

# Simulator Education Initiatives for On-Campus Practical Training in Nuclear Medicine Technology

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Because nuclear medicine diagnostic equipment has not been installed at our educational institution, we had not been able to incorporate nuclear medicine techniques into on-campus training until now. **Methods:** We have introduced a diagnostic image processing simulator to replace nuclear medicine diagnostic equipment. The simulator was used to conduct on-campus practical training on nuclear medicine technology. We also conducted a questionnaire survey of students regarding their experience with on-campus practical training using the simulators. **Results:** The survey results revealed that the on-campus practical training using simulators deepened students' understanding of the content they had encountered in classroom lectures. **Conclusion:** We successfully implemented on-campus practical training in nuclear medicine technology using a diagnostic image-processing simulator. According to the results of our questionnaire, it is possible to provide on-campus practical training to students using simulators that enhance understanding of nuclear medicine technology.

**Key Words:** diagnostic image processing simulator; on-campus training; nuclear medicine technology; surveys; questionnaires

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Educational institutions that train nuclear medicine technologists provide on-campus lectures to students so that they can acquire the knowledge and skills necessary to embark on their clinical training. Thereafter, students complete their clinical training at a hospital. After graduation, they are allowed to work as nuclear medicine technologists in hospitals. However, some educational institutions cannot provide sufficient practical training on campus, often because of a lack of access to the range of medical equipment typically used in hospitals by nuclear medicine technologists.

Simulation-based learning has become increasingly popular in medical education (1–3). In the medical field, high-fidelity educational simulation has been reported to promote learning (4). In the field of diagnostic radiology, there are diagnostic device simulators that use the cloud, making it possible to perform simulated imaging examinations.

The advantages of diagnostic device simulators are as follows. Installing a simulator is cheaper than purchasing an imaging diagnostic device, and a simulator can be used as long as a personal computer (PC) that can connect to a network is available. Additionally, simulators can be iteratively trained. Nuclear medicine technology requires more image processing than other modalities. In nuclear medicine, image quality varies greatly depending on the image processing technology applied. By using a simulator to process nuclear medicine images, students can repeatedly engage in image processing and thus acquire useful skills. Our university does not have a designated area for handling radiopharmaceuticals, so nuclear medicine diagnostic equipment has not been installed. Therefore, there are no opportunities for on-campus training using this equipment. However, a diagnostic image processing simulator has been introduced for on-campus training in nuclear medicine technology. Here, we report our efforts to conduct on-campus practical training in nuclear medicine technology using a diagnostic image processing simulator. We also conducted a survey of students to determine their level of understanding of the simulation-based on-campus practical training, and we report the results.

## MATERIALS AND METHODS

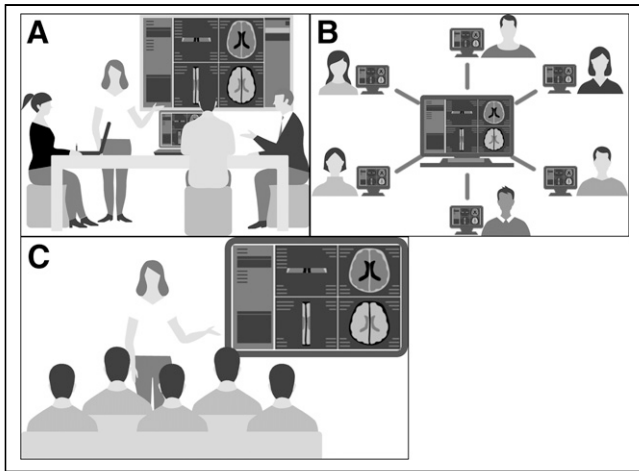
### Study Participants

The study was performed in 2023 and included 107 third-year radiologic technology students (50 men, 57 women; mean age, 20 y). In Japan, training for nuclear medicine technologists involves the same education as training for radiologic technologists. Students pursuing either type of career receive training in nuclear medicine technology and radiologic technology. Therefore, radiologic technology students were targeted for this study. The study protocol was approved by our institutional ethics committee (approval 543). Written informed consent was obtained from all students who participated in the study.

### Diagnostic Image Processing Simulator

The diagnostic image processing simulator used at our institution is the SmartSimulator (Siemens Healthineers). The SmartSimulator connects to the cloud through an Internet-connected PC, making it possible to perform simulated examinations using the various diagnostic imaging modalities installed in the simulator (i.e., MRI, CT, PET/CT, SPECT/CT, and angiography). This simulator can be used in the following ways: students can learn by operating the simulator in a laboratory, individually, or in a group, and simulator operations can be projected onto a large-screen

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**FIGURE 1.** Example uses of SmartSimulator. (A) Students' learning is supported in group laboratory setting. (B) Each student operates simulator that supports learning. (C) Teachers operate simulator during lectures, and simulator operations can be projected onto large-screen monitor to support students' learning. (Courtesy of Siemens Healthineers Co. Ltd.)

monitor during lectures to aid students' learning. Figure 1 shows examples of how the simulator is used. The SPECT/CT simulator uses SPECT data from scintigraphy, static, and CT images that can be used for image reconstruction.

### Training

During the study period (April to July 2023), 11 groups, each comprising 9–10 students, received on-campus practical training once a week. The practical training consists of 11 modules, one of which is nuclear medicine technology. In total, the 11 modules were covered over 11 wk, and all students completed their on-campus practical training during this time.

A SmartSimulator was installed on the PC operated by the students, and a SPECT/CT simulator was used. As part of their practical training, students were familiarized with the image processing technology using SPECT/CT data. Using the large-screen monitor, the instructor explained the SmartSimulator operations to the students, who then performed the same operations on their own PCs while looking at the instructor's example. The on-campus practical training continued until each group had completed the 4 tasks described below, which took approximately 3 h. The tasks involved content that had already been encountered in classroom lectures. The reason we incorporated the tasks into the on-campus practical training is that students often comment that they find it difficult to understand the classroom lectures.

*Creation of Images Using Various Reconstruction Methods.* Using SPECT data for the pelvic region obtained by bone scintigraphy, we created reconstructed images via the filtered backprojection and 3-dimensional ordered-subset expectation maximization methods. Images were also created by arbitrarily changing the reconstruction parameters (iteration and subset). The students viewed the images they had created and learned how the images differed depending on the image reconstruction method used.

*Creation of Images Using Butterworth Filter with Various Cutoff Frequencies.* SPECT data for the pelvic region obtained by bone scintigraphy were used, with filtered backprojection applied for image reconstruction. A Butterworth filter was

used as a preprocessing filter, and the cutoff frequency of the filter was arbitrarily changed to create the images. The students familiarized themselves with the effects of various cutoff frequencies on image quality.

*Creation of Images Using Various Types of Preprocessing Filters.* SPECT data for the pelvic region obtained by bone scintigraphy were used, with filtered backprojection applied for image reconstruction. The students created images using various preprocessing filters. Students gained experience in the impact of each type of preprocessing filter and learned how to adjust the cutoff frequency and order to improve image quality.

*Creation of Images With and Without Attenuation Correction.* SPECT and CT data from myocardial perfusion scintigraphy were used to create SPECT images with and without attenuation correction. Specifically,  $^{99m}\text{Tc}$  and SPECT exercise load data were used. The images were of a case in which the inferior wall of the myocardium was affected by attenuation artifacts in the diaphragm, and uncorrected images were improved by CT attenuation correction. Students were able to observe the improvement in image quality.

### User Opinion Survey

After their on-campus training, students completed a questionnaire exploring how use of the SmartSimulator contributed to their understanding of radiologic technology. The questionnaire comprised the following elements.

*Understanding of Training Content.* The questionnaire examined the students' understanding of the 4 tasks covered during on-campus training using 5 rating options (excellent, good, average, fair, and poor).

*Understanding of Nuclear Medicine Technology.* We investigated whether on-campus training using the simulator deepened the students' understanding of nuclear medicine examination technology and the importance of image processing. The survey items used the same 5 rating options as listed above.

*Understanding of How to Use SmartSimulator.* The students were asked about how they felt the SmartSimulator should be used. The response options were as follows: "Should be used in lectures," "Should be used in on-campus practical training," "Should be used in lectures and on-campus practical training," and "Does not need to be used at all."

*Interest in Nuclear Medicine Technology After Training.* The students were asked to rate their level of interest in nuclear medicine testing technology after training using the SmartSimulator. There were 5 options: excellent, good, average, fair, and poor.

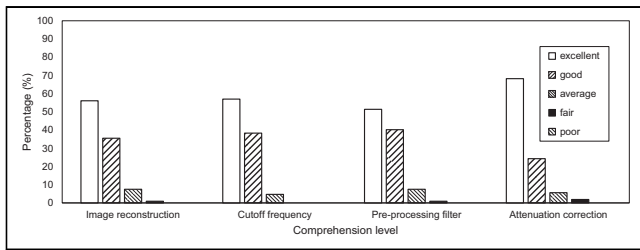
*Free-Text Description of SmartSimulator.* Students were asked to write down their opinions of the SmartSimulator. Completion of this section was optional.

## RESULTS

The user opinion survey response rate was 100%.

### Understanding of Training Content

Figure 2 shows the results regarding training content. For image reconstruction, understanding was reported to be excellent by 56.1% ( $n = 60$ ) of the respondents, good by 35.5% ( $n = 38$ ), average by 7.5% ( $n = 8$ ), and fair by 1.0% ( $n = 1$ ). No respondent reported poor understanding of image reconstruction. Regarding the cutoff frequency of

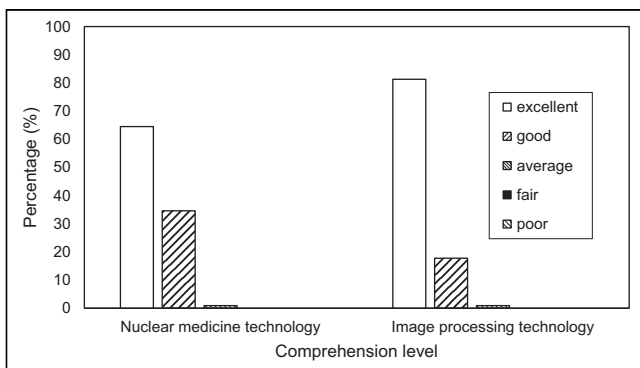


**FIGURE 2.** Level of understanding of modules of on-campus training program on nuclear medicine technology: reconstruction, preprocessing filter cutoff frequency, preprocessing filter, and attenuation correction.

preprocessing filters, understanding was rated as excellent by 57.0% ( $n = 61$ ) of the respondents, good by 38.3% ( $n = 41$ ), and average by 4.7% ( $n = 5$ ). No respondent reported fair understanding of the cutoff frequency of preprocessing filters. Regarding preprocessing filters, understanding was reported to be excellent by 51.4% ( $n = 55$ ) of the respondents, good by 40.2% ( $n = 43$ ), average by 7.5% ( $n = 8$ ), and fair by 1.0% ( $n = 1$ ). No respondent reported poor understanding of preprocessing filters. Finally, regarding attenuation correction, understanding was reported to be excellent by 68.2% ( $n = 73$ ) of the respondents, good by 24.3% ( $n = 26$ ), average by 5.6% ( $n = 6$ ), and fair by 1.9% ( $n = 2$ ). There were no reports of poor understanding of attenuation correction.

#### Understanding of Nuclear Medicine Technology

Figure 3 shows the results regarding the level of understanding of nuclear medicine technology after on-campus training. Understanding of the importance of nuclear medicine technology was reported to be excellent by 64.5% ( $n = 69$ ) of the respondents, good by 34.6% ( $n = 37$ ), and average by 1.0% ( $n = 1$ ). Understanding of the importance of image processing in nuclear medicine technology was rated as excellent by 81.3% ( $n = 87$ ) of the respondents, good by 17.8% ( $n = 19$ ), and average by 1.0% ( $n = 1$ ). There were no reports of fair or poor understanding of nuclear medicine technology or the importance of image processing.



**FIGURE 3.** Level of understanding of importance of nuclear medicine technology and image processing after on-campus training on nuclear medicine technology.

#### Understanding of How to Use SmartSimulator

The response “Should be used in lectures” was selected by 2.8% ( $n = 3$ ) of the respondents, whereas “Should be used in on-campus practical training” was selected by 61.6% ( $n = 66$ ) and “Should be used in lectures and on-campus practical training” by 35.5% ( $n = 38$ ). No student indicated that the SmartSimulator does not need to be used at all.

#### Interest in Nuclear Medicine Technology After Training

The level of interest in nuclear medicine technology after operating the SmartSimulator was rated as excellent by 33.6% ( $n = 36$ ) of the respondents, good by 61.7% ( $n = 66$ ), and average by 4.7% ( $n = 5$ ). No respondents rated their level of interest in nuclear medicine technology as fair or poor.

Table 1 summarizes the positive and negative free-text comments about the SmartSimulator.

#### DISCUSSION

In the past, our institution was not able to provide practical on-campus training in nuclear medicine technology because of a lack of diagnostic equipment. Therefore, we attempted to implement on-campus training in nuclear medicine technology using a diagnostic image processing simulator. In this questionnaire-based study, we surveyed students regarding their perceptions of the usefulness of simulator education for on-campus training.

Our on-campus practical training used SPECT data installed in the diagnostic image processing simulator. Through these data, students familiarized themselves with image reconstruction, the Butterworth filter cutoff frequency, preprocessing filters, and attenuation correction. The responses to the questionnaire showed that the students had acquired a good understanding of all these topics. Having the opportunity to perform image processing themselves gave the students an in-depth understanding that they were not able to obtain via lectures. The students were able to successfully link what they experienced in practical on-campus training with what they learned in classroom lectures, which we believe led to a better understanding of nuclear medicine technology and the importance of image processing.

Many students expressed a desire to continue using the simulator as part of on-campus practical training. However, some students wanted the simulator to be incorporated into regular classroom lectures. Before using the simulator for on-campus practical training, instructors had used the simulator in class to give students a preview of image processing methods. We believe that students will be better able to operate the simulator during on-campus practical training if they have been shown how to process images in advance during lectures in the classroom. Therefore, we plan to incorporate this educational simulator into classroom education in the future. We also found that students’ interest in nuclear medicine technology increased after on-campus practical training using the simulator. Most students expressed a preference for working in general radiography, CT, or MRI after graduation. However, we hope to increase the number of

**TABLE 1**  
Positive and Negative Free-Text Comments on Use of SmartSimulator

Positive comments	Negative comments
By actually operating image processing, I was able to deepen my understanding of work in nuclear medicine technology	I felt that speed of training should have been slowed down a bit (because it was difficult to use computer)
It was great to be able to actually experience image processing by operating PC	On instructor's preview screen, some parts were difficult to understand because text on screen was small
It was difficult, but I managed to understand it	I would like there to be improvements to PC operation screen as it was difficult to see, and cursor position was sometimes difficult to see
Practical training was a little difficult, so I wanted to write report while reviewing it	After doing practical training, I realized that image processing in nuclear medicine technology is difficult
Content of training itself was very good, and I gained a lot of knowledge through experience	Mouse response on my PC was poor, and it was difficult to make detailed adjustments
When I started working as a radiologic technologist, I realized that I wanted to be involved in nuclear medicine examinations	It was difficult to understand because characters in simulator are written in English
It's difficult to use PC, but it's fun once you get used to it	
Thank you	
I learned that image processing filters, etc., can be devised to make images easier to see	
It was great to be able to interact with images that are different from CT and MRI	
I was able to understand how to process images by performing operations myself	
It was a good experience, as I had never used a simulator before	
It was easy to understand differences between various images after image processing	

students who are interested in nuclear medicine technology by exposing them to it during on-campus training.

The feedback provided in the free-text description section of the questionnaire was generally positive, including comments such as "It was great to be able to actually experience image processing" and "I was able to deepen my understanding of work in nuclear medicine technology." These comments indicated that the experience gained by practical on-campus training, which cannot be acquired in classroom lectures, improved students' level of understanding and satisfaction. We believe that this experience will increase undergraduates' interest in nuclear medicine technology and improve their learning. However, there were some negative comments regarding the operation of the simulator. We intend to discuss these comments with the manufacturer in a way that will lead to further development of simulator use.

On the basis of our findings, we believe that on-campus practical training in nuclear medicine technology using a simulator is beneficial for students. The focus of curricula in medical schools has changed from classroom lectures to demonstrative methods that assess the abilities of learners (1). Our educational institutions that train nuclear medicine technologists are promoting education that emphasizes practical skills. Simulation education also includes active engagement in learning (5), and students can learn independently using simulators. Furthermore, simulation training is able to improve technical skills in a risk-free environment while eliminating the human factor (2). For this reason, simulation

education is currently being promoted at educational institutions that train nuclear medicine technologists. We believe that simulator education will become an essential component of future education at all educational institutions that do not have access to diagnostic imaging modalities for training.

It is important to note that students learn at different rates. There were differences in basic knowledge among our students, which led to differences in the speed at which practical training progressed. Students who had basic knowledge and were proficient in the use of PCs finished their assignments early, such that they had to wait before moving on to the next assignment. Before the on-campus practical training, all students were encouraged to review the basic practical content and were instructed to study the simulator operating manual. In the future, we would like to make adjustments to the timing and implement practical training.

In addition, we would like to use a simulator during regular classroom lectures to give presentations to students on how to process images. When students are able to understand image processing to a reasonable extent, operating a simulator during on-campus practical training will further improve their level of understanding and satisfaction. Remote education has become established because of the coronavirus disease 2019 pandemic (6–10). Some educational institutions offer a mixture of face-to-face and remote lectures (11). We believe that the simulator is an ideal teaching aid for use in remote lectures. Moreover, the simulator is loaded with data from various modalities. Currently,

only nuclear medicine technology training is conducted using this simulator during on-campus training. It is hoped that modalities other than nuclear medicine technology will soon be incorporated into on-campus practical training.

The main limitation of this research was that, although the SPECT/CT modality of the SmartSimulator allows image processing using SPECT data, it is not possible to observe the photographing operation. Because it is necessary to have experience in operating a  $\gamma$ -camera and taking pictures, consideration of these elements is also required.

## CONCLUSION

We provided on-campus practical training on nuclear medicine technology using a diagnostic image processing simulator. According to the results of the questionnaire survey, the introduction of the diagnostic image processing simulator for on-campus training was beneficial for students. At educational institutions without nuclear medicine diagnostic equipment, simulator education during on-campus practical training can improve students' understanding of nuclear medicine technology. We intend to continue to focus on research into simulator education so that on-campus training can be further improved.

## DISCLOSURE

No potential conflict of interest relevant to this article was reported.

## ACKNOWLEDGMENTS

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