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Clinical Clerkship Course for Medical Students on Lumbar Puncture Using Simulators

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Abstract

Lumbar puncture is a medical technique that physicians must learn and is, therefore, considered a basic medical procedure. The lumbar puncture simulators Lumbar-Kun (Lumbar Puncture Simulator) and Lumbar-Kun II (Lumbar Puncture Simulator II) (Kyoto Kagaku, Kyoto, Japan) are teaching aids designed for practicing spinal insertions. We describe and results of a lumbar puncture clerkship course, provided to 5th-year medical students during clinical clerkship activity. The aim of this study was to evaluate the effectiveness of the lumbar puncture clerkship course in the medical education program. Comprehension, technical achievement, and satisfaction were scored by students and instructors using a 6-point Likert scale. Scores for both comprehension and technical achievement were high, but technical achievement scores tended to be higher than comprehension scores. In addition, the scores students gave themselves were higher than the scores they were given by instructors. Student satisfaction was high. The lumbar puncture simulators, Lumbar-Kun and Lumbar-Kun II, achieved excellent overall impressions and represent useful tools for training in lumbar puncture procedures. In addition to the simulators, an appropriate preparatory text and a short lecture before training seemed to increase the educational effect of this lumbar puncture clerkship course for medical students.
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Key words: lumbar puncture simulator, lumbar puncture clerkship, medical students

Introduction

Simulation is increasingly being used to teach procedural skills and offers many potential advantages over traditional methods of medical education. These advantages include protecting patients from medical errors[1], offering the opportunity to learn and practice technical skills in a safe and controlled environment[2], and in complex situations[3], and deliberate practice[4]. Because lumbar puncture (LP) is a procedure that must be performed with confidence during residency[5], training with simulators during medical school

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clinical clerkships has been recommended[6]. The present study evaluated the effectiveness of our LP clerkship course in the medical education program.

Materials and Methods

The LP simulators used were Lumbar-Kun (Lumbar Puncture Simulator) and Lumbar-Kun II (Lumbar Puncture Simulator-II) (Kyoto Kagaku, Kyoto, Japan). From 2008 through 2010, 153 5th-year medical students took part in a required LP clerkship course during their clinical clerkships in neurosurgery. The instructor-to-student ratio was 1 : 3 to 1 : 4. The role of the instructors was to give a short lecture, to demonstrate the proper technique for LP, to assist students' procedures, and to evaluate the students. All instructors were qualified neurosurgeons. A text **(Fig. 1)** and a checklist of the procedure **(Fig. 2)** were provided to students in advance.

Before the course, a short lecture was given. The lecture followed the text and the checklist and included a review of indications, contraindications, complications, consent, procedural notes, evidence for the procedural steps, and a review of current evidence on the procedure. An instructor first demonstrated the technique while giving medical explanations. Students then tried the LP procedure using the simulator. The instructor observed each student carefully and evaluated the number of procedures until successful insertion or measurement of cerebrospinal fluid (CSF) pressure. The instructor provided feedback to students. The instructor held the simulator in place, observed the technique of the student, and judged whether the student possessed the required knowledge, prudence, and earnest attitude.

After the lecture and LP simulator practice, questionnaires were administered to the students to clarify their comprehension, technical achievement, and satisfaction **(Table 1)**. Another questionnaire was given to the instructors **(Table 2)**. Questions were answered with a 6-point Likert scale (1, strongly disagree; 2, disagree; 3, somewhat disagree; 4, somewhat agree; 5, agree; 6, strongly agree)[7]. Free comments were welcomed, and space to write them was provided on the questionnaire paper.

Results

Table 3 shows the characteristics of the students. The LP clerkship course was held in the clinical simulation laboratory room of our medical school **(Fig. 3)**. The instructor-to-trainee ratio was 1 : 3 for 93 students and 1 : 4 for 60 students. No students had previously undergone training with simulators, and none had performed LP. Four percent of the students had observed an LP procedure. One session of the clerkship course lasted about 1 hour, including the short lecture.

According to the questionnaire administered after the course, student-reported median scores were: 5.0 for comprehension (interquartile range [IQR], 4.0–5.0; range, 4–6); 5.0 for technical achievement (IQR, 4.0–5.0; range, 4–6); and 6.0 for satisfaction (IQR, 5.0–6.0; range, 4–6) **(Fig. 4)**. Instructor-reported median scores were: 4.0 for comprehension (IQR, 3.0–5.0; range, 1–6); and 4.0 for technical achievement (IQR, 4.0–5.0; range, 1–6) **(Fig. 5)**. Technical achievement scores were 5.0 for students who had observed LP (IQR, 4.0–5.0; range, 4–6) and 5.0 for students who had not (IQR, 4.0–5.0; range, 4–6) **(Fig. 6)**. Free opinions of students included: "I would like to actually try the procedure soon"; "Once I actually experienced the procedure, I understood the anatomy better"; "Even if I do well in practice, I feel I will not perform the procedure properly in an actual patient"; and "With friends looking on, I was unable to make the puncture quickly. I would like to practice alone." Free opinions from instructors indicated impressions of the simulator being nearly equal to a real patient and of good scores correlating with the motivation and attitude of the student toward the simulation course.

Discussion

Previous generations of medical students developed requisite technical skills by practicing clinical procedures on live patients, as in an apprenticeship. This unfortunate situation has, thankfully, changed with the introduction of various

LUMBAR PUNCTURE INTERNSHIP COURSE

Objectives: medical students, residents (who have finished the fundamental surgical techniques course), nurses (assistance)

Department in charge: Neurosurgery

1. Objectives

To study the procedure of lumbar puncture using a lumbar puncture simulator

2. Indications

a) Examination of cerebrospinal fluid (CSF) (for diagnosis of infection, neoplasm, hemorrhage, etc.): diagnosis of meningitis, demyelination, meningeal carcinomatosis, small subarachnoid hemorrhage

b) Drug delivery into subarachnoid space (for diagnostic and therapeutic purposes): lumbar anesthesia, diagnosis of CSF leakage or normal pressure hydrocephalus (NPH), myelography, intrathecal administration of antineoplastic or antibiotic agents

c) Removal of CSF: therapy for NPH, benign intracranial hypertension, overproduction of CSF

3. Contraindications

Presence of an intracranial mass lesion

Infection of the puncture site and route

Presence of hemorrhagic diathesis

4. Puncture point

Usually uses the L-4/L-5 interspace

Reasons: no spinal cord (filum terminale and cauda equina only)

widest subarachnoid space

widest intervertebral space

presence of landmark Jacoby line, which crosses the lumbar spine at the level of the L-4 spinous process

5. Materials needed

Skin disinfection: forceps, povidone iodine solution, sterile dressing

Preservation of puncture area: mask, sterile surgical gloves, square dressing with window

Local anesthesia: needle (23-G); syringe (3 ml); local anesthetics (1% xylocaine, 5 ml)

Lumbar puncture kit: spinal needle with stylet (23-G), three-way cock, simple column manometer, test tube

Treatment of puncture site: povidone iodine solution, sterile gauze

6. Method and technique

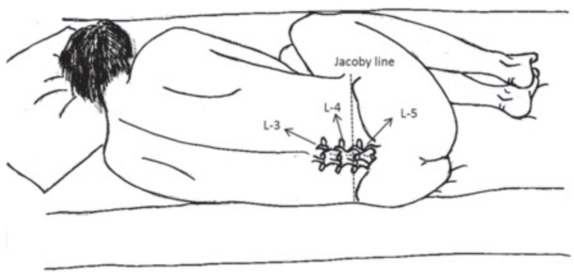
A. Position

Using a lateral position, the patient is placed with the back at the end of the bed. The knees, waist, back, and neck are flexed so that the patient can see the navel. If the patient cannot assume this position unaided, an assistant assists with the neck and knees. The shoulders and pelvis are roughly perpendicular to the floor.

B. Technique

1) Puncture point check

The intersection of a line connecting bilateral superior anterior iliac crests (Jacoby line) and the back midline corresponds to the spinous process of L-4. You can feel the puncture point in the L-4/L-5 interspace just caudal from this intersection. The L-3/L-4 interspace may also be utilized.



2) Sterile manipulation

You can wear a mask and surgical gloves. You disinfect in a circle around the puncture point using the povidone iodine solution. This should be done twice. A square dressing with window is placed so that window is over the disinfected area. The instruments and materials used hereafter are prepared near the operative field until the povidone iodine solution has dried.

3) Local anesthetic infiltration

You may subcutaneously inject xylocaine anesthetic using a 23-G needle, to infiltrate the interspinous tissue.

4) Insertion of a spinal-tap needle

Attaching a stylet for a spinal-tap needle, the cut end is turned up and inserted into the skin. The head of the puncture needle is fixed using both thumbs, and near its center the needle is fixed by both index and middle fingers. The two remaining fingers are placed as support on the skin of the patient's back. You may not touch the tip of the puncture needle. The needle is pushed forward in an axial direction at right angles to the skin and in a coronal direction at 0 to 10 degrees cephalad. When the needle tip is in the subcutaneous fat layer, little resistance is encountered. However, because resistance increases when passing through the interspinous ligament, the needle should be supported by both index and middle fingers to prevent the puncture needle from bending. When the needle has been advanced about 6 cm, the needle tip will pierce the dura mater, at which point there is a sensation of "give," a feeling of penetration. If you cannot feel "give," you should check the CSF flow by removing the stylet. If no outflow of CSF is seen, another stylet should be placed, and the needle should be advanced 2 mm. Check the CSF outflow again by removing the stylet. When the needle tip reaches the subarachnoid space, CSF will be released.

5) Measurement of opening pressure

The stylet is inserted, and the needle is rotated 90 degrees so that the cut end is on the cranial or caudal side. The stylet is then removed and a simple column manometer connected to a three-way cock. When the three-way cock is released, wait until CSF flow reaches a balance. At this point, read the numerical value for the height of CSF. The CSF pressure is expressed in millimeters of H_2O on the basis of the puncture point. Normal pressure is considered to be 50 to 180 mm H_2O, but pressure measurement is suspended if a value of 200 mm H_2O is reached. Although connection of manometers is possible for pressure measurement, this is not usually performed.

6) Collection of CSF

CSF being released from where the stylet was removed is collected into a sterile test tube. Although a syringe may be connected, you may extract CSF extremely slowly (usually <1 ml/min) without applying negative pressure.

7) Measurement of final pressure

8) Removal of the needle

The whole spinal-tap needle is removed after the stylet has been reinserted.

9) Treatment of puncture point

You may disinfect the puncture point with povidone iodine solution, apply pressure, and fix a pad of sterile gauze with tape. The patient then rests for at least 30 minutes in a supine position.

7. Complications

Brain herniation

Worsening of hemiparesis

Dermoid in spinal canal

Meningitis

Subdural hematoma

Spinal epidural hematoma

Injury of nerve roots, annulus fibrosus

CSF hypovolemia, postspinal headache

Fig. 1 Text for the lumbar puncture procedure.
This text is not only for medical students, but also for residents and nurses and thus supposes an actual patient. The underlined portions are therefore not performed at this time.

Subjective behavioral objectives (SBOs)	Self-evaluation	Instructor evaluation
I: BEFORE COURSE 1) The purpose of carrying out puncture can be described. 2) Absence of contraindications can be checked. 3) Informed consent can been obtained.		
II: POSITION 4) Posture can be explained to the patient. 5) An assistant can help with patient positioning.		
III: IDENTIFICATION OF PUNCTURE SITE 6) The Jacoby line can be identified. 7) A puncture point can be determined.		
IV: PREPARATION FOR PUNCTURE 8) Broad disinfection focusing on a puncture point can be carried out. 9) Preparation for sterile management can be achieved. 10) Puncture equipment can be checked and prepared. 11) Local anesthesia can be induced appropriately.		
V: PUNCTURE TECHNIQUE (The following are made as appropriate.) 12) Puncture site 13) Puncture angle 14) Support of the puncture needle 15) Confirmation of CSF flow 16) Connection of three-way cock and simple column manometer 17) Measurement of opening pressure 18) Collection of CSF 19) Observation of characteristics of collected CSF 20) Measurement of final pressure 21) Removal of needle 22) Management of puncture site		
VI: AFTER-PUNCTURE DIRECTIONS 23) Directions for rest can be performed. 24) Major complications and means of prevention can be stated.		

Fig. 2 Checklist for lumbar puncture.
This checklist is for trainees (students and residents) and instructors and supposes an actual patient. As a result, items 3–5, 8, 9, 11, and 23 are not performed at this time.

Table 1 Questionnaire for students

Q1)	"I have fully understood the theory behind lumbar puncture."
Q2)	"After the training, I feel confident that I can perform a real lumbar puncture."
Q3)	"The training with the simulator was useful for me, and I am satisfied with it."

Table 2 Questionnaire for instructors

Q1)	"The student seems to have fully understood the theory behind lumbar puncture."
Q2)	"After the training, the student seems to feel confident that he/she can perform a real lumbar puncture."

Table 3 Baseline characteristics of the students

Characteristics		n (%)
Sex	Male	101 (66%)
	Female	52 (34%)
Prior observation of LP	Yes	6 (4%)
	No	147 (96%)

types of simulator. Many reports have described the effectiveness of simulator-based learning for developing clinical expertise[5,8]. After simulator-based training in LP, residents often report increased knowledge and confidence[9].

Lumbar-Kun II is an advanced model of Lumbar-

Fig. 3 Photograph from the LP clerkship course held in the clinical simulation laboratory.
One of the students is trying to perform LP while the other students observe.
The instructor (left) holds the LP simulator steady and observes the student's performance.

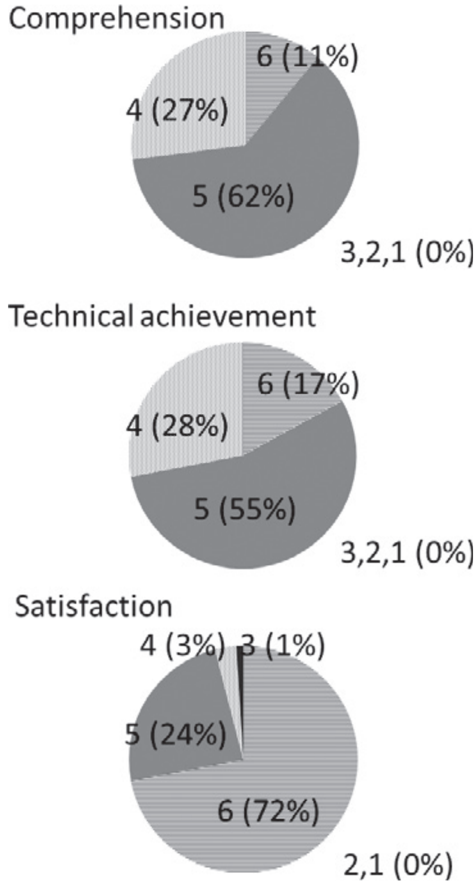


Fig. 4 These graphs show student scores for the questionnaire. Comprehension is scaled for "I have fully understood the theory behind lumbar puncture," technical achievement for "After the training, I feel confident that I can perform a real lumbar puncture," and satisfaction by "The training with the simulator was useful for me, and I am satisfied with it." Validation is provided as follows: 1, strongly disagree; 2, disagree; 3, somewhat disagree; 4, somewhat agree; 5, agree; and 6, strongly agree.

Kun in which the difficulty of puncture can be adjusted by changing the puncture pads. Lumbar-Kun II also has an epidural puncture pad and a supporter base for practicing procedures with the patient in a sitting position. The present study used Lumbar-Kun II with a normal CSF puncture block and lateral position supporter base, as well as Lumbar-Kun.

Lumbar-Kun and Lumbar-Kun II closely simulate the lumbar anatomy and include such anatomical landmarks as the iliac crest and the spinous processes of the vertebrae. The models provide life-like sensations of both skin and tissue resistance to the spinal needle but lack the sensation of penetrating the dura mater ("give"). Students can both collect CSF and measure CSF pressure under clinically realistic conditions.

Although available simulators are excellent, they do have limitations. Training for LP under complicated situations, such as in obese or elderly patients, can be simulated with the Lumbar-Kun II but not with the Lumbar-Kun. In a real patient, the clinician feels the sensation of "give" and resistance at the time of puncture, but these indicators are absent or insufficient in Lumbar-Kun and Lumbar-Kun II, although this is not thought to represent a serious obstacle to training. Furthermore, the feeling of tension that may be experienced when performing LP in a real patient cannot be reproduced by a simulator. A virtual reality simulator has been developed for training in LP in patients with complications, such as obesity, scoliosis, and spondylosis[10]. This simulator can reportedly reproduce the haptic sensation of "give" and needle insertion resistance of a real patient. However, this kind of specialized equipment is not yet practical from a cost perspective.

In Japan, medical students are usually not allowed to perform LP, even under the supervision of an instructor, unlike in the United States[11]. "The student observes and assists with LP and can carry out the

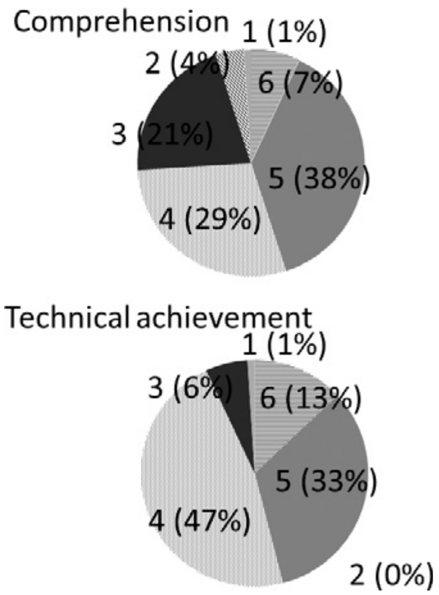


Fig. 5 These graphs show instructor scores for the questionnaire. Comprehension is scaled for "The student seems to have fully understood the theory behind lumbar puncture," and technical achievement by "After the training, the student seems to feel confident that he/she can perform a real lumbar puncture." Validation is provided as follows: 1, strongly disagree; 2, disagree; 3, somewhat disagree; 4, somewhat agree; 5, agree; and 6, strongly agree.

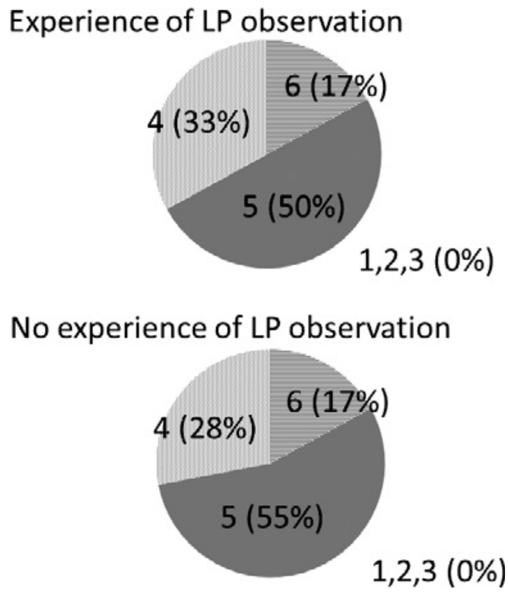


Fig. 6 These graphs show the scores of students who have previously observed a lumbar puncture and those who have not. Questionnaire results for technical achievement are scaled by "After the training, the student seems to feel confident that he/she can perform a real lumbar puncture." Validation is provided as follows: 1, strongly disagree; 2, disagree; 3, somewhat disagree; 4, somewhat agree; 5, agree; and 6, strongly agree.

procedure using a simulator" is mentioned as an attainment target in the Indicator of Medical Education Model Core Curriculum of the Japanese National Medical Practitioners Qualifying Examination[6]. Medical students need a full understanding of the anatomical features involved and the indications for LP. Training using simulators seems extremely useful for achieving this goal.

Together with the simulators, the preparation of the appropriate text for self-study and a short lecture before training are also important. In this LP simulator clerkship course, the training program was created by these preparation teaching materials and simulators.

According to the questionnaire surveys, training with simulators increased understanding of LP. The level of technical achievement appears higher than the level of comprehension. This difference may reflect the characteristics of training in which a technique can be performed until the procedure can be performed automatically. The questionnaire scores the students gave to themselves were higher than the scores they were given by instructors. Although students may think they have understood the procedure if they can perform it, instructors tend to be stricter in evaluating the finer points of the technique. Nearly all students (99%) felt that simulators helped them acquire procedural skills. Students generally showed a high degree of satisfaction with simulators and the course. Our LP clerkship program using LP simulators, the text for self-study, and a short lecture before training seemed to be effective for medical students.

The optimal instructor-to-trainee ratio in suturing techniques using simulators has been reported to be 1 : 4[12]. However, optimal ratios have not been reported for other simulator models. In our medical school, the LP clerkship course has been performed with instructor-to-trainee ratios of 1 : 3 to 1 : 4, in accordance with our curriculum. If the ratio is high, we believe that the course time will become too long and that students' concentration will decrease. On the other hand, if the ratio is low, the educational effect of observing the procedures of other trainees will decrease, and the training time will increase. For this LP course, we thought the ratio of 1 : 3 to 1 : 4, as reported for the suturing simulator model, was sufficient. The experience of observing LP had no effect on scores.

Various barriers to simulation-based education have been reported, such as the time-consuming nature of courses in the curriculum, the limited availability of simulators, the reduced realism of simulators, and the number of procedural instructors available[5]. However, in the present case, no such barriers were identified in the questionnaire, including free opinions completed by students and instructors.

Conclusion

The effectiveness of our LP clerkship course for medical students was evaluated with questionnaires. Training in clinical procedures can be effectively performed with LP simulators. In addition to the simulators, an appropriate text for self-study and a short lecture before training seems to increase the educational effect of the LP clerkship course.

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