STUDY PROTOCOL

Comparing Traditional Teaching, Peer Learning, and Artificial Intelligence (AI)-Assisted Instruction for Lumbar Puncture Training Among Resident Physicians: A Retrospective Cohort Study

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Study Design: Retrospective, single-center cohort study

Sponsor / Responsible Party: _____

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1. Background

Lumbar puncture is a core clinical procedural skill that resident physicians must master, and the degree to which it is performed in a standardized and proficient manner directly affects the safety and quality of diagnosis. Existing studies show that the success rate of lumbar puncture performed independently by resident physicians remains suboptimal, with a relatively high risk of complications, indicating persistent deficiencies in traditional training models. Although traditional clinical teaching offers the advantages of authentic clinical contexts and immediate guidance, it is limited by constrained resources, unequal opportunities for hands-on practice, insufficient standardized assessment, and poor long-term skill retention. In recent years, peer learning and artificial intelligence (AI)-assisted instruction have emerged as innovative methods of clinical skills training. However, studies directly comparing the medium- and long-term effectiveness of these three teaching modalities in lumbar puncture training remain scarce. This study therefore adopts a retrospective cohort design and uses archived training records to systematically compare the actual effectiveness of the three teaching modalities.

2. Objectives

This retrospective cohort study systematically compares the effectiveness of traditional teaching, peer learning, and AI-assisted instruction in lumbar puncture training for resident physicians, with a focus on evaluating:

- Mastery of theoretical knowledge and procedural skills in the short term (immediately after training) and in the long term (3 months after training);
- The degree of skill decay;
- Changes in procedural duration;
- Trainee satisfaction.

3. Study Design and Methods

3.1 Study Design

Design: Retrospective, single-center cohort study.

Grouping: According to the training modality actually received by resident physicians between January 2025 and December 2025, participants are divided into three exposure cohorts: (1) the traditional teaching cohort (reference group); (2) the peer learning cohort; and (3) the AI-assisted instruction cohort.

Data sources: Retrospective review of residency standardized training archives, pre-licensure training records for the National Medical Licensing Examination, and the teaching assessment database.

Assessment time points: (1) Pre-training (baseline): entry diagnostic assessment scores; (2) Immediately post-training (T0): assessment scores in the week of training completion; (3) 3 months post-training (T1): follow-up assessment scores 3 months after training.

3.2 Study Population

Inclusion criteria:

- Resident physicians taking the National Medical Licensing Examination for the first time;
- No lumbar puncture training within the 3 months prior to the study and no independent clinical lumbar puncture experience (verified against entry training records);
- Complete training records, assessment scores, and teaching evaluation records;
- Traceable skill assessment data at 3 months after training.

Exclusion criteria:

- Absence from training or assessments due to personal leave, sick leave, or maternity leave;
- Incomplete training records or assessment data;
- Simultaneous participation in other similar clinical skills teaching studies;
- Failure to complete post-training practice or assessments on schedule.

3.3 Definition of Exposures

(1) Traditional teaching cohort: Participants received the conventional clinical teaching model. The instructor organized viewing of a standardized lumbar puncture teaching video and systematically explained the indications, contraindications, procedural steps, precautions, common complications, and technical difficulties. The instructor then performed a complete demonstration on a medical simulator with simultaneous explanation of key steps and operational points. Students performed three rounds of simulated practice according to a standardized scoring scale, with the instructor supervising throughout and providing on-site guidance and error correction.

(2) Peer learning cohort: Participants received peer-assisted learning. After the instructor organized video viewing and explained the operational and scoring standards, students were paired for three rounds of simulated practice. While Student A performed the procedure, Student B was responsible for scoring and timing; roles were switched upon completion. After the first round, both parties conducted peer evaluation, and the instructor summarized common problems and clarified operational precautions for subsequent practice. The second round targeted the weaknesses identified in the first round for focused reinforcement, followed by peer evaluation and supplementary guidance. The third round simulated a formal assessment scenario, with mutual scoring and timing.

(3) AI-assisted instruction cohort: Participants received instruction assisted by an AI intelligent training system. After the instructor organized video viewing and explained the operational and scoring standards, students performed three rounds of simulated practice with the assistance of the AI system. The system, built on deep learning and multi-dimensional sensing technologies, provides real-time monitoring of key indicators such as operating angle, puncture depth, and force control; delivers immediate feedback via voice and visual interfaces; and accurately identifies operational deviations to generate corrective prompts.

3.4 Outcome Measures

(1) Primary outcome measure: Lumbar puncture procedural score (OSCE scoring scale, total possible score of 100 points): pre-procedure preparation (20 points), procedural process (65

points), post-procedure management (10 points), and overall evaluation (5 points).

(2) Secondary outcome measures:

• Theoretical examination score (total possible score of 100 points, 20 objective items);

• DOPS score (four dimensions: preoperative assessment, procedural standardization, aseptic concept, and professional competence, each scored 1–5 points, for a total score of 25 points);

• Procedural duration (total time required for successful completion of the procedure);

• Satisfaction survey (five dimensions: course resources, teaching content, classroom interaction, teaching methods, and learning burden, each scored 1–5 points).

3.5 Statistical Methods

SPSS 26.0 statistical software will be used. Continuous data are expressed as mean ± standard deviation (x■ ± s). Within-group comparisons before and after training will use the paired t-test; between-group comparisons will use one-way analysis of variance (ANOVA), with pairwise comparisons performed using the LSD-t test. Multiple linear regression or analysis of covariance (ANCOVA) will be used to control for baseline confounding factors. Categorical data are expressed as frequencies (percentages). All tests are two-sided.

4. Sample Size

As a retrospective cohort study, the sample size depends on the historical training records available within the study period. Based on the scale of previous training programs, it is expected that no fewer than 40 trainees with complete archived records can be included in each of the three cohorts, for a total sample size of no fewer than 120. If the sample size of any cohort is insufficient, the retrospective time window will be appropriately extended to meet statistical analysis requirements.

5. Data Management and Confidentiality

All study data are collected and entered by dedicated personnel through retrospective review of training archives, with a double-checking mechanism to ensure data accuracy. Original paper questionnaires and scoring sheets are kept by the research team in a locked filing cabinet; electronic data are stored on an encrypted computer with access controls, accessible only to core members of the research team. Personal information of trainees is replaced by codes, and anonymized identifiers are used during analysis so that individuals cannot be traced. After the study concludes, the original data will be retained for at least 5 years for verification purposes. All personal information of participants will be de-identified.

6. Informed Consent

This is a retrospective cohort study that mainly analyzes previously de-identified teaching, training, and assessment archive data. Upon review and approval by the hospital ethics committee, individual informed consent is waived for this study. The study strictly complies with the Declaration of Helsinki and the Measures for the Ethical Review of Biomedical Research Involving Human Subjects. All data are used for scientific research purposes only and do not involve any change to

clinical diagnosis or treatment decisions. It is specifically stated that this study will not affect trainees' prior training evaluations, assessment scores, or career development in any way.

7. Adverse Event Reporting

This is a retrospective cohort study involving no active intervention or new clinical procedures; it only analyzes previously collected training and assessment archive data. Therefore, no adverse events are anticipated. If records of serious adverse events related to prior training are identified during the retrospective data review, they will be reported and handled in accordance with hospital regulations.

8. Protection Measures for Vulnerable Populations

Given that resident physicians are at a critical stage of professional development and have a clear power imbalance with their supervising teachers and department management, this study treats them as a vulnerable population requiring enhanced protection. The following strengthened measures are taken:

(1) Voluntary participation and no-penalty guarantee. This retrospective study involves no new intervention or follow-up. During data collection, an independent research coordinator (not a supervising teacher or department manager) is responsible for archive review, ensuring that trainees' prior assessment records are not used for any form of additional evaluation. Trainees are clearly informed that the study uses only previously de-identified data and will not affect their rotation assessment scores, end-of-rotation evaluations, annual merit reviews, recommendation letters, or subsequent career development opportunities.

(2) Enhanced anonymity and privacy protection. All assessment scoring sheets, questionnaires, and electronic data are replaced with independent codes instead of real names. The code-to-identity correspondence table is kept separately by a data administrator who is not a member of the research team and is stored on an encrypted device. Only aggregated data are reported in publications, and no individually identifiable information is disclosed. If images or videos are used, secondary authorization from the trainee is required, and faces and employee IDs must be blurred. After the study concludes, the code-to-identity correspondence table will be destroyed within 6 months of data lock.

(3) Operational safety and physical protection. This retrospective study involves no new risk. All procedures in the prior training were performed on medical simulators and did not involve real patients.

(4) Psychological and academic protection. An independent psychological support channel is established: trainees who experience anxiety related to the use of study data may contact the hospital teaching department's psychological counselor anonymously; this process is independent of the research team and is not counted in any evaluation. Public comparison of individual or group scores in any teaching setting is prohibited to avoid labeling and stigmatization.

(5) Restricted use of data. Study data are used only for the purposes of this study and for subsequent anonymized secondary analysis; they must not be used in trainees' personal files, personnel assessments, or as a basis for rewards or punishments. Original materials such as

teaching videos and scoring records must not be shown to the management of trainees' departments, and members of the research team must not cite trainees' research performance in daily teaching to conduct targeted evaluations.

(6) Appeal and feedback mechanism. An ethics appeal mailbox independent of the research team is established and handled directly by the secretary of the hospital ethics committee. Trainees may raise appeals regarding any concerns or infringements of rights during the study, and the ethics committee commits to providing a written reply within 5 working days. After each round of data checking, an independent coordinator collects anonymous feedback from trainees on the research process to continuously monitor for any signs of rights violations.