radiography, showing that slot scanners can produce diagnostic-quality chest images at a lower effective dose (Abdi et al., 2021).

Reject and Repeat Analysis

Reject and repeat analysis is an important part of quality assurance. It helps identify how often images are rejected and why. In digital radiography, reject rates are generally expected to remain below 5-10%. Studies show that patient positioning errors are the most common reason for rejection, followed by anatomy cut-off and poor collimation (Serra et al., 2024).

Reject analysis should also cover different imaging modalities. A study from Belgium found higher reject rates in digital radiography (8.3%) than in CT (2.5%), but CT rejects resulted in a much greater wasted radiation dose. This shows why both modalities should be monitored (Haddad et al., 2023). Cases involving two or more repeated images can also help identify problems in technique and training (Stephenson-Smith et al.,

2021). Similar findings from hospitals in Ethiopia showed that positioning and exposure errors were common causes of rejected X-rays, showing the importance of regular reject analysis in different healthcare settings (Zewdeneh et al., 2008).

Implementation of IEC 62494-1 in Dose Indicators and Exposure Indices

The shift from film-screen to digital radiography removed the clear visual sign of overexposure. Digital systems can process an overexposed image so that it still looks acceptable, even when the patient receives more radiation than needed. This can lead to “dose creep” (Seibert & Morin, 2011). To address this, the International Electrotechnical Commission introduced the Exposure Index (EI) and Deviation Index (DI) through IEC 62494-1. The EI indicates the amount of radiation reaching the detector, while the DI compares the actual EI with the target EI for a specific examination. A DI of 0 represents the target exposure, while +3 and -3 indicate approximately twice and half the target exposure, respectively (International Electrotechnical Commission, 2008; Cohen et al., 2011).

Regular monitoring of EI and DI can help radiographers and medical physicists keep patient doses within appropriate levels and support the ALARA principle. However, EI can vary with patient body thickness, so exposure settings should be adjusted carefully rather than relying only on automatic exposure control (Yoon et al., 2021; Scott et al., 2016). Knowledge of these indices is also important. Studies among digital radiography practitioners in Nigeria have found gaps in understanding of exposure indices, highlighting the need for regular training and continuing professional development (Esien-Umo et al., 2023).

Artificial Intelligence-Assisted Tools in Image Quality Assessment and Teleradiology

Artificial intelligence (AI) is changing the way chest X-rays are assessed for tuberculosis. Tools such as CAD4TB (Computer-Aided Detection for Tuberculosis) use deep learning to analyse chest radiographs and provide an abnormality score from 0 to 100 (Murphy et al., 2020). Recent studies of CAD4TB versions 6 and 7 reported AUC values above 0.85, showing performance close to that of experienced readers in detecting lung abnormalities (Nzimande et al., 2025). By using a defined threshold, CAD4TB can help identify patients who need further testing while reducing unnecessary confirmatory tests.

The use of CAD4TB in different settings has shown its potential for large-scale TB screening. Studies from South Africa and Lesotho reported good performance under real-world conditions (Nzimande et al., 2025). In Pakistan, AI-based screening helped support large-scale screening and reduce the number of patients requiring confirmatory testing (Sajid et al., 2025). Similarly, a programme in Viet Nam showed that combining AI with private healthcare services increased screening capacity and case detection (Vo et al., 2026). These findings suggest that the benefits of AI depend not only on its accuracy but also on how well it is integrated into existing healthcare services. AI can also support faster decision-making at the point of care.

As shown in Figure 2, chest radiographs can first be assessed by AI, with suspicious cases referred for molecular testing and low-risk cases avoiding unnecessary testing. This may reduce delays and workload in areas where radiologists are limited.

Teleradiology can provide additional support by connecting rural health centres with radiologists in larger centres. Its use during the COVID-19 pandemic also helped maintain access to diagnostic services when movement was restricted (Chitungo et al., 2021). In

African settings, it can support the remote interpretation of chest radiographs and improve access to specialist care (Rudisill et al., 2024). However, wider use requires reliable digital infrastructure and clear telemedicine policies.

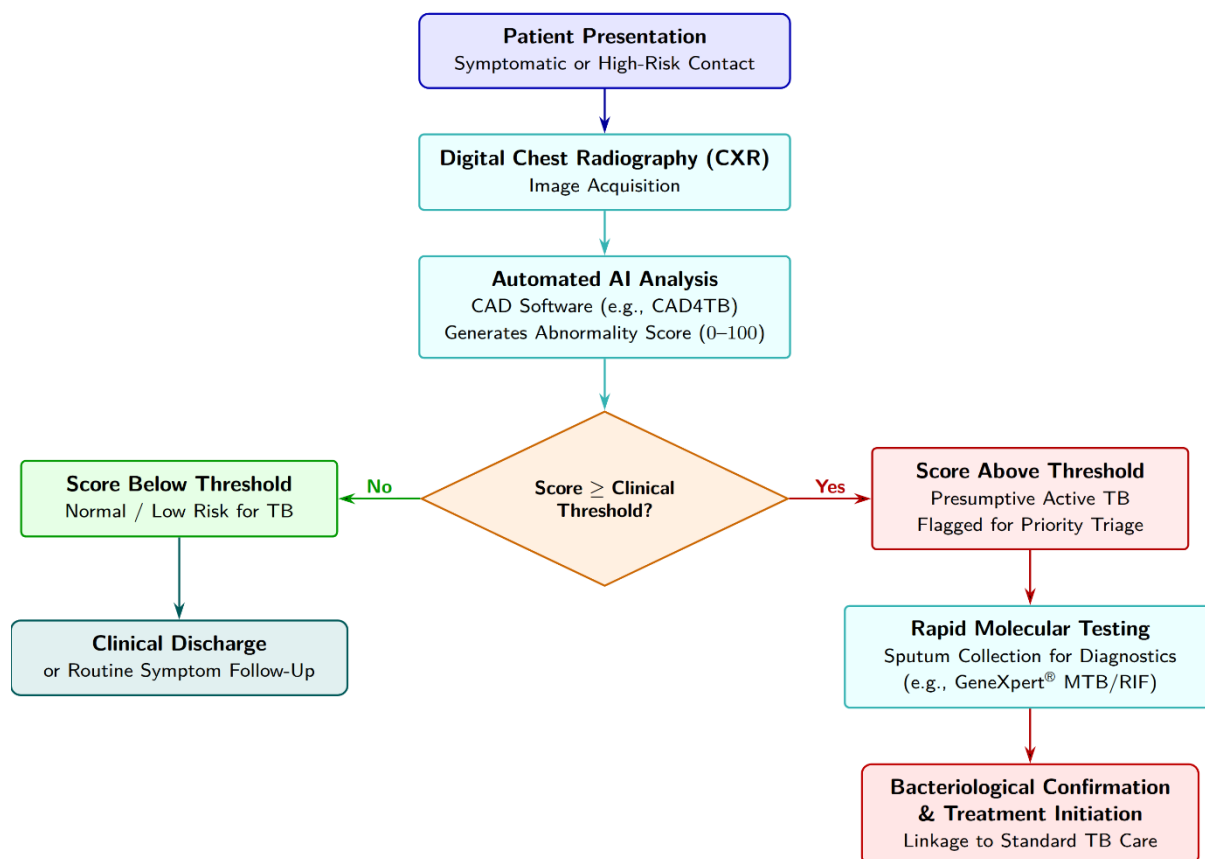


Figure 2: AI-assisted tuberculosis radiographic triage pathway. The workflow shows how AI-based chest X-ray assessment can help identify patients who require further molecular testing while reducing unnecessary testing in low-risk cases. Adapted from WHO screening guidelines and established CAD4TB operational protocols.

Relevance of European Guidelines to Cameroon

The quality and radiation-protection principles established by European radiography guidelines have important clinical relevance for Cameroon because of the country's high burden of respiratory disease and limited availability of specialized radiological services. Cameroon faces a dual burden of disease, with respiratory infections such as tuberculosis and bacterial pneumonia occurring alongside an increasing burden of non-communicable cardiothoracic diseases. Chest radiography remains an important diagnostic modality across different levels of the healthcare system for the management of these conditions (Moifo et al., 2017).

In this setting, the EUR 16260 guidelines provide standardized anatomical criteria for assessing chest radiographic image quality. By defining the anatomical structures that should be

adequately demonstrated, the guidelines provide an objective basis for determining whether an image is diagnostically acceptable rather than relying solely on subjective assessment. This is particularly relevant in healthcare settings where image acquisition and preliminary assessment may involve personnel with different levels of specialized training.

Radiation-dose optimization is also important because patients with conditions such as tuberculosis may undergo repeated chest radiographs during diagnosis and follow-up. Applying appropriate exposure parameters and the ALARA principle can help reduce unnecessary radiation exposure while maintaining adequate diagnostic image quality. However, the effective application of these principles depends on appropriate equipment, trained personnel, quality-assurance systems, and regulatory oversight.

Systemic Implementation Challenges in Cameroon and Sub-Saharan Africa

Although the principles of European guidelines are relevant to Cameroon, their implementation is constrained by interconnected workforce, equipment, regulatory, and educational limitations as shown in Table 2.

Table 2 outlines the primary implementation challenges and potential solutions.

Challenge	Effect on Image Quality	Possible Solution	Source
Shortage of Radiologists	High reliance on non-specialists leads to interpretive errors and missed subtle pathologies.	Deployment of AI triage tools (e.g., CAD4TB) and expansion of teleradiology networks.	(Rudisill et al., 2024; Nzimande et al., 2025)
Lack of Medical Physics Experts	Equipment remains uncalibrated; DRLs are not systematically calculated or enforced.	Phased academic training programs and regional collaborations for MPE certification.	(European Union, 2013)
Analogue to Digital Transition	Unmonitored digital systems lead to "dose creep" and excessive patient radiation exposure.	Mandatory monitoring of the IEC 62494-1 Deviation Index (DI) during routine clinical audits.	(Seibert & Morin, 2011)
Weak Regulatory Enforcement	High variability in entrance surface doses across different healthcare facilities.	Empowering the ANRP to link facility licensing to mandatory triennial DRL audits.	(Gnowe et al., 2019)

Opportunities and Recommendations

Despite the formidable structural challenges, several strategic opportunities exist to elevate the standard of chest radiography in Cameroon, leveraging technological innovations and phased regulatory integration.

Radiological Workforce Deficit

Cameroon has a severe shortage of specialized radiological personnel. Recent global workforce analyses estimate a density of approximately one radiologist per 500,000 population, equivalent to around two radiologists per million inhabitants (RAD-AID, 2023). This is substantially lower than the European Union average of approximately 127 radiologists per million, with some member states exceeding 270 per million (European Society of Radiology, 2021). This shortage is also evident elsewhere in sub-Saharan Africa. In Ghana, for example, the reported density is approximately three radiologists per million population, with a highly uneven geographical distribution that leaves large rural areas underserved (Sarkodie et al., 2023). The concentration of available specialists in major urban centres in Cameroon similarly contributes to a rural-urban gap in access to specialist radiological interpretation. As a result, chest radiograph acquisition and preliminary clinical assessment may involve radiographers, general practitioners, and other healthcare professionals with varying levels of specialised training. This makes standardised image-quality criteria particularly important for maintaining consistent radiographic practice where specialist support is limited.

The workforce challenge is accompanied by gaps in radiation-protection awareness among referring clinicians. Studies in Cameroon examining knowledge of irradiation, medical imaging prescriptions, and clinical imaging referral guidelines have identified inadequate understanding of radiation doses and clinical justification among physicians (Moifo et al., 2017). Radiation-dose optimization is particularly important in children, who are more sensitive to ionizing radiation and have a longer lifetime during which radiation-related effects may develop. Therefore, unnecessary repeat examinations and excessive exposure should be

minimized through appropriate justification, optimized exposure parameters, and effective quality-assurance procedures (ICRP, 2013). Such gaps may contribute to inappropriate imaging requests and unnecessary radiation exposure, further increasing the workload on an already limited radiological workforce.

Equipment Heterogeneity and the Analogue-to-Digital Transition

The radiological equipment landscape in Cameroon is highly heterogeneous. While major tertiary centres in Yaoundé and Douala have increasingly adopted digital radiography (DR) and computed radiography (CR), many peripheral and rural facilities continue to depend on analogue screen-film technologies (RAD-AID, 2023).

Analogue systems are vulnerable to film-processing errors, exhausted chemical developers, and inadequate darkroom conditions. These problems can reduce image contrast and increase reject and repeat rates, making it difficult to consistently achieve the anatomical image-quality requirements defined by EUR 16260.

The transition to digital systems also introduces new challenges. Without adequate training and exposure monitoring, digital radiography may result in dose creep. Because digital processing can produce an apparently acceptable image despite excessive exposure, this practice may increase patient radiation exposure without being immediately recognised (Scott et al., 2016). Equipment maintenance presents an additional challenge. Weak supply chains for preventive maintenance may result in prolonged equipment downtime, inadequate calibration, and deterioration of X-ray tubes and image receptors. Therefore, simply replacing analogue equipment with digital systems does not guarantee improved image quality or radiation protection.

Quality Assurance, Regulation, and Dosimetry Variability

Radiation protection in Cameroon is officially overseen by the National Radiation Protection Agency (ANRP), established under Decree 2002/250 (Guená et al., 2019), which was subsequently reorganized and renamed the Radiation Safety and

Nuclear Security Authority (ASRAN) by Presidential Decree No. 2024/599 on November 19, 2024. Although a regulatory framework exists, the implementation of routine quality-assurance audits and systematic dose monitoring remains fragmented.

The development and implementation of Diagnostic Reference Levels (DRLs) in Cameroon also remain at an early or pilot stage. A dosimetric study of adult chest radiography at Ngaoundere Regional Hospital demonstrated substantial variation in entrance surface doses associated with non-standardized exposure practices. Some centres have reported optimized entrance surface doses of approximately 0.18 mGy, whereas other facilities have shown substantially different exposure levels (Gnowe et al., 2019). Broader assessment of population exposure to ionizing radiation from medical diagnosis in Ngaoundere has similarly highlighted the need for stronger and more coordinated national monitoring (Guenia et al., 2019).

This variability extends beyond chest radiography. An evaluation of dosimetric indicators for routine adult CT examinations in two healthcare facilities in Yaoundé identified significant inter-facility variation associated with the absence of optimized scanning protocols (Severin et al., 2026). Similarly, an assessment of diagnostic reference levels, international values, and implementation challenges in mammography in Cameroon highlighted the need for stronger physical and technical oversight of specialized examinations (Tayo et al., 2026). The consequences of inadequate standardization may also affect vulnerable patient groups. A study examining medical radiation exposure among pregnant patients at the Gynaeco-Obstetric and Paediatric Hospital of Douala reported instances of unwarranted fetal irradiation, emphasizing the importance of clinical justification and dose optimization (Simo et al., 2018).

Effective implementation of radiation-protection standards also requires appropriately trained Medical Physics Experts (MPEs). MPEs can contribute to equipment calibration, dosimetric assessment, exposure-index monitoring, and local optimization programmes. However, Cameroon has an acute shortage of formally trained MPEs, limiting the ability of facilities to perform these activities proactively. Monitoring the IEC 62494-1 Exposure Index and Deviation Index (DI) could provide a useful mechanism for identifying inappropriate exposure levels in digital radiography. However, its effective use requires trained personnel, routine monitoring, and integration into quality-assurance programmes (Seibert & Morin, 2011). Similar gaps in understanding standardized exposure indices have been reported in digital radiography practices in Nigeria, suggesting that these challenges extend beyond Cameroon.

Strategic Opportunities and Recommendations

Given these limitations, implementation of European radiography principles in Cameroon should focus on adapting their core concepts to local conditions rather than directly reproducing European systems. A phased strategy should prioritize local dose benchmarks, practical quality assurance, targeted education, regulatory strengthening, and appropriate technological support.

Establishing Local Diagnostic Reference Levels

The establishment of local diagnostic reference levels (LDRLs) should be a central component of radiation-dose optimization in Cameroon. European DRLs should not simply be transferred to the Cameroonian setting because differences in

population characteristics, equipment, and clinical practice may influence radiation exposure. A relevant regional model is provided by the establishment of local diagnostic reference levels for routine chest radiography in a public-sector hospital in central South Africa (Junda et al., 2021). By measuring exposure levels in standard patient groups and calculating the 75th percentile of the dose distribution, facilities can establish practical local reference values.

For Cameroon, this process should begin with a systematic census of operational X-ray units and standardized collection of patient-dose data, such as entrance surface dose or dose-area product. These data could support the development of national or regional reference levels that reflect local equipment and clinical practice. The ANRP could subsequently incorporate periodic LDRL audits into the regulatory process, including the proposed use of triennial audits linked to equipment licensing.

Establishing a verified national database of operational X-ray units and dose measurements would also help prevent the development of "paper standards" that are not supported by adequate national evidence.

Low-Cost Quality Assurance and Targeted Education

Where sophisticated dosimetric monitoring systems are unavailable, reject and repeat analysis provides a practical and relatively low-cost quality-assurance approach. Radiography departments can maintain basic digital or physical records of rejected images and the reasons for repetition. Analysis of these records can identify recurring technical and positioning problems and guide targeted interventions.

Positioning errors can be addressed through focused training of radiographers, potentially reducing reject rates and unnecessary repeat examinations without requiring expensive dosimetric equipment (Serra et al., 2024). Such measures provide an achievable starting point for quality improvement in resource-constrained facilities. Education should also extend to referring clinicians. Continued medical education on clinical justification, radiation doses, and appropriate imaging referral can help reduce unnecessary examinations and strengthen radiation-protection practices.

Strengthening Regulation and International Collaboration

The ANRP has an important role in moving from isolated assessments and pilot activities towards a coordinated national quality-assurance system. A phased regulatory approach could combine equipment registration, routine quality-assurance assessments, patient-dose monitoring, and periodic DRL audits.

International collaboration can support this process where financial, technical, and educational resources are limited. RAD-AID, for example, has conducted Radiology Readiness Assessments evaluating infrastructure, equipment, personnel, and technological capacity in low-resource settings, including Cameroon (RAD-AID, 2023). Partnerships of this type could support targeted equipment upgrades, staff training, teleradiology development, and advanced training opportunities for medical physics personnel.

Implementation Approach

Overall, improving chest radiography in Cameroon requires a phased approach that combines standardized image-quality

assessment with locally relevant radiation-dose monitoring and practical quality-assurance measures. Strengthening education, regulatory oversight, and medical physics capacity can support sustained implementation, while teleradiology and AI may help extend specialist and screening capacity to underserved areas. The objective should not be to reproduce European systems directly, but to adapt their core principles to the epidemiological, infrastructural, workforce, and technological realities of Cameroon and the wider sub-Saharan African region.

Conclusion

European radiographic guidelines provide a useful framework for improving chest radiography quality and radiation protection in Cameroon. However, their implementation is limited by shortages of radiological and medical physics personnel, heterogeneous equipment, inadequate maintenance, variable radiation doses, and fragmented quality-assurance and regulatory systems. A locally adapted approach is therefore needed, combining standardized image-quality assessment, local diagnostic reference levels, routine reject and dose audits, targeted education, and stronger regulatory oversight. International collaboration, teleradiology, and carefully implemented AI may further support services in underserved areas. Rather than directly replicating European standards, Cameroon should adapt their core principles to its local clinical, infrastructural, and workforce realities to achieve safer and more consistent diagnostic imaging.

Declarations

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