Original Article

Development and Validation of a Questionnaire Assessing Prescribing Physicians Knowledge on the Use of Radioprotective Agents

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ABSTRACT

Backgroun

Healthcare professionals, particularly physicians who prescribe radiological examinations, must have a solid understanding of ionizing radiation principles, their biological effects, and the various preventive measures associated with them. This knowledge is essential to avoid unnecessary patient exposure and to mitigate these effects when deemed appropriate. The development of a tool capable of assessing physicians' understanding and knowledge of radioprotection represents a key strategy for strengthening a culture of safety and optimizing clinical practices.

Objective

This study aims to design and validate the psychometric properties of a questionnaire assessing prescribing physicians' knowledge of ionizing radiation effects and radioprotective agents.

Methods

A cross-sectional study design was adopted for this research. Initially, a 35-item questionnaire was developed, covering two domains: (a) effects of ionizing radiation and (b) radioprotective agents. Face validity and content validity were assessed by a panel of nine experts. Analyses were conducted to determine content validity indices in terms of relevance and clarity (I-CVI, S-CVI/Ave, and S-CVI/UA), as well as the content validity ratio (CVR). Data were collected from 134 physicians across various specialties. Internal consistency was measured using the KR-20 coefficient (Kuder-Richardson Formula 20), and temporal stability was evaluated using the test-retest method (kappa coefficient).

Results

The finalized questionnaire includes 24 items that were validated by experts. The indices obtained were I-CVI $\geq$ 0.78, S-CVI/UA = 0.98, and S-CVI/Ave = 0.91, confirming excellent relevance and clarity. Regarding internal consistency reliability, the KR-20 coefficients were 0.746 (radiation effects) and 0.62 (radioprotective agents), with an overall score of 0.802. The kappa coefficients were reported at 0.84 and 0.834, respectively, with a range of 0.74 to 0.98 across all questionnaire items.

Conclusion

The results provide strong evidence supporting the validity and reliability of the developed questionnaire, characterized by commendable content validity indices, satisfactory internal consistency, and near-perfect kappa coefficients. Further studies are needed to extend its validation to other populations and geographic contexts, and to explore its usefulness in assessing the impact of educational interventions.

Keywords

Knowledge; questionnaire; validity and reliability; prescribing physician; ionizing radiation effects; radioprotective agents

INTRODUCTION

Diagnostic imaging technologies have become indispensable tools in contemporary healthcare, with most modalities utilizing ionizing radiation for image generation. The widespread adoption of radiological procedures—especially computed tomography—has resulted in increased patient radiation exposure[1,2.] Global statistics indicate that roughly 3.6 billion imaging examinations occur each year, experiencing annual increases of 3-5% for standard radiography and up to 10% for CT imaging[(1-4)]. CT procedures deliver radiation doses approximately 5-20 times greater than traditional radiographic techniques[(5,6)]; notably, cardiac CT exposure equals that of 150 chest radiographs[(1)]. Typical radiological

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examinations produce skin doses ranging from 10-50 mGy, while interventional procedures with extended exposure times can reach several gray[2,7].

While medical radiation exposure remains controllable, the widespread application of these diagnostic and monitoring techniques generates concerns regarding potential adverse effects from ionizing radiation[1,5]. Despite medical imaging involving lower radiation doses than nuclear exposure, health risks persist. Such low-level ionizing radiation can trigger DNA damage and produce reactive oxygen species along with organic free radicals, leading to physiological, biochemical, and genetic modifications[5,8]. Additionally, dose-response patterns at low exposure levels may not follow linear relationships[9,10].

Radiation risk mitigation follows the ALARA principle (As Low as Reasonably Achievable), which emphasizes eliminating unnecessary examinations and utilizing non-radiation alternatives when feasible[11]. A critical question emerges: can patient radiation risks be reduced when dose minimization proves impractical? Extensive research has investigated radioprotective compounds, especially antioxidants, demonstrating their efficacy in risk reduction[2]. Nuclear security concerns have intensified interest in radioprotective substances[7]. Multiple publications have examined these agents' capacity to diminish oxidative stress and stochastic effects, while assessing their potential application in diagnostic and interventional radioprotection protocols[2,7].

Understanding radiological exposure's biological consequences becomes crucial for risk estimation in exposed populations. Such knowledge enables physicians to make informed, appropriate decisions when requesting radiological examinations in patients' best interests[5,10]. Various investigations have addressed this topic, predominantly focusing on radioprotection knowledge or radiation dosimetry. These investigations include knowledge-attitude assessments[12–15], compliance evaluations[16,17], and awareness campaigns[18,20]. However, limited research specifically examines biological effects and radiation's health impact[21,22]. Furthermore, questionnaires employed in these investigations vary considerably and often lack psychometric evaluation, despite WHO guidelines for "Knowledge, Attitudes, and Practices" (KAP) study questionnaires[23,24].

Research advances regarding radioprotective compounds show significant promise[2]. These investigations seek to enhance clinical practice and manage patient risks during radiological procedures, complementing ALARA principles. Despite progress, gaps persist concerning radioprotective agents' clinical integration, prompting questions about physicians' expertise in this domain.

Valid and relevant scientific results require measurement instruments meeting psychometric standards for questionnaires, including validity and reliability[25,26]. This ensures results are meaningful, reliable, unbiased, and generalizable within the research context[27,28]. Therefore, this investigation aims to develop and validate an assessment tool evaluating prescribing physicians' understanding of ionizing radiation effects and radioprotective agent utilization for prevention.

MATERIALS AND METHODS

This is a cross-sectional study designed to develop and validate a questionnaire aimed at assessing prescribing physicians' knowledge of the effects of low-dose ionizing radiation and the use of radioprotective agents for prevention. The study targets all physicians prescribing radiological examinations in public, semi-public, and private healthcare sectors. The methodological approach is based on several steps: identifying key domains, generating and developing questionnaire items, followed by content and structural validation [29][30].

a) Questionnaire Design

The questions were developed based on the two areas of the study: "the effect of low-dose ionizing radiation" and "radioprotective agents," drawing from an in-depth literature review on radiobiology, radiation protection, and radioprotectors. The questions were then reviewed during a discussion session with a focus group composed of two researchers specialized in biophysics, biotechnology, and health vigilance.

The drafted questionnaire was divided into two parts. The first part included 20 questions on the effects of ionizing radiation, the specific risks associated with low-dose ionizing radiation, the individuals most sensitive to these risks, and concepts related to the equivalence of doses received during radiological examinations in terms of natural background radiation. The second part consisted of 15 questions covering the principles of radioprotective agents, their types, and their uses.

b) Content Validity

In the first stage of validation, a version containing 35 questions was evaluated by a panel of experts. The expert group was selected based on their extensive expertise (over 20 years of experience) and their contributions to research in the field, with varied specializations to ensure complementary perspectives and an in-depth analysis of the questions, covering the different aspects of the study. The panel included:

- One professor specialized in pediatric surgery, epidemiology, and biostatistics
- Two physicians, one specialized in public health and the other in occupational medicine
- Two research scientists specialized in epidemiology and biostatistics, with expertise in radiology research dynamics
- Four research scientists specialized in biophysics, medical physics, and radiation protection, actively involved in medical research

To this end, the expert group received, via email, the research summary and objectives, along with the evaluation form. The latter was designed to assess the relevance, clarity, objectivity, specificity, and redundancy of the questions, as well as to collect their remarks on the structure and length of the questionnaire, and any suggestions for improvement.

Face and content validity is a crucial step in the development process of a new measurement instrument. It relies primarily on the logical and reasoned judgment of the researcher, as well as on expert validation(31,32). Validity reflects the ability of the questions to be understandable and precise(29,30), and ensures that the instrument effectively measures the concept under study[31].

In this regard, face validity refers to the extent to which a measure appears to be related to the specific concept being studied. It assesses the overall appearance of the questionnaire in terms of feasibility, readability, consistency, stylistic coherence, and the clarity of the language used(26,29). A dichotomous scale was used, with "yes" or "no" options, to indicate whether an item was objectively structured and could be positively included in the questionnaire[26].

Content validity represents the extent to which the items in an instrument reflect the entire content domain to which the instrument will be generalized[25]. It ensures that the instrument includes all essential elements and excludes irrelevant items for the specific construct domain[26].

The Content Validity Index (CVI) and the Content Validity Ratio (CVR) were subsequently calculated to assess the content validity of the instrument. For each item, its relevance and clarity were evaluated using a four-point Likert scale (1 = not relevant or not clear, 2 = item requires major revision to be relevant or clear, 3 = item requires minor revision to be relevant or clear, and 4 = highly relevant or very clear)[33]. This four-point scale was also used to eliminate neutral or undecided responses[34].

In the literature, for quantitative content validity, two types of Content Validity Indices (CVI) are commonly evaluated: one applied to individual items—referred to as the Item-Level Content Validity Index (I-CVI), and the other applied to the entire instrument—referred to as the Scale-Level Content Validity Index (S-CVI)(30,31).

The I-CVI score for each item is obtained by asking experts to evaluate its relevance and clarity with respect to the underlying concept(33,35). It is calculated by dividing the number of experts who rated the item as either 3 or 4 (indicating sufficient or high relevance and clarity) by the total number of experts(34,36). Items with an I-CVI value lower than 0.70 should be rejected. If the I-CVI value is between 0.70 and 0.79, the item should be revised. Items with an I-CVI above 0.90 should be retained (35). However, with nine reviewers, an item is considered acceptable if I-CVI ≥ 0.78, meaning that up to two "not relevant" ratings are permissible(34,36).

Regarding the Scale-Level Content Validity Index (S-CVI), it measures the average proportion of items deemed relevant or clear across the entire scale. Two commonly used methods are the averaging method and the universal agreement method(34,36). The average S-CVI (S-CVI/Ave) is calculated by summing the I-CVI scores of all items and dividing by the total number of items(34,36,37). As for the universal agreement index (S-CVI/UA), it represents the proportion of items that received a score of 3 or 4 from all experts[36]. S-CVI/Ave scores ≥ 0.90 and S-CVI/UA scores ≥ 0.80 indicate good content validity(37,34,38).

The Content Validity Ratio (CVR) quantifies the consensus of the expert panel in judging an item as "essential" to the performance of the study. It considers any item rated as "essential" by more than half of the experts to possess a certain degree of content validity[39]. According to Lawshe's method (1975), the expert panel was asked to rate each item as "essential," "useful but not essential," or "not necessary" [(25,35)]. The CVR for each item was then calculated using the following formula: **CVR = (Ne – N/2) / (N/2)**, where "Ne" is the number of experts rating the item as "essential" and "N" is the total number of experts [39]. Based on the number of experts, Lawshe (1975) established the minimum CVR required for an item to be considered acceptable[(26,39)]. In this study, the minimum significant Content Validity Ratio (CVR) with nine experts was found to be **0.78**, as indicated in Lawshe's table.

Following the assessment of face and content validity, necessary modifications were made. The revised questionnaire was then submitted to a sample of 15 physicians from various specialties to test comprehension and the phrasing of questions, as well as to estimate the average time required to complete the questionnaire[38]. In fact, it is recommended to conduct pilot testing to systematically evaluate the instrument's performance and minimize potential errors[30]. Minor adjustments were made to improve the clarity of the questionnaire, taking into account the feedback and suggestions received.

c) Reliability

The reliability of a questionnaire is a key indicator of its psychometric quality. It reflects the instrument's ability to produce stable and consistent results under similar conditions [(32,26,40)]. Reliability is assessed through internal consistency and stability, also known as the "test–retest" method[(40,41)]. The questionnaires were completed by 134 Moroccan prescribing physicians working in both public and private sectors, across various specialties.

Internal consistency refers to the degree of uniformity among items and ensures that they measure the same construct. For this purpose, the Kuder-Richardson Formula 20 (KR-20) was used, given that the questionnaire uses a dichotomous (yes/no) scale[(38,41,42)]. For exploratory or pilot studies, a reliability coefficient of 0.60 or higher is considered acceptable[(25,26)]. According to the literature, four thresholds are typically used to interpret reliability: excellent reliability (0.90 and above), high reliability (0.70–0.90), moderate reliability (0.50–0.70), and low reliability (0.50 and below)[(26,31)].

Temporal stability is estimated by administering the same questionnaire to the same respondents at different points in time to assess score reproducibility over a fixed period[(40)(42)]. In this phase, the questionnaire was redistributed after 3 weeks, and 80 physicians completed it for the second time. The interval between the two administrations should be long enough to avoid memory effects, yet short enough to prevent changes in knowledge. Generally, a period of two to four weeks is recommended[(31,40,41)].

The **Kappa coefficient** was used to evaluate temporal stability. It is a measure of inter-rater reliability that accounts for agreement occurring by chance. It is frequently used to assess the reliability of categorical data, such as multiple-choice questionnaire responses[43]. Kappa values range from –1 to 1, where 1 indicates perfect agreement, 0 indicates chance-level agreement (i.e., no better than random), and negative values indicate worse-than-random agreement[38]. The standard interpretation of Kappa values is as follows:

- ≤ 0: Poor agreement
- 0.01–0.20: Slight agreement
- 0.21–0.40: Fair agreement
- 0.41–0.60: Moderate agreement
- 0.61–0.80: Substantial agreement
- 0.81–1.00: Almost perfect agreement[(43)(44)].

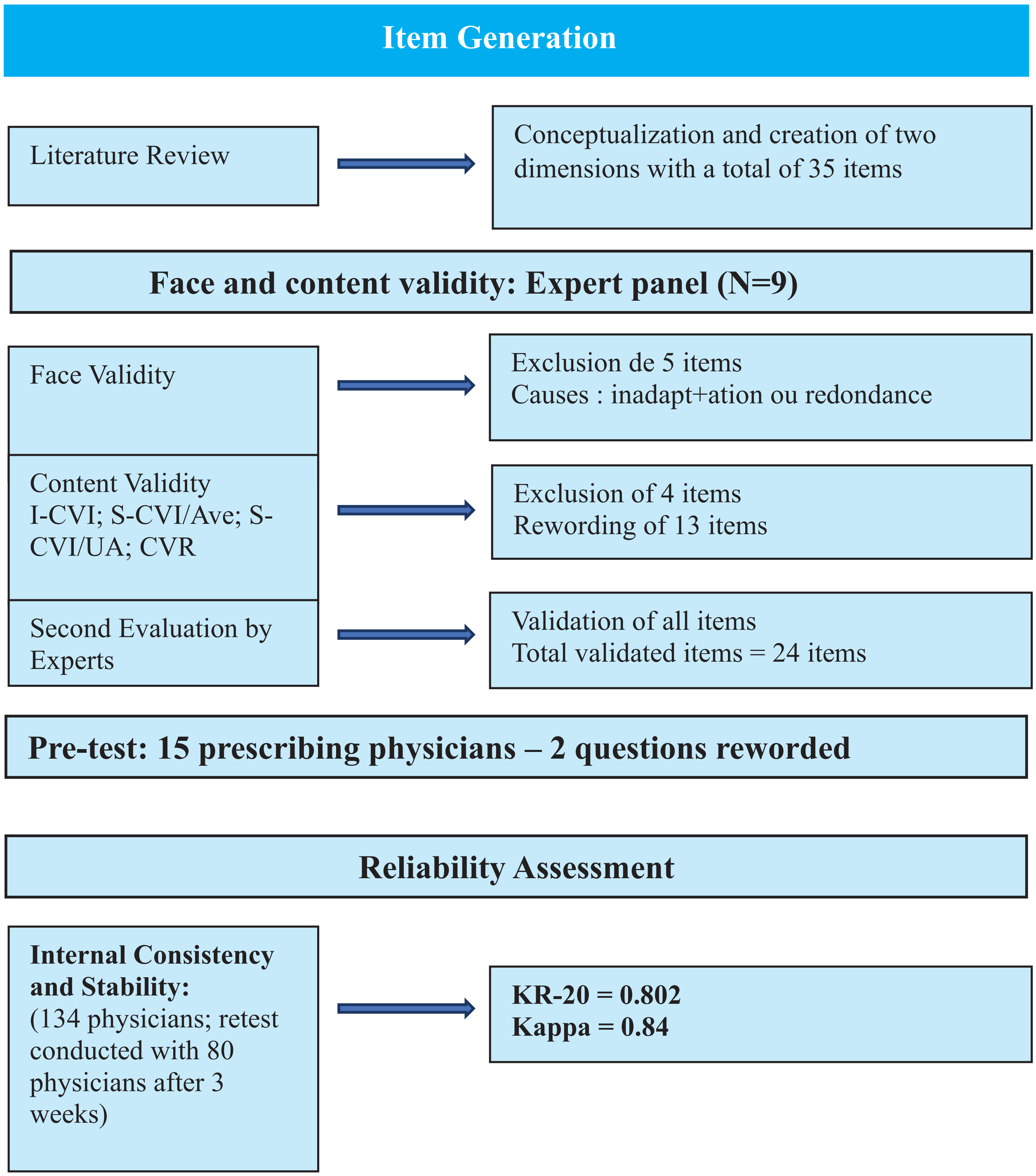
Ethical Considerations

Since the study did not involve patients, minors, or vulnerable groups, and posed no risk of psychological or physical harm to participants, ethical committee approval was not required. Additionally, participants were provided with a fact sheet about the survey, including an information note explaining the purpose of the study, the voluntary nature of participation, anonymity, confidentiality, and the procedures for data handling.

RESULTS

a) Face Validity, Content Validity, and Pre-test

Initially, 35 questions were formulated. Seven of these were eliminated after the experts' face-validity assessment because they were either inappropriate or redundant. Thus, only 28 items remained and were subjected to quantitative content-validity evaluation. Of these 28 items, 17 addressed knowledge of the



effects of ionizing radiation, and 11 concerned radioprotective agents and their uses. Following expert recommendations, the question order was revised so that general risks associated with ionizing radiation were covered first, before its effects on humans.

Quantitative content-validity analysis by nine experts indicated that further modifications were required. Three items in the ionizing-radiation effects domain and one item in the radioprotectors domain were removed owing to low CVI (item relevance and clarity) and CVR values (Table 1).

According to Lawshe's criteria, 24 questions with

CVR ≥ 0.78 were retained in the questionnaire. Fourteen items were kept with adequate CVI and CVR scores, while eight items were revised because their I-CVI scores fell within 0.70 ≤ I-CVI < 0.79. For certain items whose I-CVI *clarity* was < 0.70 but whose I-CVI *relevance* and CVR were satisfactory, the wording was revised in line with expert feedback. Based on these comments, two questions were merged into a single item (Q 2 and Q 3). All revisions were then subjected to a second expert review (Table 2).

TABLE 1. Expert Panel Evaluation of Items – I-CVI and CVR (First Round)

questions	Relevance-CVI	ClarityCVI	CVR	Interpretation
Q1. Does the body respond in the same way to low-dose ionizing radiation exposure as it does to high-dose exposure?	1,00	1,00	1	Retained
Q2. Which of the following statements describe the “linear no-threshold relationship” used to establish international radiation protection standards (ICRP) in radiobiology?	0,11	0,22	-0,78	Deleted
Q3. Which of the following statements explain the linear no-threshold relationship and its link to cancer risk?	0,78	0,67	0,78	Reworded
Q4. What are the radiation dose levels of standard radiological examinations in children? (Select the correct answers)	0,78	0,67	0,78	Reworded
Q5. What are the radiation dose levels of CT scans in children? (Select the correct answers)	0,78	0,67	0,78	Reworded
Q6. What are the radiation dose levels of standard radiological examinations in adults? (Select the correct answers)	0,78	0,67	0,78	Reworded
Q7. What are the radiation dose levels of CT scans in adults? (Select the correct answers)	0,78	0,67	0,78	Reworded
Q8. Compared to a chest X-ray, a chest CT scan delivers: (a) Less radiation (b) The same amount of radiation (c) More radiation (d) I don’t know	1,00	1,00	1	Retained
Q9. What is the estimated potential risk of developing cancer directly attributable to a single standard abdominopelvic CT scan?	1,00	1,00	0,78	Retained
Q10. What are the main effects of ionizing radiation?	1,00	1,00	0,78	Retained
Q11. Are genetic mutations the most frequent effect of ionizing radiation?	0,11	0,67	-1	Deleted
Q12. What are the biological mechanisms involved in the damage caused by ionizing radiation?	1,00	1,00	1	Retained
Q13. Are you aware that disruption of cell division and depletion of the stem cell pool are involved in radiation-induced damage?	0,11	0,67	-1	Deleted
Q14. Which populations are most sensitive to the effects of low-dose ionizing radiation?	1,00	1,00	0,78	Retained
Q15. Does pregnancy represent a special condition when it comes to exposure to ionizing radiation?	0,89	1,00	1,00	Retained
Q16. Are you aware that some individuals are genetically predisposed to be more sensitive to the effects of ionizing radiation?	0,89	1,00	0,78	Retained

questions	Relevance-CVI	ClarityCVI	CVR	Interpretation
Q17. For the following statements, which measures do you take to reduce the effects of ionizing radiation exposure during medical imaging?	0,78	0,78	1,00	Reworded
Use of optimized imaging techniques based on the "Guide to Good Radiology Practices"				
Risk-benefit assessment	1,00	1,00	1,00	Retained
Training and awareness	0,11	0,56	-1	Deleted
Use of radioprotective agents	0,78	0,67	1	Reworded
Q18. Are you aware that there are radioprotective agents that can reduce the effects of ionizing radiation exposure during a medical imaging procedure?	1,00	1,00	0,78	Retained
Q19. Which of the following statements best describe radioprotective agents?	1,00	1,00	0,78	Retained
Q20. How do radioprotective agents act to mitigate the severity of radiation-induced injuries?	1,00	1,00	1	Retained
Q21. What are the commonly used synthetic radioprotective agents?	1,00	1	1	Retained
Q22. Among the following natural products, which have documented radioprotective properties?	1,00	0,78	0,78	Reworded
Q23. For low-dose exposure in radiodiagnosis, in your opinion, radioprotective agents: (a) Are always necessary (b) Are useful in certain cases (c) Are not useful (d) I don't know	1,00	0,78	0,78	Reworded
Q24. When is it most appropriate to administer a radioprotective agent to a patient?	1,00	1,00	1,00	Retained
Q25. What are the main criteria to consider when deciding to administer a synthetic radioprotective agent to a patient?	1,00	1	0,78	Retained
Q26. What are the main criteria to consider when deciding to administer a natural radioprotective agent to a patient?	1,00	0,78	0,78	Reworked
Q27. For which radiological examinations can a radioprotective agent be used?	1,00	1,00	1,00	Retained
Q28. In practice, for low-dose radiation exposure, do you opt for the use of radioprotective agents?	1,00	1	0,78	Retained

Abbreviations: CVR – Content Validity Ratio **I-CVI** – Item-level Content Validity Index .

TABLE 2. Expert Panel Evaluation of I-CVI and CVR (Second Round)

Questions	Pertinence I-CVI	Clarté I-CVI	CVR	Interprétation
Q3. The linear no-threshold (LNT) model, used in radiation protection to estimate the risk of radiation-induced cancer, states that the risk of harmful biological effects is proportional to the radiation dose, even at low levels. It primarily applies to exposures:	1,00	1,00	0,78	Retenu
Q4. In children, what is the effective dose received during a plain abdominal X-ray (ASP), expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?	1,00	1,00	0,78	Retenu
Q5. In children, what is the effective dose received during a chest CT scan, expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?	1,00	1,00	0,78	Retenu
Q6. In adults, what is the effective dose received during a pelvic X-ray, expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?	1,00	1,00	0,78	Retenu

Questions	Pertinence I-CVI	Clarté I-CVI	CVR	Interprétation
Q7. In adults, what is the effective dose received during an abdominal CT scan, expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?	1,00	1,00	0,78	Retenu
Q17. What measures do you apply to reduce exposure to ionizing radiation in medical imaging? · Apply the ALARA principle (use non-radiating alternatives when possible) · Systematically justify the examination using the Good Practice Guidelines · Inform patients about risks and benefits (informed consent) · Use pediatric-specific protocols for children	1,00	1,00	1,00	Retenu
Q20. Radioprotective agents are synthetic or natural compounds extracted from plants or derived from phytochemicals, used to mitigate the effects of ionizing radiation. How do they act?	1,00	1,00	1	Retenu
Q25. Before administering a synthetic radioprotective agent to a patient, what criteria should be considered?	1,00	1,00	0,78	Retenu
Q26. Before administering a natural radioprotective agent to a patient, what criteria should be considered?	1,00	1,00	0,78	Retenu

Abbreviations: CVR – Content Validity Ratio ; **I-CVI** – Item-level Content Validity Index

After the second review by the expert panel, all revised items were retained due to satisfactory I-CVI and CVR values. As a result, the questionnaire was approved with a total of 24 items: 14 items related to the effects of ionizing radiation and 10 items concerning radioprotective agents and their use. Once all items were approved, they were included in the calculation of the Scale-Level Content Validity Index (S-CVI) (34). The scale validity results (Table 3) confirmed strong content validity, with an average S-CVI (S-CVI/Ave) ≥ 0.98 and a universal agreement S-CVI (S-CVI/UA) ≥ 0.91

TABLE 3. Expert Panel Evaluation of S-CVI

Dimension	S-CVI/Ave		S-CVI/UA	
	Relevance	Clarity	Relevance	Clarity
Effects of Ionizing Radiation	0.98	1	0.86	1
Radioprotective Agents	0.99	1	1	1
Total	0.98	1	0.91	1

Abbreviations: S-CVI/Ave – Scale-Level Content Validity Index/Average ; **S-CVI/UA** – Scale-Level Content Validity Index/Universal Agreement.

During the pre-test phase, administration to a small sample (15 prescribing physicians) showed a 92% approval rate for the questionnaire, indicating it was appropriate for collecting the required information and clear in terms of question wording. Minor modifications were made to two items: In Q1, the phrase *"develop the same response"* was replaced with *"different response mechanisms"*. In Q21, *"commonly used"* was changed to *"that you are familiar with"*.

The online questionnaire, including the sending and receiving of responses, functioned as intended. The average response time was 10 minutes.

b. Structural and Temporal Reliability

After validating the final version of the questionnaire consisting of 24 items, the psychometric attributes of the instrument were evaluated using a sample of prescribing physicians. A total of 134 practitioners participated in the study. Gender distribution showed a female predominance (73% women vs. 27% men). Regarding professional experience, 51% of participants had been practicing for less than 10 years, while 30% had between 10 and 20 years of experience.

From an institutional perspective, **60%** of respondents were affiliated with hospital settings (university hospitals, regional or provincial hospitals), **20%** worked in primary healthcare centers, and **10%** were in private practice. In terms of medical specialty, **30.6%** identified as general practitioners, **22.4%** as dentists, and **47%** represented various other specialties (e.g., pediatrics, rheumatology, pulmonology, etc.). Notably, only **15.7%** of participants reported having received continuing education in radiation protection within the past five years.

Table 4 presents the reliability results related to the knowledge domains assessed on the effects of ionizing radiation and radioprotective agents. The KR-20 coefficients, which indicate internal consistency, were 0.746 and 0.62, respectively. The complete scale (24 items) yielded an overall KR-20 of 0.802, indicating satisfactory internal consistency both for the subscales and the full instrument.

Une analyse de reproductibilité temporelle a été conduite auprès d'un sous-échantillon de 80 médecins, ayant répondu au questionnaire à deux reprises avec un intervalle de 3 semaines. Les résultats démontrent une concordance élevée entre les deux passations (tableau 4). Pour les éléments relatifs aux effets des rayonnements ionisants, les coefficients Kappa varient de 0,73 à 0,98 avec une valeur moyenne de 0,84, tandis que ceux associés aux radioprotecteurs s'étendent de 0,7 à 0,96 (valeur moyenne = 0,834). Ces valeurs, qualifiées de « substantielles à presque parfaites » selon les critères de Landis et Koch(45), reflètent une stabilité temporelle robuste de l'outil. Par ailleurs, toutes les analyses de concordance ont révélé une significativité statistique (p < 0,0001), excluant une explication par le seul hasard.

Table 4. Internal Consistency Reliability (KR-20)

questions	Domain KR-20	KR-20 when the item is deleted	KAPPA	p-values	Classification
Radiation Effects Domain	0,746		0,84	<0,0001	The homogeneity and integrity of the domain were almost perfect.
Q1. Does the body develop different response mechanisms when exposed to low-dose ionizing radiation compared to high-dose exposure?		0,754	0,81	<0,0001	Almost perfect
Q2. The linear no-threshold (LNT) model, used in radiation protection to estimate the risk of radiation-induced cancer, states that the risk of harmful biological effects is proportional to the dose of radiation, even at low levels. It primarily applies to exposures:		0,727	0,76	<0,0001	Substantial
Q3. In children, what is the effective dose received during a plain abdominal radiograph (ASP) expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?		0,717	0,91	<0,0001	Almost perfect
Q4. In children, what is the effective dose received during a chest CT scan expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?		0,719	0,91	<0,0001	Almost perfect
Q5. In adults, what is the effective dose received during a pelvic radiograph expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?		0,726	0,76	<0,0001	Substantial

questions	Domain KR-20	KR-20 when the item is deleted	KAPPA	p-values	Classification
Q6. In adults, what is the effective dose received during an abdominal CT scan expressed in terms of Natural Background Radiation (NBR ≈ 3 mSv/year)?		0.702	0,97	<0,0001	Almost perfect
Q7. Compared to a chest X-ray, a thoracic CT scan results in:		0,732	0,87	<0,0001	Almost perfect
Q8. The potential risk of developing cancer directly attributable to a single standard abdominopelvic CT scan is approximately:		0,716	0,74	<0,0001	Substantial
Q9. What are the main effects of ionizing radiation?		0.741	0,76	<0,0001	Substantial
Q10. What are the biological mechanisms involved in the damage caused by ionizing radiation?		0.740	0,85	<0,0001	Almost perfect
Q11. Which populations are the most sensitive to the effects of low-dose ionizing radiation?		0.738	0,74	<0,0001	Substantial
Q12. *Does pregnancy represent a specific condition regarding exposure to ionizing radiation?*		0.741	0,97	<0,0001	Almost perfect
Q13. *Are you aware that some individuals are genetically predisposed to be more sensitive to the effects of ionizing radiation?*		0.745	0,73	<0,0001	Substantial
Q14. *What measures do you apply to reduce exposure to ionizing radiation in medical imaging?* ☐ Apply the ALARA principle (use non-ionizing alternatives whenever possible) ☐ Systematically justify the examination using the Good Practice Guidelines ☐ Inform patients about the risks and benefits (informed consent) ☐ Use pediatric protocols for children		0.736	0.98	<0,0001	perfect
Radioprotectors Domain	0.62		0,834	<0,0001	The homogeneity and integrity of the domain are almost perfect
Q15. *Are you aware that there are radioprotective agents that can reduce the effects of exposure to ionizing radiation during a medical imaging examination?*		0.599	0,74	<0,0001	Substantiel
Q16. *Radioprotectors are synthetic or natural compounds derived from plants and phytochemicals, used to mitigate the effects of ionizing radiation. They act by:*		0.585	0,75	<0,0001	Substantial
Q17. *Which synthetic radioprotective agents are commonly used?*		0.599	0,91	<0,0001	Almost perfect
Q18. *Which of the following natural products have documented radioprotective properties?*		0.597	0,8	<0,0001	Substantial
Q19. In radiodiagnosis, for low-dose exposure, in your opinion, radioprotective agents:		0.577	0,86	<0,0001	Almost perfect
Q20. At what point is it most appropriate to administer a radioprotective agent to a patient?		0.632	0,9	<0,0001	perfect

questions	Domain KR-20	KR-20 when the item is deleted	KAPPA	p-values	Classification
Q21. Before administering a synthetic radioprotective agent to a patient, what criteria should be taken into consideration?		0.572	0,84	<0,0001	Almost perfect
Q22. Before administering a natural radioprotective agent to a patient, what criteria should be taken into consideration?		0.577	0,96	<0,0001	Almost perfect
Q23. For which radiological examinations can a radioprotective agent be used? Souhaitez-vous que je propose des exemples d'examens en réponse (comme le scanner, la radiographie, etc.) ?		0.589	0,88	<0,0001	Almost perfect
Q24. In practice, for low-dose radiation exposure, do you opt for the use of radioprotective agents?		0.598	0,7	<0,0001	Almost perfect
KR-20 of the scale	0.802				The homogeneity and integrity of the scale

Abbreviation: KR-20, Kuder-Richardson 20.

DISCUSSION

This investigation's primary goal involved designing and validating a psychometric instrument assessing prescribing physicians' understanding of ionizing radiation effects and radioprotective agent application for prevention. To our knowledge, this represents Morocco's inaugural study developing a validated tool for evaluating prescribers' comprehension of ionizing radiation effects. Furthermore, internationally, this investigation pioneers structured knowledge assessment related to radioprotective agents and their medical imaging applications.

The developed tool will evaluate prescribing physicians' understanding regarding ionizing radiation effects and risks. This encompasses radiation dosimetry comprehension, associated hazards, and vulnerable population awareness. The instrument also addresses multiple radioprotective agent aspects, including available types, action mechanisms, clinical uses, and safety precautions. Overall, this questionnaire aims to strengthen radiation safety culture in medical practice, identify improvement opportunities, and establish foundations for subsequent research.

Multiple investigations have examined healthcare professionals' radioprotection knowledge, representing a crucial public health dimension[12–14]. However, few employed validated instruments[29,38]. Validated questionnaires prove particularly valuable for developing interventions targeting knowledge improvement and promoting attitude and practice changes regarding ionizing radiation utilization[46]. Moreover, validation enables instrument standardization across different regions and specialties, facilitating knowledge level comparisons and training program effectiveness assessment[30,46].

Psychometric evaluation yielded positive results regarding the questionnaire's validity and reliability for assessing prescribing physicians' knowledge of ionizing radiation effects and radioprotective agent prevention applications. The instrument contains 24 items spanning two domains: ionizing radiation effects and radioprotective agents. Expert panels assessed content validity to verify questionnaire relevance and comprehensiveness. All 24 items achieved acceptable thresholds for I-CVI, S-CVI/Ave, S-CVI/UA, and CVR[29][11][34].

Reliability assessment utilized the KR-20 coefficient due to dichotomous response formats. The two subscales achieved KR-20 values of 0.746 and 0.62, considered acceptable. The complete scale demonstrated overall internal consistency of 0.802, indicating strong integrity and homogeneity[26,31]. No items required removal, as their exclusion failed to substantially enhance overall reliability coefficients.

Test-retest reliability results, measured through Kappa coefficients, spanned 0.74-0.98. These outcomes confirm the questionnaire meets psychometric measurement criteria and exhibits commendable temporal stability[43] [44].

When compared with similar validation studies for radioprotection knowledge assessment tools among healthcare professionals, existing literature emphasizes four primary areas: fundamental ionizing radiation physics and radiobiology knowledge[29,38,47–49]; safety protocols, including ALARA principles and protective equipment utilization[29,38,48,49]; regulatory standard compliance[29,38,48]; and risk perception[38,47,49]. Some investigations specifically address patient and operator protection through technical interventions (distance, shielding) and dedicated equipment like dosimeters[29,48,49]. Notably, none mention radioprotective agents as preventive strategies against radiation exposure risks—revealing a significant literature gap.

Target populations differ by context: clinical nurses working with ionizing radiation[29], dental students[48,49], dentists[38], or general populations[47]. However, no investigation explicitly targets physicians prescribing radiological examinations, despite their central role in dose justification and optimization.

Methodologically, most investigations utilize adequately large samples (n ≥ 100), enhancing construct reliability. Literature emphasizes that larger samples strengthen psychometric property robustness[40]. These investigations demonstrate varied methodological approaches for radioprotection knowledge assessment. Some utilize expert panels and content validity indices (CVI) for measurement instrument validation[29,38,49]. Simultaneously, all investigations include Cronbach's alpha as reliability indicators, consistently reporting values above 0.70, confirming tool strength. Only one investigation employed KR-20 coefficients for reliability measurement[38].

In the study by Schroderus-Salo et al., the content-validity indices (I-CVI = 0.66–1.00; S-CVI = 0.83) indicate a moderate to high degree of item adequacy, while a Cronbach's alpha of 0.98 demonstrates excellent internal consistency [26]. These results show that the instrument is suitable for evaluating clinical knowledge. In contrast, Fakhar's study reports robust content validity (I-CVI > 0.83; S-CVI = 0.98) and strong internal consistency (Kappa = 0.793–0.823). Nevertheless, the small sample size limits the generalizability of the findings. The questionnaire administered by Ramírez et al. shows only moderate reliability (ICC = 0.697–0.729; Cronbach's alpha = 0.729 and 0.727), suggesting response variability that may stem from item complexity or heterogeneous training levels among respondents. By comparison, the instrument used by Choi and Cho displays excellent internal consistency (Cronbach's alpha = 0.963) but only moderate discriminative ability (AUC = 0.709). Finally, the KAP study by Elmorabit reports strong content-validity indices (CVR ≥ 0.71; I-CVI/S-CVI ≥ 0.82), moderate to high reliability (KR-20 = 0.68–0.70; Cronbach's alpha = 0.70–0.73), and attitude ICCs ranging widely from 0.57 to 0.95, reflecting heterogeneous stability of responses—likely linked to subjective perceptions.

The importance of having validated assessment tools lies in their ability to provide a solid framework for evaluating and strengthening competencies in radioprotection. Such tools facilitate the development of targeted interventions and policies aimed at improving radioprotection practices across various healthcare specialties[38,46]. The strong psychometric properties demonstrated in these studies—particularly regarding content validity and internal consistency—confirm that these instruments are technically sound and capable of yielding meaningful and reliable data.

In this context, the present study aims to employ reliable and well-validated instruments to enhance the effectiveness of the designed questionnaire, which assesses the knowledge of physicians prescribing radiological examinations regarding *radioprotection and the use of radioprotective agents to mitigate the biological effects of ionizing radiation*. This contributes to fostering a culture of radiological safety.

Indeed, healthcare professionals must possess a solid understanding of radioprotection principles when dealing with ionizing radiation. Given the potential hazards associated with ionizing radiation, it is imperative that these professionals have sufficient knowledge of its nature, associated risks, and the necessary protective measures to prevent unnecessary exposure and safeguard patients from its adverse effects[29]. In fact, healthcare providers play a key role in minimizing effective doses through careful practices and the rational prescription of radiological exams[49]. Conversely, a lack of knowledge about ionizing radiation among healthcare workers may compromise their ability to effectively protect themselves and their patients [29,48].

This lack of understanding may also extend to radioprotective agents, with physicians potentially being unaware of the latest advances in natural and synthetic radioprotectors. Such a gap could lead to underuse or inappropriate application of these agents in clinical practice. The level of awareness regarding health-related information, particularly radioprotection, is closely tied to health promotion activities[47]. From this perspective, cultivating a proper safety culture is essential to mitigating health risks and optimizing medical practices[29].

The methodology employed in this study presents several strengths. The organization of a focus group helped to refine the research objectives and clarify key concepts, thereby facilitating the formulation of questions aligned with the study's aims[48]. For the validation process, the involvement of nine experts—consistent with methodological recommendations—enhanced the scientific rigor of the study through their recognized expertise[33].The digital design of the questionnaire provided notable logistical advantages: reduced costs, faster implementation, minimized data entry errors, and multi-platform accessibility, which encouraged broader participation. Moreover, a pre-test conducted with physicians allowed for the optimization of instructions, the relevance of items, and the technical functionality of the instrument.

The results indicate satisfactory content validity, supported by strong KR-20 and Kappa coefficients, consistent with previous research. The questionnaire demonstrates internal consistency and thematic relevance, accurately reflecting the dimensions assessed. Furthermore, the tool represents a valuable resource for evaluating physicians' knowledge regarding the effects of ionizing radiation and radioprotective agents, while also serving as a foundation for educational interventions or future research involving diverse clinical populations (e.g., radiologists, oncologists).

However, several limitations must be acknowledged. Despite the rigor of expert validation, it inherently involves subjective human judgment, which may overlook relevant dimensions if the initial conceptual framework is incomplete[25,37,40]. Although the convenience sampling was representative[40], it limits intergroup comparisons across medical specialties or professional settings. Additionally, the use of self-administered questionnaires introduces the risk of social desirability bias, as participants may overestimate their knowledge[38]. Another limitation is that the scale does not assess practical competence but rather focuses on theoretical knowledge. Moreover, its applicability to other contexts should be approached with caution and requires further validation. Finally, the lack of prior reference studies on radioprotective agents makes it difficult to discuss content validity and reliability indices specific to this domain.

CONCLUSION

This investigation's developed questionnaire demonstrated commendable psychometric integrity, encompassing validity (content and construct) and reliability measures aligned with established methodological standards^(28)^. Consequently, this instrument represents a reliable tool for assessing physicians' understanding of ionizing radiation effects and risks, along with radioprotection strategies, including potential radioprotective agent utilization.

Its application could extend to various contexts, including academic environments, clinical practice, and research. The scale facilitates knowledge gap identification during initial and continuing medical education, training module development targeting dose optimization and diagnostic imaging justification, and educational intervention effectiveness evaluation through longitudinal investigations. Nevertheless, large-scale implementation requires additional validation, particularly with multidisciplinary samples and international comparisons.

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