ORIGINAL RESEARCH

# Teaching surgical skills in a resource-limited setting: Comparing massed versus distributed practice in an ultrasound-guided breast biopsy simulator

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## Abstract

### Background
Teaching surgical skills in the simulation lab has increased markedly compared to teaching only in the operating room. Although many studies have been performed investigating the optimal teaching methodology for skills acquisition, there is no consensus on the best method. Massed and distributed practices are important methods in teaching procedural skills. Considering the limited human and logistical resources in low and middle-income settings, it is valuable to understand the optimal methodology for learning and acquiring surgical skills.

### Methods
Thirty-two core needle biopsy-naïve first-year residents and final year medical students rotating in general surgery were enrolled in and completed the study at University Teaching Hospital of Kigali, a tertiary, teaching and referral hospital in Kigali, Rwanda. They were assigned to a "massed" group (i.e., one time, 3-hour practice) or "distributed" group (i.e., 1-hour practice per week for 3 weeks). Trainees were taught ultrasound-guided core needle biopsy on a high-fidelity breast simulator. All participants completed pre- and post-tests and an evaluation of skill retention was performed one month after completion of the training. Analysis of performance was completed, and p-value ≤ 0.05 was considered statistically significant.

### Results
There was no difference between performance on the pretest (p=0.985) and the posttest (p=0.680). Both groups demonstrated improvement after implementation of the simulation training when comparing pretest and posttest results (p<0.001); there were no differences in the evaluation of skills retention after one month after the training between the two groups (p=0.273).

### Conclusions
The results of this study demonstrate that both groups have improved significantly their knowledge and skills. Trainees have similar retention of skills in ultrasound guided core needle biopsy on a breast simulator whether trained under a massed or distributed practice schedule. Both methods may be considered in our setting for teaching surgical skills.

**Keywords:** surgical simulation, resource-limited setting, global surgery

## Introduction

In medical education, and especially in surgical education, instructors try to find more efficient and impactful methods of teaching motor skills to their students to improve learning, performance and retention.[1] Limitations in resident working hours, ethical considerations of patient safety, and budgetary constraints in the operating room have compelled surgical educators to look for more effective and creative means of teaching surgical skills.[2-4] With regard to training in procedural skills, two types of educational practice are important, massed practice, described as training in continuous training blocks, and distributive practice, which involves shorter training periods with rest intervals in between.[5,6] Superiority of distributed practice compared to massed practice has been demonstrated in sports training and several fields in psychology.[6]

Worldwide, the use of simulation education dedicated to teaching procedural skills has become increasingly popular in surgical training programs.[2,7] Simulation training may even result in a set of skills that is directly transferrable to improved performance in the operating room.[8] In low and middle income countries (LMICs), there is a paucity of surgical instructors and resources, and in turn teaching surgical skills becomes even more challenging.[9,10] In Rwanda, surgical residency at the University of Rwanda has improved over the last several years through both local programmatic changes and partnerships with foreign universities; this partnership has led to an increase in the number of surgeons graduating from our training programs each year.[11] In order to improve surgical skills training, a skills simulation center was created at the University Teaching Hospital of Kigali (CHUK). Most of the simulation courses are provided in continuous blocks of time, occurring typically over a one-day practice period. An ultrasound guided core needle biopsy (CNB) training to compare massed practice to distributed practice was developed for the setting in Rwanda with the objective of developing a more effective and feasible means of teaching surgical skills in a variable resource setting.

We sought to compare outcomes after a distributed practice method of teaching surgical skills versus the massed practice method of teaching related to evaluate and to take biopsy of a breast mass using ultrasonographic guidance. Specifically, we wanted to compare baseline knowledge in performing breast CNB, retention of knowledge after one month, and the ability to perform a CNB successfully on a high-fidelity breast simulator between the two groups.

## Methods

### Study design, enrollment criteria, and randomization

This study was conducted between December 2015 and February 2016 at CHUK, a national referral hospital, located in the capital city of Kigali, Rwanda. All participants who met the inclusion criteria and accepted to participate in the study were enrolled. Briefly, prior to enrollment in the study, the purpose of the study was explained to potential study subjects, who were then asked to provide written informed consent. Consent was written in English, which is the standard language used for university students and trainee education in Rwanda. Thirty-two postgraduate year 1 (PGY-1) surgery residents and finalists undergraduate year medical students core needle biopsy naive who were rotating in the surgery department during the study period were enrolled. Residents and medical students who had completed previously an equivalent training in ultrasound-guided core needle biopsy in the past were excluded.

To evaluate the impact of a massed versus distributed practice methodology, participants were allocated into one of two groups by simple randomization using sealed envelopes. Massed practice has been described previously by Bloom and Shuell as practice or training that occurs all at one time versus distributed practice, which involves interrupted practice or training with rest intervals of up to 24 hours in duration.12 In our study, the massed practice (MP) group received all the training sessions in one day, which consisted of two lectures: 1-hour theory covering ultrasonography of the breast and breast lumps and 2-hours of hands-on practice to identify lumps in the breast and perform a core needle biopsy using a breast simulator.

The distributed practice (DP) group received the same training sessions, divided in three sessions of one hour each and given at one-week intervals.

### Simulation training, evaluation and outcome definitions

The breast simulator used was an ultrasound-guided breast biopsy simulator, the US-9 Ultrasound-Guided Breast Biopsy Phantom manufactured by Kyoto Kagaku Co., Ltd. This simulator represents the softness and resistance of the mammary gland, allows simulated fine needle aspiration (FNA) and core needle biopsy (CNB), has excellent image quality, and provides targets that are colored to confirm successful biopsy. In the case of CNB, successful biopsy was represented by blue color. For the ultrasonography, the SonoSiteM-Turbo® portable ultrasound system (FUJIFILM SonoSite, Inc., Washington, United States) was utilized. This is a system that provides adequate images with sharp resolution for proper differentiation of body structures. We utilized a Bard® Magnum® core needle biopsy instrument, gauge 14 (Bard Biopsy Systems, Arizona, United States). This biopsy kit is a spring-loaded, reusable core needle biopsy device, which is small and lightweight with high velocity and precise needle design allowing penetration of up to a depth of 22 mm.

Participants were taught a free-hand technique for performing ultrasound-guided CNB of the breast. Participants were instructed to hold the probe with one hand while the other hand guided the needle. After visualization of the lesion to be biopsied, trainees were instructed to orient the needle parallel and then perpendicular to the ultrasound probe until the needle tip was seen within the lesion, after which the biopsy could be completed. All steps of the CNB can be seen in the evaluation tool shown in Appendix A.10

Trainees were evaluated using a multiple-choice questionnaire and a CNB technical evaluation tool (see Appendix A). The trainees answered the questionnaire prior to initiation of the course ("pre-test") and then again one month after completion of the course ("post-test") (see Appendix B). Retention of skill at performing CNB was also evaluated at the time of post-test completion. The primary outcome of interest was the change in scores between pre- and post-test, as well as a comparison of a difference in pre-/post-test score change between the MP and DP comparison groups.

| Table 1: Participant Demographics by Practice Group | | | |
|---|---|---|---|
| | Massed (n = 16) | Distributed (n = 16) | p-value |
| Sex, n (%) | | | |
| Male | 13 (81) | 14 (88) | |
| Female | 3 (19) | 2 (13) | 1.00 |
| Class, n (%) | | | |
| PGY1 | 6 (38) | 7 (44) | |
| UGY6 | 3 (19) | 3 (19) | |
| UGY5 | 7 (44) | 6 (38) | 1.00 |
| Test Scores, Median (IQR) | | | |
| Pre-Test Score | 6 (4 – 6.5) | 5 (5 – 6.5) | 0.985 |
| Post-Test Score | 7 (6 – 8) | 7 (7 – 8) | 0.680 |

**PGY: postgraduate year; UGY: undergraduate year; IQR: interquartile range**
**p<0.05**

| Table 2: Pre- and Post-Training scores grouped by Low and High Score Categories | | | | |
|---|---|---|---|---|
| | | Post-Training Scores | | |
| | | Low Scores (3-6) | High Scores (7-9) | Total |
| Pre-training Scores | Low Scores (3-6) | 18 (64%) | 10 (36%) | 28 (97%) |
| | High Scores (7-9) | 0 (0%) | 2 (100%) | 2 (3%) |
| | Total | 18 (60%) | 12 (40%) | 30 (100%) |

## Scoring and Statistical analysis

Demographic variables for sex of the participant and level of training were summarized and described for each group. Continuous data was compared using the appropriate test, either Mann-Whitney test or two-sample t-test, as indicated by the distribution of the variable. Categorical variables were compared using chi-squared or Fisher's exact tests, when appropriate. Difference in mean scores on the pre- and post-tests were evaluated individually for the MP and DP groups using Student's t-test. Differences in overall score performance between pre- and post-tests for the two groups was compared using Wilcoxon rank sum. Differences in successful biopsy between the two groups were compared using Pearson's chi-squared or Fisher's exact test, where appropriate. All data were analyzed using STATA version 14.1 (StataCorp LP, College Station, TX). The Institutional Review Boards of CHUK and the University of Rwanda College of Medicine and Health Sciences (CMHS) IRB approved this study.

## Results

Thirty-two participants who met the selection criteria agreed to participate in the study (13 PGY-1 surgery residents; 19 Finalists medical students) and were immediately enrolled in the study. Thirty (94%) participants completed all aspects of the study; 2 (6%) participants did not complete the one month follow-up evaluation (1 resident and 1 medical student). Participants were predominantly male (n=27, 84%). As seen in Table 1, there were no differences in sex of the participants, class/year of training, or pre- vs post-test scores between participants in the MP compared to DP groups. Because there was no difference in pre-training test scores between groups (p=0.985), an equivalent level of pre-training knowledge was apparent in the groups. Also, there was no difference in the overall change (pre-training compared to post-training scores) between the two groups (p=0.831).

There was difference between the overall scores found before and after the training (p <0.001) suggesting that the two groups improved their level of knowledge and understanding of the procedure regardless of the method of teaching used. Finally, we compared pre- and post-training scores and grouped participants into a "Low Scores" group if they scored between 3-6 and a "High Scores" group if they scored between 6-9. Eighteen trainees were low scorers (3-6) before and after the training and 10 trainees improved from 3-6 before the training to 6-9 after the training. Only 2 students had scores within the 6-9 range both before and after the training.

There was no difference in number of successful biopsies between the massed and distributed practice groups ($X^2$ = 1.20, p=0.273), but there was a difference between residents versus medical students and biopsy success, with residents achieving greater success in performing biopsies ($X^2$=9.00, p=0.011).

## Discussion

In our study, we intended to teach ultrasound-guided core needle biopsy to medical students and PGY-1 residents utilizing a high-fidelity breast ultrasound simulator. We recruited PGY-1 residents and 6th year medical students in the surgical department who had not yet been exposed to the targeted skill. Targeting junior residents and medical students without prior experience in the procedure for train-

| Table 3: Biopsy Success Stratified by Practice Group and Training Level | | | | | |
|---|---|---|---|---|---|
| | | Biopsy Result | | | |
| | | Not Successful | Successful | Chi-Square | p-value |
| **Practice Group** | Massed, n (%) | 9 (60) | 6 (40) | 1.20 | 0.273 |
| | Distributed, n (%) | 6 (40) | 9 (60) | | |
| **Class** | PGY1, n (%) | 2 (17) | 10 (83) | 9.00 | 0.011 |
| | UGY6, n (%) | 4 (67) | 2 (33) | | |
| | UGY5, n (%) | 9 (75) | 3 (25) | | |

ing has been a method used in previous studies investigating methods of skill acquisition and teaching in surgery.[6,13] All trainees answered multiple choice questions to test their baseline knowledge in breast conditions and in core needle biopsy. Our study was conducted to address increasing evidence that simulation is a valuable technique in education of health care professionals. Simulation is also important because there is a chronic shortage of personnel, drugs, equipment and training in sub-Saharan Africa. This study is potentially important because there are few prior studies about teaching through low-cost simulation models in low-income countries.[14-16] The guidelines of the World Health Organization (WHO) for health professional education recommend high fidelity methods for training in settings with appropriate resources with a moderate level of evidence towards this recommendation.[17] Rwanda has seen considerable growth in the more than 20 years since the genocide and this time period includes major advances in the health sector. The primary teaching hospital where the present study was performed has a simulation center that is capable of teaching using a combination of both low- and high-fidelity methods. Simulation training is especially important for earlier detection of certain malignancies, which has gained attention in Rwanda in recent years, especially as more and more evidence accumulates that the greatest burden of malignancy worldwide is found in the developing word.[18,19] Given that Rwanda is moving towards earlier detection of breast masses, then this is certainly a justifiable skill to be taught in this setting. Training on the breast biopsy model should both increase the understanding among trainees of the importance of early recognition of breast masses, and likely also increase operator comfort with ultrasonography, in general; this is a skill that is needed badly among general surgeons and general practitioners in Rwanda.

The current study demonstrated no difference in baseline knowledge between the MP and DP groups. There was also no difference in retained knowledge on post-testing between the two groups; however, as expected, we did find that the training and skills session improved the overall knowledge of all trainees regardless of practice group. When comparing the ability to biopsy a lesion successfully using a high-fidelity breast simulator, there was no statistically significant difference between the MP and DP groups. The importance of this finding in a low-resource setting may be related to the ability to teach some skills in a massed or one-time setting, based on prior work in other simulation studies, with a refresher course every 1 to 2 years. Retention of skills learned in simulation is clearly reinforced with real-life application of such skills,[20] and there are plenty of opportunities for core biopsy of breast masses in our setting. In this way, the limited human capacity for teaching of such skills will be better utilized, and the small number of hours dedicated to trainee education can be used as expeditiously as possible. Furthermore, future studies should attempt to focus more on cost-effective, low-fidelity models that can be easily transferrable to any setting, whether in a low or high-income country. These low-fidelity models will make use of limited resources in a resource-constrained environment, such as Rwanda.

The MP group performed the targeted skill similarly to the DP group, a result that is different than previous, similar studies addressing other technical skills.[21-23] In a meta-analysis of the distribution of practice effect by Donovan et al., individuals in spaced practice conditions performed significantly better than those in massed practice conditions.[2]

Our results are in line with those of Mackay et al., who have studied the effect of massed and distributed practice in training of procedural skills.[13] In this study, undergraduate and postgraduate students were recruited and assigned randomly to 3 groups and were taught to grasp an object in virtual space in a virtual reality laparoscopic trainer with a laparoscopic instrument and transfer it to a second instrument before placing it in a defined position. In this study, subjects in all groups improved their skills, and there was no difference between groups for any parameter (i.e., overall score, errors, economy or time).

Our results might also be explained by the nature of the task that was taught to the trainees—training in ultrasound guided core needle biopsy must be considered as a form of single task training. In their study, Lee et al. measured the effects of distributed practice and massed practice on a continuous task and on a discrete task; their results showed a disparity of findings—retention was facilitated by distributed practice in learning a continuous task, but was facilitated by massed practice if the targeted skill was a discrete task.[5]

In another study, Van Dongen and colleagues assigned 32 medical students to four groups with different schedules and were taught seven tasks on a virtual reality simulator. They concluded that distributed practice is superior to massed practice in acquisition and retention of psychomotor skills for endoscopic surgery in virtual simulation.[6] Moulton et al. found that when 38 surgery residents were assigned randomly to one of two experimental groups and were taught to practice micro-suturing on a slit in a Penrose drain, microvascular anastomosis on a 2-mm polyvinyl chloride artery model, and microvascular anastomoses using arteries of a turkey thigh, teaching surgical skills in a distributed practice condition yielded improved transferability to a lifelike model than training under massed practice.[24]

Although some results point to the superiority of distributed practice over massed practice, a strong scientific explanation remains unknown so far.[6] An explanation may be the creation of new and efficient neurologic networks during the rest period, and thereby building the knowledge acquired.[2,6] Our study has shown an overall rapid improvement in the acquisition of the ultrasound-guided core needle biopsy on a breast simulator skill by the trainees in both groups. The current study of massed versus distributed practice in skill acquisition was performed in Rwanda—a low resourced setting. We found equivalency in these two training methods in the training of medical students and surgical trainees in the acquisition of a targeted skill, breast ultrasound and core need biopsy. Given limited resources, the training modality that makes the most expeditious use of financial and human capital should be selected in this setting. Future research will investigate the use of different practice modalities in the acquisition of both discrete and continuous tasks.

There may be a "practice effect" as a bias for our study outcome. However, it is almost impossible to completely control for this effect. The practice effect would have an equal impact on both massed and distributive practice groups. Any future study design could incorporate a delayed testing group to account for loss of skill/retention over time, however most study participants have graduated, making this much harder to accomplish for the current study. The skill studied was a single, simple task. Future studies should incorporate a more complex task, such a simple operation[25] or a series of bedside invasive procedures, such as intubation, central venous line placement, or chest tube insertion. These procedures are essential to surgical training in any setting, regardless of resource availability, and could pose a more complex challenge to surgery trainees, thus providing a means to detecting a measurable difference between massed versus distributive practice groups.

## Conclusions

Our findings suggest that simulation training in a targeted skill may improve knowledge level and procedural understanding regardless of the method of teaching. In a resource-limited environment, such as Rwanda, the ability to administer training in a massed format may be advantageous.

## Competing interests

All authors declare that they have no competing interests related to this work.

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