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Economic and Legal Implications of Radiation Safety Standards in Developing Healthcare Systems

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ABSTRACT:

Radiation safety in diagnostic centers is difficult to regulate in less developed countries such as Bangladesh, where there are financial and institutional limitations. This article evaluated the economic feasibility of 30 diagnostic institutions located in Dhaka, Chattogram, and Khulna and the institutional readiness to implement, maintain, and comply with the international technical requirements of radiation safety, including those of the IAEA as well as BAEC. The method involved both structured cost-related questionnaires and semi-structured in-depth interviews with radiologists, administrators and regulators. It reveals that public institutions largely adhere to safety regulations; however, only 46% of private facilities are up to standard. Thus, about BDT 350,000 to 550,000 per implementing basic radiation safety was the average cost to bear for small clinics. But compliant centres also reported 17% more patient trust, better staff safety, and lower legal liability. The research also emphasizes the importance of financial incentives, enhanced audits, and educational programmers to close the policy-practice gap.

Keywords: Radiation Safety, Diagnostic Centers, Compliance, Bangladesh, IAEA Standards

1. Introduction

Radiation protection in medical diagnostic practices has become a world-wide issue due to the widespread use and growing number of X-ray and other ionizing radiation methods applied in medical treatment. Compliance with radiation protection rules and regulations is required not only for the protection of the patients, but also for healthcare professionals and the public. Regulatory compliance in high-income countries is buttressed by robust institutions and financial resources. In low- and middle-income countries, such standards enforcement would be a challenge, as the countries tend not to have the financial and institutional capital needed to mount enforcement efforts.

Private diagnostic centres have expanded rapidly in Bangladesh due to high demand for imaging services in urban areas including Dhaka, Chattogram, and Khulna. Although access to health care has improved as a result of this expansion, concerns have been raised about the ability of the country to ensure the safe and appropriate use of radiation in these environments. Compliance is patchy with the international standards promoted by the International Atomic Energy Agency (IAEA), including those adopted and enforced in Bangladesh by the Bangladesh Atomic Energy Commission (BAEC).

Two important dimensions of this problem are addressed directly in this paper. First, it estimates the cost-effectiveness of introducing radiation protection practices in diagnostic facilities, in particular in small practices with prescribed income constraints. Second, it assesses the institutional readiness of such facilities to meet international safety standards, including infrastructure preparedness as well as awareness, training, and regulatory involvement. This will allow matching up quantitative data of cost factors including, but not limited to, shielding, calibration, and training, with qualitative accounts from the key stakeholders in order to generate a holistic picture of the barriers and opportunities to enhance radiation safety in Bangladesh (BGD).

The findings disclose obvious public-private disparities in compliance and the smaller private clinics seem to be more stressed financially and institutionally. However, between the increased patient trust, as well as lessened liability, it is arguable that with targeted policies (e.g., subsidies, tax incentives, regular audits), radiation safety can become cost effective. This is a part of the broader discussion on the trade-off between protecting public health and compliance with regulation in low-resource health settings.

2. Literature Review and background

The liberal use of diagnostic imaging in contemporary health care has made radiologic safety an imperative issue for public health. Worldwide, diagnostic radiology is the most important artificial source of radiation exposure to the population at large. While the advantages of radiological applications to medicine are indisputable, they must be weighed against the risks of radiation-induced harms and late health effects such as cancer. In order to reduce such risks, International Community including IAEA and World Health Organization (WHO) has approved standard safety protocols and guidelines,

which are applicable practically in all countries. These comprise shielding, equipment set-up, dosimetry, safe working practices and recurrent staff training. The level of compliance to these regulations however, varies considerably, particularly between developed and developing world.

Radiation Protection: At the Crossroads of Theory and Practice

In medical practice, radiation protection is based on three main principles: justification of the practice, optimization of protection and limitation of the dose. The Basic Safety Standards (BSS) of the International Atomic Energy Agency (IAEA) establish a general standard that has been adopted in all countries. These criteria mandate permanent shielding, periodic calibration of instruments, recording of occupational dose using personal dosimeters, and training of the medical staff.

In high income settings, these protocols are generally well adhered to as a result of robust regulatory control, sufficient funding and developed institutional structures. But, in Low- and Middle-Income Countries (LMICs) like Bangladesh several system-based barriers limit complete adherence. The ICN (2018) has summarized LMIC challenges as having insufficient technical capacity, financial limitation, poor or non-existent training programmers, insufficient regulation, and low awareness amongst health professionals by the IAEA (2018). These create high variation in safety measures among diagnostic centres, especially those in the private sector.

Regulatory Environment and Implementation in Bangladesh

The Radiation Protection Rules, 2012 has been enacted and it tries to harmonize the radiation safety of the country with the international standards by the initiative of Bangladesh Atomic Energy Commission (BAEC). BAEC is the chief regulatory body to licence diagnostic facilities, carryout regular inspections, and ensure radiation safety regulations. Despite this institutional framework, the literature indicates that enforcement is patchy.

According to Rahman et al. (2020) most of the diagnostic centres in Bangladesh are running without regular monitoring and without re-licencing. Equipment is marginally better in public hospitals, but most small private clinics particularly in semi-urban and rural areas have been unable to meet even minimal safety requirements. Their work investigating 50 centres showed a minority of centres (well below 50%) possessed a functioning dosimetry program and were involved in regular staff training [21].

This compliance gap is made more problematic by a lack of knowledge among management and caregivers. Qualitative study by Uddin and Mahmud (2021), only few radiologists and technicians had knowledge of recent changes in national safety laws and availability of refresher training programs. In addition, many diagnostic facilities were unaware that non-compliance could lead to legal penalties, closures or lack of public confidence.

Economic Limitations and the Price of Conformity

Economic aspect is one of the most stimuli in applying radioprotection program. It costs not a little to make standards of safety, safeguards and defense. These costs comprise fitting of lead shields, maintenance of machines, purchase of dosimeters and training of hospital personnel. These costs in Bangladesh are BDT 350,000 to 550,000, which is unaffordable for small scale independent diagnostic centres with low profit margin.

Similar results are mirrored in comparative studies from other LMICs. For instance, Sharma et al. (2018) in their evaluation of small diagnostic centres in India reported that because of the higher initial costs to fulfill safety requirements, investment in infrastructure was discouraged. For those clinics that did, they often shifted cost burdens to patients, raising service fees and limiting access.

Readiness of Institutions and Training Needs

In addition to budget constraints, institutional preparedness is important in order to comply with the security requirements. This encompasses access to trained radiologists and medical physicists, regulatory awareness for administrators as well as mechanisms of documentation and supervision. However, in many of the Bangladeshi centres these institutional aspects remain underdeveloped.

Ahmed et al. (2017) indicated that there is a small number of certified medical physicists in the country, which is an important challenge for the centres to comply with the international safety standards. Furthermore, the capacity is typically divided into that for public and private providers, meaning, for instance, most complicated treatment occurs in public hospitals who work under guidelines dictated by the government, while private providers have a little more freedom in how they work, which results in a two-tier system and heterogeneous standardization.

Benefits of Compliance: Health and Institutional

There is evidence to suggest that compliance can bring real benefits, despite these difficulties. For instance, Park et al. (2017) found that radiation safety investing organizations earned greater patient confidence and received fewer complaints as well as having a safer overall working environment. A similar report from Bangladesh profiled compliant facilities experiencing a 17% increase in patient retention, reputational gain and fewer legal troubles under the 2012 Radiation Protection Rules.

Additionally, radiologists and administrators who were interviewed for the study reported that compliance enhanced morale among the staff and lowered the number of staff absences caused by occupational health problems. When patients were informed of the safety protocols being adhered to, they also said they felt more confident in the care they had received.

Crossing the Chasm: Solutions from the Literature

A multidimensional approach has been suggested by the literature to bridge the gap between radiation safety principles and radiation protection in the field. Among these are government subsidies or tax incentives on smaller clinics, mandatory training and certification for staff, regular inspections with

penalties for non-compliance, public education about safety rights, and accountability between public and private healthcare providers." In the case of Bangladesh these measures adhere to international standards like Strategic Approach to Education and Training (SAET) of IAEA and from economical as well as enforcement point of view it can be integrated effectively. In a country with a rapidly growing, but uncontrolled diagnostic sector, such policies are essential. This paper fills a gap using empirical evidence and stakeholder views, which can inform national and international discussions on health system reform and diagnostic safety.

2.1 Literature Gap

Global evidence-based knowledge is available on radiation safety and regulatory enforcement in diagnostic imaging, but there are still several lacunas-especially in the context of LMICs such as Bangladesh. Previous studies by international organizations such as IAEA and WHO, and also by researchers from around the region, concentrate mainly on technical standards, broad-based compliance difficulties, as well as the risks of radiation exposure. But such studies tend to be general in nature, they do not take into consideration the particular economic and institutional set up in given countries.

There is very little research on empirical examination of economic viability of radiation safety compliance in Bangladesh. Although research in India and Nigeria has estimated the cost of safety infrastructure, there is scant evidence on how such costs may impact small and medium sized diagnostic centres in Bangladesh. The cost-benefit aspect – that is, if the investment pays off in terms of generating some positive patient trust, legal protection, staff working environment, etc. is largely neglected in the health literature in Bangladesh.

Second, institution preparedness and stakeholders' attitudes towards radiation safety has not been well characterized. The majority of literature has been dedicated to the examination of equipment, shielding, or compliance through checklists, but in reality, little is known in terms of how well prepared the diagnostic centres are in terms of administrative capability, knowledge of rules, availability of training programs, internal safety culture. Especially missing are perspectives from front-line stakeholders, including radiologists, medical physicists, administrators, and regulators where practical barriers and the potential for change can be readily recognized.

Third, despite the fact that Bangladesh promulgated its own Radiations Protection Rules in 2012, comparatively little scholarship and analysis appears to have been carried out concerning the impact and implementation of this regulation in the past decade. It is not well understood how successful the monitoring and licencing operations of the BAEC are, and whether or not private diagnostic centres are living up to the standards outlined in national laws and international protocols such as the IAEA standards.

Fourth, although private diagnostic facilities make up an important and expanding part of the urban Bangladesh health landscape, these facilities tend to be underrepresented in studies. Typically, these centres are cost constrained and subject to less formal public sector regulation, but there has been limited research conducted into compliance and safety at this level. This makes it difficult for policymakers to design interventions specifically targeted at the private sector, which is an important determinant of public health all over the world.

Lastly, International evidence supports the sustained benefits of investment in radiation safety, in terms of enhanced patient continuation of treatment and reduced occupational risks; however, there is no Bangladesh specific evidence to this effect either. Clear documentation of these results on a measurable basis is necessary for mandating this financial impact on smaller clinics, and for designing a model of policy that uses incentives to increase voluntary compliance.

3. Methodology

This research has used a mixed method; both qualitative and quantitative approach to explore the radiation safety status in diagnostic centres of Bangladesh. The objectives were to review the cost-effectiveness of the introduction of radiation protection requirements and review existent facility infrastructure within diagnostic establishments to comply with IAEA standards, as implemented by the Bangladeshi national regulatory bodies under the jurisdiction of the BAEC.

Study Locations and Sampling

The study was carried out at three large urban hubs—Dhaka, Chattogram, Khulna—which are a good reflection of the range of diagnostics available in Bangladesh. These cities were chosen based on their large number of diagnostic imaging centres, as well as the range of different ownership (public vs. private).

Thirty diagnostic centres purposively selected for this study included an almost equal number of public and private centres, as well as both small, mid-sized and large facilities. It was a mixture of government hospitals (including radiology departments) and privately owned stand-alone diagnostic centres. This was a purposive sample to enable the study to compare institutional practices in systems of various ownership and economic circumstances.

Quantitative Component

So as to evaluate the cost and benefit of compliance of radiation protection, one hundred and fifty-four facility administrators or radiologists or radiation safety officers were interviewed using structured questionnaire. Data were collected on the following:

Preliminary costs for radiation protection (lead – lined walls, etc.)

This is however in addition to the repeated service costs of equipment calibration/quality control/dosimetry and so on.

Educational costs for qualified radiologists, medical physicists and technologists

Public self-perception around service charges and patient affordability

Cost information was aggregated and analyzed with descriptive statistical methods like mean, median and range to find out the average investment needs for public and private facilities. Numbers were compared with the size of facilities, the number of treated patients and the funding type (government/non-government).

Qualitative Component

In order to examine institutional readiness semi-structured interviews were held with actors representing four groups: 1. The hospital's radiologists and medical technologists (to measure the level of awareness and attitudes towards safety). 2. Medical physicists and machine operators (to get a sense of implementation issues). 3. Heads of diagnostic centres (To consult on decision-making and budget) and; 4. Government regulators from BAEC (to hear about enforcement, licencing and compliance monitoring)

Overall, 40 interviews were conducted. The interviews were recorded, transcribed, and analyzed thematically by means of framework analysis. Common themes included: knowledge of regulations, access to training, organizational obstacles, perception of benefits to being in compliance, and suggestions for enhancing adherence.

Ethical Considerations

A university ethics review board approved the project. The participation was voluntary and written consent was obtained from every respondent. Personal or patient-level data were not collected, and all facility-level information was de-identified to ensure no facilities would be identifiable.

Triangulation and Validity

The researcher triangulated the results between the two methodological approaches to maintain validity and reliability. For example, the questionnaires' financial information was measured against the verbal attestation provided during interviews. In the same way, institutional documents (i.e. training certificates, calibration reports) were analyzed in conjunction with stakeholder accounts where possible.

Standards for Protection against Radiation

The radiation protection in medical diagnostics is led by international recommendations and national regulations. These regulations are designed to reduce the exposure to ionizing radiation for patients, health care providers, and the public, and at the same time, allow the beneficial use of diagnostic imaging.

Standards of Practice and International Standards: Guidelines IAEA aforementioned.

Basic Safety Standards (BSS) (GSR Part - 3): The International Atomic Energy Agency (IAEA) has established the internationally accepted standard for the radiation protection as GSR Part 3, named as Basic Safety Standards (BSS). These guidelines are endorsed by several organizations, including the WHO and the International Labor Organization (ILO).

The main elements of the IAEA's Basic Safety Standards are:

Justification of medical Exposures: The expectation is that each exposure offers a definite net benefit to the patient.

Protection Optimization: Radiation should be minimized; As Low As Reasonably Achievable (ALARA).

Limit on Dose: The amount of radiation that occupants and the public may receive shall not exceed prescribed limits.

Shielding and Facility Safety: Structural shielding (lead wall) requirement and room design.

Equipment calibration and maintenance: All radiation-producing equipment should be calibrated and serviced periodically.

Personal Dosimetry: Those who work in a healthcare setting where they can be exposed to radiation should wear dosimeters and be monitored for total exposure.

Training and Certification: Radiologists, medical physicists, and technologists should be trained in radiation protection techniques.

Quality Assurance **(**QA) Programs: Routine audit testing will assure uniformity and accuracy of the imaging system.

The IAEA also highlights the need for a Standards enforcement national regulatory authority, with licencing, monitoring and enforcement activities.

National Framework: Bangladesh Radiation Protection Rules, 2012

Following the IAEA requirements, Bangladesh framed the Radiation Protection Rules, 2012 under the Nuclear Safety and Radiation Control Act, 1993. The applicable authority is the Bangladesh Atomic Energy Commission (BAEC) 8, particularly the Radiation Control Division (RCD).

Under these 2012 Rules, the minimum requirements for diagnostic facilities are as follows:

i) Licencing requirement: The requirement for registration and licencing is mandatory for all organizations using ionizing radiation.

ii) Structural and Engineering Controls: All film and screen rooms are to be suitably shielded and posted with adequate radiation signs.

iii) Radiation Safety Officers (RSOs): The facility shall provide at least one trained RSO who is responsible for ensuring compliance.

iv) Record-keeping: Precise records of exposure data, staff training, and equipment maintenance shall be maintained.

v) Periodic inspections: Unexpected compliance inspections and audits are carried out by BAEC.

Enforcement and Penalties

A violation of radiation safety could be penalized by fines, loss of the revenue generating activities or even forfeiting the facility licence. The Bangladesh Atomic Energy Commission (BAEC) has strongly recommended to adapt the Diagnostic Reference Levels (DRLs) to regulate the standardization of radiation doses during radio diagnostic imaging.

Gaps in Implementation

Despite the existence of these guidelines, implementation varies widely – especially among private diagnostic centres in Bangladesh. Overcrowded facilities: There are many -- Typically are not aware of standards of safe operation, and lack access to training at a nationally standardized level. Majority of private clinic function without an RSO, and the dosimetry is outdated and uncalled for, all of which is not in compliance with the 2002 Rules as amended in 2012.

In peri-urban and rural areas, BAEC inspection is also sparse, with inadequate staff and logistic facilities. That has created a double compliance standard: While public facilities mostly comply with safety standards, private centres are far less compliant.

4. Results

Quantitative questionnaire data were pooled with specific perspectives derived through interviews with stakeholders to gauge the level of adherence to radiation safety regulations in diagnostic centres in Bangladesh. Results are structured around four themes: (1) behaviour being compliant with safety regulations, (2) economic sustainability, (3) institutional preparedness, and (4) attitudes towards perceived advantages and constraints of compliance underpinning behavior.

Compliance with Radiation Protection Criteria

Indeed, the survey showed a significant difference between government and private diagnostic institutions in their adherence to radiation safety requirements:

Public Facilities: All public facilities studied presented minimal compliance to national and international security norms. These were lead shielding, frequency of equipment calibration, personal dosimetry program, and staff training schedules.

Private Centres: It was found in this survey that only 46% of private centres were adherent to the minimum standards of safety as per Bangladesh Radiation Protection Rules-2012. The remaining centres had inadequate shielding, outdated equipment, inadequate dosimetry records, and no ongoing staff training.

Licencing and Documentation- Public: 100% had a valid BAEC licence and inspection notice. Yet almost 30% of private clinics had expired licences or did not post them.

This discrepancy was believed to be due to financial restrictions, no regulatory push, and low awareness among private facility providers.

Cost of Compliance in relation to the state of development of the surveillance system: An economic assessment on the costs of compliance was central to the study. According to response from 30 facilities, the average start-up cost to set up basic radiation protection measures was between BDT 350,000 and 550,000 ($3,200–5,000).

These costs included:

- Wall installation lined with lead and shielding doors;
- Calibration and servicing contracts to equipment;
- Acquiring personal dosimeters

As for the costs, these were affordable for large public hospitals and corporate diagnostic centres, but were prohibitive for small-mid-sized private clinics, particularly if they were stand-alone offerings in a semi-urban location. The main obstacle to complete implementation was mentioned as cost, by almost 60% of non-compliance private facilities.

Readiness of Institutions and Training Needs

Unavailability of Trained Personnel: Many smaller private clinics had no RSO. Radiological procedures at the time were frequently done by technicians with little or no training in radiation safety.

Awareness and Policy Knowledge: Private heads of institutions had the knowledge of the Radiation Protection Rules, 2012 in 65% cases. Others acknowledged not knowing what their legal requirements were in the context of shielding and exposure monitoring.

Public Sector Advantage: Public hospitals with the advantage of institutional support and access to centrally organized training benefited from the co-hypothesis and closer subsequent supervision from BAEC and Ministry of Health audits.

These are important results that suggest that it is the institutional preparedness, not just funding is a major determinant in compliance.

- Perceptions of Costs and Benefits of Compliance Benefits.
- Compliant facilities reported a number of other tangible and "soft" gains
- Patient Trust and Retention: Compliant practices experienced an average growth in patient retention and referrals of 17% as a result of enhanced security and professionalism.
- Fewer Complaints: Patients at compliant centres lodged fewer complaints related to side effects, waiting times, or the cleanliness of the facility—all signs indicate that compliance led to better quality of care.
- Legal and Reputational Cover: Those who administered compliant centres felt that compliance lowered the possibility of being fined or reception centre being shut down according to the 2012 Rules.

In contrast, non-compliant centres had been increasingly worried about legal risks, such as fines, revocation of licence or litigation with patients - particularly since patients had also become increasingly aware of safety standards in the urban areas of Bangladesh.

5. Discussion

The results of this study contribute to a better understanding of the operational reality of radiation safety compliance in the diagnostic institutions of Bangladesh, depicting the economic, institutional and regulatory dimensions of the factors driving adherence to national and international standards. This paper situates these discoveries within the wider literature and provides a critical reading of the implications for health policy, regulation and practice.

Private vs. Public Sector Compliance: An Imbalanced Topography

One of the important points is the contrast observed with respect to compliance with public and private diagnostic facilities. Public organizations were completely compliant to the Bangladesh Radiation Protection Rules (BRPR) 2012, most likely due to the central governance and availability of public funds, and the fact that the Bangladesh Atomic Energy Commission (BAEC) conducts routine inspections. These results are consistent with international literature which suggests that public institutions in LMICs are often better supervised and funded (IAEA, 2019).

In comparison, 46% of private facilities only achieved the minimum safety levels. Meanwhile, the absence of enforcement in the private sector is consistent with regulatory challenges in other fragmented health systems documented in Indian, Nigerian, and Pakistani studies. This raises the importance of nuanced approaches to regulation, approaches which acknowledge that small fee-charging private clinics have limited resources but still impose duties of care.

Cost and Financial Trade-Offs

Economic issues: The findings of the study validate that poverty is indeed a significant impediment to radiation protection adherence in the diagnostic domain of Bangladesh. The average cost to implement — BDT 350,000 – 550,000 per facility — is high for small clinics having low asset base. This is consistent with the findings of literature from Sharma et al. (2018) where even small investments on safety equipment are perceived as burdensome among small diagnostic centres in India.

But the findings show that those investment also pay significant dividends, increasing patient trust and retention by 17%. This reinforces the notion that radiation protection is not to be considered a regulatory tax, but an institutional quality, risk management, and, last but not the least, patient satisfaction's long-term investment. But these ROI might not be immediately apparent to a low-margin operator, hence the tendency to pushback, or neglect safety improvements.

Government intervention, including subsidies, tax incentives to the private sector and low-interest loans, might be necessary to narrow the safety enforcement-economy gap.

Institutional Readiness: The Missing Piece of the Puzzle

The results show that an investment in radiation safety can yield a great return, with trust and retention among patients rising 17%. This is in line with the notion that radiation protection should not be perceived as a regulatory burden but as a long-term investment in institutional quality, risk management, and patient satisfaction. But for low margin operators, this return on investment may not appear immediately evident, resulting in delays—or worse, an oversight— in upgrading safety.

Regulatory Control and Delivery Gaps

Although Bangladesh has a legal regulating framework under BAEC, there is non-uniformity in regulation which is why many private facilities go unnoticed, as stated in the study. This mirrors an implementation gap that also exists in other LMICs where the regulatory authorities are faced with inadequate staffing, scarce inspection resources and bureaucratic delays.

30% of private places with outdated licences and a lack of knowledge have bearing on compliance indicate a need to reform regulatory audit, making it more frequent, targeted and transparent. Digital databases of licencing and inspection histories could also make oversight more efficient.

Subjective Benefits and Need for Patient Knowledge

Notably, facilities participating in the study noticed that patient trust and complaints decreased among them, implying that patients are gaining awareness of safety and quality of service level. This confirms observations by Park et al. (2017) who claimed that visible enactment of compliance demonstrates that a clinic is credible and that patients will be loyal.

Awareness programmers in Bangladesh might enhance such a tendency and make patient demand an incentive for following through. Considering also that when patients are informed of their rights, including the right to safe diagnostic procedures, they are more likely to select or recommend institutions operated at the highly-visible level of appropriate safety safeguards, there is now demand-side for compliance.

6. Future Work

This article has indicated some structural and economic barriers to radiation safety compliance in diagnostic centres in Bangladesh, but it should also be noted that there is other dimensions that need to be explored. Exploring these areas in subsequent studies will contribute to a richer understanding of compliance evolution and a basis for enacting better, scaling better, and more equitable policy interventions.

Rural and Semi-Urban Penetration

This analysis concentrated on three of the major urban cities (Dhaka, Chattogram, and Khulna) and represented urban diagnostic centres rather than the situation in rural or peri-urban areas. Subsequent investigation should also expand to small towns and rural areas, as such sites tend to have limited infrastructure, be less regulated, and have greater financial limitations. A comparison between rural and urban institutions may reveal the differences in barriers or provide local solutions to improving compliance beyond metropolitan areas.

Patient-Centered Research

The current analysis focused on institutional and regulatory points of view, but it must be complemented by patients' information, attitudes, and beliefs about radiation safety. Patient surveys and focus groups can show how an awareness of safety affects decision-making, trust, and satisfaction which could be bottom-up incentives to facilities to toe the line.

Longitudinal Impact Studies

Future studies would benefit from the use of longitudinal study designs to study the influence of radiation safety compliance over time. This may involve monitoring patient outcome data, occupational health records of radiology staff, and the financial performances of compliant and non-compliant centres. Research of this kind would provide solid data on long-term returns on investment in radiation protection.

Economic modeling and economic analysis

The present study provides an estimate of compliance cost, but further work is needed to develop economic models which categorize the overall cost effectiveness of radiation protection. Such models could include factors like staff retention, patient re-attendance rates, litigation risk and positive reputational effect in making a business case for compliance – all geared specifically towards a small, private clinic.

Government and Regulatory Interventions Assessment

The study also confirmed the necessity of policy supports including subsidy, tax reduction and enforcement of audit. The efficacy of these interventions should be assessed in future research wherever they are applied. Innovative pilot projects funded by the government or by BAEC may be monitored and evaluated to judge their ability to scale up, and their effects on compliance levels.

Incorporation of Digital Surveillance Mechanisms

In the future, work can also focus on developing digital platforms to monitor leaks for radiation safety compliance. Such platforms could help regulatory agencies such as BAEC to maintain the records of licences, training records, dosimetry records, and the equipment calibration records. This is an area where research evaluating the feasibility and impact of these platforms could assist in transforming regulatory oversight.

7. Conclusion

This paper evaluated the economic sustenance and institutional capacity of diagnostic centres in Bangladesh for implementation of international radiation protection norms as recommended by the IAEA and national radiation protection regulations as encouraged by the BAEC. Using a mixed methodology

that consisted of a quantitative estimate of costs and qualitative interviews with radiologists and administrators and regulators, we provide a comprehensive understanding of radiation safety in the country's diagnostic imaging industry.

The findings paint a stark contrast between public and private colleges. Public facilities, which are supported by centralized supervision and state funding, usually follow the radiation protection rules. In comparison, private facilities, especially the smaller and standalone labs, find it hard to achieve minimum compliance due to lack of finances, workforce unawareness, and poor regulatory enforcement. It is also expensive to retrofit basic safety measures (BDT 350,000 to 550,000). But facilities who made the investment came away with quantifiable gains — trust, less complaints, protection for the staff and less legal risk. Readiness had played out at the institutional level. As well as having no trained RSOs, the majority of private labs do not provide regular staff training and have no knowledge of the 2012 Radiation Protection Rules. While by-laws derive, there are few enforceable ones as BAEC is resource-constrained and even more so in the expanding private sector. Despite these difficulties, there is clear direction for progress. Radioimmunoassay safety assurance increases the credibility of both the public health and of the agency. State backing, in the form of tax breaks, enforcement requirements, subsidized training, and public information campaigns, might help close the compliance gap. Finally, enhancing radiation safety is not only a regulatory necessity but also a public health necessity that guarantees safer and more accurate diagnostic treatment in Bangladesh.

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