Can J Anesth/J Can Anesth (2014) 61:710–716
DOI 10.1007/s12630-014-0173-2

REPORTS OF ORIGINAL INVESTIGATIONS

Low-fidelity simulation improves mastery of the aseptic technique for labour epidurals: an observational study

La simulation de basse fidélité améliore la maîtrise de la technique aseptique des péridurales pour le travail: une étude observationnelle

Naveed T. Siddiqui, MD · Cristian Arzola, MD · Iram Ahmed, MD · Sharon Davies, MD · Jose C. A. Carvalho, MD, PhD

Received: 5 October 2013 / Accepted: 17 April 2014 / Published online: 16 May 2014

Abstract

Purpose *The objective of this study was to determine the impact of a low-fidelity simulation model on mastering the sterile technique during placement of epidural catheters.*

Methods *Trainees, including residents and fellows, were given conventional teaching consisting of a lecture and a video demonstration on the appropriate sterile technique to apply during the placement of epidural catheters. The trainees were then provided with a one-on-one demonstration session using a low-fidelity Styrofoam™ epidural model, followed by a series of simulation sessions. After conventional teaching and following each simulation session, the trainees were assessed on their performance until competence was achieved based on a 15-point checklist. The retention of competence was subsequently evaluated bi-weekly in clinical practice for four assessments.*

Results *Twenty-one trainees participated in the study. The average score for the residents following conventional teaching was 6.0 out of 15 points on the checklist. Following the initial one-on-one hands-on demonstration, the average score increased to 10.8 (difference = 4.8, 95% confidence interval (CI): 3.3 to 6.2; $P < 0.001$). The average score for the fellows following conventional teaching was 7.9 out of 15 points on the checklist. Following the initial one-on-one hands-on demonstration the average score increased to 11.2 (difference = 3.3, 95% CI: 0.05 to 6.6; $P = 0.047$). During the retention of competence phase, scores ranged from 13-15 for both residents and fellows.*

Conclusion *This study describes a comprehensive teaching model for mastering the sterile technique during epidural catheter placement. It suggests that low-fidelity simulation improves the learning process when used in addition to conventional teaching.*

This study was presented in part at the 44th Annual Meeting of the Society for Obstetric Anesthesia and Perinatology, Monterey, California, May 2-5, 2012; and at the Canadian Anesthesiologists' Society Annual Meeting, Quebec City, QC, Canada, June 15-18, 2012.

Author contributions *Naveed Siddiqui*, *Cristian Arzola,* and *Jose Carvalho* designed the study, contributed to data analysis and interpretation, and wrote and revised the manuscript. *Naveed Siddiqui*, *Cristian Arzola*, *Iram Ahmed,* and *Jose Carvalho* contributed to data collection. *Iram Ahmed* and *Sharon Davies* revised the manuscript.

N. T. Siddiqui, MD (✉) · C. Arzola, MD · I. Ahmed, MD · S. Davies, MD · J. C. A. Carvalho, MD, PhD
Department of Anesthesia and Pain Management, Mount Sinai Hospital, University of Toronto, 600 University Avenue, Room 19-104, Toronto, ON M5G 1X5, Canada
e-mail: naveed.siddiqui@uhn.ca

Résumé

Objectif *L'objectif de cette étude était de déterminer l'impact d'un modèle de simulation de basse fidélité sur la maîtrise de la technique stérile de mise en place des cathéters périduraux.*

Méthodes *Des stagiaires, incluant des résidents et fellows, ont reçu un enseignement conventionnel consistant en une conférence et une démonstration vidéo sur la technique stérile appropriée à appliquer au cours de la mise en place des cathéters périduraux. Une séance de démonstration individuelle a alors été offerte aux stagiaires avec l'utilisation d'un modèle de péridurale de basse fidélité en polystyrène expansé™, suivie d'une série de séances de simulation. La performance des stagiaires a* *été évaluée après chaque enseignement conventionnel et après chaque séance de simulation jusqu'à ce que leur compétence ait été réussie en se basant sur une liste de vérification de 15 points. La rétention de la compétence a ultérieurement été évaluée toutes les deux semaines en pratique clinique, avec un total de quatre évaluations.*

Résultats *Vingt et un stagiaires ont participé à l'étude. Le score moyen des résidents après l'enseignement conventionnel était de 6,0 sur les 15 points de la liste de vérification. Après la démonstration individuelle initiale, le score moyen a augmenté à 10,8 (différence = 4,8, intervalle de confiance [IC] à 95 %: 3,3 à 6,2; $P < 0,001$). Le score moyen des fellows après l'enseignement conventionnel était de 7,9 sur les 15 points de la liste de vérification. Après la démonstration individuelle initiale, le score moyen a augmenté à 11,2 (différence = 3,3, IC à 95 %: 0,05 à 6,6; $P < 0,047$). Au cours de la phase de rétention des compétences, les scores ont été compris entre 13 et 15 pour les deux groupes, résidents et les fellows.*

Conclusion *Cette étude décrit un modèle complet d'enseignement pour la maîtrise de la technique stérile de la mise en place d'un cathéter péridural. Les résultats suggèrent qu'une simulation de basse fidélité améliore le processus d'apprentissage quand il est utilisé en supplément à l'enseignement conventionnel.*

Although infection associated with neuraxial anesthesia is rare, it may result in devastating morbidity and mortality. These potential complications vary from superficial skin infection to meningitis, paralysis, and even death.[1] The reported estimated prevalence of infection secondary to neuraxial anesthesia varies widely from 1:40,000 to 1:1,930.[2,3]

During the performance of sterile procedures, such as neuraxial anesthesia, most anesthesiologists appreciate the requirements of sterile gloves, masks, and skin preparation.[4] Nevertheless, less obvious principles of aseptic technique, such as not crossing over the sterile area with bare forearms, are not strictly observed and probably not well taught. This is likely because, historically, the general principles of asepsis have not often been taught to physicians in a formal setting; rather, they are frequently acquired in a "hit and miss" fashion.[5,6] To date, there is a lack of published guidelines that address the teaching principles required to master the sterile technique during the placement of epidural catheters. This suggests a need for the development of teaching models for this task.

In our department, Friedman *et al.*[7] tested the hypothesis that increased clinical experience would help anesthesia trainees learn the necessary manual skills and other components of epidural insertion, such as aseptic technique. Nevertheless, the results of their study showed that the trainees' manual skills improved with increasing experience, but their aseptic technique did not progress. In light of this finding, we subsequently developed a formal instruction session to teach sterile technique by incorporating both a lecture and a video demonstration of the procedure. More recently, we have incorporated a low-fidelity simulator in addition to the formal instruction session.

The purpose of this study was to assess the impact of low-fidelity simulation on the acquisition of skills required to master the aseptic technique for placement of epidural catheters. Furthermore, we sought to determine the number of simulation sessions required by trainees to master their aseptic technique.

We hypothesized that low-fidelity simulation would help anesthesia trainees improve their observance of the sterile technique during placement of epidural catheters.

Methods

Following Mount Sinai Hospital Research Ethics Board (REB #10-0283-E) approval, this study was conducted as an observational one-group before-after study. We recruited second-year anesthesia residents and obstetric anesthesia fellows who agreed to volunteer for the study. Written informed consent was obtained from all trainees and also from patients involved in this project.

At the University of Toronto, anesthesia residents rotate in a four-month obstetric anesthesia block in their second year of residency. They spend two to four day or night shifts per week on the labour floor where they acquire the bulk of their epidural anesthesia training. During their first year of residency, they practice only two months of anesthesia, and their exposure to epidural procedures is minimal. Given the small number of residents in each rotation (typically six), we planned to recruit them sequentially throughout a one-year period. Anesthesia fellows are fully trained anesthesiologists from Canada or abroad who join our one-year program for subspecialty training.

The study was completed in two phases, i.e., the teaching phase and the competence retention phase.

Teaching phase

The teaching phase consisted of a conventional teaching component and a low-fidelity simulation component.

The conventional teaching component comprised a 30-min lecture followed by a 15-min video

Fig. 1 Low-fidelity Styrofoam model

demonstration. The lecture, given by a staff anesthesiologist during the trainees' first week of rotation at Mount Sinai Hospital, covered the core topics of the sterile technique during epidural placement, including the applicable principles of the aseptic technique. The video demonstration addressed the common mistakes and the correct methods for maintaining sterility during epidural catheter insertion. This video was produced in our department and is available as an online Continuing Medical Education module at the University of Toronto, Department of Anesthesia Web site.[8]

The low-fidelity simulation component consisted of trainees performing the epidural technique on a Styrofoam™ low-fidelity simulator (Fig. 1) during which they underwent a systematic assessment using a 15-point checklist.[9] The trainees were initially provided a one-on-one hands-on detailed demonstration on the simulator. Upon completing the one-on-one demonstration, each trainee underwent individual consecutive simulation sessions until they achieved a predefined success level, i.e., mastery of the technique. This level was calculated as the number of sessions the trainee needed to achieve a perfect 15-point score on the itemized checklist plus an extra 25% of sessions with a perfect score. For example, if a trainee were to achieve a perfect score on the checklist after four attempts, another one session with a perfect score would be required to complete the teaching phase of the study.

The performance of each trainee was observed at each procedure and scored by a research assistant trained by the investigators in using the checklist. The checklist was item-based, and each of the individual items was scored as either performed (1) or not performed (0) (see Appendix 1). The study investigators conducted periodic random assessments of the scoring performed by the research assistant. After each simulation session, a debriefing session was conducted with an emphasis on education rather than on assessment. The mistakes made by the trainees were not specifically highlighted; rather, the general concepts of aseptic principles were re-emphasized. The study investigators conducted all of the debriefing sessions.

Both the demonstration session and the simulation sessions were conducted on the labour and delivery floor, and aside from replacing the patient with the Styrofoam epidural model, the routine setup was used in standard patient rooms. Trainees were able to demonstrate all the required steps of an epidural catheter insertion on this low-cost Styrofoam model, which was produced by the study authors (Fig. 1). All procedures were performed with a standard Arrow® 17G epidural needle kit (Arrow International, Reading, PA, USA). Insertions were simulated on the model in a sitting position via a midline approach.

The trainees' performance was assessed using the low-fidelity simulator at the following times: a) upon completion of the conventional teaching; b) after the initial one-on-one demonstration on the simulator; c) after each of the consecutive individual simulation sessions.

Competence retention phase

After the conventional teaching and simulation phase, the retention of competence was evaluated during epidural catheter placements on women requesting labour analgesia. During this phase, the trainees were observed one by one and scored by an investigator using the same checklist. All trainees' epidural placement procedures on labouring women were assessed at predefined time points, i.e., every second week from the point that they achieved competence on the Styrofoam model, for a total of four assessments. The sessions took place in the morning to eliminate the fatigue factor. Morbidly obese patients (body mass index > 40 kg·m^{-2} were excluded to control for technical difficulty, and epidural insertions that required assistance from staff anesthesiologists were excluded from the analysis. Similar to the teaching phase, each of these bi-weekly assessments was followed by a debriefing session; but in this phase, both the fundamental principles of the aseptic technique as well as specific errors were discussed.

Statistical analysis

The primary outcome of this study was to determine the number of sessions required to achieve competence in performing the aseptic technique with the aid of a low-fidelity simulation model. Secondary outcomes were the assessment scores during the conventional teaching and simulation phase as well as during the competence retention phase.

Table 1 Performance scores (out of 15 points) during the teaching and simulation phase

	All trainees $n = 21$ Median [IQR]	Residents $n = 12$ Median [IQR]	Fellows $n = 9$ Median [IQR]
Conventional teaching (Baseline)	6 [6-7]	6 [6-6]	7 [6-9]
Simulation 1 (Initial hands-on demonstration on simulator)	12 [9-13]	12 [9- 12]	13 [8-14]
Simulation 2	$n = 20$	$n = 12$	$n = 8$
	12 [12-14]	12 [12-14]	13 [12-15]
Simulation 3	$n = 17$	$n = 12$	$n = 5$
	14 [13-14]	14 [13-14]	13 [12-15]
Simulation 4	$n = 13$	$n = 11$	$n = 2$
	14 [13-15]	14 [13-15]	15.0 [-]
Simulation 5	$n = 7$	$n = 7$	-
	15 [14-15]	15 [14-15]	
Simulation 6	$n = 3$	$n = 3$	-
	15.0 [-]	15.0 [-]	

n = number of subjects per simulation session; IQR = interquartile range

Table 2 Performance scores (out of 15 points) during the teaching and simulation phase

	All trainees $n = 21$	Residents $n = 12$	Fellows $n = 9$
After conventional teaching (Baseline), mean (SD)	6.8 (1.9)	6.0 (0.6)	7.9 (2.6)
After Simulation 1, mean (SD)	10.9 (2.7)	10.8 (2.1)	11.2 (3.4)
Difference, mean (SD) (95% CI)	4.1 (3.2) (2.7 to 5.6)	4.8 (2.2) (3.3 to 6.2)	3.3 (4.3) (0.05 to 6.6)

CI = confidence interval

Table 3 Performance scores (out of 15 points) during the competence retention phase

Assessment	Overall $n = 20$ Mean (SD) Median [IQR]	Residents $n = 11$ Mean (SD) Median [IQR]	Fellows $n = 9$ Mean (SD) Median [IQR]
1st	13.1 (1.3); 13.5 [12-14]	13.1 (1.3); 14 [12-14]	13.1 (1.5); 13 [12-14]
2nd	14.2 (0.9); 14 [14-15]	14.2 (0.9); 14 [14-15]	14.1 (0.9); 14 [13-15]
3rd	14.9 (0.4); 15 [15-15]	14.9 (0.3); 15 [15-15]	14.8 (0.4); 15 [15-15]
4th	15.0 [-]	15 [-]	15 [-]

n = number of subjects per group; IQR = interquartile range

The sample size was determined by the number of second-year residents and fellows in the program. Prior to study initiation, we ascertained the adequacy of the sample size for assessing the outcomes of interest. Conservatively, we assumed 20 participants would yield a 95% confidence interval (CI) half-width of $\leq$ 2.7 for the average number of sessions required to reach competency and provide 80% power to detect a difference in average score of 0.6 points. Details are provided in Appendix 2.

Descriptive statistics, including means, standard deviations, medians, and interquartile ranges, were calculated for all primary and secondary outcome data. Paired Student's t tests were used to compare performance scores on the first assessment (after conventional teaching) with those on the second assessment (after the initial one-on-one demonstration on the simulator). All reported P values are two-sided.

Results

Twenty-one trainees (12 residents and nine fellows) were recruited over a one-year period, and 84 simulation sessions were conducted.

The mean number of simulation sessions required to achieve mastery of the technique was 3.9 sessions for the overall group, 4.8 sessions for the residents, and 2.7 sessions for the fellows. By definition, all trainees achieved a 15-point mark on the checklist upon mastering the technique (Table 1).

The average score for the residents following conventional teaching was 6.0 out of 15 points on the checklist. Following the initial one-on-one hands-on demonstration, the average score increased to 10.8 (difference = 4.8; 95% CI: 3.3 to 6.2; $P < 0.001$). The average score for the fellows following conventional teaching was 7.9 out of 15 points on the checklist. Following the initial one-on-one hands-on demonstration, the average score increased to 11.2 (difference = 3.3; 95% CI: 0.05 to 6.6; $P = 0.047$).

During the four subsequent assessments carried out in clinical practice during the period of competence retention, all trainees consistently scored in the range of 13-15 points on the checklist (Tables 2, 3).

A graphic representation of the performance of the trainees during both the teaching and the competence retention phases is illustrated in Fig. 2.

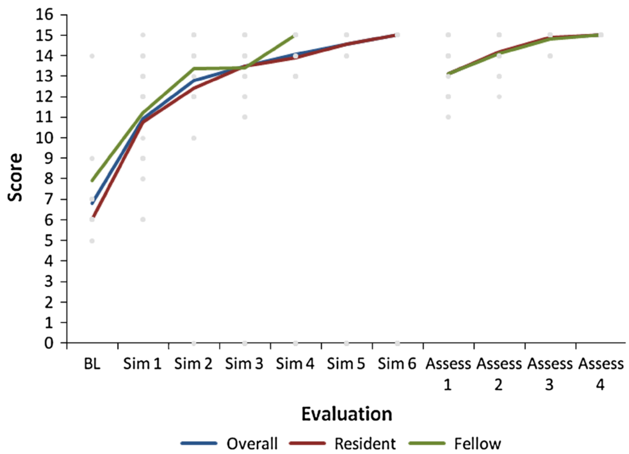


Fig. 2 Performance of trainees during the study period. The lines show the average score for each group across time points. BL = baseline (conventional teaching); Sim = simulation sessions (teaching phase); Assess = follow-up assessments (competence retention phase)

Discussion

The results of this study show that the addition of a low-fidelity Styrofoam simulation model to our conventional teaching method improves the trainees' proficiency in the sterile technique during epidural catheter insertion. Furthermore, our study shows that three to five sessions on the simulator are required before trainees can master the technique. This improvement in performance was sustained over a period of an additional two months after the teaching intervention. These results have important practical implications, as trainees should ideally master the technique on a simulator before proceeding to clinical practice. Our study clearly shows that conventional teaching may not be adequate.

The ideal design for this study would have been a randomized trial; however, we decided *a priori* that all trainees should master the technique before proceeding to clinical practice; hence, we planned the same intervention for all participants. Nevertheless, all trainees performed quite differently after the intervention in the simulator, showing that repetition of the task in a simulator facilitates learning critical elements before trainees move to procedures on patients.

Aseptic technique is an essential part of training in regional anesthesia. It has become even more relevant with the emergence of new data showing that infections secondary to neuraxial anesthesia are more prevalent than previously assumed.[1–3,10] These emerging data have increased concern over appropriate aseptic technique; as a result, it is of paramount importance at this time that anesthesia trainees acquire and implement the core principles of asepsis.

The placement of epidural catheters has been shown to be one of the most complex and difficult skills to learn in anesthesia.[11,12] Furthermore, Friedman *et al.*[7] showed that manual skills for epidural insertion improve with increasing clinical experience, while skills for applying the aseptic technique do not. Trainees tend to focus on the endpoint of correct epidural needle placement and achieving adequate analgesia. With growing experience, they become manually competent, but their poor aseptic technique becomes a fixed routine, which may be difficult to correct. Friedman *et al.*[7] also highlighted another important point. Clinician teachers judge the performance of trainees based more on the efficacy and complications of the procedure than on adherence to the aseptic technique. Principles of the aseptic technique are less concrete and perhaps more difficult to adapt and translate to the actual procedure. In our study, we used a procedure-specific checklist to teach each component of the aseptic procedure required for correct epidural placement.

In previous studies, first-year postgraduate trainees from both the United States and international medical schools showed significant gaps and poor performance of aseptic technique at the beginning of their residency.[13,14] Medical students lack thorough mastery of the aseptic technique, most likely originating from insufficient emphasis in their medical school training.[5] Typical teaching most often includes only general principles which are difficult to translate into specific procedures. As a result, residents often start their training with limited knowledge of and practice in the aseptic technique.

During residency, the teaching of aseptic skills is less focused on "theory" and teaching strategies.[5,6] The principles of the aseptic technique continue to be taught in an unstructured manner.[7] As a result of all these factors, residents fail to correlate the general principles they are taught during medical school with the specifics of the epidural anesthesia technique. Contributing to the problem of non-standardized teaching is the controversy over what is considered "essential" for aseptic technique in regional anesthesia.[4]

As educators, we usually gauge teaching as effective based on the learner's ability to perform a successful procedure without assistance, and we do not recognize breaches in the aseptic technique unless we are specifically looking for them.[9] Consequently, this issue is repeatedly overlooked by teachers throughout the clinical stages of medical education.

In our study, we assessed the performance of the trainees using a task-specific checklist as previously described by Friedman *et al.*[7] One of the limitations of a checklist is its tendency to be quantitative only. We tried to improve the qualitative capability of the checklist by introducing a two-scale feature. This translated to a score of *Yes* or *No* on each checklist item, thus enabling the observer to judge performances more accurately. Similarly, we used the same observer to grade all checklist items. While the use of only one observer may create an observation bias, it reduces the inter-observer variability of the scoring system. Another limitation of the checklist is the fact that all tasks were weighted equally. This may lead to a situation where a high score is achieved on the checklist even though critical tasks are neglected. Nevertheless, for the purpose of teaching a comprehensive aseptic technique, we considered each step on the checklist to be equally important. A potential solution for this problem would be to introduce a pass/fail component for tasks that are considered critical.

Our teaching model incorporated a low-fidelity simulator that allowed us to emphasize all principles of the aseptic technique applied to the task of epidural catheter placement. This resource markedly improved the learning process over the conventional teaching. Furthermore, the trainee's competence was sustained for at least two months. It is beyond the scope of this study to establish whether our effective teaching intervention for aseptic epidural anesthesia placement correlates with a clinical reduction in neuraxial infection rates.

This study has several limitations that need to be highlighted. First, only one person performed the assessments in our study; while this minimizes the inter-observer variability, it may reduce the generalizability of our results. Second, trainees were not randomized to a control and an intervention group, which would certainly be a better study design. Even so, we considered that this was not ethically or educationally acceptable, as we had observed important breaches in the aseptic technique performed prior to the teaching intervention. Third, a longer period for assessments in the retention phase would have been ideal; however, we were limited by the four-month duration of the resident's rotation.

It could be argued that our results simply translate the effect of repeated exposure to the procedure, which naturally occurs in clinical practice. In addition, there is bias induced with the periodicity of the assessments and with the "Hawthorne effect", i.e., the participants are being watched while performing the epidurals. Nevertheless, given the importance of the aseptic technique and the availability of an inexpensive low-fidelity simulator, it may be advisable to ensure that trainees achieve competence in those skills before performing epidural anesthesia in patients.

In conclusion, we have shown that the use of a low-fidelity simulation model helps trainees demonstrate a significant improvement in their adherence to the principles of aseptic technique during the placement of epidural catheters. Furthermore, we have quantified the number of simulation sessions required by trainees to master the aseptic technique. Our teaching method utilized an inexpensive and effective teaching tool that could be incorporated into other teaching programs. Future studies are needed to investigate retention of competence over longer periods of time. Also, studies are needed to compare our teaching model with others that may already be in place but have not been publicized.

Acknowledgement The authors thank Laarni Guerina MD for her collaboration in the recruitment of subjects and data collection.

Financial support Departmental only.

Conflicts of interest None declared.

Appendix 1

Examiner checklist

1. Removes rings and watches
2. Washes hands and arms upon entering the room
3. Wears a hat and puts on a fresh facemask
4. Prepares the skin aseptically (chlorhexidine) and waits for the solution to dry
5. Opens the outside cover of the epidural tray in way that the sterile field is not crossed
6. Washes hands with alcohol gel and air dries
7. Dons gloves in a sterile fashion
8. Opens the inside content of the epidural tray in the correct manner and sequence (top flap opened away from operator)
9. Applies the drape in a cuffed and sterile manner
10. Holds the anesthetic receptacle away from the sterile area to allow assistant to pour in required solutions or withdraw solutions in the syringe
11. Keeps all epidural equipment on the sterile tray when not in use
12. Maintains control over the catheter tip to avoid contamination
13. Dries and cleans the entry site of the epidural catheter if there is any residual antiseptic or blood in the surrounding area and covers it with a sterile dressing while maintaining sterility
14. Works in a manner that minimizes crossing of bare forearms over the sterile field /equipment
15. Maintains vigilance over all sterile fields and equipment and notes any potential breaks in technique.

Total Score out of 15.

1 = performed, 0 = not performed.

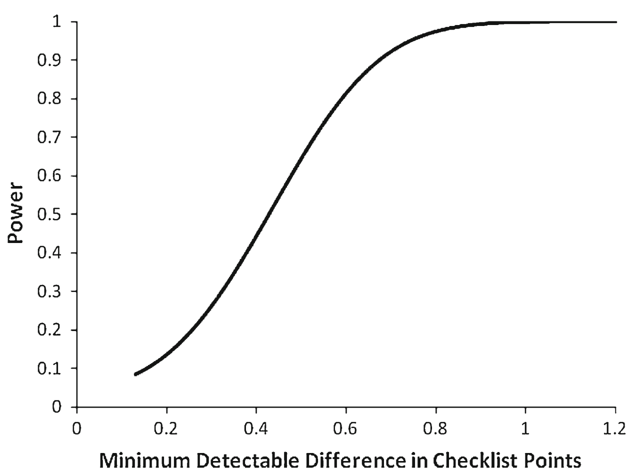
Remarks (number of attempts, management of technical difficulties etc.):

Appendix 2

a) Gamma-based 95% confidence interval half-widths according to the mean number of attempts and assuming a sample size of 20.

Mean number of attempts prior to mastery	95% confidence interval half-width
10	1.73
15	2.09
20	2.40
25	2.66

b) Power calculation



Statistical power as a function of minimum detectable difference in checklist points over four measurements, r = 0.70, SD = 2.4, two-tailed alpha = 0.05, $n = 20$.

Sample size formula

Based on the recommendations of Sundberg (2001), the level of precision based on sample size was calculated using the Chi square estimation approach, where the confidence interval for a non-normal (Poisson) distributed estimate can be calculated as:

$$I = \left(2nY/\chi^2_{2n,(1-p/2)},\ 2nY/\chi^2_{2n,p/2}\right)$$

Where:

I is the confidence interval
Y is the mean of variable Y
n is the sample size
$\chi^2_{2n,(p/2)}$ is the p/2-quartile of a χ^2 distribution with 2n degrees of freedom

Reference

Sundberg R. Comparison of confidence procedures for type I censored exponential lifetimes. Lifetime Data Analysis 2001; 7: 393-413.

References

1. *Baer ET*. Post-dural puncture bacterial meningitis. Anesthesiology 2006; 105: 381-93.
2. *Moen V*, *Dahlgren N*, *Irestedt L*. Severe neurological complications after central neuraxial blockades in Sweden 1990-1999. Anesthesiology 2004; 101: 950-9.
3. *Wang LP*, *Hauerberg J*, *Schmidt JF*. Incidence of spinal epidural abscess after epidural analgesia: a national 1-year survey. Anesthesiology 1999; 91: 1928-36.
4. *Sellors JE*, *Cyna AM*, *Simmons SW*. Aseptic precautions for inserting an epidural catheter: a survey of obstetric anaesthetists. Anaesthesia 2002; 57: 593-6.
5. *Leeper K*, *Stegall MS*, *Stegall MH*. Basic aseptic technique for medical students: identifying essential entry-level competencies. Curr Surg 2002; 59: 69-73.
6. *Norris TE*, *Cullison SW*, *Fihn SD*. Teaching procedural skills. J Gen Intern Med 1997; 12(Suppl 2): S64-70.
7. *Friedman Z*, *Siddiqui N*, *Katznelson R*, *Devito I*, *Davies S*. Experience is not enough: repeated breaches in epidural anesthesia aseptic technique by novice operators despite improved skill. Anesthesiology 2008; 108: 914-20.
8. *Davies S, Friedman Z*. Aseptic Technique for Epidural Catheter Insertion. Information & Communication Technology for the Faculty of Medicine. Mount Sinai Hospital, University of Toronto. Video available from URL: http://admin.med.utoronto.ca/streamer/index.cfm?code=bnXBXzfeUHSy2gY (accessed April 2014).
9. *Friedman Z*, *Katznelson R*, *Devito I*, *Siddiqui M*, *Chan V*. Objective assessment of manual skills and proficiency in performing epidural anesthesia – video-assisted validation. Reg Anesth Pain Med 2006; 31: 304-10.
10. *Phillips JM*, *Stedeford JC*, *Hartsilver E*, *Roberts C*. Epidural abscess complicating insertion of epidural catheters. Br J Anaesth 2002; 89: 778-82.
11. *Kopacz D*, *Neal JM*, *Pollock JE*. The regional anesthesia "learning curve": what is the minimum number of epidural and spinal blocks to reach consistency? Reg Anesth 1996; 21: 182-90.
12. *Konrad C*, *Schupfer G*, *Wietlisbach M*, *Gerber H*. Learning manual skills in anesthesiology: is there a recommended number of cases for anesthetic procedures? Anesth Analg 1998; 86: 635-9.
13. *Wagner DP*, *Hoppe RB*, *Lee CP*. A patient safety OSCE for PGY-1 residents: a centralized response to the challenge of culture change. Teach Learn Med 2009; 21: 8-14.
14. *Lypson ML*, *Frohna JG*, *Gruppen LD*, *Woolliscroft JO*. Assessing residents' competencies at baseline: identifying the gaps. Acad Med 2004; 79: 564-70.