Volume 4, No. 8 August 2026
p-ISSN 3032-3037 | e-ISSN 3031-5786

ADVANCES IN SOCIAL HUMANITIES RESEARCH

Level of Knowledge Among UNPRI Medical Students Regarding the Dangers of X-Ray Radiation and the Risk of Anemia

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Keywords:
X-ray radiation; knowledge; medical students; anemia risk; radiation safety

Abstract

X-ray radiation is a form of ionizing radiation widely used in medical services; however, uncontrolled exposure may produce biological effects on radiosensitive tissues, including the hematopoietic system. Medical students, as future healthcare professionals, require adequate knowledge of radiation hazards and their potential association with anemia risk. This study aimed to determine the knowledge level of 2023 medical students at Universitas Prima Indonesia (FK UNPRI) regarding the hazards of X-ray radiation and anemia risk, identify factors associated with knowledge levels, and analyze the relationship between knowledge of X-ray radiation and knowledge of anemia risk. An analytical quantitative cross-sectional design was employed. A total of 159 students were recruited using total sampling. Data were collected using a 25-item closed-ended multiple-choice questionnaire and analyzed using univariate analysis, the Chi-Square test, and Spearman's rho correlation analysis. Most students demonstrated a good overall knowledge level, with 73 respondents (45.9%) categorized as having good knowledge, 44 respondents (27.7%) having sufficient knowledge, and 42 respondents (26.4%) having poor knowledge. Attendance at radiology lectures and experience in radiology practice were significantly associated with knowledge level (both $p < 0.001$), whereas age ($p = 0.754$) and sex ($p = 0.165$) were not significantly associated. A strong and significant positive correlation was identified between knowledge of X-ray radiation and knowledge of anemia risk ($r = 0.698$; $p < 0.001$). This study evaluated students' knowledge and understanding rather than actual radiation exposure, hemoglobin levels, or clinical anemia status. In conclusion, students generally demonstrated good knowledge; however, understanding of anemia risk should be further strengthened through structured radiation safety education and practical training.

Introduction

The use of X-rays as a primary tool in medical diagnosis has become widespread globally, including in Indonesia. According to data from the Ministry of Health of the Republic of Indonesia (Kemenkes RI, 2022), more than 10 million radiological procedures are performed annually. Although X-rays provide substantial benefits in healthcare, exposure to ionizing radiation may also cause adverse biological effects, including damage to tissues and cellular structures. One potential consequence of chronic exposure is disruption of the hematopoietic system, which may contribute to hematological disorders, including anemia (Chinelo et al., 2022; Folaranmi et al., 2026; Marques et al., 2022; Ng & Newson Smith, 2022; Obeagu, 2026; Witeska et al., 2023). Anemia is characterized by reduced hemoglobin levels and may be

associated with radiation-induced damage to bone marrow, thereby interfering with red blood cell production or erythropoiesis (Sari & Pratiwi, 2021).

The advancement of medical technology in Indonesia has contributed to the increasing use of X-rays as a diagnostic support modality in healthcare services (Chandramohan et al., 2024; Raja et al., 2023; Rayan et al., 2025). Despite their clinical benefits, exposure to ionizing radiation presents potential health risks that require adequate understanding, particularly among medical professionals (Di Maria et al., 2024; Eddy et al., 2025; Lopes et al., 2025; Mainprize et al., 2023; Rincón et al., 2024; Rodrigues et al., 2024; Talapko et al., 2024). Medical students, as future physicians, play an important role in promoting safe radiation practices; however, previous studies have indicated that their understanding of radiation-related health effects remains suboptimal. Previous research reported that only approximately 45% of college students were aware of the association between X-ray exposure and hematological disorders, including anemia (Hidayat et al., 2020).

Anemia is a condition characterized by reduced hemoglobin levels or erythrocyte counts below normal ranges, which may result from impaired red blood cell production in the bone marrow (Chinelo et al., 2022; Iolascon et al., 2024; Leung et al., 2024). Hematopoietic tissue is highly sensitive to ionizing radiation; therefore, X-ray exposure may damage hematopoietic stem cells, inhibit erythrocyte production, and affect red blood cell survival. Repeated exposure or inadequate radiation protection may increase the risk of hematological disturbances. At the Faculty of Medicine, Universitas Prima Indonesia (FK UNPRI), students participate in academic and clinical activities involving environments equipped with radiology facilities. However, data regarding their knowledge of the relationship between X-ray exposure and anemia risk remain limited. Radiation-related hematological effects may develop gradually without noticeable symptoms, yet prolonged exposure could negatively affect individual health and potentially influence the quality of healthcare services (Alyami et al., 2025; Feller et al., 2025; Iolascon et al., 2024; Lin et al., 2026).

The novelty of this research lies in its specific focus on the relationship between knowledge of X-ray radiation and knowledge of anemia risk among medical students, an area that has received limited attention in previous studies. While earlier research has primarily examined general radiation safety knowledge, few studies have investigated whether students understand the biological mechanisms linking radiation exposure to hematological disorders. This study aimed to evaluate the knowledge level of FK UNPRI students regarding the risk of anemia associated with X-ray radiation exposure, identify factors related to knowledge level, and analyze the relationship between knowledge of X-ray radiation and knowledge of anemia risk. The findings of this research may provide empirical evidence for radiology curriculum development, support radiation safety training programs, and contribute to the broader literature on medical students' understanding of radiation hazards. By identifying specific knowledge gaps, this study may assist educational institutions in developing more effective strategies to improve radiation safety competencies among future physicians (ICRP, 2021; IAEA, 2022).

Based on the aforementioned background, this study was conducted to evaluate the knowledge level of FK UNPRI students regarding the risk of anemia associated with X-ray radiation exposure.

Method

This study employed an analytical quantitative design with a cross-sectional approach to assess the knowledge level of 2023 medical students at the Faculty of Medicine, Universitas Prima Indonesia (FK UNPRI) regarding the hazards of X-ray radiation and its association with anemia risk. The cross-sectional design enabled the measurement of variables simultaneously without intervention, allowing the study to examine the relationship between students' knowledge of X-ray radiation and their understanding of anemia risk. The research was conducted at the Faculty of Medicine, Universitas Prima Indonesia, Medan. The study population consisted of all active students enrolled in the Medical Education Study Program, class of 2023. Because the population was limited to a single cohort, total sampling was applied, including all students who met the inclusion criteria.

The inclusion criteria consisted of active FK UNPRI students from the 2023 cohort who agreed to participate and completed the research questionnaire. Participants were excluded if they submitted incomplete questionnaires or withdrew from the research process. The study variable was students' knowledge regarding X-ray radiation hazards and anemia risk, measured through questionnaire scores covering aspects of X-ray radiation, radiation classification, radiation-induced DNA damage mechanisms, bone marrow radiosensitivity, and the relationship between radiation exposure and anemia risk. Knowledge levels were measured using an ordinal scale and categorized as good (≥76%), moderate (56–75%), and poor (<56%). The questionnaire indicators were developed based on radiobiology, hematopoiesis, and anemia-related concepts.

Results and Discussion

This study describes the level of knowledge of FK UNPRI students in the class of 2023 regarding the dangers of X-ray radiation on the risk of anemia. The discussion was prepared by interpreting the results of the analysis of respondent characteristics, the distribution of knowledge levels, the understanding of X-ray radiation, the understanding of the risk of anemia, factors related to the level of knowledge, and the relationship between the understanding of X-ray radiation and the understanding of anemia risk. Thus, the discussion not only explains the numbers in the table, but also emphasizes the meaning of research results for the radiology and radiation safety learning process.

Students' Level of Knowledge about the Dangers of X-Ray Radiation on the Risk of Anemia

The results showed that the level of knowledge of students in general was in the good category as many as 73 respondents (45.9%). These findings show that almost half of the respondents already have an adequate understanding of the dangers of X-ray radiation to the risk of anemia. In addition, there were 44 respondents (27.7%) with the sufficient category. If the categories are good and enough to be seen together, most students actually already have a sufficient knowledge base about the research topic.

However, there are still 42 respondents (26.4%) who are in the poor category. This figure needs attention because the topic of X-ray radiation is related to the safety of patients, health workers, and students involved in clinical education activities. Lack of knowledge can cause students to not fully understand the risks of radiation exposure, the principles of radiation protection, and possible biological effects that can occur if exposure is not properly controlled. The findings regarding this knowledge gap are in line with the research of Hassan et al. (2022)

and Demirtaş et al. (2023), which found that medical students still have limitations in understanding the dosage and radiation risks of imaging examinations.

The range of the percentage of respondents' knowledge varied, from 26.4% to 100%, indicating a gap in understanding between respondents. These variations can occur due to differences in learning experience, interest in radiology materials, access to information sources, and student involvement in practical activities. Therefore, the results of this research can be the basis for educational institutions to re-equalize students' basic understanding through strengthening radiology material and radiation safety.

Students' Understanding of X-Ray Radiation

The understanding of X-ray radiation in this study includes the definition of radiation, types of radiation, characteristics of X-rays, the process of X-ray formation, the use of X-rays, and the effects of radiation on body cells. The results showed that 63 respondents with good understanding (39.6%), while the sufficient category was 61 people (38.4%). This shows that most respondents have understood the basic concept of X-ray radiation, although the level of understanding is not entirely in the good category.

Students who understand the basic concepts of X-ray radiation will find it easier to understand why radiological examinations should be conducted based on clear indications and using safety principles. This understanding is important because X-rays include ionizing radiation that can interact with body tissues. In the context of medical education, students are not only required to know the benefits of X-ray examinations for diagnosis, but also understand that their use must be accompanied by proper dose control and protection. This is in accordance with the radiological protection system that places justification and optimization as the main principles of the use of ionizing radiation in healthcare (International Commission on Radiological Protection [ICRP], 2023).

There were still 35 respondents (22.0%) with an understanding of X-ray radiation in the low category indicating that the basic material of radiation needed to be strengthened. Students who do not yet understand the nature of radiation, biological effects, and protective principles may have difficulty studying advanced risks, including the relationship between radiation and disorders in blood cells. Therefore, radiation learning should be given gradually, starting from the basic concepts, working mechanisms, clinical benefits, biological risks, to how to protect yourself.

Students' Understanding of the Risk of Anemia

In contrast to the understanding of X-ray radiation, which is dominated by the good and adequate categories, students' understanding of the risk of anemia is actually the most in the poor category, namely 65 respondents (40.9%). These results show that the relationship between X-ray radiation and the risk of anemia is still not evenly understood by college students. This condition can occur because material on anemia due to disorders of the hematopoietic system requires a more complex understanding than a general introduction to X-ray radiation.

The risk of anemia in the context of radiation exposure is related to the understanding of bone marrow, the process of blood cell formation, erythrocytes, hemoglobin, and possible hematopoiesis disorders. The bone marrow is a radiosensitive tissue because it contains stem cells and hematopoietic progenitors that actively divide. Exposure to radiation at high enough doses can suppress the production of erythrocytes, leukocytes, and platelets so that in severe

conditions anemia and other hematological disorders can appear (Zhang et al., 2024). However, the dose on routine diagnostic radiographic examination is generally much lower than the dose that gives rise to hematopoietic syndrome. Therefore, the term anemia risk in this study needs to be understood as knowledge about the biological potential of radiation to the hematopoietic system, not as evidence that one routine X-ray examination directly causes anemia (Ahmed, 2023; Zhang et al., 2024).

The percentage of respondents with an understanding of the risk of anemia in the good category was 60 respondents (37.7%). This figure shows that some students have been able to understand the relationship between radiation and the blood formation system. However, since the underserved category is still the largest group, learning about the effects of radiation on the hematopoietic system needs to be emphasized, especially in the form of case examples, clinical discussions, and easy-to-understand explanations of biological mechanisms.

Factors Related to Student Knowledge Level

The results of the Chi-Square test showed that the history of attending radiology lectures had a significant relationship with the level of knowledge of students ($p < 0.001$). Students who have participated in radiology lectures are more in the category of good knowledge, namely 66 respondents, while students who have not participated in radiology lectures are more in the category of lack of knowledge, namely 33 respondents. These results show that exposure to formal learning plays an important role in shaping students' understanding of the dangers of X-ray radiation and the risk of anemia. This relationship supports the importance of a radiology curriculum that provides a structured understanding of radiation dosage, biological effects, and safety from the undergraduate education stage (Demirtaş et al., 2023; Hassan et al., 2022; Vassileva et al., 2022).

In addition to radiology lectures, the experience of participating in radiology practice is also significantly related to the level of student knowledge ($p < 0.001$). Students who have participated in radiology practice are more in the category of good knowledge, namely 48 respondents. Radiology practices can provide hands-on experience of how radiological examinations are performed, how tools are used, and how safety principles are applied. This experience makes it easier for students to connect theory with real situations in the field. Practice-based learning allows students to observe the application of exposure time restrictions, distancing settings, use of shields, and dose control firsthand, making theory easier to internalize (Demirtaş et al., 2023; Hassan et al., 2022).

Age and gender did not show a significant relationship with students' knowledge levels. Age has a p value = 0.754 and sex has a p value = 0.165. The insignificance of age can be understood because the majority of respondents are in relatively close age ranges as students of one batch. Meanwhile, the insignificance of gender suggests that knowledge about X-ray radiation and the risk of anemia is not determined by gender, but rather is influenced by learning opportunities, material exposure, and practical experience.

These results give an idea that improving student knowledge is more effective through strengthening the learning process rather than just looking at demographic characteristics. Radiology lectures can provide a theoretical foundation, while radiology practice can strengthen understanding through hands-on experience. The combination of the two is important so that students not only know the definitions and theories, but also understand the reasons why radiation safety should be implemented in a disciplined manner. This approach is

in line with the recommendation that radiation protection competencies should be built through a combination of education, training, supervision, and periodic evaluation (Vassileva et al., 2022).

The Relationship of Understanding X-Ray Radiation to Understanding the Risk of Anemia

The results of the Spearman test showed a strong and significant positive relationship between the understanding of X-ray radiation and the understanding of anemia risk, with a correlation coefficient of 0.698 and a p< value of 0.001. The direction of the positive relationship shows that the better the student's understanding of X-ray radiation, the better the student's understanding of the risk of anemia. These findings reinforce that a basic understanding of radiation is the foundation for understanding more specific biological impacts.

Cross-tabulation showed that of 63 respondents with a good understanding of X-ray radiation, as many as 42 respondents also had a good understanding of the risk of anemia. On the other hand, of the 35 respondents with a poor understanding of X-ray radiation, as many as 33 respondents were also in the category of understanding the risk of anemia that was lacking. This pattern suggests that a weak understanding of the basic concept of radiation can lead to a weak understanding of the biological impact of radiation.

This strong relationship can be explained because the concept of the risk of anemia due to radiation exposure cannot be understood in isolation from the concept of radiation itself. Students need to understand the nature of X-rays, the mechanisms of radiation interaction with tissues, and organs or cells that are sensitive to radiation before they can understand possible disturbances in blood cell formation. Thus, learning about the risk of anemia should not be given as stand-alone material, but directly linked to learning about the biological effects of radiation. Radiobiologically, an understanding of radiation interactions with DNA, cell death, and tissue radiosensitivity is fundamental for understanding disorders in bone marrow and blood cell formation (Zhang et al., 2024).

Although the associations found are strong and significant, these results still need to be interpreted proportionally. The research design used describes the relationship between variables, but cannot confirm the direct cause-and-effect relationship. This means that a good understanding of X-ray radiation is related to a good understanding of anemia risk, but this study has not been able to confirm that an increase in radiation understanding directly leads to an increase in understanding of anemia risk without being influenced by other factors such as information sources, learning methods, student interests, or academic experience.

Implications of Research Results

The results of this study have important implications for the learning of medical students. Radiology material needs to be provided not only in terms of diagnostic benefits, but also in terms of radiation safety and its biological effects. Students need to understand that X-ray examinations have great benefits in the world of medicine, but their use must still pay attention to the indications, protection, and principles of exposure control. The principles of justification and optimization must be part of students' basic competencies so that diagnostic benefits are still obtained with the lowest possible exposure that is reasonable (ICRP, 2023; Vassileva et al., 2022).

Educational institutions can use the results of this research as a basis to strengthen

radiology learning through more applicable methods. Material on X-ray radiation, radiation protection, bone marrow, hematopoiesis, hemoglobin, and anemia can be arranged in one interconnected learning flow. In this way, students not only memorize concepts, but also understand the relationship between radiation exposure and its possible impact on the body's systems. Such cross-disciplinary integration can help students connect aspects of radiation physics to tissue biological responses and their clinical consequences.

In addition, debriefing before radiology practice needs to be strengthened. Students who will take part in the practice should get an introduction to personal protective equipment, safe distance, exposure time limits, and the importance of following the direction of the radiology officer. Evaluation of knowledge before and after lectures or practice can also be done to see the effectiveness of learning and find out the parts of the material that students still do not understand. Debriefing also needs to include the use of personal dosimeters when relevant, understanding radiation warning signs, and compliance with operational and supervision procedures in the radiology room (ICRP, 2023; Vassileva et al., 2022).

Limitations of Discussion

This study has several limitations that need to be considered in interpreting the results. First, the research was conducted on one batch of FK UNPRI students, so the results could not necessarily be generalized to students from other batches or institutions. Second, this study assesses the level of knowledge and understanding, so that it has not described the real behavior of students in applying radiation safety principles while in a practical environment.

Third, this study uses an analytical approach based on questionnaire data, so that the results can be influenced by the respondents' ability to understand the questions and the seriousness of the respondents in answering. Fourth, this study has not included several other factors that may affect knowledge, such as the source of information, the frequency of reading radiology material, the intensity of academic discussions, the experience of seeing radiology examinations, and exposure to radiation safety education outside of formal lectures.

Fifth, this study did not measure the actual exposure dose, the frequency of X-ray examinations received by respondents, hemoglobin levels, or other hematological parameters. Therefore, the results of the study cannot be used to conclude a clinical relationship between X-ray exposure and the incidence of anemia. This research is limited to assessing student knowledge and understanding.

With these limitations, the results of this study are still useful as an initial overview of the level of students' knowledge about the dangers of X-ray radiation on the risk of anemia. Further research can use a wider range of respondents, more in-depth instruments, and add behavioral assessments or radiation safety skills to make the results more comprehensive.

Conclusion

Based on the results of the study on the knowledge level of FK UNPRI students regarding the hazards of X-ray radiation and anemia risk, it was concluded that the knowledge level of 2023 FK UNPRI students was predominantly categorized as good, with 73 respondents (45.9%), followed by the moderate category with 44 respondents (27.7%) and the poor category with 42 respondents (26.4%). Factors significantly associated with students' knowledge levels were attendance at radiology lectures and experience in radiology practicums, both with p-values of < 0.001. In contrast, age and sex were not significantly

associated with students' knowledge levels. Furthermore, a strong and significant positive correlation was identified between students' knowledge of X-ray radiation and their knowledge of anemia risk, with a correlation coefficient of 0.698 and a p-value of < 0.001, indicating that higher knowledge of X-ray radiation was associated with better understanding of anemia risk. However, this study only assessed students' knowledge and understanding and did not measure radiation exposure doses, hemoglobin levels, or the actual incidence of anemia. Therefore, the findings should not be interpreted as evidence that routine diagnostic X-ray examinations directly cause anemia among respondents.

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