BMJ Open

Quantitative analysis of International Health Regulations Annual Reports to identify global disparities in the preparedness for radiation emergencies

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To cite: Sharma UC, Attwood K, Pokharel S. Quantitative analysis of International Health Regulations Annual Reports to identify global disparities in the preparedness for radiation emergencies. *BMJ Open* 2022;**12**:e052670. doi:10.1136/bmjopen-2021-052670

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-052670).

Received 25 April 2021
Accepted 05 August 2022

Check for updates

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ABSTRACT

Objectives Radiation emergencies are rare but can have minor confined effects to catastrophic consequences across the large geographical territories. Geographical disparities in the preparedness for radiation emergencies can negatively impact public-safety and delay protective actions. We examined such disparities using the global and regional radiation preparedness data from the revised annual International Health Regulations (IHR) data sets.

Settings We used IHR State Party Annual Reporting (SPAR) tool and its associated health indicators developed to mitigate public health risk from radiation emergencies. Using the most recent (2019) SPAR database developed for radiation emergencies, along with 12 other cross-sector indicators, we examined the disparities among WHO state and region-wide capacity scores for operational preparedness.

Results Based on the analysis of the 2019 annual reporting data sets from 171 countries, radiation emergency was one of the top three global challenges with an average global preparedness capacity of 55%. Radiation emergency preparedness capacity scores showed highest dispersion score among all 13 capacities suggesting higher disparities for preparedness across the globe. Only 38% of the countries had advanced functional capacity with ≥80% operational readiness, with 28% countries having low to very low operational readiness. No geographical regions had ≥80% operational readiness for radiation emergencies, with 4/6 geographical regions showing limited capacity or effectiveness. Global data from 171 countries showed that the capacity to respond to radiation emergencies correlated with the capacity for chemical events with a correlation coefficient (ρ) of 0.70 (CI 0.61 to 0.77).

Conclusion We found major global disparities for the operational preparedness against radiation emergencies. Collaborative approaches involving the public health officials and policymakers at the regional and state levels are needed to develop additional guidance to adapt emergency preparedness plans for radiation incidents.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ There are limited data examining the global disparities in the preparedness against radiation emergencies.
⇒ Failure to recognise the degree of emergency preparedness influences its capacity to recover.
⇒ Major discrepancies in operational readiness for cross-sector preparedness for infrastructure, legislation and coordination also existed globally and across different geographical regions.
⇒ This study highlights the need for further research to identify most appropriate approaches to addressing the disparities accounted for radiation emergency planning.

INTRODUCTION

Recent reports on the status of country preparedness capacity prepared in coordination with the Global Preparedness Monitoring Board (GPMB), the WHO has highlighted that a threat to public health anywhere in the world is now a threat to public health everywhere in the world.[1 2] Although we cannot predict the origin, nature or severity of next global health emergency, radiation emergencies constitute a major threat to human well-being.[3 4] The extent of injuries from high-dose radiation exposure can be acute, subacute or late, manifesting several decades after the incident event.[5 6] The late effects of radiation exposure from Hiroshima and Nagasaki disasters are still being realized.[5]

Radiation exposure can be latent and subtle, and early recognition of its adverse effects can be challenging.[7 8] Once detected, complete reversal of radiation-induced injuries is not possible and treatment remains supportive or palliative.[9] Such latent properties of ionising radiation pose major public health hazard. More importantly, a large-scale radiation exposure may expand beyond the geographic boundaries putting a large human population at risk.[10] Early detection and reporting of such risks and implementing plans and policies for the mitigation of adverse effects will require a multidisciplinary approach involving the public health

officials, healthcare providers and emergency preparedness team.[11–13]

In 2005, International Health Regulations (IHR) developed State Party Self-Assessment reporting tools to allow WHO Secretariat to compile a report for the statistics of health capacities of individual countries.[1 14 15] This annual voluntary reporting tool has 13 capacities, with specific indicators associated with these capacities. Each indicator is graded in five levels of performance, for which discreet action elements or attributes are defined. States are encouraged to respond to all the indicators, so that an accurate view of the national capacities can be determined.[1 14 16]

Of the 13 various capacities included in the IHR state party self-assessment annual reporting tool, radiation emergencies (radiological emergencies and nuclear accidents) constitute potentially catastrophic disasters with large scale of biological consequences. The guidelines for the preparedness and response for radiation emergencies have been reported previously by International Atomic Energy Agency.[17] However, there are no clear data comparing radiation emergency preparedness capacities in relation to other cross-sector emergency preparedness indices. Since radiation exposure can be widespread, there needs to be multinational and strategic coordination to confine risk and mitigate the harmful effects.

To this end, we have analysed the individual and combined IHR indicators for radiation emergencies as well as other cross-sector indicators, including national health emergency framework, finances, legislation, surveillance, human resources, coordination of efforts, health service provision and risk communications. We have also studied the global and regional disparities in IHR indicators that influence the capacities and resources used to address radiation emergencies.

METHODS

The Electronic State Party Self-Assessment Annual Reporting Tool (e-SPAR) is publicly accessible web-based data reporting platform, under the WHO IHR Monitoring and Evaluation Framework. The SPAR tool has 13 capacities and number of indicators that are graded into five levels of performance. The states are instructed to select one of the five levels for their implementation status for each indicator. Irrespective of the status of elements in the higher level(s), the lowest level is considered valid if two or more levels were selected. In the event of no selection, the final score for the capacity indicator was calculated as zero.[14 15]

The *primary goal* of this analysis was to study radiation emergencies (C13) and each of the indicators related to the state capacities and resources (C13.1). The selected SPAR indicators and corresponding levels (1–5) are provided in online supplemental table 1.

The *secondary goal* was to further examine the cross-sector preparedness for infrastructure, legislation and coordination. We first analysed IHR-SPAR Indicators from 2019 in relation to the capacities to be prepared for radiation emergencies. Additionally, 24 IHR-SPAR indicators among the 13 capacities (online supplemental table 2) were used for the analytical approaches comparing the capacity scores for radiation emergency preparedness in relation to the overall public health risk score across the globe as well as six unique geographic regions.

Combined indices for global and regional capacity scores included in this analysis

We analysed the overall capacity indices for the preparedness of radiation emergencies and its relationship with other 12 trans-sector capacities using a mathematic model similar to the one previously reported by Kandel *et al*.[18] For this analysis, we included 24 indicators that were all determined to be relevant to assess the operational capacity for radiation emergency preparedness. We aggregated the key indicators and calculated arithmetic average to develop an ordinal scale of levels 0–5 or a percentage scale of 0% to 100% (0 as 0%, 1 as 20%, 2 as 40%, 3 as 60%, 4 as 80% and 5 as 100%) on the basis of overall scores. Since many countries did not submit part or all of the data, complete data sets were available for analysis from a total of 171 countries. The combined indices used in our analysis are comparable to the overall capacity levels used to assess health capacity algorithm developed by IHR-SPAR.

Statistical analysis for the calculation of global and regional variations (disparities) in the capacities for the preparedness

To study the global and regional variations on radiation emergency preparedness, we calculated the dispersion of the health capacity indices using SD and interquartile ranges. Unlike conventional total range analysis approaches, IQR has a breakdown point of 25% and, thus, is often preferred for such analyses. To study the global and regional relationship between radiation readiness and other reported capacities, we used the Pearson correlation coefficient with 95% CIs obtained using Fisher's z-transformation.

For the statistical analyses, categorical and continuous variables were reported as percentage and mean±SD, respectively, where appropriate. All 13 capacities and 24 SPAR indicators are graded into five levels of performance and presented as percentages when appropriate. The overall capacity and radiation emergency preparedness scores were compared using the two-sided paired t test (with Normality assessed using the Anderson Darling test). The scores were compared between regions using a one-way analysis of variance (ANOVA) model with Tukey-adjusted pirwise comaprisons. A p value of <0.05 was considered statistically significant for all statistical analyses. Statistical analyses were performed using Microsoft Excel (16.47.1, 21032301) and SAS V.9.4 (Cary, North Carolina).

Patient involvement

Patients were not involved in this study.

RESULTS

We used composite determinants of all capacities and individual IHR capacity metrics to assess global public health security. In particular, we first analysed the most IHR-SPAR indicators in relation to the capacities for operational readiness to respond to radiation emergencies. We then examined how the preparedness against radiation emergency relates to 12 other reported capacities and their corresponding indicators. The IHR monitoring and evaluation framework categorised countries in to five levels across these indices, in which level 1 represented lowest level of the national capacity and level 5 as the highest[15 19] (online supplemental table 1). In addition, we comparatively analysed the data at the six WHO geographic regional levels. A total score of the 24 IHR-SPAR Indicators were used among the 13 capacities (online supplemental table 2).

Comparative analysis of the global and regional capacities for radiation emergency preparedness

The analysis of the 2019 annual reporting data from 171 countries showed that the radiation emergency preparedness was one of the top three global challenges with an average global score per capacity of 55%. When the preparedness levels were closely examined, 28% of the countries scored none to very low on the operational capacity (level 0 or 1). Similarly, 34% of the 171 countries had the capacity scores ranging between level 2 and 3, and only 38% had the advanced level of preparedness with the capacity scores ranging between level 4 and 5 (table 1).

At the regional level, 51% of the countries had very low and 6% had no capacity in the WHO African (AFRO) region. Only 4% of the countries in this region had advanced capacity (level 4 or 5). In the WHO Region for the Americas (AMRO), 24% of the 29 countries had very low or no capacity for radiation emergency preparedness, whereas 41% had the higher level preparedness (level 4 and 5). In WHO Eastern Mediterranean Region (EMRO), 19 countries were included for analyses, of which 11% had no capacity, 21% had very low capacity and 47% had the capacity levels of 4 to 5. The WHO European Region (EURO) countries were relatively better prepared for the radiation emergencies with 33% of the countries falling into the capacity levels of 2 to 3, and 67% with the capacity scores of 4 to 5. In contrast, in the WHO South-East Asia Region (SEARO), 36% of all the countries reported no or very low levels of radiation emergency preparedness capacity, and only 18% had the advanced level capacity. In the WHO Western Pacific Region (WPRO), data from 14 countries were examined, which showed the capacity levels of very low to low in 28% of the countries and advanced level of operational readiness in 43% of the countries. Radiation emergency preparedness capacity scores showed highest dispersion score among all 13 capacities suggesting higher disparities across the globe.

Inter-relationship between overall and individual core capacities and its relationship with the preparedness for radiation emergencies

The major global challenges were points of entry (56% overall score per capacity), radiation emergencies (55% overall score per capacity) and chemical events (53% overall score per capacity). Relationship between radiation emergency preparedness capacity and other reported capacities at global and regional levels are summarised in table 2.

Analyses of the global data from 171 countries showed that capacity to respond to radiation emergency strongly correlated with capacity for chemical events with a correlation coefficient (ρ) of 0.70 (CI 0.61 to 0.77). Other closely associated indicators included legislation and financing (ρ=0.68; CI 0.59 to 0.75), national health emergency framework (ρ=0.63; CI 0.53 to 0.71), health service provision (ρ=0.66, CI 0.56 to 0.73) and IHR coordination and national IHR focal point functions (ρ=0.59; CI 0.49 to 0.68). The lowest correlation was noted with the risk communication and point of entry (ρ=0.45 each).

The analyses of the regional data, however, showed variable inter-relationship within specific geographic regions. In the AFRO region, data from all 47 countries were included. Overall, a 32% score per capacity was reported

Table 1 Summary of radiation emergency preparedness capacity at global and regional levels

	No capacity	Level 1 capacity	Level 2 and 3 capacity	Level 4 and 5 capacity	Number of reporting countries
All data (Global)	5	23	34	38	171
AFRO	6	51	38	4	47
AMRO	3	21	34	41	29
EMRO	11	21	21	47	19
EURO	0	0	33	67	51
SEARO	9	27	45	18	11
WPRO	5	23	34	38	14

Data presented in column 2, 3, 4 and 5 represent the percentage of the countries at different capacity scores.
AFRO, WHO African Region; AMRO, WHO Region for the Americas; EMRO, WHO Eastern Mediterranean Region; EURO, WHO European Region; SEARO, WHO South-East Asia Region; WPRO, WHO Western Pacific Region.

Table 2 Relationship between radiation emergency preparedness capacity and other reported capacities at global and regional levels

	Legislation and financing	IHR coordination and NIHR focal point functions	Human resource	National health emergency framework	Health service provision	Points of entry	Chemical events
All data (Global)	0.68 (0.59, 0.75)	0.59 (0.49, 0.68)	0.53 (0.41, 0.63)	0.63 (0.53, 0.71)	0.66 (0.56, 0.73)	0.45 (0.32, 0.56)	0.70 (0.61, 0.77)
AFRO	0.61 (0.39, 0.76)	0.43 (0.17, 0.64)	0.36 (0.08, 0.59)	0.49 (0.23, 0.68)	0.43 (0.16, 0.64)	0.36 (0.09, 0.59)	0.70 (0.51, 0.82)
AMRO	0.52 (0.18, 0.74)	0.13 (−0.25, 0.48)	0.48 (0.14, 0.72)	0.42 (0.06, 0.68)	0.36 (−0.01, 0.64)	0.49 (0.15, 0.73)	0.34 (−0.03, 0.63)
EMRO	0.62 (0.23, 0.84)	0.57 (0.15, 0.81)	0.33 (−0.15, 0.68)	0.43 (−0.04, 0.74)	0.48 (0.02, 0.76)	0.41 (−0.06, 0.73)	0.60 (0.20, 0.83)
EURO	0.29 (0.02, 0.53)	0.47 (0.24, 0.67)	0.22 (−0.07, 0.46)	0.47 (0.18, 0.63)	0.61 (0.33, 0.72)	0.07 (−0.26, 0.29)	0.49 (0.23, 0.67)
SEARO	0.74 (0.23, 0.92)	0.66 (0.08, 0.90)	0.85 (0.48, 0.96)	0.66 (0.08, 0.90)	0.22 (−0.44, 0.72)	0.79 (0.33, 0.94)	0.85 (0.50, 0.96)
WPRO	0.79 (0.44, 0.93)	0.73 (0.31, 0.90)	0.76 (0.38, 0.92)	0.76 (0.38, 0.92)	0.89 (0.69, 0.97)	0.81 (0.49, 0.94)	0.89 (0.67, 0.96)

Data presented represent correlation coefficients. CIs for the Pearson correlation coefficients were obtained using Fisher's z transformation. Pearson correlation coefficient (95% CI).
AFRO, WHO African Region; AMRO, WHO Region for the Americas; EMRO, WHO Eastern Mediterranean Region; EURO, WHO European Region; IHR, International Health Regulations; SEARO, WHO South-East Asia Region; WPRO, WHO Western Pacific Region.

for the radiation emergency readiness. The other health capacity indicators from AFRO region showed similar capacity scores, including a 32% score for chemical events. Again, capacity to respond to radiation emergency strongly correlated with chemical events preparedness (ρ=0.70, CI 0.51 to 0.82), which was followed by legislation and financing (ρ=0.61, CI 0.59 to 0.76).

In the AMRO, data from 29 countries were analysed and six were excluded due to incomplete reporting. The relationship between capacity for radiation emergency versus legislation and financing were the strongest among all capacities (ρ=0.52, CI 18 to 0.74), which was followed by point of entry (ρ=0.49, CI 0.15 to 0.73) and human resource (ρ=0.48, CI 0.14 to 0.72). The relationship with IHR coordination and National IHR focal point functions was found to be relatively weak (ρ=0.13, CI 0.25 to 0.48).

In the EMRO, data from 19 countries were included for analyses. Strong correlation was noted between radiation emergency preparedness and legislation and financing and chemical events (all ρ≥0.6).

In the EURO, radiation emergency preparedness showed a strong relation with health service provision (ρ=0. 61, CI 0.33 to 0.72).

Data from all 11 countries were included for analysis for the SEARO. SEARO region demonstrated trends that were either similar to the overall global data, or to EURO and AMRO regions. For example, the SEARO radiation emergency preparedness was strongly related to the chemical events (ρ=0.85, CI 0.50 to 0.96) and IHR coordination and national IHR focal point functions (ρ>0.66), which are similar to global capacity indicators. On the other hand, a strong relationship between the capacity for radiation emergency and the capacities for human resources (ρ=0.85, CI 0.48 to 0.96) and point of entry (ρ=0.79, CI 0.33 to 0.94) shared identical patterns as in the EURO and AMRO regions.

In the WPRO, radiation emergency preparedness capacity showed the strongest relationship with chemical events and health service provision (ρ=0.89 each). Additionally, a strong correlation was noted between the capabilities for radiation emergency and legislation and financing, IHR coordination and IHR focal point functions, human resource, national health emergency framework, health service provision and point of entry (ρ>0.7 each). Of the 27 countries reporting data from this region, complete data were available only from 14 countries, which were further analysed. The summary of all data in relation to the highly correlated individual capacity scores has been presented in table 2.

Global and regional disparities in overall and radiation emergency preparedness capacities

A large dispersion indicates that the capacity indices spread far from the average capacity for operational readiness, which requires interstate multisectoral coordination mechanisms. Our data analysis showed striking disparities in radiation emergency preparedness capacities when compared with the overall capacities. We found

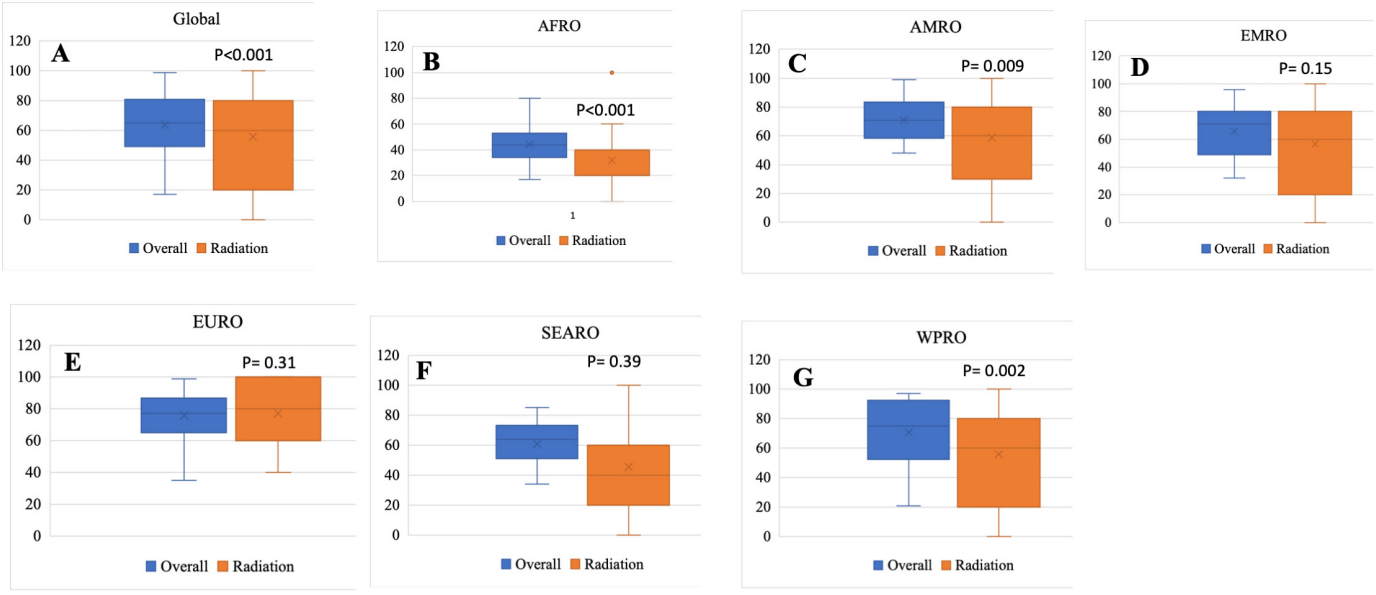

Figure 1 Box and whisker plots comparing overall versus, radiation emergency preparedness data dispersion across the globe. (A) represents global data; (B) shows the data from WHO African Region (AFRO); (C) demonstrates the data from WHO Region for the Americas (AMRO); (D) depicts the data from WHO Eastern Mediterranean Region (EMRO); (E) shows WHO European Region data; (F) depicts the data from WHO South-East Asia Region (SEARO) and (G) represents the data from WHO Western Pacific Region (WPRO). The overall capacity and radiation emergency preparedness scores were compared in the overall sample and by region using a two-sided paired t-test (normality was assessed using the Anderson Darling test). There were significant differences globally, as well as in the AFRO, AMRO and WPRO regions.

that radiation emergency capacity was widely dispersed as compared with the overall IHR capacity scores at the global level (figure 1). The IQR for overall capacity score was 49–81, and IQR for radiation emergency preparedness score ranged between 20 and 80. The lowest reported overall capacity was 17, but the lowest reported capacity score for the radiation emergency preparedness was 0 (p<0.001), indicating absolute unpreparedness. In the AFRO region, the overall capacity IQR was calculated at 34 to 53 with the median score of 44. In contrast, the IQR for radiation emergency preparedness was at 20–40 with the median score of 32 (p<0.001). Unfortunately, the lowest overall and radiation emergency capacity scores were at 17 and 0, respectively. In the AMRO, IQR for overall capacity was at 58–83 with a median score of 71. The lowest reported capacity was 48 with a highest score of 99. For radiation emergency preparedness, the IQR was at 30–80 with a median score of 59 (p=0.009). However, the data demonstrated a wide dispersion and ranged from 0 to 100.

In the EMRO, the overall capacity score ranged from 32 to 96 with an IQR between 49 and 80, while the capacity for radiation emergency preparedness ranged between 0 and 100 with an IQR of 20–80.

The data from the EURO showed a stronger capacity score for radiation emergency preparedness compared with other geographic regions. The IQR for the overall capacity was between 65 and 86 with a range between 35 and 99. For radiation emergency preparedness, the IQR was between 60 and 100 with the lowest reported value of 40 and the median capacity of 77 (p=0.31). Examination of data from the SEARO followed similar trends as the global capacity scores. The IQR for the overall capacity was between 51 and 73 with a range of 34–85. For radiation emergency preparedness capacity, the data ranged from 0 to 100 with and IQR of 20–60. This difference, however, was not statistically significant (p=0.39), likely due to a high SD. In the WPRO, the IQR for overall capacity was between 52 and 92, while that for radiation emergency preparedness was at 20 to 80 with the lowest reported value of 0 (p=0.002).

DISCUSSION

This study analyses 2019 radiation emergency preparedness data from 171 countries. Most striking findings are that only two-thirds of the countries are operationally prepared to counteract the catastrophic effects of radiation emergencies. In addition, major discrepancies exist between the individual countries within each geographical region. More importantly, several countries reported a non-uniform level of preparedness for individual health capacities, which implies operational challenges for collaborative action in such emergencies. Compared with average overall national capacity score, global preparedness for radiation emergencies showed lower operational capacity and higher levels of dispersion across the globe.

Our data analysis from 171 countries showed that radiation emergency preparedness was one of the top three global challenges. It was noted that 28% of the countries had low to non-existing capacity for radiation emergency. EURO appeared better prepared than the rest of

the geographic regions followed by EMRO and AMRO regions, indicating a major regional variation. Radiation emergencies are not confined by geographical limits and can be widespread across these boundaries. WHO IHR database is a validated platform developed by experts and can provide objective scoring capacities to mitigate radiation hazard in ways that are commensurate with and restricted to public health risks.[20] Our analyses showed that almost one-third of the countries across the globe had either non-existent or underdeveloped preparedness levels. Importantly, disproportionate variations in the operational capacities among different countries indicate that there can be delays in coordinated management process, including emergency procedures at site, safe evacuations and shelter.

Innovative health capacity scores developed for global radiation emergencies are crucial to recognise the overall radiation risk preparedness. Such risk-scoring approach also helps to coordinate with parties across other sectors and capacities.[2 14] Our data show that the capacity for radiation preparedness is closely related to other health indicator capacities. For example, our global data analysis showed that capacity to respond to radiation emergency strongly correlated with capacity for chemical events and legislation and financing. Overall, having an objective risk assessment approach sets up standards and obligations for the state parties to develop and maintain essential core capacities to act against such emergencies of international concern.[19] This stated that one limitation of our study is that the radiation emergency preparedness data are self-reported by individual countries and are not independently verified. However, prior publications have reported that SPAR data strongly correlate with other externally evaluated data such as the Joint External Evaluation results.[18 21]

This analysis also highlights striking global discrepancies that exist for the mitigation of radiation emergencies. Compared with overall capacity score, the radiation emergency preparedness score varied widely across the globe with lowest reported capacity score of zero, which shows absolute unpreparedness. With the exception of EURO, this variation persisted at the regional level with the capacity score ranging from non-existent to advanced level preparedness. As radiation disasters are not limited by geographical borders, such variation in cross-country preparedness levels can put larger population at risk. A large-scale emergency across the wide geographic boundaries requires a synchronous response and inadequate and skewed responses from individual parties can destabilise the entire operation. In this context, we should also learn our lessons from novel coronavirus (2019-nCoV) pandemic that challenged our capacities for case detection, surveillance and preparedness and response, both at national and international levels.[18 22] Emergency preparedness against radiation challenges is no exceptions to the urgent actions recommended by GPMB, which recommends states commit to preparedness by implementing their obligations by dedicating resources for emergency preparedness.[1 2 23] A rapidly evolving radiation emergency, whether accidental or deliberate, requires robust preparedness, with means to share medical countermeasures across the countries.[11 24 25]

Side by side comparison of radiation emergency capacity with the overall IHR capacity scores showed that radiation emergency capacity was widely dispersed as compared with the overall IHR capacity scores at the global level. According to US Department of Health and Human Services, a radiological or nuclear incident can be through contamination of food or water with radioactive material, placement of radiation sources in public places or other severe measures including detonation, high-level nuclear waste and improvised devices.[10] Although the IHR capacity scores developed for radiation emergencies are expected to represent the operational readiness, it is crucial to interpret these data in line with the cross-sector preparedness for infrastructure, legislation and coordination (C1).[18 24] For such coordinated efforts, government bodies, ministries and agencies need to collaborate and involve other sectors including environment, transport, points of entry, travel, radiation safety, disaster management, emergency services (C2).[26] This is highlighted by our data showing strong inter-relationship between the capacity for radiation emergency and other capacities including chemical events, legislation and financing and health service provision at the global and regional levels.

Additional capacities including well-trained and multisector workforce (C7), and a robust national health emergency framework (C8) and health service provision (C9) facilitate timely response and aid surge capacity for scaling up large national events.[27] For a concerted approach across the geographical boundaries, a coordinated public health surveillance between points of entry (C11) and national health surveillance system are recommended.[28] The radiation emergencies from technological incidents, natural disasters deliberate events and contaminated foods and products use the similar resources for detection and alert system as in the management capacity outlined for chemical events (C12).[29] In addition to public health preparedness capacities, the healthcare providers, who are among the first responses against such emergencies, should have specific guidelines, recommendations and training.[17] IHR indicators (C13) are inclusive to embrace most of these needs.[20]

Radiation emergency capacity of a country and the region as a whole is affected by several factors, including the existence of institutional framework, adherence to the policy and protocols, prevention and control measures, population density, etc. When the radiation emergency occurs as a result of major events such as nuclear accidents or conflicts involving the nuclear weapons, the capacity to mitigate the harm is directly related to the population density and the resources available. Analysis of the other risk variables associated with managing the radiation emergencies would benefit from understanding the existing country capacities, vulnerabilities due to socioeconomic conditions and lack of health infrastructures.

The information and data from these assessments should be analysed to build the readiness and response plans for preventing and controlling health emergencies, including radiation emergencies.[18]

As reported by Keeshmiri and colleagues,[30] identification of the risk and systematic preparation is the best way to mitigate impact of public health risk. Effective healthcare delivery systems and the hospital readiness, in particular, represent a major foundation for reducing the impact of the crisis such as radiation emergencies. Additionally, several intrasectoral and intersectoral communication, coordination and preparedness are required at the national level for managing the radiation incidents to prevent inconsistent response following the incidence. Just like controlling COVID-19 pandemic, an integrated and multidisciplinary approach towards local and regional management of casualties in the event of a radiation emergency is needed. This involves several pillars, including skilled staff, the hospital's physical space, equipment, coordination, structure, organisation, processes, guidelines and information systems in intrasectoral and intersectoral multidisciplinary arrangements. Coordination among the various hospital departments and with different non-healthcare organisations is a fundamental principle in times of crisis. Regular manoeuvres and continuous training of the numerous occupational groups involved in the response team are the key factors in maintaining the readiness and appropriate response of healthcare systems to radiation emergencies.[31]

In summary, we have found major discrepancies in the preparedness for radiation emergencies across the globe. Failure to recognise the degree of emergency preparedness influences its capacity to recover. Protecting all communities to the highest extent possible should be the overall goal of the radiation emergency preparedness.[32] Currently, resources related to radiation play active roles in our daily lives. In certain countries or region, its utility could be of limited scope such as those used for medical diagnostic or therapeutic purposes (X-ray and gamma-knife radiation) while other countries could be more leliant in nuclear energy such as nuclear power plants and the weapons of defence. Due to their importance and widespread presence, there needs to be a realisation of dangers related to radiation accidents and the greater need for preparation to respond in the event of such accidents. Recent global COVID-19 pandemic displayed the disconnect between the incident and timely response.[22] Many countries that have lower level of preparedness rank at the bottom of leading health and economy indicators. However, disasters such as Chernobyl, Fukushima, and similar cases have shown that lack of attention to the necessary safety considerations can have irreparable risks for the human community, which are of varying intensity and scope. Beyond healthcare capacities, our study also highlights the need for further research to identify most appropriate approaches to addressing the disparities accounted for radiation disaster planning.

Contributors UCS was responsible for the conceptualisation, manuscript writing and data analysis. KA provided expert help with the statistical analyses. SP was responsible for conceptualisation, data review, manuscript editing and overall supervision. UCS acts as guarantor for the paper.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplementary information.

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