Simulation-Based Educational Curriculum for Fluoroscopically Guided Lumbar Puncture Improves Operator Confidence and Reduces Patient Dose

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Rationale and Objectives: Fluoroscopically guided lumbar puncture (FGLP) is a commonly performed procedure with increased success rates relative to bedside technique. However, FGLP also exposes both patient and staff to ionizing radiation. The purpose of this study was to determine if the use of a simulation-based FGLP training program using an original, inexpensive lumbar spine phantom could improve operator confidence and efficiency, while also reducing patient dose.

Materials and Methods: A didactic and simulation-based FGLP curriculum was designed, including a 1-hour lecture and hands-on training with a lumbar spine phantom prototype developed at our institution. Six incoming post-graduate year 2 (PGY-2) radiology residents completed a short survey before taking the course, and each resident practiced 20 simulated FGLPs using the phantom before their first clinical procedure. Data from the 114 lumbar punctures (LPs) performed by the six trained residents (prospective cohort) were compared to data from 514 LPs performed by 17 residents who did not receive simulation-based training (retrospective cohort). Fluoroscopy time (FT), FGLP success rate, and indication were compared.

Results: There was a statistically significant reduction in average FT for the 114 procedures performed by the prospective study cohort compared to the 514 procedures performed by the retrospective cohort. This held true for all procedures in aggregate, LPs for myelography, and all procedures performed for a diagnostic indication. Aggregate FT for the prospective group (0.87 ± 0.68 minutes) was significantly lower compared to the retrospective group (1.09 ± 0.65 minutes) and resulted in a 25% reduction in average FT ($P = .002$). There was no statistically significant difference in the number of failed FGLPs between the two groups.

Conclusions: Our simulation-based FGLP curriculum resulted in improved operator confidence and reduced FT. These changes suggest that resident procedure efficiency was improved, whereas patient dose was reduced. The FGLP training program was implemented by radiology residents and required a minimal investment of time and resources. The LP spine phantom used during training was inexpensive, durable, and effective. In addition, the phantom is compatible with multiple modalities including fluoroscopy, computed tomography, and ultrasound and could be easily adapted to other applications such as facet injections or joint arthrograms.

Key Words: Lumbar puncture; fluoroscopy; dose reduction; simulation training.

Lumbar puncture (LP) is a commonly performed procedure used to provide access into the intrathecal subarachnoid space, either for diagnostic and/or therapeutic collection of cerebrospinal fluid or for the intrathecal administration of medications such as contrast media or chemotherapeutic agents. Although classically performed at the bedside using visual and palpable landmarks, the use of image guidance is associated with increased success rates and has been shown to decrease the rate of traumatic LP (1). The use of image guidance is particularly useful for difficult cases such as patients with

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severe scoliosis, lumbar hardware, or morbid obesity (2). Fluoroscopically guided LP (FGLP) is considered a core competency and is listed in the diagnostic radiology residency milestones by the American College of Graduate Medical Education and the American Board of Radiology (3,4).

Fluoroscopy is an essential component of many image-guided procedures because it provides real-time visualization of procedural instruments and patient anatomy. However, the use of fluoroscopy is not entirely benign. Fluoroscopy exposes both the patient and staff members to potentially high levels of ionizing radiation (5). In 2006, the National Council on Radiation Protection released a report describing a 5.7-fold increase in annual effective radiation dose per individual in the US population owing to medical imaging from 1980 to 2006 (6). More recently, a Sentinel Event Alert from the Joint Commission in 2011 regarding the radiation risks of diagnostic imaging noted that the average radiation exposure in the United States is 4.7 times that of the global population (3 mSv per individual in the United States compared to 0.64 mSv per individual globally) (7).

Because physicians directly control the fluoroscope during image-guided procedures, radiation dose is significantly affected by physician technique (8). It is extremely important that operators of fluoroscopic equipment be appropriately trained in the safe use of such machines and that all exposure to ionizing radiation is kept as low as reasonably achievable (9). Prior studies have shown that formal training programs regarding the safe and appropriate use of fluoroscopy during image-guided procedures can result in significantly reduced radiation doses (10). The purpose of this article is to present the results of a formal training program designed to prepare radiology residents at our institution to safely and efficiently perform FGLP.

Finding or creating an appropriate model is an essential step in the development of any hands-on simulation-based training program. As part of the simulation-based LP training curriculum developed at our institution, we designed and created a custom lumbar spine phantom that is similar anatomically and fluoroscopically to human anatomy. This prototype FGLP phantom is inexpensive, robust, and durable and is designed to provide the visual and tactile simulation of FGLP necessary for resident training (11). This work evaluates whether the use of this phantom in combination with a short didactic training session can improve operator confidence and reduce procedure time and radiation dose while maintaining patient safety for FGLPs performed by resident trainees.

MATERIALS AND METHODS

Data and survey collection for this project was performed with institutional review board approval. Written consent was obtained from all resident trainees who participated in this study.

The formal FGLP training program consisted of a 1 hour didactic curriculum with prelecture and postlecture surveys designed to assess knowledge of technique and anatomy, followed by multiple simulated LPs using the fluoroscopically accurate lumbar spine phantom. Before starting the didactic portion of the training, each resident completed a baseline survey to assess his or her understanding of lumbar spine anatomy and fluoroscopic technique. The didactic lecture provided a review of the relevant anatomy, discussed indications and contraindications for performing FGLP, and outlined the risks and potential complications of the procedure. Pertinent anatomic and radiographic landmarks of the lumbar spine were reviewed, including the vertebral body, facet, pedicle, lamina, spinous process, intervertebral foramen, supraspinous ligament, interspinous ligament, ligamentum flavum, and dura. Common indications and risks for both diagnostic and therapeutic LP were discussed and the procedural differences outlined in detail. The didactic lecture (available in the Appendix) was given to each resident individually immediately before the start of their first neuroradiology rotation. After completion of the didactic training, the residents each performed 20 FGLP simulations over a 1-week time frame using our original lumbar spine phantom.

The lumbar spine phantom was created from materials selected on their tactile and fluoroscopic similarity to bone and soft tissue. A lumbar spine model made of injection-molded polyvinyl chloride (PVC) was used for the core of the phantom, and the soft tissue substitute was made with a thermoplastic polymer (Kraton D1111 K polystyrene-polyisoprene–polystyrene triblock thermoplastic polymer; Kraton Performance Polymers, Inc.). This synthetic tissue substitute was selected because it was inexpensive, colorless, radiolucent, and provided a tactile feel similar to that of human tissue. After mixing the thermoplastic polymer with mineral oil and heating until liquefied, the PVC lumbar spine model was suspended in the gelatin solution, and the phantom was allowed to cool. The creation process for the lumbar spine phantom required 10 hours to complete (including heating time to liquefy the polymer and cooling time to allow the polymer to set). This phantom has a total material cost of approximately US$148.00 and is anatomically accurate when viewed under fluoroscopy as shown in Figure 1. Further details related to the construction of this phantom can be found elsewhere (11). After 20 simulated LPs, residents were asked to subjectively rate confidence in their ability to perform an FGLP, both before and after completion of the training program (on a scale of 1–10; 1: very little confidence, 10: very confident).

FGLP was performed with either personal or direct supervision from an attending physician, and informed consent was obtained from each patient before the start of the procedure. FGLPs were performed using sterile technique with the patient in either the prone or the prone oblique position, and intrathecal access was obtained primarily at the L3–L4 or L2–L3 levels. All prospective and retrospective procedures considered in this study were performed on one of two identical Philips Super 80 CO fluoroscopic units (Philips Healthcare, Andover, MA). Recorded data (for both retrospective and prospective procedures) included the type of procedure performed (diagnostic LP, myelogram, and so forth), indication for the procedure, primary operator (and additional operators in the case of unsuccessful attempts), and total fluoroscopy time (FT, minutes).