Using the ACNP Proficiency Testing Program to Develop Critical Thinking

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Critical thinking is cited as one of the essential skills for clinical practice. Educators need to be aware of barriers that may hinder the development of this skill in students and cultivate strategies to encourage it. This article describes one strategy to develop critical thinking.

Methods: Students participated in a critical thinking exercise by imaging the American College of Nuclear Physicians (ACNP) Renal Imaging Proficiency Test Phantom, critiquing their results, and comparing their results to results collected nationally in other nuclear medicine facilities and the true values reported by the ACNP. Students were instructed to review pertinent imaging principles before discussing the imaging results. They also were supplied with a list of questions pertinent to the review.

Results: Students experienced the complexity of designing a SPECT imaging protocol and how the final results are affected by the choices made by the technologist. They learned the importance of and method for proper matrix selection, determination of pixel size and the necessity for quality control.

Conclusion: The imaging exercise was a successful means of helping students connect clinical practice with theory through the use of critical thinking.

Key Words: critical thinking; proficiency testing; professional practice

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Achieving desired outcomes is a theme in both education and medicine today. The ability to think critically has been cited as a necessary educational outcome for students at all levels, including allied health students (*1–5*). New technology, the growing expectations of patients and employers, and the demands of working in a managed care environment are factors that require practitioners to think critically and creatively.

What is critical thinking? There is no standard definition for this term. For this article, critical thinking is defined as "an analytical process that applies inquisitive and creative thought patterns to the evaluation and organization of information" (*3*). Characteristics of a critical thinker include someone who is "habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit" (*6*). Kyzer summarizes these characteristics and applies them to clinical practice in a model that includes a combination of the practitioner's knowledge and experience, attitudes, thinking strategies and skills (Fig. 1) (*7*).

How easily are these characteristics cultivated in nuclear medicine technology (NMT) students? Students enter NMT programs already having adopted a learning style. This style may or may not encourage the development of critical thinking skills. For example, students may be accustomed to thinking that making a mistake is always bad, that there is only one right or best way to do things, or that the answer is always a definitive one and the faculty knows what it is (*4*). Likewise, faculty may have developed a teaching style that does not foster critical thinking. They may believe that technical proficiency indicates understanding of the task or that mastery of course content automatically translates into the ability to think critically (*4*).

What strategies can be used to promote critical thinking in the NMT student? First, faculty must value critical thinking as a desirable skill. Then they must develop an environment where critical thinking is expected and practiced. While it is necessary to provide students with clinical experience performing routine patient procedures, it does not always challenge them to think critically and analyze applications.

There are a variety of strategies to teach thinking. This article describes one method. Since 1973, the College of American Pathologists has produced imaging phantoms twice a year for assessing practice proficiency (*8*). In 1994, the American College of Nuclear Physicians (ACNP) assumed operational responsibility for the Nuclear Medicine Imaging Proficiency Testing Program. Each phantom is unique, demonstrating actual clinical problems in technique and diagnosis found in

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Skills	Technical Time Management Prioritization Assertiveness Communication Negotiation Problem solving
Thinking Strategies	Gathering facts & ideas Thinking in a new way Using organizing procedures Thinking from all perspectives Seeing patterns
Attitudes	Attentive ..... Autopilot Open/flexible . . Closed/Rigid
Foundations	Experience . . . . Inexperience Knowledge . . . . Lack of knowledge

PRACTITIONER

FIGURE 1. The practitioner model. Reprinted with permission from: Kyzer SP. Sharpening your critical thinking skills. *Orthopaedic Nursing* 1996;15:68.

nuclear medicine practice. We used the test phantom to reinforce principles of imaging and choice of imaging parameters, and the value of quality assurance testing.

METHODS

In the fall of 1996, the NMT program in Buffalo, New York obtained the ACNP Renal Imaging Proficiency Test Phantom for a class project. With this phantom, five students performed the imaging exercise on five different cameras at five clinical sites. Two additional students performed the imaging exercise on two different cameras at a clinical site that was an Imaging Proficiency Testing Program subscriber. Each of the seven students worked with a different staff or supervising technologist. Results for all seven cameras were submitted to the ACNP for evaluation.

The 1996 Renal Emission Phantom was designed for SPECT or planar imaging. The kidneys are positioned at different depths within the phantom, and each kidney contains several lesions of various sizes and shapes. The student project focused on the first four goals, listed below, since the fifth goal was primarily the responsibility of the physician. The goals of the exercise were to:

1. Compare the resolution capabilities of SPECT and/or planar imaging;
2. Identify the number and location of lesions in each kidney;
3. Measure the size of the largest lesion;
4. Determine the ratio of the activity in the two kidneys using different calculation methods; and
5. Give a clinical interpretation that would be most consistent with the lesions visualized for symptoms reported by a hypothetical patient.

The data collected on the submission result forms were summarized in tables for class review. Several of the tables are shown here as examples. There were four different camera/computer manufacturers. No two systems used the same software version (Table 1). On six cameras, the phantom was imaged using both planar and SPECT techniques (Table 2). The parameters listed in Table 2 were the parameters reported at the time that the phantom was imaged. On one camera, only planar images were obtained. Table 3 lists the location and the size of the lesions visualized in each kidney.

The data from the seven cameras was reviewed twice in class: once before receiving the ACNP's critique of the results and once after reviewing the critique. The students were given the tables summarizing the data for all seven cameras. Before the second review of the data, the students were given copies of the ACNP's critique. Before and in preparation for each class discussion, the students were given a set of questions and specifics to review (Appendices 1 and 2).

RESULTS

The first review focused on the matrix size chosen for SPECT imaging, the listed pixel sizes and the ability to consistently identify the lesions. None of the sites performed clinical renal SPECT at the time the phantom was imaged. For this reason, parameters to image the phantom were not existing

TABLE 1
Instrumentation Data

Camera	Manufacturer	Year of installation	No. of detectors	FOV cm	Collimator LEHR	Collimator LEAP
1	A	1990	1	42 C		X
2	B	1989	1	41 C	X	
3	C	1989	1	41 C	X	
4	D	1986	1	39 C		X
5	B	1993	1	51.5 × 39	X	
6	A	1994	1	42 C		X
7	B	1994	1	51.5 × 39	X	

C = circular.

TABLE 2
Acquisition and Processing Parameters

Camera	Planar Matrix size	Planar Pixel size (mm)	SPECT Matrix size	SPECT Pixel size (mm)	No. of stops	Time/Stop (sec)	SPECT Counts/Stop (K)	Orbit	Filter used
1	128 × 128	3.11	64 × 64	6.23	64	30	1K	C	Butterworth
2	256 × 256	0.66	64 × 64	10.5	64	30	—	C	Butterworth
3	128 × 128	3.2	64 × 64	6.4	64	30	—	E	Modified Shepp and Logan
4	128 × 128	1	128 × 128	1	64	15	—	E	Hanning/Ramp
5	256 × 256	1.1	—	—	—	20	~3K	C	Butterworth
6	128 × 128	3	64 × 64	6	64	40	—	C	Butterworth
7	256 × 256	2.4	64 × 64	9.6	64	20	—	E	Butterworth

C = circular; E = elliptical.

procedures. One site used the same matrix size for both planar and SPECT imaging of the renal phantom. Five sites that performed a SPECT acquisition used a smaller matrix size for SPECT acquisition than that used for the planar acquisition. In all six clinics that performed a SPECT acquisition, the matrix size for SPECT was chosen by consulting the equipment support service, the equipment operations manual or by calling other sites for suggestions.

The matrix size chosen for imaging should preserve resolution. One must know the camera's resolution to properly select matrix size (*9*). In didactic coursework, students were instructed about appropriate matrix selection. This material was reviewed with the students during the review of the phantom results.

Achieving high (optimal) resolution with a larger matrix size is an acceptable practice in standard planar imaging. In SPECT imaging, using a larger matrix size (128 versus 64 or 256 versus 128) will result in a fourfold increase in disk space, uniformity correction statistics, network transition time, processing time, archiving space and acquisition statistics (*10*). This may be the reason that five sites used a smaller matrix size for SPECT.

How to measure pixel size and the importance of accurate pixel size also was reviewed. An accurate pixel size is critical to determining lesion size. An estimate of pixel size can be made by dividing length or diameter of the field of view by the matrix size (64 or 128 or 256). For three cameras in the study, the pixel size listed appeared to be correct. For the remaining four cameras, it appeared to be incorrect.

The phantom's right kidney had a 0.9-cm lesion in the upper pole and a 1.9-cm lesion in the mid segment. The phantom's left kidney had a 1.9-cm lesion in the upper pole and a 1.2-cm lesion in the lower pole.

Images from all seven cameras visualized a lesion in the middle right kidney and upper left kidney. Other findings were variable. Lesions were found or suspected in all other areas of the kidneys. The measured size of the largest lesion visualized ranged from 1.1–3.4 cm.

The second review focused on why the class results (lesions detected and largest lesion size) varied so much. The significance of the activity ratios also was discussed.

Nationally, more sites that used a 128 × 128 matrix size for SPECT imaging, compared to a 64 × 64 matrix size, identified

TABLE 3
Size and Location of Visualized Lesions versus Actual Lesions

Camera	Interpretation: Right kidney U	Right kidney M	Right kidney L	Left kidney U	Left kidney M	Left kidney L	Largest lesion (cm)
1	1	2	1	2	1	1	3.1
2	2	2	0	2	0	1	1.4
3	1	2	0	2	2	0	—
4	0	2	0	2	0	0	1.8
5	0	2	0	2	0	1	1.1
6	0	2	0	2	0	1	1.4
7	0	2	1	2	0	0	3.4
True lesion size (cm)/location	0.9	1.9	—	1.9	—	1.2	

U = upper pole; M = mid segment; L = lower pole.
0 = no lesions; 1 = possible lesions; 2 = definite lesions.

the locations of the smaller lesions correctly and correctly measured the size of the largest lesion. Of the seven cameras used in the class project, only one demonstrated all lesions correctly and had no false-positives. Another camera correctly demonstrated the correct size of the largest lesion within $\pm$ 15%. Three cameras demonstrated a lesion in a place where one did not exist (false-positives). There was no correlation between the age of the camera or the type of collimator and the findings.

None of the students had calculated activity ratios for the kidneys in their clinical experience. Activity ratios for the kidneys may be calculated to estimate the percent functional tissue in each kidney. The ACNP's results stated that most participants found that both the arithmetic and geometric means of the anterior and posterior counts obtained for each kidney provided a more reliable basis for estimating the true activity ratios for the two kidneys than did using the ratio of either anterior or posterior counts. This is significant in cases where the kidneys are located at different depths from an anterior-posterior perspective, such as may occur in transplant patients or in cases where one kidney has been displaced for anatomic or pathologic reasons.

DISCUSSION

Some students felt that neither they nor the mentoring technologists took the exercise seriously enough because it was a student project. They were also, in most cases, rushed for time. In some cases, the findings (lesions seen in each kidney) were determined without physician input. Since technologists do not interpret images, the reported findings may be flawed in these cases.

Nevertheless, the class project raised student awareness and appreciation for the necessity of quality control and proficiency testing. They also learned how parameters are developed for new imaging protocols. The students all commented that this class project was both interesting and a worthwhile exercise for their professional development. When asked what they might do if they obtained the results of this experiment in their own department, the students suggested the following:

- Image a resolution phantom to see what the resolution capability is;
- Experiment with different filters;
- Acquire more counts (by increasing the matrix size and/or counts per stop);
- Repeat the study until it is correct (by altering acquisition and/or reconstruction choices); and
- Defer any renal SPECT imaging until further phantom testing is performed.

CONCLUSION

This exercise is an example of how educators can prepare students to be self-directed learners through developing critical thinking skills. Educators sometimes assume incorrectly that students can make the connection between theory and practice if they have mastered content; however, just as we teach content we also must teach how to think to arrive at an answer or draw a conclusion. In fact, the emphasis on content mastery may kill or minimize thinking mastery. While content mastery may serve students in the short run, it does not equip students to handle the unique problems that arise in clinical practice or the rapid changes that characterize today's health care environment.

Another assumption that NMT educators make is that the connection between theory and practice occurs during the clinical practicum. Clinical demands (patient care comes first) require that students apply their knowledge and skills to the immediate task at hand. Also, clinical instructors may not have time or be adept in helping students apply their knowledge. Developing psychomotor skills is important; certainly a technologist needs to be proficient in positioning patients or inserting intravenous lines. But just as critical is the intellectual connection between clinical practice and theoretical insight (*11*). Class projects such as the one described in this article can bridge the gap between scientific knowledge and practical knowledge that are frequently viewed as mutually exclusive in clinical practice. If clinical practice is to improve, scientific knowledge must be valued as much as practical knowledge, and the intellectual connection between theory and practice strengthened. When this happens, practitioners are said to be reflective, that is, their actions are "based on an internal autonomy rather than an external authority" (*12*). They "reflect on the environment, consider possible approaches to a given problem and pay attention to his or her own internal feelings and educated intuitions" (*12*).

Along with increasing knowledge, the goal of an educational program should be to increase students' skepticism (*13*) by encouraging them to question assumptions about clinical practice. In this instance, proficiency testing results were used to initiate the critical thinking process. How many times have one of the following answers been offered to the question "Why?": "We've always done it this way," or "The doctor likes it this way," or "It's what works in our clinic." The followup questions to each of these responses might be: Why did we start to do it this way in the beginning; what is the reason behind the doctor's preference; what doesn't work and what else has been tried? Exercises such as the one described in this article are useful for experienced technologists as well as students.

Subscribing to the philosophy of lifelong learning, practitioners may consider themselves to be students as well. When we question our clinical practice, we discover that we are all learners and we are all teachers, that we all have something to contribute to our understanding of clinical practice.

Incorporating critical thinking into the NMT curriculum in various ways can help our graduates be more competitive in a constantly changing workplace. Reflective technologists who use critical thinking skills only can improve and expand the practice of nuclear medicine technology.

APPENDIX 1

Review of Data and Comparison of Results

1. How did you choose the matrix size for imaging and determine the associated pixel size?

2. Comment on your matrix size choice for SPECT. Is it a reasonable choice and why?
3. Is your listed pixel size correct? Explain why (how you are certain).
4. What is the significance of pixel size?
5. Review the lesions found in different regions of each kidney. What were the consistent findings? What were the inconsistent findings?
6. Did clinics using a high-resolution collimator find more lesions?
7. Ideally, what should the right/left activity ratio be?
8. Look at right/left anterior and posterior count ratios listed. What things might account for the range of values listed?
9. Comment on the correlation between the geometric means and the arithmetic means.
10. Why would a clinical nuclear medicine department want to do an exercise such as this one?

APPENDIX 2

Comparison of Class Results with ACNP Report

SPECT Versus Planar Imaging

1. Were you able to see the large lesions with planar imaging?
2. Do you think SPECT imaging helped to improve lesion detection? In other words, did you identify a lesion correctly using SPECT that was not identified with planar imaging?

Number and Location of Lesions

3. How many cameras in our class project identified all the lesions correctly and had no false-positives? (We will accept 1 = possible as having identified the lesion.)
4. Did you have any false-positives?
5. How many false-positives did we have in the class?
6. Did the newer equipment (equipment less than 5 yr old) do a better job identifying the lesions correctly?
7. List some possible reasons why we did not identify all of the lesions and/or had false-positive.

Measure the Size of the Largest Lesion

8. How many from our class correctly identified the size of the largest lesion within +15% (1.6–2.2 cm)?
9. How does this compare with others around the country who did the exercise (ACNP Report, page 4)?
10. Why does a larger matrix size improve the ability to visualize small lesions?

Calculation of Activity Ratios

11. Which of the ratios (anterior counts, posterior counts, geometric mean, arithmetic mean) most closely approximated the true ratio for you?
12. How does your result compare with the ACNP's summary report? Which ratios are more reliable and why? (ACNP Report, pages 4–5)
13. How are activity ratios for kidneys calculated and why?

Other

14. Review the discussion in the report on pixel size (ACNP Report, page 7). We will discuss it further in class. Also review the discussion on types of filters (ACNP Report, pages 8–9).
15. If you were a chief technologist that participated in the proficiency phantom exercise and got less than perfect results, what actions would you take and why?
16. What did you learn from this exercise specifically about nuclear medicine instrumentation and imaging?
17. What principles of imaging and/or instrumentation taught in class did this exercise clarify or reinforce for you?
18. Was this a worthwhile exercise for your professional development?

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