

Exploring perceptions of data risks in AI-enabled nursing research: A qualitative study

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Xiudi Yin^{1,2}, Hongxia Song², Joaquim Paulo Moreira^{3,4} , Ci Song^{1,5}, and Yue Sun^{1,2}

Abstract

Aim: To explore the data risk perception structure and connotation in the entire process of generative AI-enabled nursing research and to identify healthcare management and training needs as applied to digital health developments. **Background:** Nursing research highly relies on contextualized and unstructured data. General generative AI still faces shortcomings in professional adaptation, data governance, and responsibility definition, which may lead to risks such as privacy leaks, amplified bias, academic misconduct and accountability vacuums. The study focusses on the perceptions of Future nursing professionals. **Methods:** Purposeful maximum variance sampling was used to recruit 20 participants from 3 universities, and semi-structured one-on-one interviews were conducted. The report followed the COREQ Protocol checklist. **Results:** Five data risk awareness themes were identified: data adaptation risk, data security risk, data quality risk, data ethics risk, and response risk, presenting risk concerns throughout the entire process of “use—generation—sharing—responsibility”. **Conclusion:** The data risk perception of nursing master’s students regarding generative AI-enabled nursing research presents a clear five-dimensional structure, unfolding along the chain of “input—processing—output—diffusion—attrition.” This structure supports the development of a framework for defining boundaries of AI use, data governance, ethical compliance, and capacity building in nursing research settings and digital health developments.

Keywords

AI-enabled nursing research, nursing management, data risk perception, qualitative research, digital health

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¹Shandong First Medical University, Jinan, Shandong, China

²Nursing Department, The First Affiliated Hospital of Shandong First Medical University & Shandong Provincial Qianfoshan Hospital, Jinan, Shandong, China

³International Healthcare Management Research & Development Centre (IHM-RDC) at the First Affiliated Hospital of Shandong First Medical University & Shandong Provincial Qianfoshan Hospital, Jinan, Shandong, China

⁴Health Management, Atlantica Instituto Universitario, Oeiras, Portugal

⁵Department of Health and Respiratory Medicine, Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, Shandong, China

Corresponding authors:

Hongxia Song, Nursing Department, The First Affiliated Hospital of Shandong First Medical University & Shandong Provincial Qianfoshan Hospital, Jinan, Shandong, China.

Email: xy-song1983@foxmail.com

Joaquim Paulo Moreira, International Healthcare Management Research and Development Centre (IHM-RDC) at the First Affiliated Hospital of Shandong First Medical University & Shandong Provincial Qianfoshan Hospital, Jinan, Shandong, China; Health Management, Atlantica Instituto Universitario, Oeiras, Portugal.

Email: jpm2030@outlook.com



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Introduction

Background

Artificial Intelligence (AI) is an algorithmic system that learns from large-scale data and performs inference, prediction, and decision support and it is part of the broad reality of Digital Health and health systems development^{1–5} With the data-driven transformation of the healthcare field and the continuous improvement of nursing information systems, AI enhances nursing efficiency, predicts nursing outcomes, and supports decision-making by analyzing large amounts of nursing data.^{6–8} Machine learning-based nursing sensitive outcome prediction models have demonstrated powerful predictive capabilities and dynamic monitoring advantages.^{9,10} These applications have not only improved the efficiency and accuracy of nursing work but also had a profound impact on nursing research.

However, some studies have pointed out the shortcomings of artificial Intelligence in nursing and medical management applications. Research by Chen¹¹ shows that AI does not adequately consider the needs of specific nursing scenarios, and its discussion of data privacy, security, acceptability, and ethical, legal, and social issues is limited. Katherine¹² argues that a digital divide exists between the accessibility and application of AI tools and that some AI tools are not fully adapted to actual nursing workflows. Currently, insufficient technology adaptability and a lack of risk control remain pressing problems that need to be addressed.^{7,13–15}

Research by Sobhia et al.¹⁶ highlights that the primary data risks associated with AI applications in the healthcare field include privacy breaches, insufficient data authenticity, algorithmic bias and lack of fairness, inadequate model interpretability, and unclear attribution of responsibility. In her review of AI ethics research, Adrianna¹⁷ proposed that the ethical risks of AI in the healthcare field can be correlated with the core principles of “autonomy, authenticity, non-harm, and impartiality.” She emphasized that these risks stem not only from the technology itself but also from data governance systems, the definition of institutional responsibility, and user behavior norms. Özbay et al.¹⁸ also believed that ethical concerns, infrastructure limitations and insufficient training of artificial intelligence restrict its effective integration and application. The application of AI is not merely a technological issue but also relates to the core human-centered philosophy of nursing.¹⁷ Unlike highly structured data such as medical images and laboratory test results, nursing data exhibits a distinct characteristic—nursing assessments often involve substantial subjective judgment and unstructured records. It is precisely this unique attribute of nursing that makes the risks associated with AI in nursing research even more complex.

In the context of nursing, the risks associated with AI-related data exhibit strong context-dependent and discipline-specific characteristics. Nursing research data often originates from real clinical care scenarios and frequently contains sensitive information, such as patient identification and nursing assessment records. If researchers lack awareness of data anonymization, access control, and compliance when using AI tools for text processing, data analysis, or paper writing assistance, the risk of privacy breaches and unauthorized sharing may increase.¹⁹ Nursing data contains a high proportion of unstructured text, subjective judgment indicators, and dynamic assessment content, and discrepancies in data collection and recording standards further hinder data processing. The study by Hongshin Ju et al.²⁰ found that AI-generated nursing records suffer from a lack of specific details, inappropriate use of medical terminology, and an overall textbook-like, rigid style. Nursing research emphasizes the interpretability and clinical usability of evidence. If AI models rely excessively on black-box algorithms and lack traceable explanation mechanisms, it will not only weaken clinical nurses’ trust in research evidence but also undermine their confidence in AI models. However, it may also reduce the feasibility of translating research findings into clinical practice.²¹ Nursing research often involves special populations such as the elderly, children, and patients with chronic diseases. If models are biased or yield misleading conclusions, this can lead to unfair interventions or harm to specific populations, thereby fostering more complex ethical and safety consequences in nursing research.²²

It is noteworthy that recent research in nursing education has increasingly focused on the attitudes, literacy levels, and ethical understanding of nursing teachers and students towards AI technology.^{23–26} Sarikahya et al.²⁷ showed that nursing teachers believe AI tools have the potential to enhance nursing education by supporting theoretical learning, improving efficiency, and promoting personalized learning experiences. At the same time, Research by Heather et al.²⁴ suggests that undergraduate nursing students recognize the potential of AI to enhance work efficiency; however, they also worry about the risks of over-reliance on artificial intelligence and the dangers of a lack of regulation. Joyce et al.²⁸ suggest that AI writing tools can help graduate nursing students enhance their writing skills and achieve academic success; however, a balance must be struck between AI use and the cultivation of independent critical thinking, while maintaining academic integrity. Existing research suggests that generative AI can enhance learning efficiency and care plan generation; however, it also raises concerns, including academic integrity issues, weakened critical thinking, and data privacy risks. These problems not only affect the quality of education but may also extend to the research training stage, potentially impacting the research literacy of nursing graduate students.^{29,30}

Overall, existing research still has three shortcomings: First, nursing AI research primarily focuses on model predictive efficacy and clinical application prospects, with less systematic discussion from the perspective of nursing research practitioners regarding the data risk perception structure and behavioral mechanisms in AI use³¹; second, research on nursing graduate students often remains at the level of attitudes, acceptance, or user experience, lacking empirical evidence on risk identification capabilities, understanding of usage boundaries, and implementation of prevention and control measures³²; third, existing training and guidance often emphasize technical operations or principle explanations, lacking a risk identification and response support framework covering the entire nursing research process.³³

Nursing graduate students play a crucial role in the standardization and advancement of high-quality nursing research. Their risk perception and response capabilities are not only related to research compliance and academic integrity, but also affect the reliability of research results and their clinical translational value. Therefore, it is necessary to analyze the characteristics, formation mechanisms, and support needs of data risk perception during AI use from the perspective of nursing graduate students, providing a basis for constructing AI use norms and educational intervention strategies that conform to the characteristics of the nursing discipline.

Given the above shortcomings, this study employs a qualitative research method to provide an in-depth description of the subjective experience of “risk perception.” Compared with quantitative surveys, interviews can more fully reveal how nursing graduate students understand data risks in the real context of AI-assisted research, how they weigh convenience and compliance, and their concerns and confusions in the “use-generation-sharing-responsibility” chain, providing more context-explanatory evidence for the subsequent development of targeted training strategies and governance frameworks.

Research objectives and questions

This study aims to explore the perceptual structure and connotation of data-related risks among nursing master’s students during the process of using artificial Intelligence to empower nursing research, and to propose suggestions for research management and postgraduate training based on this. The research questions are: ① What data risks do nursing postgraduate students mainly focus on throughout the entire process of AI-assisted research? ② How are these risks understood and expressed?

Methods

This research report was written in accordance with the 32-item list of COREQ (Consolidated Criteria for Reporting Qualitative Research).³⁴

Research design and theoretical framework

This study employs a qualitative theme analysis approach, using original interview data as the basis for analysis. Through a systematic coding and extraction process, it identifies, analyzes, and interprets recurring core themes and patterns in the data, ultimately constructing an analytical framework that provides a deep explanation of the research phenomenon. The research team, research environment, data collection, and analysis processes will be presented clearly and transparently to enhance research transparency and traceability.

Research team and reflective approach

Team composition and qualifications

During the research implementation phase, the interviews were conducted by the first author. The first author holds a Master of Nursing degree and has received systematic training in qualitative interviewing, possessing experience in coding and analyzing qualitative research data. Research assistants assisted in recording the interviews and noting nonverbal cues. The research team had no prior teaching or management affiliation with the respondents, and most respondents were meeting the interviewers for the first time. Before the interviews, the research team fully informed the respondents of the research topic, their identities, and the declaration of no conflict of interest, clarifying that the research was solely for academic analysis and that all data would be anonymized. Before the interviews began, the team reiterated their identities, research objectives, and confidentiality measures, and guided the respondents into a narrative state with brief greetings and non-evaluative questions to establish trust.

The research team members are qualified as follows: Both corresponding authors hold doctoral degrees and are respectively an associate chief nurse and director of the International Medical Management Research Center at the First Affiliated Hospital of Shandong First Medical University, possessing extensive clinical practice and research experience.

The remaining authors are second-year master's students in nursing, with experience in nursing education and research, and have received systematic training in qualitative research. This study invited two nursing research experts and one qualitative research methodology expert (all with senior professional titles and doctoral degrees) to serve as external advisors, responsible for methodological guidance and academic supervision in research design, data analysis, and results interpretation. All data collection personnel were female, and the interviews strictly adhered to the principles of neutrality, respect, and non-judgmental listening to minimize the impact of gender and identity differences on the respondents' expressions.

Researcher reflection and bias control

This study incorporated reflective practices throughout the process. Initial written records documented the team's existing perspectives and risk assessments regarding the application of AI in nursing; reflective memos were written after each round of interviews; during the analysis phase, continuous comparison and retrieval of counterexamples reduced interpretative bias; weekly reflective meetings were held to review and record potential subjective biases throughout the research process. Standardized training was conducted before coding to reach a consensus and mitigate bias; the analysis adhered to data center principles and underwent repeated verification through member checks and expert reviews to reduce the impact of bias on the conclusions.

Research subjects and recruitment

Selection of research subjects

This study employs a purposive sampling strategy combined with a maximum variance sampling approach to recruit nursing master's students from three comprehensive universities and medical colleges as research subjects from November to December 2025. The sample encompasses various grades, types of institutions, and nursing research directions, aiming to yield richer perspectives and greater diversity in experiences, thereby enhancing the research data's diversity and interpretability.

Inclusion and exclusion criteria

Inclusion criteria

- ① Currently enrolled nursing master's students;
- ② Have been exposed to AI-enabled nursing research in their research studies or practice, or have preliminary practical experience;
- ③ Voluntarily participate in the research and sign an informed consent form;
- ④ Have good communication skills and be able to describe their own understanding and practical experience clearly.

Exclusion criteria

- ① Those whose research practice was interrupted for more than 6 months due to leave of absence, long-term leave, etc., making it difficult to review or provide relevant experiences fully;
- ② Those who also have an AI-related professional background or have received systematic AI research training.

Sample size determination

This study employed a qualitative topic analysis approach, with data saturation as the primary criterion for determining sample size. A small purposive maximum difference sample was selected to conduct exploratory data collection and initial coding. As the study progressed, the sample size was dynamically adjusted, and new sample data were repeatedly compared with the extracted themes and coding results using a continuous comparison method. Data saturation was achieved when no new initial codes or secondary themes emerged from 3–4 consecutive participants, and the existing data sufficiently supported the extraction of the core themes, at which point sample collection ceased. The final sample size was set at 20 participants. During recruitment, 22 potential respondents were contacted, but two were unable to participate in the formal interviews due to scheduling conflicts. No participants withdrew during the formal interview phase. In the event of withdrawal, the research team will maintain the same confidentiality regarding the information provided, in accordance with the informed consent agreement, and will not pursue further follow-up.

General information of respondents

Of the 20 respondents, 16 were female and four were male; aged 22-26; 5 were first-year students, 11 were second-year students, and 4 were third-year students; 17 were professional Master's students and 3 were academic Master's students; their research interests covered 12 fields including geriatric nursing, obstetric nursing, and chronic disease nursing; and they had been using AI for 2-4 years. See [Table 1](#) for details.

Data collection

Based on the research objectives and literature review, a preliminary analytical framework was constructed, and four nursing master's students were selected for pre-interviews. One-on-one online interviews were conducted, each lasting 20-30 minutes, with the entire interview recorded and transcribed within 24 hours. After refining the framework based on feedback from the pre-interviews, two nursing research experts and one qualitative methodology expert were invited to review its effectiveness, ultimately establishing the formal interview framework.

Core interview questions included

- ① How do you view data security and privacy issues when using AI to assist in research?
- ② If a nursing intervention based on your AI research results is widely adopted in the future, but it is later discovered that the results have potential problems, how do you view your responsibility in this situation?
- ③ How do you view the relationship between AI technology and "humanistic care" in nursing?
- ④ Regarding your thoughts on data risks, what do you consider to be the most critical challenge currently? How do you usually seek support? In what areas do you think schools or hospitals should strengthen their support?

Interview implementation process

This study employed topic analysis to systematically analyze the data. Researchers read through the interview transcripts line by line, initially coding content related to data risk perception, extracting key semantic units, and aggregating semantically similar codes to form preliminary topics. Through continuous comparison, the relationships between topics were repeatedly

Table 1. General information of interviewees (n=20).

ID number	Gender	Age (years)	Grade	Degree category	Research direction	Duration of artificial intelligence use (years)	Institution
A1	female	25	2	Professional	Geriatric Nursing	3	C
A2	female	22	1	Professional	Obstetric Nursing	2	C
A3	female	23	2	Academic	Chronic Disease Nursing	3	C
A4	Male	23	3	Professional	Weight Management	3	A
A5	female	24	2	Professional	Pediatric Nursing	3	A
A6	female	23	1	Academic	Oncology Nursing	2	A
A7	Male	24	2	Professional	Bone and Joint Nursing	3	A
A8	female	23	1	Professional	Neonatal Nursing	2	C
A9	female	26	2	Professional	Health Care Nursing	3	C
A10	female	25	3	Academic	Neurological Nursing	2	A
A11	Male	25	2	Professional	Chronic Disease Nursing	2	B
A12	female	23	2	Professional	Community Nursing	3	C
A13	female	26	2	Professional	Psychiatric Nursing	3	C
A14	Male	22	1	Professional	Adult Nursing	2	C
A15	female	23	2	Academic	Geriatric Nursing	2	B
A16	female	26	3	Professional	Obstetric Nursing	4	B
A17	Male	24	2	Professional	Health Care Nursing	3	C
A18	Male	23	1	Professional	Rehabilitation Nursing	2	B
A19	female	25	3	Professional	Chronic Disease Nursing	3	C
A20	female	24	2	Professional	Chronic Disease Nursing	2	C

compared to clarify the internal logic and gradually form a clear hierarchical topic structure. Data analysis was conducted independently by two researchers, followed by comparison and discussion; disagreements were resolved through team consultation, and qualitative research experts were invited to review and verify the data. To ensure data authenticity and reliability, 15%–20% of the transcripts were randomly selected for verification against the original recordings. The study established a hierarchical structure of “initial concept—aggregated concept—topic” during the coding process, clarifying the logical connections between topics around the use, generation, sharing, and responsibility of AI-enabled research. Ultimately, five core topics and 20 sub-topics were extracted, and the original sentence index was retained to construct a traceable “concept-evidence” correspondence system, improving analytical transparency and the credibility of the results.

Data transcription and organization

To protect the privacy of respondents, all identifying information that might reveal specific institutions or individuals in the transcribed text was anonymized and replaced with codes, such as “School A,” “A1,” and “A2.” After transcription, two researchers independently cross-validated the text against the original recordings to ensure an accurate and comprehensive reconstruction of the interview content.

Data analysis

Coding team and tools

Data analysis was conducted jointly by two researchers with nursing research backgrounds and familiarity with artificial Intelligence. The entire analysis process was completed using NVivo 12 software to assist in coding and data management. Before formal coding began, all participating researchers received intensive training to ensure a unified understanding of the research objectives, coding rules, and operational procedures, thereby reducing subjective bias during coding.

Coding process

This study strictly followed the three-level coding process of classical grounded theory for data analysis. Researchers meticulously read the transcribed text line by line, extracting initial concepts related to data risk perception, and categorizing and integrating semantically similar concepts to form preliminary categories. The study employed a continuous comparative approach, repeatedly comparing relationships across categories to clarify their inherent logical connections and gradually establish a relatively systematic system of main and subcategories. Core categories were extracted from the main categories, and a logically clear “storyline” was constructed to connect the categories organically, ultimately forming a holistic theoretical framework. Two researchers independently coded and then compared and discussed their results. If coding disagreements arose, a consensus was reached through team consultation, and qualitative research experts were invited to participate in the review. 15%–20% of the transcribed text was randomly selected and compared with the original recordings to ensure the accuracy of the data source and the reliability of the analysis. To improve analytical transparency, a three-level structure of “initial concept—aggregated concept—category” was established during the open coding stage, and a condition-action-outcome relationship chain was established during the central axis coding stage around “AI-enabled research process (use—generation—sharing—responsibility)”. The final coding tree comprises five main themes and 20 sub-themes (see [Table 2](#)), retaining the original sentence index of key concepts to form a traceable “concept-evidence” correspondence table.

Research limitations

Participants came from different cities, and while variations were sought in grade level, type of institution, and nursing specialty, they were all nursing master’s students at three universities in the same region. Although this region can represent the socio-economic development and university education levels of most cities in China, its geographical concentration may limit the generalizability and applicability of the conclusions. The participants’ educational backgrounds were highly homogeneous, making it difficult to comprehensively present differences in AI usage experience and risk perception across educational levels, and to deeply analyze the potential impact of demographic characteristics, such as educational background, on related cognition and experience. While qualitative thematic analysis can systematically uncover the core themes and inherent patterns in the original data and explain the essential characteristics of the research phenomenon, it cannot quantify risk perception factors or explore specific correlations between variables.

Future research directions

Subsequent research could expand the sample to include nursing graduate students from different regions, levels, and types of institutions and compare risk perceptions across scenarios. Consideration should also be given to conducting mixed-mode research, developing measurement tools based on qualitative research, and using questionnaires, statistical modeling, or data analysis to validate key concepts, explore the formation mechanism of risk perception and its possible causal chains, and

Table 2. Themes and subthemes.

Themes and Subthemes	
Theme 1: Data Adaptation Risks	1.1 Insufficient adaptability to professional scenarios 1.2 Difficulty in processing unstructured data 1.3 Fragmented AI model system
Theme 2: Data Security Risks	2.1 Leakage of research information 2.2 Leakage of sensitive information 2.3 Blurred boundaries of use 2.4 Misuse of research data 2.5 Intellectual property infringement
theme 3: Data Quality Risks	3.1 Fabrication of Professional Information 3.2 Data Output Bias 3.3 Bias Towards Conformity to Results 3.4 Amplification of Data Bias
theme 4: Data Ethics Risks	4.1 Bias in the perception of responsibility 4.2 Unclear ethical boundaries
Theme 5: Related Response Risks	5.1 Lack of risk awareness 5.2 Widespread lack of protective measures 5.3 Lack of training on usage guidelines 5.4 Inadequate legal constraints 5.5 Insufficient platform security protection 5.6 Lack of research guidelines

provide more direct and operational empirical support for the standardized application and high-quality development of AI-enabled nursing research.

Research rigor, credibility, and ethical considerations

Member check

After transcription, the research team anonymized the verbatim transcript and, with respondents’ consent, returned portions of the transcript for fact-checking to reduce transcriptional and comprehension bias. Once the themes were established, the core themes were submitted to the respondents for peer review to ensure that the research interpretations aligned with their actual experiences.

Expert review

This study invited a review panel composed of experts from nursing research, qualitative research methodologies, and statistics to comprehensively evaluate the research design, data collection process, coding analysis methods, and thematic refinement results. The expert panel provided specific suggestions for improvement regarding potential issues at each stage, and the research team responded and adjusted accordingly to further ensure the scientific rigor of the research process and the soundness of the conclusions.

Audit track

Throughout the research process, we recorded key information, including sample selection logs, interview outline revisions, and coding decisions at each stage, forming a complete and coherent audit track.

Methodological consistency

This study strictly adheres to the core principles of qualitative topic analysis: “objective extraction and systematic induction,” thus avoiding the influence of researchers’ preconceived judgments on the results. Through unified pre-coding training, regular communication during coding, cross-checking, and expert arbitration, we maximized the consistency of data analysis and the reliability of research conclusions.

Ethical approval

This study was conducted in accordance with the relevant ethical requirements for biomedical research involving human subjects and has been approved by the Ethics Committee of Shandong First Medical University (Approval No.: R202512220524).

Informed consent

Prior to the commencement of the study, all participants were fully informed of the research objectives, procedures, risks and benefits, and data confidentiality measures, and signed written informed consent. Participants may withdraw unconditionally at any stage of the study without affecting their rights; if a participant withdraws midway, the collected data will still be properly preserved and processed in accordance with confidentiality regulations and used solely for this study.

Privacy protection and data management

Interview data were de-identified in this study. Identifiable information in the transcribed text was replaced with numbers or abbreviations. Audio and text data were encrypted and stored with an access control mechanism, accessible only to members of the research team within the scope of the research. After the research, all data will be retained for three years in accordance with relevant regulations; thereafter, they will be destroyed.

The core coding and analysis of the study were based entirely on the original Chinese interview data, with translation only conducted during the paper writing and reporting stages. The Chinese-to-English translation of this study's interview transcripts was aided by Google Translate, with translation quality guaranteed by a professional team comprised of native English speakers and researchers with study abroad experience in English-speaking countries and experience publishing qualitative research in English journals. To address potential conceptual loss during translation, the research team meticulously checked key expressions sentence by sentence during the Chinese-English comparison process. They repeatedly discussed and revised semantically significant technical terms and participants' original statements to ensure the English translation remained faithful to the original Chinese meaning, preserving conceptual connotations and contextual details. The study employed systematic back-translation to verify semantic consistency and invited non-researchers with English expertise to review the translations. Professional personnel conducted both forward and reverse back-translation comparisons to further verify translation accuracy and minimize information bias.

Results

The results of this study are presented using a three-tiered framework of "topic—subtopic—typical statement citation," extracting a total of 5 topics and 20 subtopics, as shown in [Table 2](#). To enhance traceability and readability, citations are presented using respondent numbers (A1–A20). The selected citations adhere to the principle of "typicality + difference," encompassing both high-frequency consensus viewpoints and incorporating a few different or contradictory statements to present the internal tension and boundaries of the topics. All identifiable information has been deleted or replaced with pseudonyms.

Core risk themes and sub-themes

Theme 1: Data adaptability risk

While artificial intelligence tools can process large amounts of data quickly, their insufficient adaptability to the professional scenarios and data types of nursing research can affect research efficiency and quality.

Insufficient adaptability to professional scenarios. AI cannot support professional data processing and in-depth analysis in core scenarios such as highly rigorous scientific research and clinical practice. A1: "When dealing with large amounts of data, it helps me quickly complete the screening and classification, greatly improving my efficiency... However, in terms of in-depth data interpretation and clinically based data mining, some human intervention is still needed." A5: "In aspects requiring subjective judgment, I feel that AI's judgment is very vague."

Difficulty in processing unstructured data. While artificial intelligence can process structured data quickly, its ability to interpret, extract, and analyze unstructured text data is limited, making it difficult to meet research needs. A1: "Because nursing data contains a lot of unstructured text... a certain clinical background is needed for analysis. However, AI may lack this clinical background." A12: "AI technology... is not very supportive of the use of many nursing documents in work."

Fragmented AI model system. A lack of systematic AI models closely integrated with the nursing discipline. A1: "Most AI tools on the market now are general-purpose; there is not a dedicated tool specifically for nursing research." A8: "There is a lack of systematic AI models closely integrated with the nursing discipline. Current learning models are mostly fragmented and lack a coherent system."

Topic 2: Data security risks

In the process of AI empowering nursing research, data privacy, usage rights, and intellectual property rights face risks of leakage and misuse.

Leakage of research information. Researchers' research ideas, unpublished results, academic creativity, and other private information are at risk of being leaked by AI. A15: "For example, in terms of papers, if I tell AI some of my ideas and ask it to help me, will it leak my ideas?" A5: "I also worry that if I give it some data or my ideas, it might feed them to others, resulting in my research topic being stolen."

Leakage of sensitive. Information-sensitive information, such as patient conditions and identity details, involved in nursing research, may be leaked during AI processing. A9: "In our clinical work, patient privacy and safety are involved... I do not think there is absolute safety." A10: "AI also analyzes patient information and questions... which may involve leaks."

Blurred boundaries of use. AI data logging and storage rules are opaque, leading to issues such as unauthorized reuse of internal data and cross-platform tracking and push notifications. A7: "I used AI to search for something, and Douyin and Xiaohongshu kept pushing related content... I feel like I am being eavesdropped on." A6: "When I asked a question before, I fed the AI some internal information. The next time I asked a similar question, it extracted parts of the information I fed it and used them."

Misuse of research data. AI uses received nursing research data without authorization for its own model training or other non-research purposes. A2: "I feel he might be backing up data to train the AI's logic, etc." A14: "I am definitely worried about data leaks or intrusion into his computing system when using AI."

Intellectual property infringement. AI's indiscriminate integration of online resources and user-uploaded data can easily lead to disputes over the ownership of intellectual property rights for research results. A6: "AI will disregard copyright and take everything from the internet and mix it up." A5: "The things it gives me seem like someone else's stuff... If I use them, I am afraid of high duplication rates or being accused of plagiarism."

Topic 3 data quality risks

There are risks of defects in the authenticity, accuracy, and representativeness of nursing research data generated or processed by AI.

Fictitious professional information. AI may arbitrarily fabricate nursing terminology and create non-existent references. A6: "AI will arbitrarily fabricate some fixed medical terms." A4: "The documents it provides are not real... and some data is sometimes not very accurate either."

Data output bias. AI outputs contradictory and inaccurate results when processing the same problem, or erroneous outputs due to a misunderstanding of instructions. A9: "You ask it a question, and it tells you the answer is B. If you ask it again, 'I think the answer is D,' it will say, 'You are absolutely right.'" A18: "It gives one answer for the first question, and another answer for a related question. These two answers are not particularly relevant and are not coherent."

Result catering tendency. AI deliberately outputs data to conform to the researcher's preconceived notions, violating the principle of scientific objectivity and neutrality. A6: "AI analyzes your expected questions and gives you the answers you prefer." A9: "It follows the user's line of thinking... Without verification, the results will be biased."

Data bias amplification. AI algorithms can further amplify inherent data biases, leading to a lack of representativeness in the output. A1: "Population characteristics and regional differences usually influence research data. If the data used to train the AI is biased, the AI may amplify these biases." A9: "AI is trained by continuously incorporating network data, rather than understanding data based on real samples, so that it may introduce biases in interpretation or judgment."

Topic 4 data ethics risks

In AI-enabled nursing research, research ethics risks arise from unclear division of responsibilities and ambiguous ethical boundaries.

Bias in responsibility perception. Some researchers have a “no-responsibility misconception” or inaccurately judge their primary and secondary responsibilities. A16: “If this happens, the responsibility is definitely not mine; it is definitely the developer or the company. The overall responsibility should belong to them.” A2: “I do not think I bear much responsibility because many interventions are not entirely beneficial; the benefits outweigh the drawbacks.”

Unclear ethical boundaries. The application of AI in nursing research lacks clear ethical guidelines, making it difficult to define the boundaries between compliance and violation. A5: “I feel that neither the school nor the hospital told me the extent to which I could use AI, what level was acceptable, and that going further would violate some ethical or usage norms.” A9: “First, there is the issue of research integrity. We, students, are still in the stage of forming our values, and we need the school and hospital to correct us and establish a framework.”

Theme 5 related risk responses

Researchers face risks related to AI-related data due to a lack of awareness, insufficient coping mechanisms, and inadequate support systems, resulting in ineffective risk management.

Lack of risk prevention awareness. There is a lack of awareness and prevention regarding the data risks associated with the use of AI. A16: “I have not paid attention to data security and privacy issues because I thought I would not leak much, and I have not taken any protective measures.” A19: “When I collected data myself during my undergraduate studies, I did not realize how important this matter was.”

Widespread lack of protective measures. There is a general lack of adequate protective measures for data security, and no feasible solutions to potential risks. A3: “As for protective measures, I do not really have any special ones.” A7: “Even if you delete it, there will still be traces, after all, we do not have any powerful preventative measures.”

Lack of training on usage standards. Institutions have not provided precise and targeted training on AI usage standards. A4: “I think firstly, schools should offer lectures or elective courses... to explain the usage scenarios and applicable situations of these AIs to students.” A9: “Secondly, there should be training on AI tools, such as ‘AI illusions,’ which requires cultivating our critical thinking and analytical skills.”

Insufficient legal constraint mechanisms. The legal regulations governing the use of AI data in nursing research are incomplete and lack rigid constraints. A15: “I think there must be laws to constrain it so that it might be more cautious.” A6: “Relevant laws should be enacted, and relevant technologies should be developed to restrict this.”

Inadequate platform security. The AI platform lacks protective functions such as “delete records after completion.” A4: “Could it delete records after use? This could be improved.” A6: “We hope the technology company behind it can provide more options, such as one-click protection to prevent submitted information from being uploaded, and deletion after completion.”

Lack of research standards and guidelines. We hope that universities will provide relevant measures to support AI-assisted nursing research. A8: “I think universities could offer courses specifically teaching us how to use AI critically and responsibly in nursing research, such as courses on ethics and data security standards; another is to establish a consulting team composed of multidisciplinary experts (such as informatics experts and senior nursing researchers) so that we have clear channels for seeking help when we encounter difficulties.” A9: “Standardized research guidelines can be provided to guide us on how to use AI tools correctly.”

Discussion

The structural contradiction between the professionalism of nursing research and the generality of AI technology

This study shows that the usability of current AI tools in the nursing professional context is limited. Artificial intelligence has shown great potential in the medical field due to its advantages in efficient data processing, pattern recognition and automation. However, the essential attributes of nursing are misaligned with the logic of existing AI technology, which limits the deep application of AI in nursing practice. When faced with a large amount of unstructured nursing research data, general models exhibit comprehension bias and unstable information extraction. The root of this bias lies in the fact that the

worldview of general AI is built on massive amounts of general-language data, lacking an internalized understanding of nursing's unique knowledge system. Its algorithmic logic focuses on statistical correlation patterns, while nursing professional thinking integrates practical wisdom that combines scientific evidence, clinical experience, ethical judgment, and humanistic care. This contradiction makes general models prone to semantic loss and context stripping when dealing with nursing professional issues, resulting in outputs that lack professional depth and accuracy. Kwan et al.³⁵ also noted that the nursing field contains a large amount of unstructured text data, which often needs to be placed in a specific clinical context to be accurately interpreted. Especially in high-risk scenarios such as emergency and psychiatric care, AI output needs to provide clear evidence to establish clinical trust.^{36,37} However, some studies hold the opposite view, arguing that, through natural language processing, AI systems can effectively analyze unstructured text in nursing records and identify subtle changes in patients' emotions or early signals of potential complications.^{38–40} Overall, the training datasets of current mainstream artificial intelligence models have not fully captured real-world nursing scenarios, making it difficult for these models to effectively identify and extract core professional information in nursing practice. This has led nursing researchers to repeatedly try multiple artificial intelligence tools when dealing with data closely related to clinical decision-making. Morey et al.⁴¹ further emphasized that in clinical decision support, when AI recommendations deviate from the actual situation, they may interfere with nurses' judgment. These phenomena reflect the nursing field's expectations for artificial intelligence tools: they not only need to be efficient and fast, but also need to truly understand the inherent clinical logic and humanistic care of nursing work.⁴²

Existing research has proposed relatively clear directions for improvement. Ruan et al.⁴³ believe that the nursing professional knowledge system should be deeply embedded into model training, rather than relying solely on general corpora. Martin et al.⁴⁴ explored the potential of introducing emerging technologies, such as multimodal large language models, into nursing practice in a review, emphasizing their potential to reduce paperwork burden and improve clinical efficiency. Multiple studies^{13,45,46} have consistently shown that to effectively promote the integration of AI into nursing practice, nurses must be involved from the early stages of development, incorporating nursing professional judgment into the selection of training data, the verification of clinical scenarios, and the formulation of assessment standards. Only by integrating professional judgment into the underlying technology can the "nursing applicability" of the model be fundamentally improved.⁴⁷ Therefore, nursing education should proactively promote interdisciplinary integration, foster deep collaboration among nursing, computer science, linguistics, and other fields, and cultivate talents with both nursing professional and technical application skills. Courses such as nursing informatics and health data science can be added to cultivate nursing students' data literacy and critical technology thinking. By leveraging real-world nursing data to train in AI-assisted decision-making, students can improve their ability to identify and evaluate AI suggestions, while emphasizing that AI should serve only as a decision-making aid for nurses, not a replacement. Nursing experts will lead the optimization of workflows, seamlessly integrating AI tools into daily nursing work and clearly defining responsibilities. Simultaneously, they can lead the development of AI models specifically designed for nursing, using standardized nursing data for professional training, allowing the technology to better adapt to actual clinical nursing needs.

The dual challenges of sensitive data protection and AI technology characteristics

The risks of research information leakage, sensitive data breaches, and data misuse identified by respondents in this study are highly consistent with international discussions on the risks of AI applications in healthcare. Artificial intelligence essentially relies on large amounts of data and pattern recognition to operate. In the process of continuously optimizing performance, it is very likely to cross the bottom line of privacy protection inadvertently. Even anonymized data may still be re-identified through model memory and reverse reasoning.⁴⁸ Although multi-center data aggregation can expand the sample size, it also creates a more concentrated pool of sensitive data, which is more harmful if leaked.⁴⁹ If the training data itself has historical biases, AI may also reinforce and amplify them, causing group injustice in the allocation of nursing resources and elevating the problem from a privacy issue to a social fairness issue.⁵⁰ Nursing plans generated by large language models have been proven to have "subtle but reproducible biases", which may exacerbate inequality in the allocation of medical resources.⁵¹ In studies of diseases such as cardiovascular disease and cancer, if group biases related to demographic variables are not corrected, they will directly affect the fairness of clinical decision-making.⁵² Faced with the dual challenges of data security and the application of technology, the nursing field needs to build an active protection and adaptation system at the educational and clinical levels. In nursing education, health data ethics courses should be integrated, and case-based teaching should be conducted through real-world AI scenarios to cultivate students' data ethics judgment.⁵³ In clinical practice, it is necessary to establish a privacy-first intelligent application environment, conduct ethical and safety assessments before introducing AI tools, actively understand and pilot cutting-edge privacy protection technologies such as federated learning and synthetic data generation, strengthen patients' right to know and participation, and have nurses do a good job in

communication and rights protection, and use intelligent technologies safely under the premise of transparency and compliance.^{54,55}

The risks identified in this study are dual and overlapping: they involve both the leakage of sensitive patient information and the protection of researchers' academic intellectual property. A systematic review notes that privacy leakage is the most prominent risk of medical artificial intelligence, primarily manifested in the disclosure of sensitive patient information and the theft of researchers' intellectual property.⁵⁶ This is closely related to the lack of transparency in the data storage and reuse process of artificial intelligence.⁵⁷ Nursing research includes both patient data and unpublished research ideas, pathways and interim results, thus facing a dual risk of leakage. However, the risks caused by the blurred boundaries of use have not received sufficient attention. Students are generally concerned that artificial intelligence may undermine academic integrity, so it is essential to clarify its boundaries of use.²⁸ The reuse of internal data by artificial intelligence systems and the dissemination of information across platforms are directly related to their data storage mechanisms. Researchers' insufficient understanding of the mechanisms underlying artificial intelligence data processing will significantly exacerbate security risks.⁵⁸ In this study, nursing graduate students have limited knowledge of relevant rules, which amplifies the potential risks of infringement and leakage. Content generated by artificial intelligence is very likely to cause serious copyright ownership disputes and may escalate into academic misconduct disputes.⁵⁹ Therefore, it is necessary to clarify the auxiliary role of artificial intelligence in nursing research, strictly define its application scope, and avoid the decline in research rigor due to over-reliance on technology.⁶⁰ In the face of the above risks, it is imperative to build a systematic governance framework. The comprehensive governance model, based on risk classification, established by the EU Artificial Intelligence Act, provides an important reference for policy design in nursing.⁶¹ The Act emphasizes technological transparency and accountability mechanisms and, through regulation, promotes the efficient use of artificial intelligence while effectively controlling the risk of information leakage, providing a valuable framework for the standardized application of artificial intelligence in nursing research.

The core tension between AI output objectivity and research rigor

The risks of research information leakage, sensitive data leaks, and data misuse identified by respondents in this study are consistent with those associated with AI applications in international healthcare. The respondents' concerns that AI could amplify inherent social biases in data are consistent with the findings of Andrew et al.⁶² The core contradiction in the application of artificial intelligence in nursing lies in the inherent conflict between its technical objectivity and the requirements of research rigor. The uninterpretable nature of the decision-making process of complex models contradicts the requirements of nursing research for logical clarity and rigorous causality.⁶³ At the same time, fixed models trained on historical data are difficult to adapt to the dynamic, highly individualized and complex situations in clinical practice.⁶⁴ The research by Rengers et al.⁶⁵ further confirms that large language models may exhibit a bias toward specific results when generating content. The conclusions produced by AI systems appear objective and fair, but in reality, they are deeply dependent on data quality, labeling subjectivity, and algorithm design. Their black-box nature also fundamentally contradicts the principles of traceability and verifiability required by scientific research.⁶⁶ This contradiction is particularly prominent in nursing research evaluating the effects of clinical interventions, because artificial intelligence tends to generate answers that conform to the user's pre-set ideas. Such bias may potentially affect the safety of nursing practice.⁶⁷ In addition, the respondents' concerns about artificial intelligence providing false data and literature echoed the findings of Heather et al.,²³ which found that artificial intelligence does indeed create illusions in academic writing, including falsifying references and tampering with data.

Faced with the above challenges, the nursing field needs to build a critical integration of artificial intelligence capabilities in education and practice.⁶⁸ In education, research methods and AI literacy should be integrated into teaching, and content related to health AI assessment should be offered to cultivate students' critical thinking ability. Through interdisciplinary collaborative learning, AI models should be made more interpretable and verifiable.⁶⁹ In clinical practice, the auxiliary research role of AI should be clarified, and its results should be verified through scientific research and clinical judgment before they are used. A localized verification and routine monitoring mechanism for AI models should be established, and transparent reporting standards should be followed in research publications to form a rigorous human-machine collaborative closed loop and ensure the scientificity and reliability of artificial intelligence applications.^{70,71} In terms of academic integrity, it is particularly important to establish an effective mechanism for identifying and verifying AI-generated content. The study by Miriam et al.⁷² pointed out that the frequency of use of specific conjunctions and high-frequency words can serve as clues to distinguish between original writing by nursing students and AI-generated text. This suggests that the nursing research field needs to establish a more targeted AI output verification mechanism that focuses on the accuracy of terminology, the verifiability of cited literature, the reliability of data sources, the representativeness of samples, and the absence of jumps in the reasoning chain. Only by constructing a multi-dimensional and structured verification framework can

we leverage artificial intelligence to improve research efficiency while upholding the bottom line of rigor and authenticity in nursing academic research.

The dual deficiencies in responsibility division and ethical norms

In the context of the deep empowerment of nursing research by artificial intelligence technology, traditional research ethics faces a double challenge: the ambiguity of the responsible party and the failure of ethical boundaries. When AI participates in, or even dominates, research areas such as data analysis and risk prediction, the responsible party becomes unclear. This ambiguity of responsibility makes it difficult to hold people accountable effectively and remedy problems when they occur. Current ethical norms are primarily designed for human behavior and are difficult to apply directly to AI systems that possess a degree of autonomy, can evolve dynamically, and employ opaque decision-making logic, creating a gap in ethical oversight in practice.^{73,74} The emphasis on empathy and humanistic care in the nursing profession itself further exacerbates the complexity of ethical judgment. This dilemma of ambiguous responsibility has been confirmed in empirical research. The decision-making of artificial intelligence blurs the boundaries of responsibility between nurses, developers, and institutions, making it difficult to hold people accountable when adverse events occur. This conclusion is consistent with the research results of Wesam et al.⁶¹ Vayena et al.⁵⁷ also noted a general lack of accountability in the application of medical artificial intelligence. Nursing graduate students are more likely to fall into the trap of “not holding people accountable” and attribute the risks and responsibilities to the artificial intelligence developers. At present, there is no clear international division of responsibility for artificial intelligence-assisted research, and there is also a lack of established regulations for assigning responsibility in nursing research ethics education. The lack of responsibility determination and norms in the use of artificial intelligence by schools, hospitals and other related institutions has further led to the rationalization of students’ “lack of responsibility awareness”. At the same time, the blurring of ethical boundaries has become another urgent problem. Nursing graduate students generally report a lack of clarity about the compliance boundaries for the use of artificial intelligence. This phenomenon is consistent with the research results of Maggie et al.,⁷⁵ reflecting the reality that the development of artificial intelligence ethics norms lags behind technological development. Nursing research is both academic and practical, and its ethical boundaries cover multiple dimensions, including research integrity, patient rights protection and technology application.⁷⁶ The American Nurses Association clearly stated in its position statement that nurses must ensure that advanced technology does not harm the core interpersonal and relational nature of the nursing profession.⁷⁷ Elendu et al.⁷⁸ also emphasized that traditional ethical principles such as autonomy, benevolence, non-harm and justice should continue to serve as the basis for guiding medical artificial intelligence practice. However, existing international ethical norms do not provide specific regulations for the application of artificial intelligence in nursing research, leaving practice without clear guidance. The emphasis on empathy and humanistic care in the nursing profession itself further exacerbates the complexity of ethical judgment.⁷⁹

In response to shortcomings in both responsibility and ethics, the nursing profession needs to proactively develop ethical management capabilities suited to the intelligent era across both teaching and practical work. In education, artificial intelligence and nursing ethics should be included as core courses for postgraduate nursing students. Through scenario simulation, case studies and interdisciplinary dialogue, students’ ethical awareness and sense of responsibility should be cultivated.⁸⁰ Studies have shown that structured artificial intelligence ethics education can effectively improve students’ ethical capabilities.⁸¹ For example, the curriculum framework proposed by Emily et al.⁸² integrates critical artificial intelligence literacy into pre-nursing education, aiming to systematically cultivate graduates’ core competencies in technology assessment, ethical awareness and clinical integration. Tuba et al.⁸³ combined artificial intelligence with nursing ethical decision-making using the REST model, providing a theoretical framework for constructing an educational framework. In terms of practice and governance, a management system with clear responsibilities, traceability and supervision should be established to allocate responsibilities and conduct ethical reviews throughout the entire AI process, from research and development to use.^{38,60} The core values of the nursing profession should always be upheld, the auxiliary role of artificial intelligence should be clearly defined, and the bottom line of humanistic care and professional ethics should be maintained.⁷³ In terms of standard-setting, we can refer to the “cross-domain artificial intelligence principles” proposed in the UK government white paper and take nursing ethics theory as the core guide.^{84,85} We should follow a multi-stakeholder collaboration model, with universities, medical institutions, technology developers and ethics experts jointly developing “Guidelines for the Ethical Application of Artificial Intelligence” specifically for nursing research, to clarify the responsibilities and behavioral boundaries of all parties.⁸⁶ Only through the dual paths of educational improvement and institutional norms can we ensure that nursing research consistently adheres to rigorous ethical standards and professional responsibilities in the era of artificial intelligence, while promoting the empowerment of technology.

The vicious cycle of lack of support systems and inadequate coping capabilities

This study found that nursing graduate students generally face multiple challenges when dealing with the risks of artificial intelligence data, including weak risk awareness, insufficient protective measures and insufficient systematic training. This phenomenon reflects the lack of initiative in risk prevention and control among this group. This passive state is not only due to individual negligence, but also to the structural dilemma caused by the lack of a support system and individual coping ability. The failure of educational and clinical institutions to provide systematic data risk training, clear protection standards and related technical support has led to insufficient risk awareness and a lack of coping methods among nursing students and practitioners. Their weak ability further reduces their willingness to seek help actively or to promote improvements in the system, forming a vicious cycle. In the end, it not only threatens patient data security and nursing quality but also undermines the ethical autonomy and industry trust of the nursing profession in the digital age. Heinrichs et al.⁸⁷ also noted that a lack of early technical experience and professional empowerment will continue to fuel practitioners' concerns about artificial intelligence; by contrast, as familiarity with use and professional ability improve, such concerns will be significantly reduced. Existing practices have sought to improve clinical trainees' understanding of AI principles and limitations through structured teaching, demonstrating the effectiveness of the educational intervention.⁸⁸

To address this dilemma, the nursing education system needs to incorporate data literacy into the core competencies of nursing, offer compulsory courses in nursing informatics and data ethics at the postgraduate level and cultivate risk identification, ethical decision-making and cross-team communication skills through scenario simulation, case studies and interdisciplinary collaboration.⁸⁹ Medical institutions should formulate clear guidelines for the use of AI tools and for data security operations, establish dedicated nursing information positions to facilitate technical communication, incorporate data risk management into quality evaluation, build a non-accountability, learning-oriented safety culture, and establish a feedback channel for school-hospital collaboration. Through collaborative development of dynamically updated training modules, establishment of clinical data security practice archives, and regular multidisciplinary seminars, the educational content and clinical risk scenarios can be updated synchronously to optimize the protection system continuously.

Legal constraints and platform protection are also key factors affecting the effectiveness of risk management. Minssen et al.⁵⁷ noted that there is a general lack of laws and regulations worldwide that comprehensively regulate the use of data in artificial intelligence research. At present, most artificial intelligence research platforms lack data security features, such as data destruction after a response is completed. This reflects the disconnect between the supply of platform technical services and the data security needs of nursing research, which further exacerbates the prevention and control of risks. David et al.⁹⁰ suggested that governments and universities should strengthen cooperation to jointly regulate the application of artificial intelligence technology in medical education. The nursing graduate students in this study called for stronger legal constraints, consistent with the international trend toward stronger regulation of artificial intelligence.

The specific demands raised by nursing graduate students in the interviews, such as the establishment of specialized courses and the formation of multidisciplinary consultation teams, provide a clear direction for building an effective support system. This is highly consistent with the recommendations of many institutions in the study by Paulina et al.,⁹¹ which emphasized "interdisciplinary cooperation" and "providing advanced artificial intelligence literacy training for graduate students." The Nursing and Artificial Intelligence Leadership Collaboration Alliance also emphasizes that universities should establish interdisciplinary cooperation projects, such as joint training programs for nursing and technical students, to encourage students to directly participate in the development and governance of artificial intelligence technologies.² This study suggests that universities can explore implementing a dual-mentor system for artificial intelligence research, with joint guidance from experts in nursing and information science. This will significantly enhance nursing graduate students' ability to identify, assess, and respond to risks associated with artificial intelligence data, laying a solid foundation for them to conduct standardized, safe, and innovative intelligent-assisted research.

Regarding the relevance of this research and its topic to nursing and healthcare management, several key points can be discussed. This study, through interviews and qualitative topic analysis, identifies a five-dimensional structure of nursing graduate students' perceptions of data risks in AI-enabled nursing research: data adaptation, data security, data quality, data ethics, and risk management. It highlights a comprehensive risk focus of "use-generation-sharing-responsibility," offering empirical evidence for nursing managers to identify and address AI data risks. When promoting AI implementation, healthcare management should simultaneously build a data governance and quality assurance system, strengthen ethical compliance requirements, clarify responsibility boundaries, and institutionalize these practices across relevant research and management processes. Strengthening support for talent development and institutional supply is crucial to reducing systemic risk exposure. From a global perspective, the lag in current regulations and the inadequacy of platform security are prevalent in various contexts. Therefore, the findings of this study can provide empirical evidence for countries and institutions to build

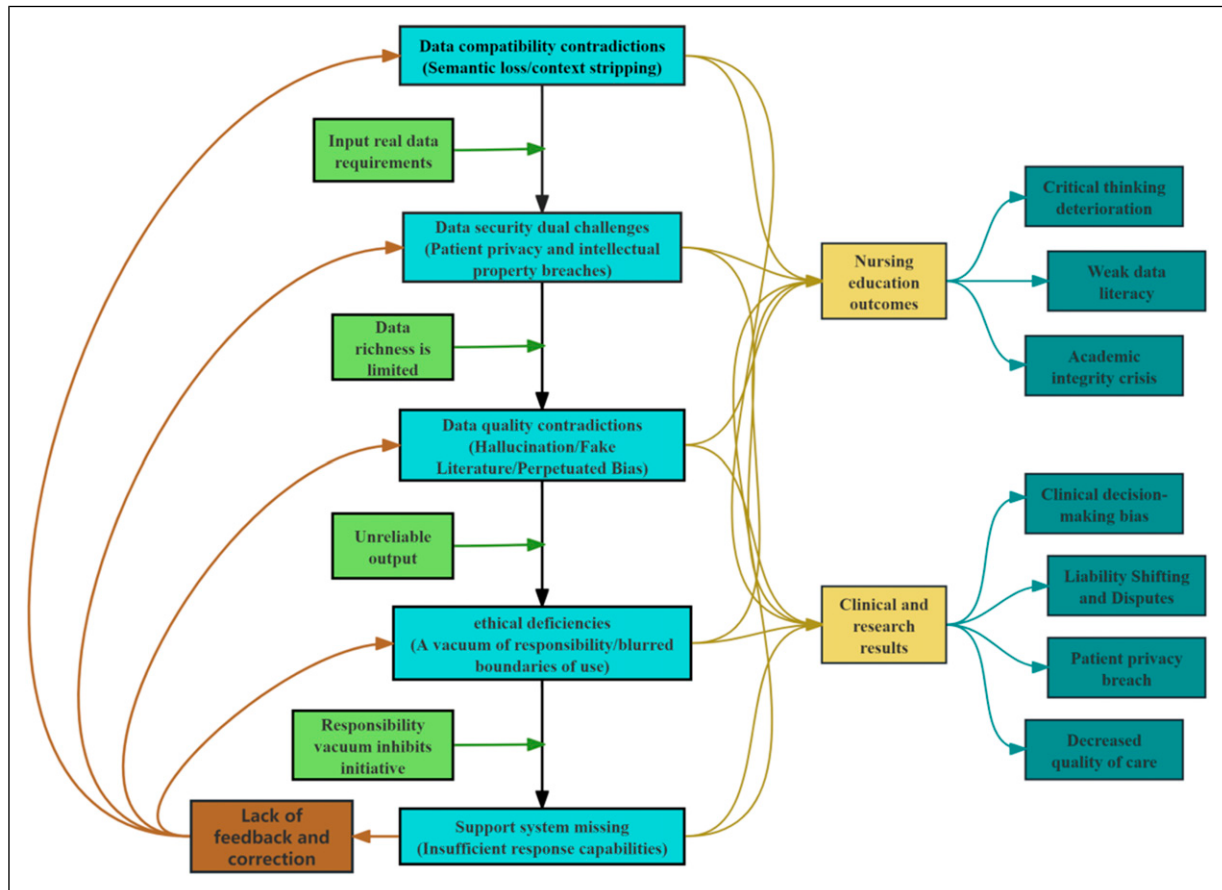


Figure 1. A conceptual model illustrating the proposed framework.

governance systems, talent development mechanisms, and standards for AI-assisted nursing research, ensuring synergistic optimization of safety and sustainability while improving efficiency (Figure 1).

Conclusion

This study used qualitative topic analysis to extract five themes from nursing graduate students' perceptions of data risk in AI-enabled nursing research: data adaptation, data security, data quality, data ethics, and responses to related risks. Their risk concerns exhibit a full-chain characteristic, permeating the entire process, from the use of AI tools and content generation to data sharing and the attribution of responsibility. This finding provides empirical evidence for identifying data risks and analyzing key aspects in nursing research. It lays a theoretical foundation for constructing a risk management system that spans the entire process.

Based on the findings of this study, nursing management and graduate student training should be collaboratively promoted across three key dimensions: technology, systems, and capabilities. Promote the adaptation and co-construction of AI tools in nursing professional scenarios, enabling nursing professionals to participate in key aspects such as needs definition, data selection, and clinical validation; establish a data governance and quality assurance mechanism covering the entire research process, strengthening data anonymization, access control, usage boundaries, and AI output verification, and institutionalizing ethical compliance and responsibility definition into research management; improve support systems and capacity building, conducting standardized training on AI data security, research integrity, ethical decision-making, and critical use, and exploring multidisciplinary consultation support and "dual-mentor" training models to enhance nursing graduate students' risk identification, assessment, and response capabilities.

In the future, mixed-signal studies can be conducted on a broader sample to develop measurement tools further and examine the mechanisms and key pathways of risk perception, providing more operational empirical support for the standardized application and high-quality development of AI in nursing research.

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ORCID iD

Joaquim Paulo Moreira  <https://orcid.org/0000-0002-3644-1022>

Ethical considerations

The Research Ethics Subcommittee of the Medical Ethics Committee of Shandong First Medical University accepted this study under Ethics No. R202512220524. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee, as well as the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards.

Consent for publication

Informed consent was obtained from all patients in this study. All patient data were analyzed anonymously.

Author contributions

XY: Research conception and design, data collection and processing, thesis writing. HS: Conceptualization, Methodology, Writing– review & editing. PM: validation, Writing-review & Editing. CS: Research design, data collection, data verification. YS: Research design, data collection, and data verification.

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Data Availability Statement

The data supporting the results of this study are available from the corresponding authors upon reasonable request.

Declaration of application of generative artificial intelligence and AI-assisted technology in the writing process

During the research preparation phase, the authors used ChatGPT software to optimize language expression and readability. After using this tool, the authors made necessary revisions to the content and assumed full responsibility for the content of the published paper.

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