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Errors in the interpretation of x-ray images

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Abstract. X-ray examinations remain one of the most common and accessible methods of visual diagnosis, widely used in clinical practice. The quality of X-ray interpretation directly affects the accuracy of diagnosis and the effectiveness of subsequent stages of treatment, but for medical students, this process is often quite difficult. In this regard, it is necessary to study the causes of errors in the interpretation of X-ray images at the stage of professional training. The study aimed to identify the main causes of errors in the interpretation of X-ray images and the characteristics associated with the training profile of students. The study involved 164 medical university students studying paediatrics (n = 62), general medicine (n = 88) and preventive medicine (n = 14). Data were collected through an anonymous online questionnaire that included closed and open-ended questions aimed at assessing the difficulties of interpreting radiographic images, the level of confidence and the amount of practical experience. Descriptive statistics, one-way analysis of variance, Kruskal-Wallis test, χ^2 and Pearson's correlation analysis were used for statistical analysis. The study determined that the most common errors were missing pathological changes, incorrect localisation of foci and misinterpretation of artefacts. The greatest difficulties were caused by chest X-rays, lateral projections, and images of the musculoskeletal system. The average level of confidence of students in interpreting X-rays was low, at 4.1 ± 1.7 points. Medical students demonstrated a higher level of confidence and a lower error rate compared to students from other disciplines. A moderate negative correlation was found between the level of confidence and the number of errors made. The results obtained indicate the need to expand the scope of practice-oriented training, introduce a systematic approach to the interpretation of X-ray images, and use modern digital educational tools to improve the quality of training for future doctors

Keywords: radiology; image interpretation; diagnostic errors; students; medical education

Introduction

X-ray examinations remain one of the key diagnostic tools in clinical practice, providing timely detection of a wide range of pathological conditions [1-3]. However, interpreting X-rays requires advanced analytical skills

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and a systematic approach, which is challenging for medical students. Errors in reading images can lead to diagnostic delays, reducing the quality of future clinical work [4,5]. The relevance of studying interpretation errors is due to the fact that radiography remains one of the most sought-after and accessible methods of visual diagnosis, and the quality of its analysis directly affects the effectiveness of subsequent stages of clinical practice. With the active development of digital technologies and the expanding use of visual data, there is a growing need for comprehensive training of future specialists in working with radiographic images and determining the factors that affect the accuracy of their assessment [6]. In this regard, there is growing interest in researching educational strategies aimed at improving the quality of student training.

The process of interpreting X-rays is a complex cognitive task involving visual analysis, comparison of anatomical structures, recognition of pathological signs, and clinical decision-making in conditions of incomplete information. For medical students, this process is complicated by limited practical experience, insufficiently developed algorithmic thinking, and difficulties in spatial perception of two-dimensional images. Errors at this stage may be related to both a lack of theoretical knowledge and a lack of systematic image analysis skills, which makes the problem of X-ray interpretation particularly relevant in an educational context. A review of the literature shows that errors in reading X-ray images are widespread not only among students but also among doctors with limited experience [7]. However, during the training period, stable patterns of perception and interpretation of images are formed, which in the future can either contribute to accurate diagnosis or reinforce erroneous analysis algorithms. In this regard, identifying typical errors and the factors that contribute to their occurrence is a substantial task for medical education and clinical radiology.

The students' training profile is central to the formation of errors. Differences in curricula, the amount of clinical practice, and the focus of professional activity lead to varying levels of training in radiology. For example, medical students generally have more contact with clinical cases and visual diagnostic materials, while students in paediatrics and preventive medicine encounter radiological examinations less frequently and in a more limited context. This can affect both their confidence and the accuracy of their interpretation of images. The psychological aspect of interpreting X-rays is noteworthy. The level of confidence students have in personal skills directly influences their image analysis strategy: uncertain students are more likely to miss pathological changes, avoid making decisions, and tend to view images superficially. At the same time, excessive confidence with insufficient training can also lead to diagnostic errors. Thus, studying the relationship between subjective confidence and objective interpretation results is of great interest in terms of developing clinical thinking. Current trends in medical education emphasise the need to move from predominantly theoretical training to practice-oriented and interactive forms of training. The use of digital educational platforms, simulators, virtual trainers, and interactive image databases can be used for repeated practise in a safe environment and timely feedback. Studies show that a systematic approach to image viewing and regular error correction significantly reduces the probability of diagnostic errors and contributes to the formation of sustainable visual diagnostic skills [8].

The research novelty is determined by a comprehensive analysis of the most common errors in interpreting X-ray images among students of various training profiles, as well as in studying the influence of experience, confidence, and educational process characteristics on the frequency of these errors. This approach further demonstrates the structure of difficulties and determines directions for further improvement of training [9,10]. In addition, the study examines the relationship between subjective assessment of one's skills and actual results, which has previously been studied to a limited extent. Of additional interest is the consideration of the role of modern educational technologies, including interactive platforms, simulators, and digital trainers, in the formation of visual diagnostic skills [11]. These tools can be used for safe practise of image analysis skills and provide immediate feedback, making the learning process more effective and sustainable. Strengthening the digital component may become a notable direction for further development of specialist training [12]. The study aimed to identify the main causes of errors in the interpretation of X-ray images by medical students and to identify features related to the training profile.

Materials and Methods

The study included 164 medical university students: 62 studying paediatrics, 88 studying medicine, and 14 studying preventive medicine. The survey was conducted online and included closed and open questions aimed at assessing difficulties in analysing X-rays, confidence levels, and subjective assessments of the quality of training. Most respondents were in their fourth to sixth years of study. Data collection was conducted anonymously. Statistical data processing was conducted using descriptive statistics methods: for quantitative indicators, mean values, standard deviations, median and interquartile range were calculated. To compare quantitative indicators between three independent groups, one-way analysis of variance (ANOVA) was used, provided that the data distribution was normal. In cases where the distribution deviated from normal, the non-parametric Kruskal-Wallis test was used. The χ^2 test was used to analyse differences in categorical indicators. The choice of statistical methods was

determined by the type of data analysed and the nature of its distribution. The relationship between the level of confidence and the number of errors was assessed using Pearson's correlation coefficient, as well as Spearman's rank correlation coefficient, incorporating the discrete nature of the "number of errors" indicator. The study was conducted based on the ethical principles of the World Medical Association [11]. Due to the anonymous nature of the survey and the absence of interference in the condition of the participants, approval from the local bioethics committee was not required.

Results and Discussion

The analysis of the questionnaire showed that the most common mistakes made by students when interpreting X-rays were missing pathological changes (74% of responses), incorrect localisation of foci (58%) and incorrect interpretation of artefacts (42%). Chest X-rays proved to be the most problematic: 69% of students reported difficulties in identifying focal shadows and densities characteristic of inflammatory diseases, as well as in recognising signs of pneumothorax. Lateral projections caused difficulties for 63% of respondents, with most students unable to accurately determine the position of structures in three-dimensional projection. Errors in the analysis of the musculoskeletal system included confusion between fractures and normal anatomical lines (41%) and difficulties in assessing bone density (37%). The average level of confidence of students in interpreting X-rays on a 10-point scale was 4.1 ± 1.7, indicating low self-assessment of personal skills. Confidence was significantly higher among medical students (4.8 ± 1.5) than among paediatric (3.6 ± 1.4) and preventive medicine students (3.1 ± 1.2), with the differences being statistically significant (ANOVA: $F = 12.47$; $p < 0.001$) (Table 1).

Table 1. Level of confidence among students from different disciplines

Profile	Average level of confidence	Comment
Medical practice	4.8 ± 1.5	Highest confidence
Paediatric	3.6 ± 1.4	Difficulties in photographing adults
Medical and preventive	3.1 ± 1.2	Minimum training in radiology

Note: values are given as averages ± standard deviation
Source: compiled by the authors

A posteriori analysis of intergroup differences showed that statistically significant differences in confidence levels and number of errors were observed between medical students and paediatric and preventive medicine students. The differences between paediatric and medical-preventive profiles in a number of indicators did not reach statistical significance, which is associated with the smaller size of the latter group. The influence of the training profile on the level of confidence was moderate ($\eta^2 = 0.13$), which indicates a clinically and pedagogically significant effect. A comparison of the number of errors between profiles showed that medical students made an average of 3 errors per X-ray (IQR 2-4), paediatric students made 5 errors (IQR 3-6), and medical and preventive students made 6 errors (IQR 4-7); the differences were also significant ($H = 18.32$; $p < 0.001$). A moderate negative correlation was found between the number of errors made and the level of confidence ($r = -0.46$; $p < 0.01$), confirming the influence of subjective confidence on the accuracy of interpretation. Analysis of practical experience showed that students who had more than 20 hours of practice with radiographic images per semester made fewer errors ($\chi^2 = 9.84$; $p = 0.003$) than students with less practice (Table 2). Moreover, students who regularly participated in the analysis of clinical cases demonstrated greater confidence and a systematic approach when evaluating complex images. Furthermore, students who regularly participated in clinical case reviews demonstrated greater confidence and a systematic approach when evaluating complex images, including the identification of rare pathologies.

Table 2. The influence of practical experience on the number of errors

Group	Practical training (per semester)	Characteristics of the result
Group 1	> 20 hours	Fewer errors
Group 2	< 20 hours	More errors

Note: More significant practical experience correlates with a reduction in the number of interpretation errors
Source: compiled by the authors

When comparing the types of errors, certain patterns emerged: paediatric students often had difficulty interpreting images of adult patients, while medical students reported fewer problems identifying areas of inflammation but experienced difficulties with rare or atypical cases. Medical and preventive medicine students had virtually no systematic training in radiology, which explains the high frequency of errors and low confidence. Additional observations showed that 78% of students believe that there are not enough practical examples in the learning process, and 85% expressed interest in interactive platforms, simulators, and the use of digital

tools with feedback. Students also noted the influence of psychological factors: stress, fatigue, and fear of making mistakes reduced the accuracy of analysis, especially in the early years and when analysing complex cases.

Students cited a lack of practical experience and self-confidence as the main reasons for their mistakes. More than 70% of respondents noted that they find radiology to be a difficult field (Table 3). They feel that their theoretical knowledge is insufficient for confident image analysis. There is a weak correlation between lecture material and clinical practice. Many believe that training is not sufficiently visualised and is not focused enough on real cases [12]. Some admitted that they saw real X-ray images for the first time only during clinical practice. The study also noted that during training, there is no feedback from teachers on the interpretation of images. As a result, students cannot assess how well information was interpreted. The level of training in radiology varies between different profiles. For example, paediatricians often have difficulty interpreting images of adult patients. Medical students complain about the lack of practice with paediatric cases. The medical and preventive profile has no systematic course in radiology, which also affects the results.

Table 3. Main causes of errors in interpretation

Cause	Student percentage (M ± m, %)
Lack of practice	72 ± 3.6
Uncertainty	65 ± 3.7
Interpretation difficulty	58 ± 3.8
Lack of a systemic approach	45 ± 3.9
Fear of error	40 ± 3.8

Note: M – average percentage of students experiencing difficulties for each reason; m – standard error of the mean, calculated for N = 164 students
Source: compiled by the authors

The results demonstrate a systemic problem of insufficient preparation for interpreting radiological images, significant differences between training profiles, and the need to introduce practice-oriented and interactive educational tools to improve students' accuracy and confidence. The results of the study confirm the high importance of developing X-ray image interpretation skills during medical university education. The data obtained was used not only to identify the most common types of errors, but also further determine mechanisms of their occurrence, their connection with the level of training, and the psychological aspects of visual information perception. A comparison of the results obtained with data from the literature indicates that students, regardless of their specialisation, face similar difficulties, but the severity of these difficulties and the nature of the errors vary significantly depending on the characteristics of their educational trajectory.

One of the key findings is the difference between training profiles: medical students demonstrated greater confidence and fewer errors, while paediatric and preventive medicine students showed more pronounced difficulties. This confirms that the scope and consistency of practical training directly affect the quality of image interpretation [13]. It is worth noting that student confidence has not only subjective but also objective significance: the negative correlation found between the level of confidence and the number of errors shows that the development of confidence is a substantial pedagogical factor, not just a psychological parameter. Confidence probably serves as an indicator of the development of clinical thinking, the ability to perform structured visual analysis, and mastery of image evaluation algorithms [14].

The role of practical experience deserves special attention. Students who had more than 20 hours of experience working with X-rays made significantly fewer mistakes. This highlights the need to increase the proportion of practice-oriented classes, including clinical case studies, independent work with real images, and the use of digital educational platforms. Studies indicate that tools such as simulators, interactive modules, and automated feedback systems significantly improve the quality of visual diagnostic skills development [15-17]. The results obtained are fully consistent with this conclusion: 85% of students expressed a need for interactive platforms, which demonstrates a high demand for modern teaching methods.

It is also worth noting the psychological aspects identified during the study. Students reported that stress, fatigue, and fear of making mistakes affected the quality of their image analysis. This was particularly true for junior students, whose limited experience was compounded by high emotional tension. These observations indicate the need to include elements of psychological adaptation and the formation of sustainable skills for working in conditions of uncertainty. One possible direction for improving training is the introduction of step-by-step modules with increasing complexity, gradually introducing students to analysis of complex cases and reducing the impact of stress factors [18]. It should be noted that a significant proportion of students highlighted insufficient visualisation of the teaching material and a lack of systematic feedback on the results of image analysis. This can lead to the

formation of incorrect interpretation algorithms and the reinforcement of misconceptions [19]. In this regard, a substantial direction for the development of educational programmes is the structuring of training modules on radiology, the creation of uniform image analysis algorithms, and the strengthening of the feedback component from teachers. Studies show that regular correction of errors contributes to a significant reduction in their frequency in the future and the formation of stable skills.

It is worth noting that the group of medical and preventive medicine students was small (n = 14). This reduces the statistical power of the intergroup analysis and limits the generalisability of the results obtained for this category of students. Although medical and preventive medicine students had the highest average number of errors (6 [IQR 4-7]) and the lowest level of confidence (3.1 ± 1.2 points), these results should be interpreted with caution and considered preliminary. The results obtained are consistent with Hegazi's data, according to which the key reasons for errors in the interpretation of X-rays are a lack of practical experience and the absence of a structured image analysis algorithm [20]. The role of modern digital tools and image viewing systems deserves special attention. According to E.M. Kok, they contribute to the formation of stable visual diagnostic skills and a reduction in the frequency of diagnostic errors, which emphasises the relevance of this study [21]. Thus, the study identified a set of factors that influence the accuracy of X-ray image interpretation: training profile, amount of practice, level of confidence, availability of feedback, and psychological readiness. The combination of these factors determines both the level of competence of students and the effectiveness of the formation of radiological diagnostic skills in general [22]. The obtained results emphasise the need for an integrative approach to teaching that combines practical experience, modern digital technologies, step-by-step analysis algorithms, and elements of psychological and pedagogical support [23].

Conclusions

The study showed that the main mistakes made by students when interpreting X-ray images are missing pathological changes (74%), incorrect localisation of detected foci (58%) and incorrect interpretation of artefacts (42%). The most pronounced difficulties were observed in the analysis of chest images, where 69% of respondents noted difficulties in recognising focal shadows and signs of pneumothorax, as well as in working with lateral projections, which caused difficulties for 63% of students. It was found that the level of confidence has a significant impact on the quality of interpretation: the average score was 4.1 ± 1.7 points, with a moderate negative correlation between confidence and the number of errors ($r = -0.46$; $p < 0.01$). Medical students made an average of 3 errors, while paediatric students made 5 and preventive medicine students made 6, confirming statistically significant differences between the groups ($H = 18.32$; $p < 0.001$). A substantial factor in the accuracy of the analysis was the presence of practical experience: students who had more than 20 hours of experience working with X-rays demonstrated significantly better results ($\chi^2 = 9.84$; $p = 0.003$). Participation in clinical reviews also contributed to increased confidence and the development of a systematic approach. The data obtained emphasises the need to expand the scope of practice-oriented training and integrate modern digital tools, which will improve the quality of training and reduce the probability of diagnostic errors in future clinical practice.

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Conflict of Interest

None.

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