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# National Diagnostic Reference Levels in General Radiography: A Scoping Review

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## Abstract

The aim of this scoping review was to explore the state of proposed and established national diagnostic reference levels (NDRLs) in general radiography. It examined survey harmonization, radiological examinations, doses, and 20-year international trends in NDRLs. It also highlights NDRL survey strategies for dose optimization. A scoping review of the literature was carried out in accordance with the guidelines of the Preferred Reporting Items for Systematic and Meta-Analyses extension for Scoping Reviews. Searches were conducted in gray literature and electronic databases such as ScienceDirect, PubMed, CINAHL via EBSCOhost, and MEDLINE for NDRLs in general radiography for papers published from January 01, 1990, to April 20, 2024. A total of 4932 studies were identified with 22 articles selected for review. These articles were those based on an adult-human dosimetry survey. The NDRLs were set at the 75th percentile of 7 radiographic examinations and 13 projections. These have been presented with thematic analysis, narrative synthesis, and descriptive statistics. A consistent adherence to guidelines for NDRL surveys was observed despite methodological variations. NDRLs were less prevalent in low- and lower-middle-income countries. Chest PA and lumbar spine examinations were commonly reported, with lumbar spine LAT yielding the highest and chest PA the lowest doses. Proposed NDRLs from 2004 to 2013 indicated higher doses than those from 2014 to 2024, aligning with established NDRLs in the last decade. The introduction of quality control tests and radiographic image quality assessments is recommended to enhance result reliability and support dose optimization strategies, addressing gaps in current practices.

**Keywords:** Diagnostic reference levels, optimization, radiation dose, radiography, scoping review

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## INTRODUCTION

Despite the upsurge of advanced imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI), general radiography remains the most widely used method for medical imaging.<sup>[1]</sup> However, X-rays could inflict stochastic effects.<sup>[2]</sup> X-ray doses in diagnostic radiography, therefore, need to be optimized to ensure patient safety while acquiring radiographs of optimum diagnostic quality. An effective optimization approach involves comparing recorded patient doses with dose data from regulatory agencies.<sup>[3]</sup>

Consequently, the term “investigation levels” of radiation doses was introduced in publication 60 by the International Commission on Radiological Protection (ICRP)<sup>[3]</sup> to be chosen by a regulatory agency. To buttress this concept, ICRP introduced the term “diagnostic reference

level” (DRL) to ensure that radiation dose to patients is kept as low as reasonably achievable (ALARA)<sup>[4]</sup> or in the United Kingdom (UK) setting, as low as reasonably practicable (ALARP).<sup>[5]</sup> DRLs are used in radiological imaging to indicate whether the radiation dose is unusually high or low for that procedure.<sup>[6]</sup> This concept was enhanced by ICRP’s practical recommendations.<sup>[7]</sup> ICRP, in Publication 103, recommended DRLs as an advisory measure to improve optimization, by identifying unusually high or unusually low patient dose levels, which might not be justified based on image quality requirements.<sup>[8]</sup> DRLs have also been adopted

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by the International Atomic Energy Agency (IAEA)<sup>[9]</sup> and the European Directive 2013/59/Euratom<sup>[10]</sup> as a tool for radiation dose optimization in diagnostic radiological examinations. Several attempts have been made to establish DRLs using guidelines set by either the European Commission (EC)<sup>[11]</sup> or those outlined by ICRP.<sup>[6]</sup>

Surveys or registry data of patients are used to set national DRLs (NDRLs) for radiological procedures in a country. The NDRL is defined as the 75<sup>th</sup> percentile value of the distribution of median values of a measured radiation dose at healthcare institutions across a nation relative to a particular examination.<sup>[6]</sup> To establish NDRLs, it is vital to survey diagnostic facilities that represent the surveyed country's geographical area and population.<sup>[12]</sup> Medium-to-large hospitals with substantial workloads offer current practice data within a reasonable timeframe. In smaller countries with under 50 facilities, ICRP recommends an initial study of 30%–50% of the facilities.<sup>[6]</sup> In countries with hundreds of healthcare facilities, ICRP suggests surveying about 30 randomly chosen hospitals with a large patient sample size as a reasonable starting point.<sup>[6]</sup> NDRL dosimetric quantities should be simple to measure and be based on doses that are measured in routine clinical practice. The EC<sup>[11]</sup> and ICRP<sup>[6]</sup> recommend the use of incident air kerma ( $K_{a,i}$ ), entrance surface air kerma ( $K_{a,e}$ ), and dose area product (or air kerma area product) ( $P_{KA}$ ), as dose metrics in general radiography.  $K_{a,e}$  can be measured directly using thermoluminescent dosimeters (TLDs) affixed to patient skin or indirectly by estimating  $K_{a,i}$  from measured X-ray output and exposure factors, then applying a backscatter factor.<sup>[13]</sup>  $P_{KA}$  can be measured using an ionization chamber that integrates the air kerma over the X-ray beam's cross-sectional area.

Regional DRLs (RDRLs) could be determined by using the median of NDRLs from several countries within that region.<sup>[14–16]</sup> These can serve as a prompt for neighboring nations to review their imaging techniques/protocols when their NDRLs exceed the RDRLs.<sup>[6]</sup> ICRP suggests updating NDRLs and RDRLs every 3–5 years or more frequently with advancements in imaging and technology.<sup>[6]</sup> Local DRLs (LDRLs) are based on surveys in a facility.<sup>[17]</sup> They are beneficial in optimization at a radiology unit or where there are no NDRLs.<sup>[6]</sup> Radiologic staff should integrate LDRLs into regular quality assurance programs, comparing local doses with NDRLs for continuous improvement of patients' radiation safety. NDRLs are not applied to individual patients, as radiation needs vary with patient demographics and imaging task requirements.<sup>[6]</sup> Furthermore, NDRLs should neither be applied as dose limits<sup>[11,18]</sup> nor dose constraints<sup>[7]</sup> to avert compromising patient safety and/or diagnostic outcomes. NDRLs should be applied flexibly, considering radiographic quality and sound clinical judgment.

However, national surveys to propose general radiography NDRLs have not received the needed attention,<sup>[19]</sup> especially in some low-income (LI) and lower-middle-income countries

(LMICs)<sup>[20]</sup> due to data scarcity, budget constraints, ineffective collaboration between key stakeholders, and regulatory gaps.<sup>[20]</sup> To assess the extent, scope, and characteristics of NDRL research and identify gaps in the literature, a scoping review approach is preferred.<sup>[21,22]</sup> This scoping review thus explored the state of NDRLs based on the following questions: To what extent have LI and LMICs focused on the development of NDRLs? Are harmonized methods used in surveys to establish NDRLs in general radiography? What are the commonly reported radiological examinations and their typical doses in NDRL surveys? How have proposed NDRLs evolved over 20 years across countries – increased, decreased, or remained consistent? How can NDRL surveys be improved to influence dose optimization strategies?

## METHODS

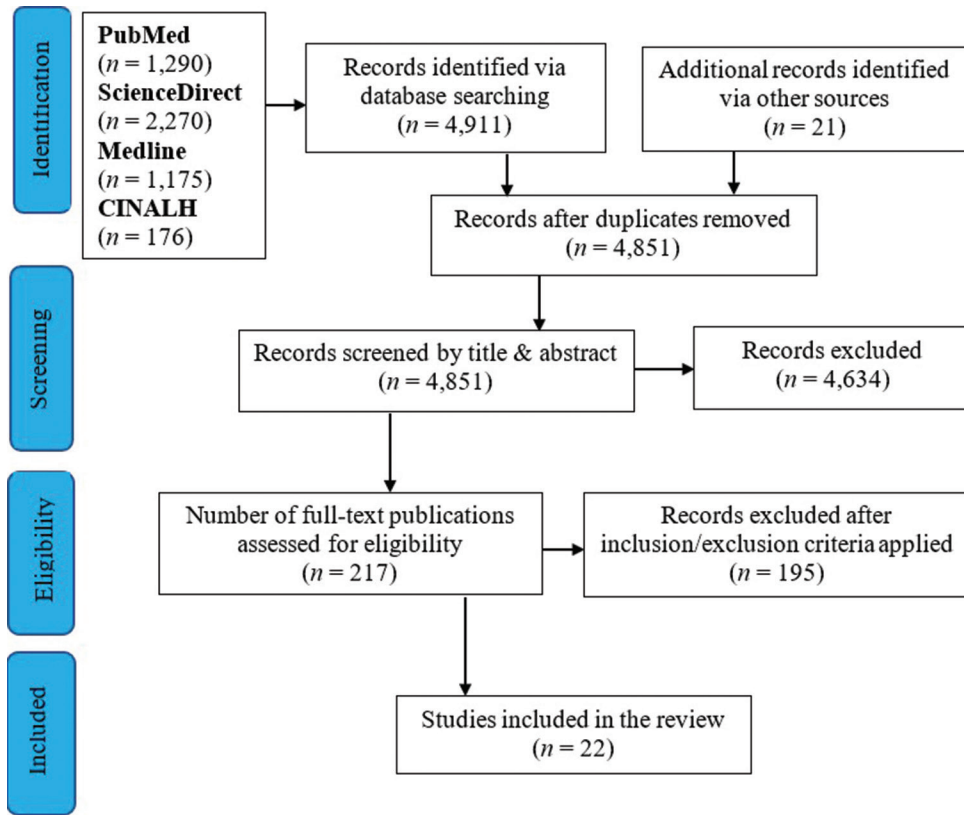
### Strategy for literature search

To guide this review, the five stages of Arksey and Malley's framework were used which involves identification of the research questions, selection of relevant studies, making study selections, charting, collating and summarizing the data, and finally, reporting the findings.<sup>[23]</sup> A scoping review of medical imaging and medical physics journals in gray literature, ScienceDirect, PubMed, CINAHL via EBSCOhost, and MEDLINE databases, was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR)<sup>[24]</sup> guidelines. No published copy of the review protocol was available. Additional supplementary searches were done in Google Scholar, reference lists, and radiography-oriented journals for articles not indexed in the selected databases for literature published from January 01, 1990, to April 20, 2024. The resulting flowchart of the search is presented in Figure 1.

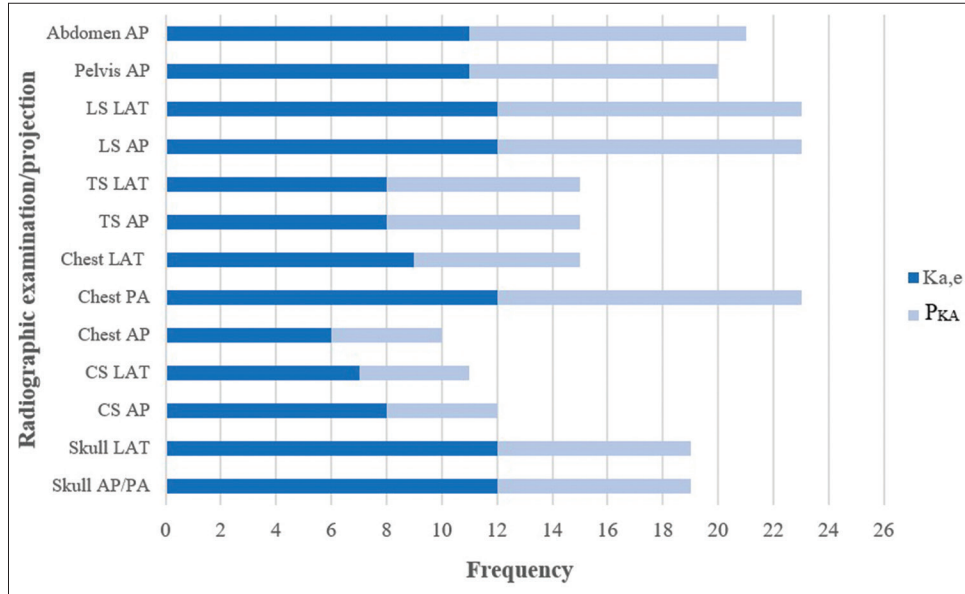
### Selection of relevant studies

This review utilized the Population, Intervention, and Comparative Observation (PICO) technique to choose the best keywords and search phrases.<sup>[25]</sup> *Cohort* and *Intervention* were substituted for the PICO parts.<sup>[26]</sup> In this review, “Cohort” refers to *radiography* procedures, and “Intervention” refers to *diagnostic reference levels*. This led to the creation of the search phrases “radiography” and “diagnostic reference levels,” and other search phrases synonymous with these two main search phrases, presented in Table 1. Among the authors, three senior medical physicists, also research scientists, and one experienced radiographer validated search terms to ensure appropriateness in identifying pertinent studies on DRLs in general radiography.

The search terms on *general radiography* and *diagnostic reference levels* were developed using Medical Subject Headings<sup>[27]</sup> indicated in Table 2 as [mh]. Both indexed terms and free text words [tw] are presented in Table 2 and were used to capture the following concepts: diagnostic reference levels, general radiography, diagnostic, X-ray, and radiographic imaging. A step-wise search was conducted for each term or



**Figure 1:** Preferred Reporting Items for Systematic Reviews and Meta-Analysis flowchart for literature search



**Figure 2:** Frequency of performed radiographic examinations/projections

phrase from the selected databases in line with PRISMA-ScR’s recommendations.<sup>[27]</sup> The search results from the PubMed database are presented in Table 2.

**Inclusion and exclusion criteria**

Articles were included if NDRLs were set for adult patients in general radiography for examinations that contribute to higher

effective doses (EDs) and increased risk to radiosensitive tissues/organs. Selected articles were those dating back to the 1990s since the concept of DRLs was first introduced in 1990 by ICRP.<sup>[3]</sup> Only English language publications with reporting NDRLs with the requisite study design were included. Articles excluded were those that disqualify a study upon further study such as reviews, case studies, insufficient review parameters,

**Table 1: Search terms and phrases with Boolean operators for the cohort and intervention**

Cohort	Intervention
Radiography	DRLs
OR	OR
General radiography	Dose reference levels
OR	OR
Radiographic examinations	Reference dose levels
OR	OR
Radiographic procedures	Reference levels
OR	OR
Radiographic imaging	DRLs
OR	OR
Diagnostic examinations	DRL
OR	OR
Diagnostic procedures	Dose audit
OR	
Diagnostic imaging	
OR	
Diagnostic radiography	
OR	
Projection radiography	
OR	
X-ray	
OR	
X-ray examinations	
OR	
X-ray procedures	
OR	
X-ray imaging	

DRLs: Diagnostic reference level

inaccessibility of full-text, LDRL and RDRL publications, and nongeneral radiographic NDRL publications.

### Making study selection

All the authors evaluated search results, determined relevance by skimming titles and abstracts, and removed duplicates. Three authors independently reviewed full copies of potential papers, consulting the wider team to resolve inclusion discrepancies for the final review. All authors were involved in the final review of the selected publications. As a scoping review explores the extent and nature of the literature, formal quality appraisal of included and excluded studies was not required,<sup>[22,28]</sup> thus a dedicated quality appraisal was not conducted.

### Charting and data collation

Charting was conducted using a structured form designed in Microsoft Excel to capture detailed information from the studies included in the review. Extracted data included study subjects, sample sizes (patients and hospitals), the country and year of NDRL proposal, methods of NDRL estimation, radiographic examinations reported, dosimetric quantities assessed and their results, radiographic image quality ( $R_{IQ}$ ) considerations, and whether quality control (QC) tests were conducted before data collection. The initial charting of data for each publication was performed by the first author and subsequently reviewed

**Table 2: Grouped terms and key search phrases with Boolean operators**

Number GI	Search phrases or terms	Number of publications
GI-1	“dose reference level*” [tw] OR “diagnostic reference level*” [tw] OR “reference dose level*” [tw] OR “reference level*” [tw] OR DRL [tw] OR DRLs [tw] OR “dose audit*” [tw]	108 897 72 3030 1331 573 74
GI-2	“diagnostic reference level*” [mh] OR	143
GI-3	radiograph* [tw] OR “general radiograph*” [tw] OR (radiograph* AND examination*) OR (radiograph* AND procedure*) OR (radiograph* AND imaging) OR “diagnostic examination*” [tw] OR “diagnostic procedure*” [tw] OR “diagnostic imaging” [tw] OR “diagnostic radiograph*” [tw] OR “projection radiograph*” [tw] OR “X-ray*” [tw] OR “X-ray examination*” [tw] OR “X-ray procedure*” [tw] OR “X-ray imaging” [tw]	401,201 201 52,858 59,659 301,841 1650 19,725 1,254,077 560 1496 841,670 3,707 184 4763
GI-4	radiograph* [mh] OR “diagnostic imaging” [mh]	849,039 2,280,845
Number GI	Combinations made	Number of publications
GI-5	#GI-1 OR #GI-2	4175
GI-6	#GI-3 OR #GI-4	2,931,493
GI-7	#GI-5 AND #GI-6	1290

\*Truncation symbol that searches for a root word and retrieve word variations of the root word. [tw]: Text word search for terminologies in titles, abstracts, and other text fields, [mh]: Medical subject heading terminologies used to search controlled vocabularies for indexing articles, GI: Grouped item, DRL: Diagnostic reference level

and validated by all authors. Findings were synthesized through thematic analysis to identify key patterns and gaps in qualitative data while quantitative data (NDRL values) were summarized numerically. These were supplemented by narrative synthesis to provide a comprehensive summary of the reviewed content. In addition, a numerical summary was presented to describe key characteristics of the included studies, as proposed by Arksey and Malley.<sup>[23]</sup>

### Summarizing and reporting of the findings

This was conducted by integrating both quantitative and qualitative data to answer the review questions. Quantitative findings were summarized using descriptive statistics such as frequency, standard deviation, mean, and median. These these have been presented in tables and figures. Thematic and narrative analyses of qualitative data were used to provide a cohesive summary and interpretation of the findings across the included publications.

## RESULTS

Figure 1 presents a total of 4932 records which were identified through database searching and supplementary sources. After screening and full-text evaluation, 22 publications, including 12 proposed NDRLs (NDRLs<sub>p</sub>) [Table 3] and 10 established NDRLs (NDRLs<sub>E</sub>) [Table 4], were selected for the review. Table 3 presents primary review parameters, including methodologies for estimating patient K<sub>a,e</sub>. Table 3 also presents the World Bank’s income classification of countries.<sup>[29]</sup> Table 4 provides a reduced subset due to limitations arising from parameter unavailability and the varied presentation formats of NDRLs<sub>E</sub> publications. NDRL values for the frequently performed X-ray examinations/projections featured across the publications are presented in Table 5 (NDRLs in K<sub>a,e</sub>) and Table 6 (NDRLs in P<sub>KA</sub>). To set NDRLs, priority should be given to radiographic procedures contributing significantly to collective ED<sup>[52]</sup> and performed frequently. It is essential to specify the projections and the clinical imaging task related to the procedure.<sup>[6]</sup> Key examinations include chest, cervical spine (CS), pelvis, thoracic spine, abdomen, skull, and lumbar spine (LS).<sup>[45]</sup> Despite the low dose, chest X-rays are significant

due to their high frequency,<sup>[53]</sup> with an estimated 8.3 million requests in England between 2019 and 2020.<sup>[54]</sup>

Tables 7 and 8 present the mean value ( $\bar{d}$ ) ± standard deviation ( $\sigma$ ) and median of the examination-specific NDRLs for K<sub>a,e</sub> and P<sub>KA</sub>, respectively, for NDRLs<sub>p</sub> from 2004–2013 to 2014–2024. These were compared with NDRLs<sub>E</sub> between 2014 and 2024 to illustrate how NDRLs<sub>p</sub> have changed over the last 20 years.

## DISCUSSION

### Efforts and initiatives in low-income and lower-middle-income countries

All identified NDRLs<sub>E</sub> were from high-income countries, indicating less attention to NDRL establishment in LI and LMICs. In Table 3, 40% of NDRLs<sub>p</sub> were in LI and LMICs, compared to 60% in upper-middle and high-income countries. The variation in NDRL values across countries highlights the need for each country to establish its own NDRLs. In LI and LMICs, factors such as older equipment and fewer qualified radiography personnel<sup>[20]</sup> necessitate NDRL establishment. LI and LMICs could enhance capacities for national dosimetry by incorporating NDRLs<sub>p</sub> and

**Table 3: Summary of key parameter-data extracted from the national diagnostic reference levels<sub>p</sub> publications**

Study	Year	Country	Sample size		NDRL dose metric		Procedure frequency		QC	IQ	Income classification <sup>[29]</sup>
			Patients	Facilities	Quantity	Method	Examinations	Projections			
Welarathna <i>et al.</i> <sup>[30]</sup>	2024	Sri Lanka	894	6	P <sub>KA</sub>	Direct (DAP meter)	3	4	N/A	Yes	LMI
Ahmed <i>et al.</i> <sup>[31]</sup>	2020	Sudan	1629	29	K <sub>a,e</sub>	Indirect	5	7	N/A	N/A	LI
Dimov <i>et al.</i> <sup>[32]</sup>	2018	Bulgaria	5731	>20 <sup>a</sup>	P <sub>KA</sub>	Direct (DAP meter)	6	9	Yes	N/A	HI
Wachabauer <i>et al.</i> <sup>[33]</sup>	2019	Austria	15,305	312	P <sub>KA</sub>	Direct (DAP meter)	5	9	N/A	N/A	HI
Deevband <i>et al.</i> <sup>[34]</sup>	2018	Iran	10,080	75	K <sub>a,e</sub>	Indirect	7	11	N/A	N/A	UMI
Korir <i>et al.</i> <sup>[35]</sup>	2018	Kenya	1206	10	K <sub>a,e</sub>	Indirect	15	24	Yes	Yes	LMI
Hiswara <i>et al.</i> <sup>[36]</sup>	2016	Indonesia	1208	44	K <sub>a,e</sub>	Direct (TLD)	8	13	Yes	N/A	UMI
KhiaA <i>et al.</i> <sup>[37]</sup>	2016	Sudan	1490	15	K <sub>a,e</sub>	Indirect	8	11	N/A	N/A	LI
Kharita <i>et al.</i> <sup>[38]</sup>	2010	Syria	1308	26	P <sub>KA</sub>	Direct (DAP meter)	8	9	N/A	N/A	LI
Asadinezhad and Bahreyni Toossi <sup>[39]</sup>	2008	Iran	1601	31	K <sub>a,e</sub>	Direct (TLD)	7	14	Yes	Yes	UMI
Škrk <i>et al.</i> <sup>[40]</sup>	2006	Slovenia	>2000	33	K <sub>a,e</sub>	Indirect and direct (TLD)	9	15	N/A	N/A	HI
Aroua <i>et al.</i> <sup>[41]</sup>	2004	Switzerland	N/A	N/A	K <sub>a,e</sub>	Indirect	8	12	N/A	N/A	HI

<sup>a</sup>Authors reported this as the number of X-ray systems. N/A: Unable to explicitly infer from publication, LI: Low-income, LMI: Lower middle-income, UMI: Upper middle-income, HI: High-income, TLD: Thermoluminescent dosimeters, NDRL: National diagnostic reference level, DAP: Dose area product

**Table 4: Summary of the key data extracted from the national diagnostic reference levels<sub>E</sub> publications**

	Ireland <sup>[42]</sup>	Poland <sup>[43]</sup>	UK <sup>[44]</sup>	Malta <sup>[45]</sup>	Saudi Arabia <sup>[46]</sup>	France <sup>[47]</sup>	Italy <sup>[48]</sup>	Japan <sup>[49]</sup>	Germany <sup>[50]</sup>	Korea <sup>[51]</sup>
Year	2023	2023	2022	2022	2022	2019–2021	2020	2020	2019	2016
DRL metric	P <sub>KA</sub>	P <sub>KA</sub>	K <sub>a,e</sub> , P <sub>KA</sub>	P <sub>KA</sub>	P <sub>KA</sub>	P <sub>KA</sub>	K <sub>a,e</sub> , P <sub>KA</sub>	K <sub>a,e</sub>	P <sub>KA</sub>	K <sub>a,e</sub>
Procedure frequency										
Examinations	7	6	9	8	2	7	3	7	8	15
Projections	12	10	16	15	3	12	7	9	12	22

DRL: Diagnostic reference level

**Table 5:  $K_{a,e}$  (mGy) national diagnostic reference levels for frequently performed radiographic examinations (with three projections; anterior-posterior, posterior-anterior, and lateral) from 12 of the selected publications**

Study	Skull		Cervical spine		Chest			Thoracic spine		Lumbar spine		Pelvis	Abdomen
	AP/PA	LAT	AP	LAT	AP	PA	LAT	AP	LAT	AP	LAT	AP	AP
<b>NDRLs<sub>p</sub></b>													
Ahmed <i>et al.</i> <sup>[31]</sup>	3.50	1.70	--	--	--	0.60	--	--	--	3.70	8.00	2.60	2.70
Deevband <i>et al.</i> <sup>[34]</sup>	1.30	1.17	0.77	0.85	--	0.63	1.11	1.73	2.35	2.69	4.22	1.62	2.00
Korir <i>et al.</i> <sup>[35]</sup>	7.00 <sup>a</sup>	0.30	2.00	3.00	1.00	0.50	5.00	7.00	9.00	5.00	11.00	5.00	4.00
Hiswara <i>et al.</i> <sup>[36]</sup>	1.58	1.38	0.89	0.92	--	0.33	1.18	--	--	3.14 <sup>b</sup>	5.84	1.98	2.60
Khiar <i>et al.</i> <sup>[37]</sup>	1.90 <sup>c</sup>	1.20	1.35	1.67	--	0.54	--	--	--	6.43	18.50	3.00	3.00
Asadinezhad and Bahreyni Toossi <sup>[39]</sup>	2.85/2.83	1.93	1.83	0.93	0.97	0.41	2.03	2.72	5.29	3.43	8.41	3.18	4.06
Škrk <i>et al.</i> <sup>[40]</sup>	2.54	2.02	1.73	1.83	0.35	0.35	1.20	7.69	10.13	7.98	19.67	5.83	6.18
Aroua <i>et al.</i> <sup>[41]</sup>	5.40	3.50	3.10	--	--	0.20	0.40	7.00	21.00	8.70	26.00	7.80	7.00
<b>NDRLs<sub>e</sub></b>													
UK <sup>[44]</sup>	1.80	1.10	--	--	0.20	0.15	0.50	3.50	7.00	5.70	10.00	4.00	4.00
Compagnone <sup>[48]</sup>	2.50	2.00	--	--	--	0.30	1.00	--	--	6.00	15.00	--	--
Japan <sup>[49]</sup>	2.50	--	0.80	--	--	0.40 <sup>d</sup> , 0.30 <sup>e</sup> , 0.20 <sup>f</sup>	--	3.00	5.00	3.50	9.00	2.50	2.50
Do <sup>[51]</sup>	2.70	3.11	--	--	1.75	0.58	3.08	4.09	9.22	4.74	12.7	3.94	3.90

<sup>a</sup>Value in the publication was for only AP, <sup>b</sup>Value in the publication was for both AP and PA, <sup>c</sup>Value in the publication was for only PA, <sup>d</sup>At <100 kV, <sup>e</sup>At ≥100 kV, <sup>f</sup>Medical checkup ≥100 kV. -- Data unavailable from the publication. AP: Anterior–posterior, PA: Posterior–anterior, LAT: Lateral, NDRLs: National diagnostic reference levels

**Table 6: PKA (Gy cm<sup>2</sup>) diagnostic reference levels for frequently performed radiographic indications from 12 of the selected publications**

Study	Skull		Cervical spine		Chest			Thoracic spine		Lumbar spine		Pelvis	Abdomen
	AP/PA	LAT	AP	LAT	AP	PA	LAT	AP	LAT	AP	LAT	AP	AP
<b>NDRLs<sub>p</sub></b>													
Welarathna <i>et al.</i> <sup>[30]</sup>	--	--	--	--	--	--	--	--	--	1.43	2.38	--	2.24
Dimov <i>et al.</i> <sup>[32]a</sup>	0.80	0.75	--	--	--	0.45	--	1.10	2.20	2.40	3.60	2.30	3.00
Wachabauer <i>et al.</i> <sup>[33]</sup>	0.49	0.49	--	--	0.20 <sup>b</sup>	0.13	0.42	--	--	1.76	3.10	1.94	1.84
Kharita <i>et al.</i> <sup>[38]</sup>	2.13	--	--	--	--	1.68	--	--	--	8.62 <sup>c</sup>	18.47	5.76 <sup>d</sup>	6.57
<b>NDRLs<sub>e</sub></b>													
Ireland <sup>[42]</sup>	--	--	0.16	0.19	0.13	0.12	--	0.76	1.80	1.60	2.24	1.91	1.70
Jasieniak <i>et al.</i> <sup>[43]</sup>	1.10	1.00	--	--	--	0.20	1.00	2.20	3.20	3.20	8.00	5.00	5.00
UK <sup>[44]</sup>	--	--	0.15	0.15	0.15	0.10	--	1.00	1.50	1.50	2.50	2.20	2.50
Malta <sup>[45]</sup>	0.62/0.67	0.47	0.18	0.13	--	0.15	0.80	0.99	1.61	3.75	2.92	2.35	1.76
Saudi Arabia <sup>[46]</sup>	--	--	--	--	0.49	--	--	--	--	--	--	--	--
France <sup>[47]</sup>	--	--	--	0.27	--	0.16	0.41	0.76	0.90	2.04	3.09	2.71	2.59
Italy <sup>[48]e</sup>	1.00	1.00	--	--	--	0.25	1.00	--	--	1.50	4.00	--	--
Germany <sup>[50]</sup>	0.60	0.50	--	--	--	0.15	0.40	1.10 <sup>c</sup>	1.40	2.00 <sup>c</sup>	3.50	2.50	2.30

<sup>a</sup>Dose data from the third national survey, <sup>b</sup>Authors reported this figure for bedside chest, <sup>c</sup>Value in the article was for both AP and PA, <sup>d</sup>Value in the publication was for both pelvis AP and hip AP, <sup>e</sup>Some values have been rounded off to two decimal places, --:Data unavailable from the publication. AP: Anterior–posterior, PA: Posterior–anterior, LAT: Lateral, NDRLs: National diagnostic reference levels

institutional dose data. Legislative and regulatory measures should be established to ensure regular updates, compliance, and policymaker involvement for effective NDRL implementation.

### Facilities and subjects

All the reviewed studies adhered to the ICRP recommendations<sup>[6]</sup> on the selection of facilities for the

NDRL survey. Welarathna *et al.*<sup>[30]</sup> selected six facilities from five of Sri Lanka’s nine provinces, choosing locations based on annual workload and population density, making it suitable for inclusion in this review. NDRLs<sub>e</sub> are typically from an extensive facility sample size using a standardized repository of dose information,<sup>[44]</sup> including dose data from professional institutions.<sup>[50]</sup> For instance, 320 hospitals covering at least

**Table 7: Mean and median  $K_{a,e}$  (mGy) values of national diagnostic reference levels from the reviewed articles**

	Skull		Cervical spine		Chest			Thoracic spine		Lumbar spine		Pelvis	Abdomen
	AP/PA	LAT	AP	LAT	AP	PA	LAT	AP	LAT	AP	LAT	AP	AP
NDRL <sub>Sp</sub> (2004–2013)													
$\bar{d} \pm \sigma$	3.6±1.6	2.5±0.9	2.2±0.8	1.4±0.6	0.7±0.3	0.3±0.1	1.2±0.8	5.8±2.7	12.1±8.0	6.7±2.9	18.0±8.9	5.6±2.3	5.7±1.5
Median	2.8	2.0	1.8	1.4	0.7	0.4	1.2	7.0	10.1	8.0	19.7	5.8	6.2
NDRL <sub>Sp</sub> (2014–2024)													
$\bar{d} \pm \sigma$	3.1±2.4	1.2±0.5	1.3±0.6	1.6±1.0	0.7±0.5	0.7±0.3	3.1±2.8	4.4±3.7	4.8±3.6	4.7±1.5	8.7±6.5	3.0±1.2	2.9±0.8
Median	1.9	1.2	1.1	1.3	0.7	0.6	3.1	4.4	3.1	5.0	8.0	2.6	2.9
NDRL <sub>SE</sub> (2014–2024)													
$\bar{d} \pm \sigma$	2.4±0.4	2.2±0.9	0.8		1.0±1.1	0.3±0.2	1.5±1.4	3.5±0.6	7.1±2.1	5.0±1.1	11.7±2.7	3.5±0.9	3.5±0.8
Median	2.5	2.3			1.0	0.3	1.0	3.5	7.0	5.2	11.4	3.9	3.9

AP: Anterior–posterior, PA: Posterior–anterior, LAT: Lateral, NDRLs: National diagnostic reference levels

23% of health facilities with diagnostic X-ray systems were used for the UK NDRL<sub>SE</sub>.<sup>[44,55]</sup>

NDRLs for adults are preferably established by standardizing patient sizes using a weight range of about 50 kg to 90 kg to achieve a mean weight of  $70 \pm 10$  kg depending on the weight distribution of the country.<sup>[6]</sup> This practice was followed in all reviewed publications. While anthropomorphic phantoms aid dose-delivery experiments, using them for DRLs is not recommended as they may not align with typical clinical requirements for an imaging task.<sup>[6,52]</sup>

### Dosimetric quantities

This review notes a predominance of NDRL<sub>Sp</sub> set for  $K_{a,e}$ , emphasizing its reliability,<sup>[56]</sup> reproducibility, and ease of estimation.  $K_{a,e}$  was estimated in eight NDRL<sub>Sp</sub>, out of which five were through the indirect method and two through the direct method with TLDs. Škrk *et al.*<sup>[40]</sup> reported both direct and indirect methods for assessing  $K_{a,e}$ .  $P_{KA}$  was assessed in four NDRL<sub>Sp</sub>. Conversely,  $P_{KA}$  was predominantly estimated across eight NDRL<sub>SE</sub> as opposed to four for  $K_{a,e}$ . Among the reviewed NDRL<sub>Sp</sub>, reporting of  $P_{KA}$  increased from one (2004–2013) to three in the last decade. The comprehensive inclusion of both  $K_{a,e}$  and  $P_{KA}$  metrics in literature could facilitate future NDRL comparisons irrespective of the chosen dose metric for a DRL study. This would also enhance analytical comparability and data synthesis.

Kharita *et al.*<sup>[38]</sup> and Korir *et al.*<sup>[35]</sup> reported ED (Sv), as a dose metric, while Vodovatov *et al.*<sup>[57]</sup> recommended ED for setting NDRLs in Russia using a pooled method. ED is useful in estimating radiation risk to patients; however, its use in setting NDRLs is discouraged<sup>[6,52]</sup> because it does not directly evaluate ionizing radiation for medical imaging tasks, it is relatively challenging to measure, and may not be readily available for frequent comparisons as required for NDRLs.<sup>[6]</sup>

### Setting of national diagnostic reference levels

All the NDRLs presented in the reviewed articles were set at the 75<sup>th</sup> percentile. Significant differences were seen in NDRL values among the reviewed publications for each examination. This is further highlighted with the large standard deviations observed across different studies, especially for

spine examinations. Variations in NDRL values may be attributed to factors such as differences in body mass index density distribution of patients in different countries,<sup>[58]</sup> influencing exposure factor selection and patient dose.<sup>[59]</sup> In addition, variations in X-ray systems, imaging techniques, and the absence of QC tests before surveys<sup>[60]</sup> could contribute to country-to-country differences in NDRL values. Only Asadinezhad and Toosi,<sup>[39]</sup> Hiswara *et al.*,<sup>[36]</sup> and Korir *et al.*<sup>[35]</sup> among the reported that QC tests were done before the patient survey.

### Radiographic examinations and doses

Radiographic examinations of the extremities,<sup>[35,36,38]</sup> shoulders,<sup>[35,37,38]</sup> clavicle,<sup>[35]</sup> knee joint,<sup>[37]</sup> hip,<sup>[35,38,40,41,51]</sup> urinary system,<sup>[38]</sup> lumbosacral joint,<sup>[40]</sup> and mandible<sup>[35]</sup> were seen in the literature but were infrequently reported. Hence, these examinations were not included this review. Chest PA, LS AP, and LS LAT were the most reported for the combination of  $K_{a,e}$  and  $P_{KA}$ . Chest AP was the least reported. Figure 2 further illustrates the frequency of radiographic examinations reported in the reviewed articles. The emergence of CT and MRI imaging has resulted in a gradual decrease in reliance on general radiography for spine<sup>[61]</sup> and skull<sup>[62]</sup> examinations. However, limited availability and nonaffordability of CT and MRI services in LI and LMICs make general radiography systems an often-utilized modality for skull and spine imaging. Consequently, there is a need for incorporating skull and spine examinations in NDRLs where necessary, especially in LI and LMICs.

The median LS LAT  $K_{a,e}$  for the combined NDRL<sub>Sp</sub> and NDRL<sub>SE</sub> (NDRL<sub>S<sub>c</sub></sub>) was 3.29 mGy lower than the EU RDRL<sup>[14]</sup> median for LS LAT (16 mGy). Similar trends were observed for  $P_{KA}$  NDRLs. The higher LS LAT dose is because this exposure is to an anatomical region with high X-ray attenuation and longer transverse plane, requiring increased beam energy to penetrate the pelvic bones. Chest PA for NDRL<sub>S<sub>c</sub></sub> exhibited the lowest radiation exposure with a  $K_{a,e}$  of  $\bar{d} = 0.41$  mGy, while chest AP had the lowest  $P_{KA}$  for NDRL<sub>S<sub>c</sub></sub> ( $\bar{d} = 0.24$  Gy $\text{cm}^2$ ). However, NDRL<sub>SE</sub> for chest PA showed a lower  $P_{KA}$  of  $\bar{d} = 0.33$  Gy $\text{cm}^2$  compared to the chest PA  $K_{a,e}$  mean for both NDRL<sub>Sp</sub> and NDRL<sub>S<sub>c</sub></sub>. The low dose associated with chest PA and AP

**Table 8. Mean and median  $P_{KA}$  ( $Gy\ cm^2$ ) values of national diagnostic reference levels from the reviewed articles**

	Skull		Cervical spine		Chest		Thoracic spine		Lumbar spine		Pelvis		Abdomen	
	AP/PA	LAT	AP	LAT	AP	PA	AP	LAT	AP	LAT	AP	LAT	AP	LAT
NDRL <sub>sp</sub> <sup>a</sup> (2004–2013)	2.13	2.13	--	--	--	1.68	--	--	8.62	18.47	5.76	6.57		
NDRL <sub>sp</sub> (2014–2024)	0.6±0.2	0.6±0.2	--	--	0.2	0.3±0.2	1.1	2.2	1.9±0.5	3.0±0.6	2.1±0.3	2.4±0.6		
Median	0.6	0.6	--	--		0.3			1.8	3.1	2.1	2.2		
NDRL <sub>se</sub> (2014–2024)	0.80±0.23	0.74±0.30	0.19±0.05	0.19±0.06	0.26±0.20	0.20±0.13	1.14±0.54	1.74±0.78	2.23±0.89	3.75±1.96	2.78±1.12	2.64±1.21		
Median	0.67	0.75	0.17	0.17	0.15	0.15	1.00	1.56	2.00	3.09	2.43	2.40		

<sup>a</sup>σ and medians are excluded because only one publication was in this year range. -- Not available, NDRLs: National diagnostic reference levels, AP: Anterior–posterior, PA: Posterior–anterior, LAT: Lateral

projection is due to the thinner chest tissue thickness and less dense anatomical structures within the thoracic cavity.

### Variation of proposed national diagnostic reference levels over time

The mean  $K_{a,e}$  for LS LAT in NDRL<sub>sp</sub> (12.71 mGy) exceeded that of NDRL<sub>se</sub> by 1.03 mGy, largely due to variations between older NDRL<sub>sp</sub> data (2004–2013,  $\bar{d}$  = 18.0 mGy) and more recent data (2013–2024,  $\bar{d}$  = 8.7 mGy). For chest PA examinations, a significant reduction in average  $P_{KA}$  was observed in the last decade compared to 2004–2013, although an increased average  $K_{a,e}$  was noted for publications from 2014–2024, influenced by the high  $K_{a,e}$  of 1.18 mGy reported by Hiswara *et al.*<sup>[36]</sup> NDRL<sub>se</sub> for chest PA  $K_{a,e}$  examinations (0.3 mGy) was the same for NDRL<sub>sp</sub> chest PA  $K_{a,e}$  for the 2004–2013 period. In CS LAT examinations, NDRL<sub>sp</sub>  $K_{a,e}$  increased by 14.3% among the publications within the 2014–2024 period, which was largely influenced by the  $K_{a,e}$  reported by Korir *et al.*<sup>[35]</sup> for CS LAT examination (3.0 mGy). Nevertheless, Japan’s<sup>[49]</sup> NDRL<sub>se</sub>  $K_{a,e}$  for the CS LAT examination in 2020 was 42.9% lower than the 2004–2013 NDRL<sub>sp</sub> CS LAT examinations’  $K_{a,e}$ . Overall, NDRL<sub>sp</sub> for other examinations reported by the publications in 2014–2024 were lower than those reported in 2004–2013, likely due to advancements in X-ray technology, improved detector systems, and optimized imaging protocols. This highlights the necessity for regular updates of existing NDRL<sub>se</sub> to avoid reliance on obsolete dose data.

### Quality control tests and radiographic quality considerations

Before dosimetric surveys, conducting QC tests is essential to ensure parameters influencing patient exposure and  $R_{IQ}$  are within acceptable limits. Given the volume of facilities and time constraints in nationwide surveys, simple QC procedures targeting exposure factors and image quality could be considered. However, explicit reporting of QC test conduction was absent in most reviewed studies. A simple visual grading assessment of  $R_{IQ}$  for survey radiographs is also suggested. Achieving optimal patient safety requires balancing dose reduction with adequate  $R_{IQ}$ ,<sup>[6]</sup> as reliance on NDRL values alone, without  $R_{IQ}$  considerations, is insufficient.<sup>[6]</sup> Kharita *et al.*<sup>[38]</sup> reported including only diagnostically acceptable radiographs, whereas Asadinezhad and Toosi<sup>[39]</sup> and Korir *et al.*<sup>[35]</sup> included  $R_{IQ}$  evaluations in their studies. Incorporating QC tests and  $R_{IQ}$  assessments enhances NDRL surveys by increasing result reliability and identifying optimization opportunities, such as addressing high patient doses due to exposure factors exceeding tolerance limits.

### Limitations

The review included only articles published in English Language, potentially excluding relevant publications in other languages, which may limit the comprehensiveness of the findings. The relatively small number of studies meeting the inclusion criteria reduces the generalizability of the results. Furthermore, the NDRLs reported in the included studies were

derived from patient populations with varying demographics, which limits the applicability of the findings to specific national contexts or uniform implementation. In addition, variations in methodologies, imaging protocols, and equipment across studies could introduce potential inconsistencies in the reported NDRLs analysis.

## CONCLUSION

A scoping review of 22 publications that presented NDRLs for 7 examinations and 13 projections commonly performed in general radiography has been conducted using the PRISMA-ScR guidelines. NDRL<sub>p</sub> and NDRL<sub>e</sub> in LI and LMICs are scanty in literature. Despite the nonharmonization in survey methodologies, the methods used by the surveyed publications were consistent with established guidelines. NDRLs were proposed for K<sub>PA</sub> and K<sub>a,c</sub>, with both being extensively used as dose metrics. Chest PA, LS AP, and LS LAT were the most frequently reported; LS LAT exhibited the highest patient dose, while chest PA showed the lowest dose. Overall, NDRL<sub>p</sub> from 2004 to 2013 reported higher doses than both NDRL<sub>p</sub> and NDRL<sub>e</sub> published from 2014 to 2024. QC tests and R<sub>IQ</sub> assessments are needed to complement and enhance confidence in NDRL values while providing opportunities for dose optimization. Furthermore, researchers and countries are encouraged to increase dose surveys for NDRL establishment by fostering collaboration among key stakeholders for the establishment of NDRLs to assist in patient radiation dose optimization.

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## Conflicts of interest

There are no conflicts of interest.

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