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# RADIOLOGIC TECHNOLOGY

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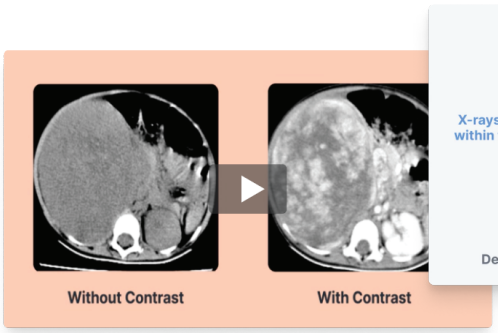


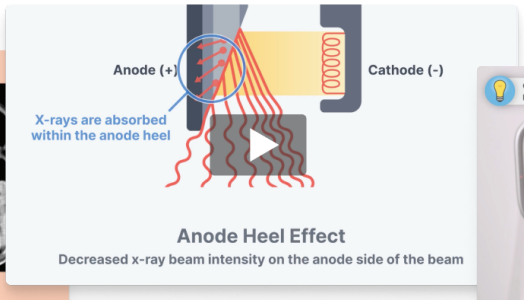


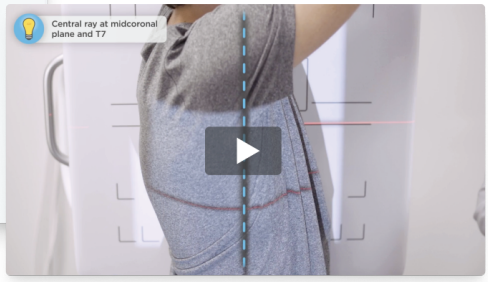


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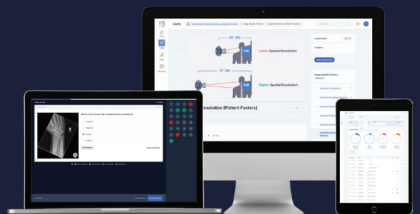

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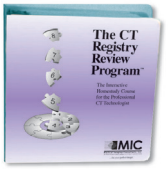


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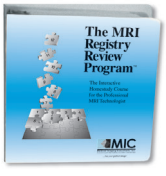


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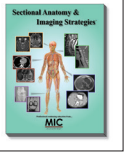


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RADIOLOGIC TECHNOLOGY

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**ON THE COVER**

*Joy Zitko, R.T.(R), of Cincinnati, Ohio, created "Wide Open View," an oil painting demonstrating the correlation between the difficulty of achieving the perfect odontoid (open mouth) radiograph and picking a hidden image out of a landscape.*

**Mission Statement**

The mission of the ASRT journals is to be an indispensable educational resource that fosters professional growth while building a unified voice for the profession.

# Using Computed Tomography to Rule Out Cryptorchidism in a Muntjac Deer

Bradford Gildon, MALS, R.T.(R)
Daniela Yuschenkoff, DVM

**Background** This case describes a Reeves' muntjac deer (*Muntiacus reevesi*) with a suspected undescended testicle or cryptorchidism. The cryptorchid testicle could not be palpated or visualized with sonography. Contrast-enhanced computed tomography (CT) imaging was performed to avoid an exploratory surgical operation, but no cryptorchid testicle was discovered. The final diagnosis was a singular testicular anorchia.

**Discussion** Cryptorchidism and hypogonadism affect a relatively small population of male infants but are the most common male genitourinary anomalies. Identifying the location of the undescended testicle is paramount because surgical intervention should occur before the individual's first birthday. Although sonography and magnetic resonance imaging can help identify the location of undescended testicles, when the testicle is intra-abdominal, surgical intervention often is required to identify or confirm the location.

**Conclusion** Although CT is not a first-line imaging modality in human infants with suspected cryptorchidism because of the associated radiation exposure, this case serves as evidence that it might be useful.

Keywords | *deer, computed tomography, cryptorchidism, testicles*

Cryptorchidism, a condition where 1 or both testicles do not descend from the abdomen into the scrotum, affects 2% to 5% of male human infants and is the most common male genitourinary anomaly.[1] There is a link between hypogonadism and cryptorchidism; hypogonadism can be a cause as well as an effect of cryptorchidism.[2] Early intervention through orchiopexy, a surgical operation to move the undescended testicle, is required to reduce the risk of cancer and infertility. This case study examines the current clinical practices for identifying and treating cryptorchidism. However, this case is unique because the patient is an approximately 4-year-old, 11-kg Reeves' muntjac (*Muntiacus reevesi*). Also called *rib-faced deer* or *barking deer*, muntjacs are known for their unique tusks and their numerous facial glands, which can inflate so much that they evert entirely (see **Figure 1**).

The University of Oklahoma Health Sciences Center radiography program has a working relationship with the Oklahoma City Zoo and occasionally provides computed tomography (CT) scanning to help with diagnoses in various animals. In fall 2023, the Oklahoma City Zoo presented the opportunity to image the Reeves' muntjac with a suspected cryptorchid testicle after a physical examination and sonography failed to identify the second testicle. A surgical intervention was planned tentatively to coincide with a routine hoof trim during which the animal would be anesthetized. However, before the intervention, a CT scan was requested to locate the unidentified testicle before surgical operation. This case study discusses cryptorchidism diagnosis and treatment and compares findings in this muntjac and the human population.

## Examination and Diagnosis

Palpation using a 2-handed technique is the preferred method for initial identification of cryptorchidism in humans.[3] This technique allows for more accurate identification of location and mobility,

**Figure 1.** *A young muntjac (*Muntiacus reevesi*) demonstrating scent glands near the eyes and visible tusk. Photograph courtesy of Emily Workman.*

distinguishing between gliding or inguinal, penile ectopy, and hypermobile testicle, all of which are named based on the placement of where the ectopic testicle resides.[3] However, if the testicle is intra-abdominal, identification using palpation might not be possible. In inconclusive cases, sonography with a high-resolution transducer (> 7.5 MHz) can provide highly accurate identification (84%) of nonpalpable testicles.[4] Magnetic resonance (MR) imaging also can provide an accurate diagnosis (85%) with a higher sensitivity and specificity compared with sonography.[4] Although initial research on gadolinium-based MR angiography demonstrated high sensitivity (96%) and specificity (100%) for localizing intra-abdominal testicles,[5] with newer MR imaging techniques, the use of gadolinium might not be required. In the 1980s, CT was used successfully on a limited number of patients with undescended testicles, but more than 60% of these were identified as likely palpable in the inguinal canal.[6,7] Although CT is helpful, it is avoided in current clinical practice because of the ionizing radiation risk for a young patient population.[8]

When the testicle cannot be palpated or visualized with sonography in the inguinal or ectopic penile region, it often is located intra-abdominally. The final method of identification when these imaging studies fail is a surgical examination, which can be diagnostic or therapeutic (ie, orchidopexy).[9] Surgical examination is considered the gold standard. Some have stated that there is no benefit from imaging studies, so only surgical intervention should be completed when the testicle cannot be palpated with physical examination.[10,11] There are 2 surgical methods: conventional open surgical operation and a laparoscopic approach. Open exploratory surgical operations for intra-abdominal cryptorchidism has a success rate of 74%,[12] and laparoscopic orchidopexy has a much higher success rate of 96%.[9]

## Treatments

Although surgical correction is preferred and historical clinical practice adhered to an "earlier is better" mindset, more recent publications recommend waiting until the infant is aged 6 months or older to allow the opportunity for spontaneous descent.[3] After this period, a combination of hormonal therapy and surgical treatment can be employed and should be completed before the child's first birthday.[3] Hormonal therapy can include luteinizing hormone-releasing hormone and human chorionic gonadotropin.[3]

## Risks if Left Untreated

Unless cryptorchidism is treated promptly, several subsequent conditions can occur, including hormonal imbalances, infertility, and testicular cancer.

### *Hormone imbalance*

Without both testicles, primary hypogonadism, where little to no sex hormones are produced, is likely,[2] which can affect Sertoli cell and Leydig cell function. The manifestations of hypogonadism, such as those experienced as a result of Klinefelter syndrome, might

have personal effects on daily life, including poor judgment and learning difficulties, as well as psychological ones, such as depression.[13] However, hormone replacement therapy is seen by some as controversial due to its low success rates of promoting testicular descension, and might not be deemed as useful for solitary management of cryptorchidism.[2]

### *Infertility*

Cryptorchidism is associated with diminished fertility rates.[14-17] Individuals with unilateral cryptorchidism had higher paternity rates compared with those with bilateral cryptorchidism, with an average of 71% to 92% for unilateral, and 33% to 62% for bilateral.[15] In addition, fertility decreases as the distance between an intra-abdominal testicle and the external inguinal ring increases.[15] Although hormone levels in individuals with cryptorchidism are not vastly different compared with the general populations, inhibin and gonadotropin levels vary significantly and lead to a greater risk of infertility.[15] Early identification and surgical treatments are recommended.

### *Malignancy*

An individual with cryptorchidism is 32 times more likely to develop a testicular germ cell tumor, with an overall incidence of 1 in 2000, and this risk increases if the testicle is intra-abdominal.[3] Surgical correction might not decrease the risk of malignancy, though it might allow easier examination and identification of a tumor once the testicle is relocated in the scrotum.[3]

## Case Description

Possible cryptorchidism was diagnosed in the Reeves' muntjac during a routine physical examination, and the cryptorchid testicle could not be palpated within the inguinal canal, nor visualized with sonography. Because of the possible intra-abdominal location, the low sensitivity and specificity of sonography, and the risks of exploratory laparotomy in a ruminant, an alternate examination was warranted before an exploratory surgical operation. With no access to MR imaging equipment, and taking into account the established University of Oklahoma Health Science Center and Oklahoma City Zoo partnership, a CT examination was planned.

On the day of the scan, the muntjac was anesthetized and transported to the university campus. The room was prepped, and the muntjac was placed prone, feet first, on the CT table. Scout images were acquired, followed by axial images using 2.5 mm slices with 2.5 mm interspaces, and with coronal and sagittal reformats. Images were acquired from the midthorax region inferiorly through the distal aspect of the pelvis and midfemur to ensure adequate visualization in the abdominal cavity in case the testicle's location was extremely anomalous.

Neither the scout images nor the first series of images provided visualization of any mislocated testicle, though the descended testicle was well visualized in the scrotum. No other structures of similar radiographic density were visualized on any of the images.

The veterinary staff requested the use of iodinated contrast media to attempt a differential diagnosis confirmation. A second scan was set up and acquired using the same 2.5 mm slices with 2.5 mm interspaces. A bolus of 20 mL of iohexol (Omnipaque 240 mg/dL) was administered manually during a period of 15 seconds, followed by a mechanical saline bolus. Image acquisition commenced after a 30-second delay. The second set of images allowed for vascular enhancement of the testicular artery of the previously visible, descended testicle (see **Figure 2**). No other testicle or abnormal vascularization was visualized, confirming that the suspected cryptorchidism was instead singular testicular anorchia. The deer was returned to the zoo and made a full recovery from the anesthesia after the hoof trim was complete. Although the animal received a small dose of radiation, he was spared a potential surgical procedure and the recovery process, and the procedure was deemed a success.

## Discussion

Cervids include various hoofed mammals of the taxonomic family *Cervidae*, and include elk, deer, and moose. Most of the males grow antlers, which are shed yearly. Cryptorchidism and hypogonadism in cervids presents a unique issue in this taxon, as antler development depends on appropriate seasonal testosterone influence.[18,19] These testicular abnormalities can be associated with antler abnormalities in various species

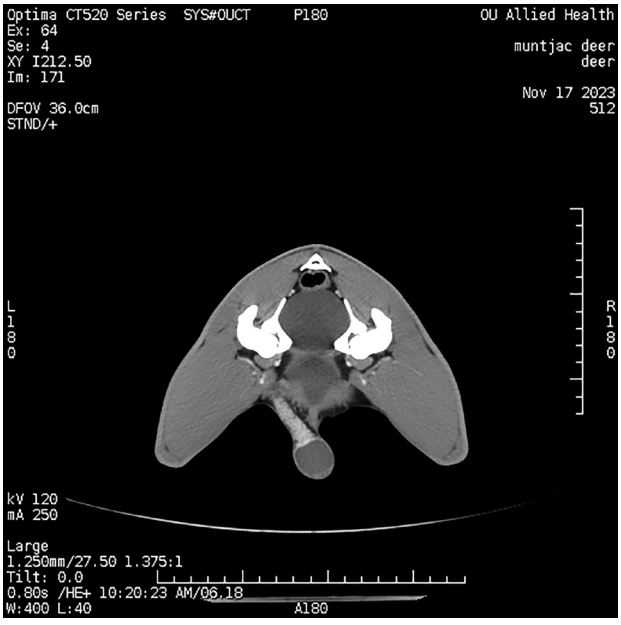


**Figure 2.** *Axial computed tomography image of the animal's pelvis with contrast-enhanced testicular vasculature of the monorchid testicle. Image courtesy of the authors.*

of deer.[18,20] Retained velvet and deformed antlers have been noted in other cervid species with testicular hypogonadism.[21,22] However, in Reeves' muntjac, there is less seasonal variation in testosterone concentrations and testicular size compared with other cervids, which might explain why the individual in this case did not have any antler abnormalities. Often, severe testicular atrophy is noted on histopathological evaluation of cryptorchid or hypogonadal testicles, indicating infertility.[23] It should be noted that reports of hypogonadism in cervids typically describe bilateral hypogonadism, not a complete lack of testicular development, as was seen in this case.

Like what is noted in humans and other animals, neoplasia has been reported in cases of unilateral cryptorchidism in cervids. A gray brocket deer (*Mazama gousoubira*) kept under human care was castrated after a cryptorchid right testicle in the abdomen was identified by sonography, and on histopathology a seminoma was diagnosed in the abdominal testicle.[24]

Because of the hormonal influence of testosterone on the antler formation cycle, castrating adult cervids might result in premature antler casting, permanently velveted antlers, or perruque antlers, which are antlers with excessive proliferation of antler bone and velvet tissue without the typical mineralization and casting.[18,19] In Reeves' muntjac, castration has been associated with growth of permanently velveted antlers without perruque formation.[25] Similar to the treatment of cryptorchidism in other animal species, orchiectomy would have been the treatment of choice in this individual, even with the increased risk of abnormal antler development. Both open and laparoscopic castration have been described in equids (eg, horses, zebras) and ruminants (eg, cattle, giraffes, and sheep),[26,27] and a laparoscopic-assisted cryptorchidectomy also has been performed in an adult reindeer (*Rangifer tarandus*).[28] Exogenous testosterone has been used as an antler-stimulating hormone in other species of deer and could have been considered in this case if antler abnormalities were noted after castration.[19,29]

## Conclusion

Monorchism prevalence is not well documented in muntjacs. The first-line diagnosis and treatment option for suspected intra-abdominal cryptorchidism in humans will continue to be laparoscopic orchiopexy. Despite the unique nature of this patient, and the unorthodox modality of imaging, this case serves as a reminder that although imaging studies such as MR and MR angiography can be helpful, contrast-enhanced CT can provide a reasonable alternative when access to imaging services is limited or the patient is a poor candidate for MR imaging.

*Bradford Gildon, MALS, R.T.(R), is associate professor and radiography program director for the University of Oklahoma Health Sciences Center in Oklahoma City.*

*Daniela Yuschenkoff, DVM, is veterinary resident at the Oklahoma City Zoo and Botanical Garden.*

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# Predictive Validity of the HESI Radiography Exit Exam and Best Practices for ARRT Certification Exam Success

Christine Gouveia, PhD
Ryan S Baker, PhD
Scott Wimer, MSEd, R.T.(R)
Peter Granville, MSEd
Ben Babcock, PhD

**Purpose** To determine the predictive validity of Health Education Systems Incorporated (HESI) Exit Exam scores for student first-time success on the American Registry of Radiologic Technologists (ARRT) certification exam and to analyze whether schools' policies on the HESI Exit Exam are associated with end-of-program student success.

**Methods** Twenty-five radiography program directors provided retrospective data on ARRT certification exam student outcomes, and 24 program directors completed the HESI Exit Exam program policy survey. Data analysis was performed to examine the correlation between students' HESI Exit Exam scores and their first-time ARRT certification exam outcomes and to investigate the relationship between program policies and performance on both exams.

**Results** First-time ARRT certification exam outcomes were obtained for 1265 program graduates who took the HESI Exit Exam from 2018 through 2021. Students achieving acceptable (700-749) and recommended (750-799) HESI Exit Exam scores exhibited significantly higher certification exam pass rates of 79.4% and 86.4%, respectively. ARRT certification exam pass rates were higher for those scoring 800 or above (94.5-100%). Implementation of a minimum HESI Exit Exam score requirements and a required exam preparation were significantly associated with more favorable ARRT certification exam outcomes.

**Discussion** There was a significant positive relationship between higher HESI Exit Exam scores and more successful outcomes on the ARRT certification exam. Two program policies regarding use of the HESI Exit Exam (minimum exit exam score required, required test prep) emerged as best-practice approaches for ARRT certification exam success.

**Conclusion** The HESI Exit Exam was predictive of success on the ARRT certification exam. The results presented in this study can be used to improve radiography education. Future research on how additional educational resources affect HESI Exit Exam and ARRT certification exam success is warranted.

Keywords | *HESI, radiography, ARRT, certification, certification and registration*

Radiologic technologists are highly regarded worldwide for their expertise in delivering diagnostic imaging and therapeutic services to patients. The radiologic technology profession has witnessed substantial advancements in recent years, such as digital imaging, image processing, awareness of imaging risks, and expansion of care settings.[1] These developments, combined with changes in educational technology and teaching methods, have introduced new instructional challenges for radiography programs.[2-5] These challenges have been addressed in several ways, resulting in substantial variations in educational approaches throughout programs.

Today, radiography education offers a range of curricular and program design options and diverse pathways for students pursuing careers as radiologic technologists. To better prepare students for professional practice, many radiography programs use standardized exams, such as the Health Education Systems Incorporated (HESI) Radiography Exit Exam. These exams are used to assess students' readiness for

the American Registry of Radiologic Technologists (ARRT) certification exam.

However, there is insufficient evidence on the validity of HESI Exit Exams to predict students' first-time success on the ARRT certification exam. Although the predictive validity of HESI Exit Exams in nursing has been extensively studied, there is a lack of similar research focused on the HESI Exit Exam in radiography programs. Previous national-level research found that HESI Exit Exams have predictive validity for certification exams in prelicensure nursing education and that specific program policies regarding the use of HESI Exit Exams can substantially improve outcomes.[6,7] In radiography education, Vealé et al and Wimer et al demonstrated that the HESI Exit Exam has predictive validity for the ARRT certification exam.[8,9] However, these studies were limited to a single radiography program, warranting validation throughout a broader range of radiography programs.

Beyond assessing the predictive validity of the HESI Exit Exam, gaining insight into which program policies related to the HESI Exit Exam contribute to increased student success on the ARRT certification exam is crucial. Institutional policies have considerable influence on the use of standardized exams and can substantially affect student performance on these assessments.[10,11] Furthermore, these policies have an important role in promoting accountability and facilitating well-informed decision-making regarding the competency levels of program graduates.[12]

Driven by these dual objectives, this study sought to assess the HESI Exit Exam's ability to predict first-time ARRT certification exam success in a national sample of radiologic technology students and to examine which HESI Exit Exam program policies support radiologic technology student success.

## Literature Review

A literature search was conducted by selecting subject headings (ie, descriptors) listed in the Cumulative Index to Nursing and Allied Health (CINAHL) and the Education Resources Information Center (ERIC) databases, including academic achievement, achievement test, education, radiologic technology, program evaluation, and student success.

### *Radiography Education*

In the United States, radiography programs encompass a range of educational pathways, including hospital-based certificates and degrees at the associate or baccalaureate level. Each program operates with a unique educational framework and process to achieve desired outcomes. Professional and academic standards serve as guiding principles to ensure consistent and appropriate learning outcomes.[12]

Radiography programs often structure their curriculum to align with established standards and state regulations. More than 75% of states have licensing laws governing the practice of radiography.[13] Obtaining a state license to be a fully practicing radiographer often requires certification and registration through the ARRT.[13]

Quality evaluation of radiography education often involves 2 key considerations that rely on objective evidence. First, radiography programs need evidence to indicate they have prepared students for professional practice. Second, they must demonstrate evidence of continuous quality improvement. Student performance on standardized exams, such as the HESI Exit Exam, provides objective evidence to support both considerations. These exam results also enable comparisons of learning among students and throughout programs.

### *HESI Exit Exam*

HESI Exit Exams are computer-based, comprehensive exams designed to measure a student's readiness for the ARRT certification exam, and they closely resemble its format.[13] Items on the exam are grouped into 4 major topics that focus on patient care, safety, image production, and procedures. The HESI Exit Exam contains items developed by subject matter experts who have received extensive item writing training. All exam items are piloted and rigorously evaluated for validity and reliability. Two versions of the HESI Exit Exam are offered to facilitate independent measurements for repeat testing.

Numerous national research studies, spanning 20 years, have consistently supported the predictive validity and reliability of HESI Exams.[6,7,10,14-21] These studies have demonstrated that the HESI Exit Exam is a reliable predictor of success for students in registered nursing (RN) and practical nursing programs on the

National Council Licensure Examination (NCLEX). A study by Shah et al[7] reaffirmed that achieving a high score on the HESI Exit Exam remains a strong predictor of students' first-time success on the NCLEX-RN.

Studies conducted in single programs or higher education institutions have examined the predictive validity of the HESI Exit Exam concerning student success on the ARRT certification exam.[8,9] In a 10-year study of a radiography program, Wimer et al investigated the HESI Admissions Assessment (A2) and HESI Exit Exam as predictors of graduates' ARRT certification exam success.[9] The findings revealed a positive connection between HESI Exit Exam scores and outcomes on the ARRT certification exam. Significant differences were observed in the mean HESI Exit Exam scores between graduates who passed the ARRT certification exam on their first attempt and those who did not. The second administration of the HESI Exit Exam was particularly effective in predicting ARRT certification exam success. Similarly, Vealé et al conducted a study investigating the predictive validity of the HESI A2 and HESI Exit Exam for student success in a radiography program.[8] Their findings also supported the predictive validity of both exams concerning ARRT certification exam success. Collectively, these results provide evidence supporting the effectiveness of HESI Exit Exams as valuable tools for assessing student achievement and readiness for the ARRT certification exam.

Program policies have a crucial role in radiography education, influencing program effectiveness and shaping students' abilities to achieve their educational goals. Although program policies are widely recognized as essential components of radiography education, their potential as predictors of student success has received limited attention in research. Previous studies of radiography program policies have focused on exploring the relationship between admission criteria and outcomes, such as student persistence, program completion, and success on certification exams.[22-24] Few studies have specifically examined the effect of test preparation and remediation policies on ARRT certification exam outcomes.[8,9,25] Thus far, there has not been an investigation into which program policies related to HESI Exit Exams lead to better performance on the ARRT certification exam.

Although single-site studies in radiography education have provided insights into the effect of the HESI Exit Exam on student outcomes, further research is needed to validate these findings and determine the effectiveness of the HESI Exit Exam scores and program policies as reliable predictors of student success on the ARRT certification exam. This study examines predictors of success in a national study of radiography programs.

## Methods

This descriptive study had 2 main objectives: to determine the predictive validity of the HESI Exit Exam in relation to ARRT certification exam success and to examine HESI Exit Exam school policies that support student success on the ARRT certification exam. The study addressed the following research questions:

- To what extent is the HESI Exit Exam predictive of first-time success on the ARRT certification exam?
- Which program policies related to HESI Exit Exams are associated with first-time success on the ARRT certification exam?

### *Sampling*

Convenience sampling was used to collect ARRT certification exam student outcomes and HESI Exit Exam program policy information from radiography programs in the United States. Administrators were invited to participate in the study if they met the eligibility criteria: affiliation with a radiography program at a private or public institution in the United States and their students took the HESI Exit Exam between August 1, 2018, and July 31, 2021.

After Institutional Review Board approval (Teachers College, Columbia University, protocol 20-388), 103 radiography program administrators were sent an invitation to participate in the research study. Administrators from 32 radiography programs consented to participate in the study. Participants from 25 radiography programs provided overall ARRT certification exam outcomes (pass, fail, or did not take

the exam) for 1265 graduates. Administrators further provided ARRT certification exam scaled scores for 445 of those graduates. Participants from 24 programs completed the HESI Exit Exam policy survey.

Most administrators reported that their programs had accreditation from the Joint Review Committee on Education in Radiologic Technology (JRCERT) (n = 22). One program was in the process of seeking accreditation, and another program reported institutional accreditation. Most programs were in the Midwest (n = 10), with remaining programs in the South (n = 8), Northeast (n = 4), and West (n = 3). Programs varied in size from 18 to 96 graduates, with a median program size of 52 total graduates.

### *Data Collection Process*

Program participants were enrolled in the study, and individual program folders were developed and populated into a research site. All research data were securely stored in the restricted-access platform Evolve (Elsevier Inc). Participants were able to access their individual program folders, where they downloaded their confidential lists containing graduate names, a unique identifier, and student HESI Exit Exam scores. They were asked to provide ARRT certification exam outcomes (pass, fail, or did not take) and an ARRT certification exam scaled score if available. After identifying ARRT certification exam outcomes, participants were instructed to remove graduates' names before uploading the data to Evolve, providing a fully deidentified dataset for research use. As a second step in the data collection process, program participants accessed the link to a HESI program policy survey to provide program-specific information.

### *Measures*

The HESI Exit Exam for radiography is designed to measure students' readiness to pass the ARRT certification exam. The HESI Exit Exam has 200 scored items with an additional 20 unscored pilot items. The exam yields a HESI score based on a proprietary mathematical model. Scores on the HESI Exit Exam typically range from 0 to 1500. An acceptable score ranges from 700 to 749, and a recommended score is 750 or higher.[6]

The ARRT certification exam comprises 200 items throughout 4 content categories and employs a scaled scoring system that ranges from 1 to 99. To pass the exam, graduates are required to achieve an overall scaled score of 75.

Program directors were asked to complete a 25-item HESI program policy survey, which was adapted from Shah et al.[7] Survey questions asked about the placement of the HESI Exit Exam in the curriculum, minimum score requirements, retesting options for students, and required preparation and remediation activities. The survey also provided insight into whether the HESI Exit Exam score was included as a graded component of a course, and if so, the percentage of the overall program grade.

### *Data Analysis*

After individual program data were downloaded, a review was conducted to identify missing information and verify the removal of student names from the spreadsheet. A unique program identifier was used to link student and graduate outcomes with the HESI program policy survey. These individual program datasets were then compiled into a single dataset.

Program policy survey responses were used to create variables indicating the use of 6 distinct policies:

- P1 – a minimum HESI Exit Exam score requirement for program completion
- P2 – a requirement to repeat the HESI Exit Exam if a minimum score is not achieved
- P3 – allowing students to take the HESI Exit Exam more than once
- P4 – including the HESI Exit Exam as a component of students' final grades
- P5 – requiring specific test preparation
- P6 – requiring remediation if repeated testing is needed

Each of these independent variables was treated as binary, but the specifics of policy implementation could vary by program; for example, one might use a minimum score of 750, and another might use a threshold of 800.

Because the study spans 3 academic years (2018-2019, 2019-2020, and 2020-2021), ARRT certification exam pass rates were analyzed for whether they varied significantly by academic year using chi-square ($\chi^2$)

tests for independence. The sample sizes for these 3 years were 274, 183, and 280 students, respectively, with corresponding ARRT certification exam passage rates of 96.4%, 96.2%, and 94.3%, respectively. None of the $\chi^2$ tests comparing academic years showed significant differences ($P > .05$). For reference, the national ARRT certification exam pass rate during the time of the study (2018 to 2021) was 87.6%.[26]

To test whether performance on the HESI Exit Exam was predictive of performance on the ARRT certification exam, $\chi^2$ tests were used to determine whether students who met benchmarks on the HESI Exit Exam were significantly more likely to pass the ARRT certification exam. The $\chi^2$ tests also were used to determine whether a program's use of each of the 6 policies predicted ARRT certification exam passage, and similar tests were used to determine the relationship between policies and students' HESI Exit Exam benchmark attainment.

After identifying the policies that had significant relationships to the HESI Exit Exam and ARRT certification exam, path analyses were used to determine if the HESI Exit Exam was a mediating factor in the relationship between each policy and ARRT certification exam outcomes. Path analysis helped to disentangle policies' effects on ARRT certification exam passage (the dependent variable) from policies' effects on HESI Exit Exam scores (the mediator variable).[27] Students often take the HESI Exit Exam multiple times, leading to several possible options for creating a single measure of HESI Exit Exam performance. Different benchmarks can be used as a proxy for recommended scores. To test the sensitivity of the findings, a statistical test was performed for each combination of test measures (first score, last score, highest score, or average score) and cutoff (750 or 800). A HESI Exit Exam cutoff of 750 was used, and for students with multiple HESI Exit Exam scores, their average score was used. Finally, the performance of students in programs that use each best practice were compared with the performance of students in all other programs. For those comparisons, $\chi^2$ tests were used for passing the ARRT certification exam and meeting HESI Exit Exam benchmarks, which are binary outcomes, and Mann-Whitney *U* tests for average HESI Exit Exam scores, which are numerical.

Table 1

**HESI Exit Exam Scores and ARRT Exam Pass Rates**

| No. of students (N = 1265) | Average HESI Exit Exam score | ARRT pass rate, % |
|---|---|---|
| 37 | < 600 | 29.7 |
| 52 | 600-649 | 65.4 |
| 66 | 650-699 | 68.2 |
| 97 | 700-749 | 79.4 |
| 118 | 750-799 | 86.4 |
| 128 | 800-849 | 94.5 |
| 138 | 850-899 | 97.8 |
| 123 | 900-949 | 97.6 |
| 506 | ≥ 950 | 100.0 |

*Abbreviations: ARRT, American Registry of Radiologic Technologists; HESI, Health Education Systems Incorporated.*

## Results

The extent that the HESI Exit Exam score was predictive of first-time success on the ARRT certification exam was measured. As a descriptive analysis of the relationship between the HESI Exit Exam and first-time passage on the ARRT certification exam, the ARRT certification exam pass rates of students were calculated and grouped by the numeric range of their average Exit Exam scores using increments of 50 (see **Table 1**). For all HESI scores (ranging < 600 to ≥ 950), the ARRT certification exam pass rate increased or was approximately equal from one group to the next as the average HESI Exit Exam increased.

To determine whether HESI Exit Exam scores predicted first-time ARRT certification exam passage, $\chi^2$ tests were performed (see **Table 2**). All HESI Exit Exam scores were significantly predictive ($\chi^2_1 > 170$, $P < .001$), indicating that the HESI Exit Exam was predictive of success on the ARRT certification exam.

Using an average HESI Exit Exam score benchmark of 750 yielded the highest chi-square value ($\chi^2_1 = 230.7$, $P < .001$) for performance on the ARRT certification exam, followed by an average HESI Exit Exam score benchmark of 800 ($\chi^2_1 = 210.1$, $P < .001$). The conclusion was that a student's average HESI Exit Exam score was the best measure of proficiency on the Exit Exam and

Table 2

**Chi-Square Results for Whether ARRT Exam First-Time Pass Rates are Higher for Students With HESI Exit Exam Scores Above Cutoff**

| Test (cutoff score) | $\chi^2$ | *P* value[a] |
|---|---|---|
| First Exit Exam (750) | 194.5 | < .001 |
| First Exit Exam (800) | 196.1 | < .001 |
| Last Exit Exam (750) | 181.1 | < .001 |
| Last Exit Exam (800) | 186.8 | < .001 |
| Highest Exit Exam (750) | 174.2 | < .001 |
| Highest Exit Exam (800) | 202.4 | < .001 |
| Average Exit Exam (750) | 230.7 | < .001 |
| Average Exit Exam (800) | 210.1 | < .001 |

[a] *Significant at* P < .05 *level.*

Table 3

**Chi-Square Test Results for Whether Policy Variables Predict Higher First-Time ARRT Exam Pass Rates**

| Policy | $\chi^2$ | *P* value[a] |
|---|---|---|
| Minimum Exit Exam score required (P1) | 16.6 | < .001 |
| Requirement to repeat Exit Exam if minimum score not met (P2) | 2.2 | .14 |
| More than 1 Exit Exam allowed or repeat testing permitted (P3) | 1.4 | .23 |
| Exit Exam as component of final grade (P4) | 3.4 | .07 |
| Required test preparation (P5) | 26.0 | < .001 |
| Required remediation (P6) | 3.7 | .05 |

[a] *Significant at* P < .05 *level.*

used an average HESI Exit Exam score benchmark of 750 as an indicator of good performance on the HESI Exit Exam below. All methods of using the HESI Exit Exam that were tested emerged as significant, valid predictors.

### *Program Policies Related to the HESI Exit Exams*

To test whether each of the 6 independent policy variables predicted first-time ARRT certification exam passage, $\chi^2$ tests were performed (see **Table 3**). The $\chi^2$ tests of 2 policies, minimum exit score required (P1) and required test preparation (P5), were significant ($\alpha = .05$). The $\chi^2$ tests of 2 other policies, the HESI Exit Exam is a component of the final grade (P4) and remediation is required (P6), had *P* values slightly greater than .05 but less than .10.

**Table 4** summarizes the ARRT certification exam pass rates of students in programs with and without a given policy. Some programs' policy survey responses did not indicate whether certain policies were used or not, which is why the total sample sizes for policies P2 (n = 939) and P6 (n = 1014) are lower than the rest (n = 1196).

The minimum Exit Exam score required (P1) and required test preparation (P5) policies were significantly and positively associated with greater rates of first-time passage of the ARRT certification exam. The policy Exit Exam as component of final grade (P4) showed a negative relationship. Programs that did not require the Exit Exam as a component of the final grade had an ARRT certification exam pass rate of 94.3% compared with 89.7% for programs that did.

To understand the role that HESI Exit Exam performance has in mediating these relationships, the relationship between these 6 policy variables and HESI Exit Exam performance was studied. In addition, whether HESI Exit Exam performance mediated the relationship between the policies and passing the ARRT was analyzed (see **Table 5**).

**Table 6** summarizes the HESI Exit Exam benchmark attainment rates of students in programs with and without a given policy. Some programs' policy survey responses did not indicate whether certain policies were used or not, which is why the total sample sizes for policies P2 (n = 952) and P6 (n = 1027) are lower than the rest (n = 1211). Also, throughout policies, total sample sizes are slightly greater than they are for tests of ARRT certification exam pass rates because 15 students in the study took the Exit Exam but did not take the ARRT certification exam.

These findings indicate that the minimum Exit Exam score required (P1), required test preparation (P5), and required remediation (P6) policies are associated with greater rates of meeting the Exit Exam benchmark of 750. The same tests also were performed

Table 4

**ARRT Exam First-Time Pass Rates for Students in Programs With vs Without Each Policy**

| | With policy | | Without policy | |
|---|---|---|---|---|
| Policy | No. of students | ARRT pass rate, % | No. of students | ARRT pass rate, % |
| Minimum Exit Exam score required (P1)[a] | 939 | 92.3 | 257 | 83.7 |
| Requirement to repeat Exit Exam if minimum score not met (P2) | 528 | 91.1 | 411 | 93.9 |
| More than 1 Exit Exam allowed or repeat testing permitted (P3) | 828 | 89.7 | 368 | 92.1 |
| Exit Exam as component of final grade (P4) | 1003 | 89.7 | 193 | 94.3 |
| Required test preparation (P5)[a] | 703 | 94.2 | 493 | 85.2 |
| Required remediation (P6) | 772 | 90.9 | 242 | 86.4 |

[a] *Significant differences.*

using an Exit Exam score of 700 and found identical conclusions of significance for all 6 policies.

Policies P1 and P5, minimum Exit Exam score required and required test preparation, were significant predictors of first-time passage of the ARRT certification exam ($P < .001$). Programs that did not use P4 (Exit Exam as component of final grade) outperformed programs that used P4. Policies P1, P5, and P6 significantly predicted students' attainment of an average Exit Exam score of 750 ($P < .001$). Based on this evidence, policies P1, P5, and P6 were positively correlated with meeting benchmarks on the HESI Exit Exam, and policies P1 and P5 were positively correlated to first-time passage on the ARRT certification exam. Policy P6 was potentially correlated to first-time passage on the ARRT certification exam ($P = 0.5$).

### *Path Analysis*

Path analysis was performed to detect whether there were mediation effects of the HESI Exit Exam on the ARRT certification exam outcome based on each policy. This helped to determine if each policy's effect on the ARRT certification exam was explained by the policy's effect on the HESI Exit Exam score or if the policies directly affected ARRT certification exam results and were not explained by improvements to HESI Exit Exam scores (see **Table 7**).

Table 5

**Chi-Square Results for Whether Each Policy Was Associated With a Significantly Different Proportion of Students With HESI Score Above 750 Benchmark**

| Policy | $\chi^2$ | *P* value[a] |
|---|---|---|
| Minimum Exit Exam score required (P1) | 22.4 | < .001 |
| Requirement to repeat Exit Exam if minimum score not met (P2) | 0.7 | .41 |
| More than 1 Exit Exam allowed or repeat testing permitted (P3) | 0.3 | .57 |
| Exit Exam as component of final grade (P4) | 0.3 | .85 |
| Required test preparation (P5) | 50.1 | < .001 |
| Required remediation (P6) | 9.3 | .002 |

[a] *Significant at* P < *.05 level.*

None of the policies had significant direct effects on ARRT certification exam outcomes. However, in every case, the policy's indirect effect on ARRT certification exam outcomes was found to be significant. This indicates that each policy's benefit for the ARRT certification exam manifests as improvements in knowledge that also can be measured through the HESI Exit Exam.

Table 6

**Proportion of Students With HESI Exit Exam Scores Above 750 Benchmark in Programs With vs Without Each Policy**

| | With policy | | Without policy | |
|---|---|---|---|---|
| Policy | No. of students | 750+ Exit Exam rate, % | No. of students | 750+ Exit Exam rate, % |
| Minimum Exit Exam score required (P1)[a] | 952 | 82.7 | 259 | 69.1 |
| Requirement to repeat Exit Exam if minimum score not met (P2) | 538 | 83.6 | 414 | 81.4 |
| More than 1 Exit Exam allowed or repeat testing permitted (P3) | 841 | 80.3 | 370 | 78.6 |
| Exit Exam as component of final grade (P4) | 1016 | 79.6 | 195 | 80.5 |
| Required test preparation (P5)[a] | 708 | 86.7 | 503 | 70.0 |
| Required remediation (P6) | 780 | 82.1 | 247 | 72.9 |

[a] *Significant differences.*

Table 7

**Results of Path Analyses Investigating Direct and Indirect (Mediated by HESI) Effects of Each Program Policy On ARRT Exam Pass Rates**

| | Direct effect | | Indirect effect | |
|---|---|---|---|---|
| Policy | β | *P* value[a] | β | *P* value[a] |
| Minimum Exit Exam score required (P1)[a] | .03 | .095 | .05 | < .001 |
| More than 1 Exit Exam allowed or repeat testing permitted (P3) | −.03 | .11 | .003 | < .001 |
| Required test preparation (P5) | .02 | .23 | .07 | < .001 |
| Required remediation (P6) | −.01 | .60 | .06 | < .001 |

[a] *Significant at* $P < .05$ *level.*

Programs that employ all best-practice policies (P1, P5, and P6) were compared with other programs along key student performance metrics (see **Table 8**). **Tables 9**, **10**, and **11** display results by the individual policies of P1, P5, and P6, respectively. The **Figure** displays the HESI Exit Exam results displayed in Tables 8-11.

Mann-Whitney *U* tests showed that programs using any or all the 3 best-practice policies outperformed comparison programs in HESI Exit Exam scores, whether measured in terms of students' first, last, highest, or average score. Using HESI Exit Exam score thresholds of 700 and 750, programs that used all 3 best practices and those that used P1 outperformed comparison programs in the share of students who obtained the threshold score or higher. For programs that used P5, the $\chi^2$ test using a HESI Exit Exam benchmark showed significant ($P < .001$) differences compared with comparison programs.

The ARRT certification exam pass rates of programs that used P1, programs that used P5, and programs that used all 3 best-practice policies were significantly higher than the pass rates of comparison programs. However, programs that used P6 did not have significantly higher ARRT certification exam pass rates than did comparison programs.

In programs that used P1 and those that used P5, average ARRT certification exam scores were higher than comparison programs. However, programs that used P6 or those that used all 3 best-practice policies did not have average ARRT certification exam scores higher

Table 8

**Comparing Results for Programs Using Best-Practice Policies (P1, P5, and P6) With Other Programs**

| Measure | Using P1, P5, and P6, n = 439 students | All other programs, n = 841 students | *P* value[a] |
|---|---|---|---|
| First Exit Exam scores, mean (SD) | 978 (177) | 852 (189) | < .001 (*U*) |
| Last Exit Exam scores, mean (SD) | 980 (174) | 890 (178) | < .001 (*U*) |
| Highest Exit Exam scores, mean (SD) | 981 (173) | 900 (173) | < .001 (*U*) |
| Average Exit Exam scores, median (range) | 980 (429-1426) | 854 (468-1537) | < .001 (*U*) |
| 700+ Exit Exam score, % | 94.5 | 88.0 | < .001 ($\chi^2$) |
| 750+ Exit Exam score, % | 91.3 | 80.0 | < .001 ($\chi^2$) |
| First-time ARRT pass rates, % | 95.0 | 88.9 | < .001 ($\chi^2$) |
| Average ARRT score | 82.9 | 81.9 | .14 (*U*) |

*Abbreviations:* U, *Mann-Whitney* U *test;* $\chi^2$, *chi-square test.*

[a] *Significant at* P < .05 *level.*

Table 9

**Comparing Programs With a Minimum Exit Exam Score Required Policy (P1) With Other Programs**

| Measure | Using P1, n = 952 students | All other programs, n = 328 students | *P* value[a] |
|---|---|---|---|
| First Exit Exam scores, mean (SD) | 915 (190) | 836 (195) | < .001 (*U*) |
| Last Exit Exam scores, mean (SD) | 936 (176) | 878 (191) | < .001 (*U*) |
| Highest Exit Exam scores, mean (SD) | 941 (173) | 890 (183) | < .001 (*U*) |
| Average Exit Exam scores, median (range) | 921 (429-1443) | 836 (468-1537) | < .001 (*U*) |
| 700+ Exit Exam score, % | 91.7 | 86.0 | .003 ($\chi^2$) |
| 750+ Exit Exam score, % | 86.2 | 77.1 | < .001 ($\chi^2$) |
| First-time ARRT passage rate | 92.3 | 87.1 | .005 ($\chi^2$) |
| Average ARRT score | 83.7 | 80.8 | .01 (*U*) |

[a] *Significant at* P < .05 *level.*

than comparison programs, suggesting that P6 should not be considered a best-practice policy going forward.

In summary, policies P1 (minimum Exit Exam score required) and P5 (required test preparation) were strongly associated with desirable outcomes in terms of HESI Exit Exam scores and ARRT certification exam scores and passage. Policy P6 (required remediation) did not show the same degree of separation from comparison programs in terms of average ARRT certification exam scores, neither did programs with all 3 best-practice policies. However, fewer participants with ARRT certification exam scaled scores were available compared with ARRT certification exam pass rates. Programs with all 3 best-practice policies had the highest first-time ARRT certification exam passage rates (95%), even when compared with programs that used the P1 policy or the P5 policy.

## Discussion

This study represents the first large-scale examination of the HESI Exit Exam in a national sample of radiography programs. Similar to previous research conducted in nursing programs,[6,7] HESI Exit Exam program policies that supported nursing student success,

Table 10

**Comparing Programs With a Required Test Preparation Policy (P5) With Other Programs**

| Measure | Using P5, n = 708 students | All other programs, n = 572 students | *P* value |
|---|---|---|---|
| First Exit Exam scores, mean (SD) | 953 (185) | 823 (182) | < .001 (*U*) |
| Last Exit Exam scores, mean (SD) | 954 (183) | 880 (171) | < .001 (*U*) |
| Highest Exit Exam scores, mean (SD) | 955 (183) | 894 (164) | < .001 (*U*) |
| Average Exit Exam scores, median (range) | 948 (429-1537) | 834 (477-1400) | < .001 (*U*) |
| 700+ Exit Exam score, % | 91.7 | 88.5 | .07 ($\chi^2$) |
| 750+ Exit Exam score, % | 86.9 | 80.2 | .001 ($\chi^2$) |
| First-time ARRT passage rate, % | 94.2 | 87.0 | < .001 ($\chi^2$) |
| Average ARRT score | 83.0 | 81.2 | .003 (*U*) |

[a] *Significant at* P < *.05 level.*

Table 11

**Comparing Programs With a Required Remediation Policy (P6) With Other Programs**

| Measure | Using P6, n = 780 students | All Other Programs, n = 500 students | *P* value |
|---|---|---|---|
| First Exit Exam scores, mean (SD) | 917 (197) | 860 (185) | < .001 (*U*) |
| Last Exit Exam scores, mean (SD) | 941 (178) | 889 (183) | < .001 (*U*) |
| Highest Exit Exam scores, mean (SD) | 943 (176) | 904 (176) | < .001 (*U*) |
| Average Exit Exam scores, median (range) | 925 (429-1537) | 861 (477-1443) | < .001 (*U*) |
| 700+ Exit Exam score, % | 91.8 | 87.8 | .02 ($\chi^2$) |
| 750+ Exit Exam score, % | 85.5 | 81.4 | .06 ($\chi^2$) |
| First-time ARRT passage rate, % | 90.9 | 91.1 | 1.0 ($\chi^2$) |
| Average ARRT score | 82.0 | 82.5 | .36 (*U*) |

[a] *Significant at* P < *.05 level.*

such as requiring a minimum Exit Exam score and requiring Exit Exam preparation, also contributed to the success of radiologic technology students. In addition, a policy involving remediation based on HESI Exit Exam results showed a potentially positive association with ARRT certification exam outcomes.

Findings from this national study align with past research in single-site radiologic technology studies that also explored the relationship between HESI Exit Exam scores and students' success on the ARRT certification exam.[8,9] Students who achieved higher HESI Exit Exam scores demonstrated greater success on the ARRT certification exam. What distinguishes this study is its novel exploration of various HESI Exit Exam program policies and their effects on student outcomes for both the HESI Exit Exam and the ARRT certification exam.

### *Limitations*

When interpreting the findings of this study and considering their applicability to radiography programs overall, acknowledging limitations is important. Although the sampling strategy used in this study was national, it was limited to programs that use the HESI Exit Exam and require program graduates to complete the ARRT certification exam. Therefore, the findings might not be representative of radiography programs

nationwide. The participating programs tended to be high-performing and mostly accredited by JRCERT, with above-average ARRT certification exam pass rates. The study did not evaluate differences based on accreditation status due to sample size limitations. However, previous research suggests minimal variation in ARRT certification exam results based on accreditation status.[28]

There also are limitations given the timing of this research. The student data collected spanned from August 2018 to July 2021, which encompassed the COVID-19 pandemic period. The substantial challenges faced by radiography programs during this time, such as disruptions in clinical training and changes in educational delivery, might have influenced the study's findings and their generalizability to other periods. Data for the HESI program policy survey were collected between February to June 2022. Because the students in the study graduated from radiography programs throughout different school years, whether program policies remained consistent throughout all academic years is unclear. Variations in program policies for different student cohorts could potentially affect the outcomes and findings of the study. Lastly, the passing standard of the ARRT certification exam is now more stringent. This change in the exam's scoring requirements raises questions about the future applicability of the study's results because the findings might not fully align with the outcomes of students taking the exam under the revised passing standard.

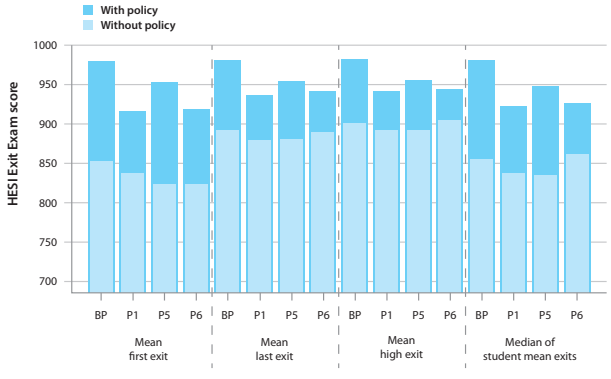


**Figure.** *Graph comparing Health Education Systems Incorporated (HESI) Exit Exam scores based on programs using vs not using given policies. Best-practice (BP) programs included programs that implemented policies 1, 5, and 6 (P1, P5, P6) together. All differences between programs with and without policies were significant (P < .05). Figure courtesy of authors.*

### *Implications for Radiography Education and Research*

This study has substantial implications for radiography education, providing a comprehensive understanding of the relationships between the HESI Exit Exam, program policies, and student success on the ARRT certification exam. By examining the program policies associated with higher levels of student success on HESI Exit Exams, researchers and educators can gain valuable insights into factors contributing to positive educational outcomes and identify areas for improvement. Despite the discussed sampling limitations, the inclusion of a diverse sample of radiography programs from various regions in the United States enhances the generalizability and external validity of the study's findings compared with previous research.

The findings of this study have practical applications for evidence-based teaching practices. First, consistent with previous research,[8,9] the HESI Exit Exam can be used as a predictor of future success on the ARRT certification exam, supporting its use as an objective quality indicator of program outcomes. Second, there appear to be several best practices that correlate with higher exam scores. The evidence indicates that implementing certain measures, such as setting a minimum HESI Exit Exam score, requiring HESI Exit Exam preparation, and providing targeted remediation based on HESI Exit Exam results, contribute to improved student achievement as reflected in performance scores.

Future research in this area is warranted. Although this study was larger than previous validity studies in radiography education, 25 radiography programs participated in this study, sampling more programs, particularly those with more varied ARRT certification exam pass rates, would enhance the generalizability of findings. Also, with recent changes in certification exam passing standards, determining if the current HESI Exit Exam performance standards maintain their predictive validity will be necessary. Recent research

has recommended evaluating new benchmark scores for the HESI Exit Exam, emphasizing the need for ongoing investigation and refinement of end-of-program assessment practices.[9]

Furthermore, future research could explore additional educational resources that might correlate with the HESI Exit Exam and the ARRT certification exam. Although the present study focused on HESI Exit Exam preparation and remediation, investigating other resources, such as the modular exams (patient care, safety, image production, and procedures) or the didactic midcurricular exam, could provide insights into their contributions to teaching and student learning outcomes.

## Conclusion

This study demonstrated that the HESI Exit Exam serves as a reliable predictor of ARRT certification exam success. In addition, specific program policies, including the requirement of a minimum HESI Exit Exam score, mandatory test preparation, and required HESI remediation, exhibit strong correlations with positive outcomes. This comprehensive strategy, based on evidence, supports students in acquiring a solid foundation of radiography knowledge before they undertake the ARRT certification exam and begin their professional journey.

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*Christine Gouveia, PhD, worked for Elsevier during the writing of this manuscript and currently works for the University of Pennsylvania.*

*Ryan S Baker, PhD, works for Baker EDM Lab, Inc and the University of Pennsylvania.*

*Scott Wimer, MSEd, R.T.(R), is an independent consultant and Director of Radiographic Sciences Lewis-Clark State College in Lewiston, Idaho.*

*Peter Granville, MSEd, is an independent scholar in Washington, D.C.*

*Ben Babcock, PhD, is psychometrician for the American Board of Radiology in Tucson, Arizona.*

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# Relationship Between Professional Behaviors and Radiologic Technologists' Demographics

Laura Aaron, PhD, R.T.(R)(M)(QM), FASRT, FAEIRS
Kelli Welch Haynes, EdD, R.T.(R), FASRT, FAEIRS

**Purpose** To determine whether the professional behaviors of radiologic technologists differ based on demographic variables.

**Methods** An invitation was sent to 10 000 radiologic technologists to participate in the study. Participants completed the Haynes Scale of Professionalism for Radiologic Technology and answered demographic questions. Kruskal-Wallis tests and analyses of variance were conducted to identify the relationship between demographic variables and professional behaviors. Post hoc analyses were performed to identify differences between groups.

**Results** A significant difference was identified for the demographic variable of age and the professionalism subscale of quality patient care ($P < .001$). The demographic variable of years as a technologist had significant differences with the subscales of quality patient care ($P = .007$), ethical performance ($P = .008$), personal and professional development ($P = .02$), and the total professionalism score ($P = .01$). A significant difference was found for the highest degree and the subscale of quality patient care ($P = .007$).

**Discussion** The demographic variables of age, years as a technologist, and highest degree affected the technologist's professional behavior scores. Technologists who were older or had more years of experience had higher professional behavior scores.

**Conclusion** Certain demographic variables can affect the professional behavior of technologists. These results help to highlight the factors that influence the development of professional behaviors.

Keywords | *professionalism, demographics, values, behaviors*

The concept of professionalism embodies the commitment of health care professionals to act ethically, responsibly, and compassionately toward their patients and colleagues.[1] Brennan and Monson posited that professionalism is associated with many advantages to health care organizations and patient safety and care.[2] Developing professionalism is an essential part of any health care profession. For radiologic technologists, professionalism is a multifaceted concept that includes clinical expertise, communication skills, empathy, and adherence to the American Registry of Radiologic Technologists (ARRT) Standards of Ethics and the American Society of Radiologic Technologists (ASRT) Practice Standards.[1] In 2020, Haynes found that radiologic technologists perceived that professional values, including accountability, altruism, caring, excellence, integrity, professional duty, and social responsibility, were all important to the profession.[1]

Demographics, including factors such as age, gender, years of experience, job title, education level, and others, can affect an individual's perspective on professional values and how often these behaviors are performed.[3] Professionals can have complex identities influenced by a combination of these factors. In the radiologic sciences and other health care professions, the research on professional behaviors is sparse and often involves students' perceptions rather than practitioners' perceptions. Haynes found that demographic variables do not affect radiologic technologists' perception of

the importance of professional values.[1] However, the professional behaviors that technologists demonstrate have not been explored in relation to demographic variables. Demographics also can provide insights into potential behavior patterns. Professional values are the guiding beliefs and principles that influence work behavior. These values often serve as a moral compass, influencing decisions and behaviors in the workplace. Professional values reflect what individuals consider important, ethical, and essential for maintaining a high standard of professional conduct. Common professional values include accountability, respect, excellence, integrity, teamwork, and a commitment to continual learning and growth.[3]

Much of the research on professional behaviors and demographics has been conducted in nursing. Nursing research has identified several demographic variables related to higher levels of professional behaviors, such as age, years of experience, and education level.[4-7] Based on the need to determine the relationship between professional behaviors and radiologic technologists' demographics, this research question was addressed: Do professional behaviors of radiologic technologists differ based on demographic variables?

## Methods

A web-based survey was used to explore whether there was a relationship between professional behaviors and the demographic characteristics of age, years of experience, degree earned, primary modality, current job, or employment status. A quantitative, nonexperimental, cross-sectional methodology was employed for the study. The Northwestern State University Institutional Review Board granted exempt status to conduct this study (06.22.003). The ASRT Research Department produced a simple random sample of the ASRT members who were certified in any imaging or therapeutic modality and working in a clinical role. Technologists who worked primarily in radiography, nuclear medicine, radiation therapy, magnetic resonance (MR) imaging, computed tomography, sonography, mammography, vascular sonography, radiologist assistant, breast sonography, cardiac interventional radiography, or vascular interventional radiography were included in the sample.

### *Data Collection*

An invitation to participate in the study and a link to an electronic survey were sent to 10 000 technologists by the ASRT Research Department during the summer of 2022. A follow-up reminder was sent 2 weeks later, and the survey closed 1 month after the initial invitation. The survey asked several demographic questions, including age, years as a technologist, education level, modalities in which the respondent was certified, primary employment modality, employment status, and job title. In addition, participants completed the Haynes Scale of Professionalism for Radiologic Technology (HSPRT), which has a reliability of $\alpha = .958$.[8] The HSPRT consists of 34 items with 5 subscales including quality patient care (12 items, $\alpha = .910$), professional advocacy (7 items, $\alpha = .933$), ethical performance (7 items, $\alpha = .885$), personal and professional development (5 items, $\alpha = .901$), and social responsibility (3 items, $\alpha = .917$). Each item described a professional behavior, and participants rated how often they performed the behavior on a Likert scale of never, rarely, occasionally, often, and always.

### *Data Analysis*

SPSS Statistics version 26 (IBM) was used to determine descriptive statistics for the demographics and Kruskal-Wallis test and analyses of variance (ANOVA) to determine the relationship between the demographic variables and professional behaviors. G*Power 3.1.9.7 (Axel Buchner) was used to conduct an a priori analysis for the sample size.[9] To achieve 80% power for identifying a medium effect size at $P < .05$ significance, 216 participants were needed.

Before data analysis began, the data file was cleaned. Cases with missing data were deleted, and the aggregate score was computed. The scores for each item were summed to create a total score for the subscale, and then the subscale scores were summed to create a total score for the instrument. The total subscale scores (quality patient care, professional advocacy, ethical performance, personal and professional development, and social responsibility) and total scores for the instrument were the dependent variables for the analysis. The independent variables were the technologist's primary modality, job position, employment status, age, years

of experience, and education. Before the inferential statistics were computed, the assumptions for an ANOVA were calculated. The normality and homogeneity assumptions were violated in some cases, and the Kruskal-Wallis test was used for these differences. When the difference was significant, the Tukey test was used to identify differences between groups for the ANOVAs, and Dunn test with a Bonferroni adjustment for multiple comparisons was used for the Kruskal-Wallis test.[10]

## Results

Of the 10 000 technologists invited to complete the survey, 599 participated for a 5.99% response rate. Of the 599 who participated, 426 met the criteria to participate in the study. Those excluded were 52 who did not work in 1 of the primary modalities being examined, 92 who were not working in a clinical role, 7 who were not currently employed, and 22 who did not complete the survey. Most of the technologists whose responses were included worked primarily in radiography (47.2%), were staff technologists (74.4%), employed full time (77.2%), aged 55 or older (36.6%), held an associate degree (47.4%), and had been a technologist for more than 25 years (37.3%). **Table 1** summarizes the demographic variables.

Descriptive statistics for the HSPRT scores were computed (see **Table 2**). The mean for each scale and the mean total score were calculated. The lowest scores were reported for the professional advocacy subscale, whereas the highest scores were for the ethical performance subscale.

The instrument's reliability was calculated on the observed data from the current study. Cronbach α for the HSPRT subscales were all > .70, indicating that the scales were reliable. The results were compared with the previously published research and are displayed in **Table 3**.

A series of 1-way ANOVAs and Kruskal-Wallis tests were used to determine whether there were differences in professional behaviors based on the technologist's demographic profile. **Table 4** displays the results of hypothesis testing for the HSPRT scores and the demographic variables.

No significant differences were identified for primary modality, current job, or employment status.

Table 1

**Demographic Variables**

| Variable | n[a] (%) |
|---|---|
| Primary modality | |
| Radiography | 201 (47.2) |
| Radiation therapy | 30 (7.0) |
| Magnetic resonance imaging | 37 (8.7) |
| Mammography | 68 (16.0) |
| Radiography | 53 (12.5) |
| Other[b] | 37 (8.7) |
| Current job | |
| Staff technologist | 317 (74.4) |
| Senior, lead, or chief technologist | 98 (23.0) |
| Locum tenens | 11 (2.6) |
| Employment status | |
| Full time | 329 (77.2) |
| Part time | 58 (13.6) |
| Per diem/contingent | 39 (9.2) |
| Age, y | |
| 18-34 | 65 (15.3) |
| 35-44 | 87 (20.4) |
| 45-54 | 118 (27.7) |
| ≥ 55 | 156 (36.6) |
| Years as a technologist | |
| 0-4 | 28 (6.6) |
| 5-10 | 75 (17.6) |
| 11-15 | 70 (16.4) |
| 16-20 | 53 (12.5) |
| 21-25 | 41 (9.6) |
| > 25 | 159 (37.3) |
| Highest degree | |
| Certificate or diploma | 70 (16.5) |
| Associate | 202 (47.5) |
| Bachelor's | 132 (31.1) |
| Master's | 21 (4.9) |
| Doctorate | 0 |

[a] *Except for highest degree, total N for all groups = 426. For highest degree, N = 425.*

[b] *Includes nuclear medicine technology, sonography, cardiac interventional radiography, and vascular interventional radiography.*

Table 2

**Descriptive Statistics for Haynes Scale of Professionalism for Radiologic Technology Scores**

| Scale | n[a] | Mean | Mean total score (SD) | Maximum possible score |
|---|---|---|---|---|
| Quality patient care | 401 | 4.69 | 56.26 (3.80) | 60.0 |
| Professional advocacy | 409 | 2.72 | 19.05 (6.09) | 35.0 |
| Ethical performance | 409 | 4.93 | 34.53 (1.21) | 35.0 |
| Personal and professional development | 410 | 3.99 | 19.97 (3.72) | 25.0 |
| Social responsibility | 411 | 3.40 | 10.21 (3.57) | 15.0 |
| Total score | 356 | 4.12 | 139.97 (13.93) | 170.0 |

[a] *n varies because of incomplete responses*

Table 3

**Instrument Reliability Subscale**

| Scale | Current study | Haynes et al, 2021 |
|---|---|---|
| Quality patient care | .854 | .910 |
| Professional advocacy | .882 | .933 |
| Ethical performance | .756 | .885 |
| Personal and professional development | .867 | .901 |
| Social responsibility | .891 | .917 |
| Total score | .914 | .958 |

Table 4

**Haynes Scale of Professionalism for Radiologic Technology *P* values for Each Demographic Variable**

| Variable | Quality patient care | Professional advocacy | Ethical performance | Personal/ professional development | Social responsibility | Total |
|---|---|---|---|---|---|---|
| Primary modality | .076 | .858 | .109 | .866 | .968 | .722 |
| Current job | .398 | .458 | .219 | .103 | .926 | .375 |
| Employment status | .960 | .983 | .517 | .692 | .418 | .677 |
| Age | < .001[a] | .455 | .654 | .843 | .854 | .180 |
| Years as a technologist | .007[b] | .155 | .008[b] | .016[b] | .073 | .010[a] |
| Highest degree | .007[b] | .082 | .054 | .103 | .992 | .451 |

[a] *Analyses of variance (ANOVA)*

[b] *Kruskal-Wallis*

Significant differences were found for age, years of experience as a technologist, and highest degree.

### *Age*

A 1-way ANOVA indicated a significant difference between age and quality patient care scores ($F_{3,397} = 6.66$, $P < .001$, $\eta^2 = .048$). Tukey post hoc analysis showed that technologists in the 18 to 34 years age group with a mean score of 54.52 and a standard deviation of 4.09 were significantly different from all other age groups; 35 to 44 years with a mean score of 56.25 and a standard deviation of 3.93 (P = .02); 45 to 54 years with a mean score of 57.11 and a standard deviation of 3.17 (P < .001); and 55 years or older with a mean score of 56.38 and a standard deviation of 3.82 (P = .005).

### *Years of Experience*

Most of the differences were identified for the independent variable of years as a technologist. ANOVA results showed a significant difference between technologists' years of experience and total score ($F_{5,350} = 3.08$, $P = .010$, $\eta^2 = .042$). The post hoc analysis demonstrated that technologists with 0 to 4 years of experience with a mean score of 133.2 (14.48) were significantly different from those with more than 25 years of experience with a mean score of 141.82 and a standard deviation of 12.72 (P = .049). In addition, Kruskal-Wallis results revealed a significant difference between technologists' years of experience and quality patient care scores ($\chi^2_5$, $P = .007$). Pairwise comparisons demonstrated a significant difference between technologists with 0 to 4 years of experience (mean rank = 133.05) and 16 to 20 years of experience (mean rank = 217.34, $P = .028$), and more than 25 years of experience (mean rank = 217.17, $P = .005$). No other combinations were significant.

Another significant difference was between years of experience and ethical performance scores ($\chi^2_5$, $P = .008$). The Kruskal-Wallis test post hoc analysis demonstrated that technologists with 0 to 4 years of experience (mean rank = 160.29) scored lower than technologists with 25 years of experience (mean rank = 218.05, $P = .019$). Finally, years of experience and personal and professional development scores differed significantly ($\chi^2_5$, $P = .016$); however, post hoc tests did not indicate significant differences.

### *Level of Education*

Kruskal-Wallis results displayed a significant difference between the highest degree and quality patient care scores, ($\chi^2_3$, $P = .007$). Pairwise comparisons exhibited a significant difference between technologists with bachelor's degrees (mean rank = 178.87) and certificates or diplomas (mean rank = 225.76, $P = .042$) and master's degrees (mean rank = 253.78, $P = .037$).

## Discussion

This study found that technologists' professional behaviors differed based on some demographic variables. Specifically, the demographic variables of age, years as a technologist, and highest degree influenced technologists' professional behaviors. These findings are like other studies of professionalism and demographic values.[4-6,11]

### *Age*

In the current study, for the age variable, technologists in the 18 to 34 years age group had significantly lower quality patient care scores than did technologists in all other age groups. In addition, technologists aged 50 years or older reported higher professional behavior scores than did those younger than 50 years. These findings are like the results of Kim-Godwin et al and Rabie, who found that older nurses reported higher professional behavior scores as measured by Hall's Professionalism Scale.[4,5] In general, older individuals in the workforce tend to have more experience, which can contribute to a higher level of professional behavior. Individuals often gain a deeper understanding of workplace norms, ethics, and expectations with age, leading to a more seasoned and mature approach to their work.[5] Employers should value the professionalism that older technologists have and work to retain these individuals.

### *Years of Experience*

The years of experience as a technologist variable affected multiple professional behavior scores, including quality patient care, ethical performance, personal

and professional development, and the total professionalism score. Quality patient care scores were lower for technologists with 0 to 4 years of experience compared with technologists with 16 to 20 or more than 25 years of experience. Similarly, ethical performance scores were lower for technologists with 0 to 4 years of experience compared with those with more than 25 years of experience. Finally, for the total professionalism score, technologists with 0 to 4 years of experience had lower scores than did technologists with more than 25 years of experience. All significant differences identified showed that technologists with the least experience differed from technologists with more years of experience. The findings are similar to Rabie's and Wynd's results.[5,6] Rabi and Wynd found that years of experience were positively related to the professional behavior scores of nurses.[5,6] In addition, Lombarts et al found that physicians and nurses with more years of experience had higher professional attitude scores.[11] Experience and maturity can cause professionals to view their work differently, leading to higher professional values scores.[6]

Regarding years of experience and quality patient care, the findings in this study are similar to those of Gallegos and Sortedahl.[12] Gallegos and Sortedahl found that baby boomers (1946 to 1963) and silent generation (1925 to 1945) nurses regarded quality patient care as essential, more so compared with their younger colleagues.[12] With more years of experience, employees often gain a deeper understanding of their field, the work environment, the technology, and best practices.[12] Quality patient care also depends on other factors, including clinical expertise, diagnostic accuracy, procedural skills, communication skills, and clinical judgment.[12] Technologists with more experience are valuable to the workforce because they can deliver high-quality patient care. These technologists should be appreciated by employers because of the skills they bring to their institutions.

In the current study, years of experience as a radiologic technologist affected the total professionalism score. Rabie also found a positive correlation between years of experience and overall professionalism.[5] Rabie determined that nurses aged 50 years or older had a higher professionalism score than did those with fewer years of experience.[5] Gradually, professionals tend to develop greater confidence in their abilities. This confidence contributes to a more heightened sense of overall professionalism.[5]

### *Highest Degree*

The highest degree completed demographic variable demonstrated some noteworthy differences in quality patient care scores. Technologists with bachelor's degrees had lower quality patient care scores than did technologists with either certificates and diplomas or master's degrees. However, there was no significant difference between bachelor's and associate degree students. This finding contradicts the typical conclusion that education level increases professionalism found in several studies in nursing.[4-7] Research and evidence suggest that health care professionals with higher education and specialized training often provide higher-quality patient care.[4,6] Rabie noted that recognizing that the quality of patient care depends on various factors beyond the level of education is essential, including attitude and empathy, work environment, and systemic factors such as health care systems and policies.[5] Sibandze and Scafide's systematic review of the literature determined that nurses with a bachelor's degree or higher had a higher awareness of professional values.[7] They contended that education has an essential role in developing professional values.[3]

### *Frequency of Professional Behaviors*

In completing the survey, technologists were asked to indicate how often they performed specific behaviors. The behaviors for the ethical performance subscale were rated the highest with a mean score of 4.93, revealing that technologists performed these behaviors most often. Haynes et al defined ethical performance as "adhering to ethical principles and professional standards."[8] Therefore, it is reassuring that this is the subscale that was rated the highest, demonstrating that these behaviors were well demonstrated in practice.

The second highest subscale was quality patient care with a mean score of 4.69. Quality patient care was defined as "providing safe, compassionate, and effective care to the patient."[8] The high scores for this subscale indicate that most technologists exhibit professionalism in the patient care they deliver.

The lowest subscale was professional advocacy with a mean score of 2.72, which was defined as "supporting and promoting the profession and having a positive effect on the health of the public."[8] This shows that technologists were less likely to demonstrate these behaviors. Items for this scale included involvement in professional activities beyond the practice setting, such as community volunteerism, political activism, societal health goals, understanding current health issues and the relationship to the radiologic sciences, community leadership, and collaboration with other health professions and the public.[8] Haynes explored the level of importance that technologists perceived for specific professional values.[1] Haynes found that behaviors related to social responsibility were perceived as less important to radiologic technologists than were behaviors associated with other professional values. Therefore, not only do technologists perceive these behaviors as less important, but they also are less likely to demonstrate these behaviors. This is a concerning finding because advocacy is crucial for any profession because it serves essential purposes that contribute to the advancement and well-being of the profession and its practitioners.[13] Advocacy involves promoting and defending the interests, rights, and well-being of a profession and its members. Advocacy empowers professionals to take an active role in shaping the future of their profession. When professionals advocate for their profession, they become change agents who can positively affect the direction and development of their area of expertise.[13]

### *Limitations*

The research participants were limited to radiologic technologists who were ASRT members in any of the imaging or therapeutic modalities and working in a clinical role. Imaging technologists who are not members of ASRT might differ from those who are members; therefore, generalizations might not apply to other populations.

Participants' values were not explored, which might have influenced this study's outcomes because response bias might have been present. In addition, social desirability bias might have been created. Participants might have scored an item high because they thought that was what they should do instead of scoring as a reflection of their values.

### *Future Research*

Many aspects of technologists' professional behavior could be explored in the future. The HSPRT could be used for a longitudinal study of imaging students or technologists to examine how professionalism develops throughout time. In addition, long-term investigations can identify the factors contributing to professional behavior and attitude changes. Imaging science educators could be surveyed to determine the role of education and professional training in shaping professionalism.

## Conclusion

This study aimed to determine whether there was a difference in professional behaviors based on technologists' demographic profiles. Results from this research indicate that no significant differences were identified for primary modality, current job, or employment status. However, significant differences were found for age, years of experience as a technologist, and highest degree, highlighting that employers should make efforts to retain technologists with experience. Patient care, ethical performance, and personal and professional development are all positively affected by technologists with more experience. The workplace might have adverse effects when experienced technologists leave and are replaced by individuals with substantially less experience. Creating a culture that values experienced technologists and permits them to mentor new technologists can help generate a high level of professionalism in the workplace.

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*Laura Aaron, PhD, R.T.(R)(M)(QM), FASRT, FAEIRS, and Kelli Welch Haynes, EdD, R.T.(R), FASRT, FAEIRS, are professors for Northwestern State University in Shreveport, Louisiana.*

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*Department, 15000 Central Ave SE, Albuquerque, NM 87123-3909, or emailed to publications@asrt.org.*



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# History of Cardiac CT and Conventional, Invasive Fractional Flow Reserve's Effect

Kevin L Wininger, BS, BS, R.T.(R)(CT)(CI)

In a 2023 article published in *Radiology* by Bluemke and Lima, 2 leaders in the field of cardiovascular imaging, key changes to the practice of cardiac computed tomography (CT) were forecasted for a 20-year period based on the progress in this specialty. The authors claimed[1]:

- Photon-counting CT will replace conventional CT, making plaque quantification and characterization the standard of care for coronary artery evaluations and routine chest scans.
- Postprocessing will be fully automated for coronary CT angiography (CCTA).
- CCTA will routinely include flow and pressure gradient estimates.
- CCTA will transition from being the gatekeeper to the cardiac interventional suite to serving as an essential component of preventive cardiology.

Several predictions also were made concerning the respective trajectories for molecular imaging, multimodality imaging, and magnetic resonance imaging with respect to diagnosis and staging of nonischemic diseases of the heart muscle itself. However, analysis incorporated certain roles that artificial intelligence will play, especially in conjunction with plaque quantification.[1] This article showcases the history of cardiac CT and also outlines the effect of conventional invasive coronary physiology testing.

## Cardiac CT History

After releasing the first-ever, nonsuperimposed images of the human brain for evaluation by neuroradiologist James Ambrose in 1971, electrical engineer and Nobel Prize winner Sir Godfrey Hounsfield endorsed the mounting clinical desire to capture CT images of the heart. In his 1979 Nobel speech for the award in medicine and physiology (shared with physicist Allan Cormack) for making the CT scanner a reality, Hounsfield supported continuing efforts toward freezing cardiac motion when addressing the modality's future:

> *Various attempts have been made to achieve useful pictures of the heart. The time available for taking a picture of the heart is obviously longer than one heartbeat. Some experiments were conducted some time ago using conventional CT machines but in which the traverse of the detectors was synchronised to the heartbeat via an electrocardiograph, passing over the heart in diastole (when the heart movement is at a minimum). . . . The heart chambers can be discerned by a little intravenous injected contrast media.*
>
> *Another approach is being made at the Mayo Clinic, Rochester, America, where a large machine is being constructed with 27 x-ray tubes designed to fire sequentially. It is hoped to take a sequence*

*of pictures in a fraction of a second during one heartbeat. However, the complexity and cost may rule out such a machine being used worldwide.*

*A further promising field may be the detection of coronary arteries. It may be possible to detect these under special conditions of scanning.*[2]

In terms of the creative steps to achieve cardiac scans and understand human heart structure and function, scrutiny of Hounsfield's remarks provides a lens with which to review the history of cardiovascular CT.

### *Heart's Dynamic Nature and Early CT Scanner Design*

The heart has a quick, dynamic nature. Whereas a single heartbeat (1 cardiac cycle) lasts 0.80 seconds at a heart rate of 75 bpm, a heartbeat of 65 to 85 bpm lasts 0.92 to 0.71 seconds, respectively. Early experiments used older scanner designs—most likely the translate-rotate designs of the first- and second-generation CT scanners.[3] These scanners required that the tube and detector array traverse the anatomy of interest in chorus to assign a field of view, then simultaneously rotate the gantry to again traverse the anatomy in the opposite direction (see **Figure 1**). Third-generation scanners could rotate continuously.

### *Importance of Cardiac Gating*

For cardiac imaging to be successful, timing of the phases of the cardiac cycle was critical. Examiners needed information to track diastole, the phase consisting of the least amount of heart motion and comprising two-thirds of the cardiac cycle.[4] In the modern era using contemporary CT, temporal resolution achieves 250 ms to freeze the heart for rates up to 70 bpm.[5] Yet as heart rate increases to 100 bpm, the appropriate temporal resolution moves closer to 150 ms. Conversely, freezing the heart's motion in systole necessitates pushing the envelope for temporal resolution to 50 ms for rates up to 70 bpm.

### *Promise of the Dynamic Spatial Reconstructor*

One of the first CT machines depicted instant-to-instant regional changes in shape and dimension of the heart and lungs, as well as showed spatial distributions of myocardial and pulmonary blood flow—the fundamental determinants of cardiopulmonary function and reserve.[6] The planning for this machine (known as the *dynamic spatial reconstructor [DSR]*) began in 1975 under leadership from the Biodynamics Research Unit

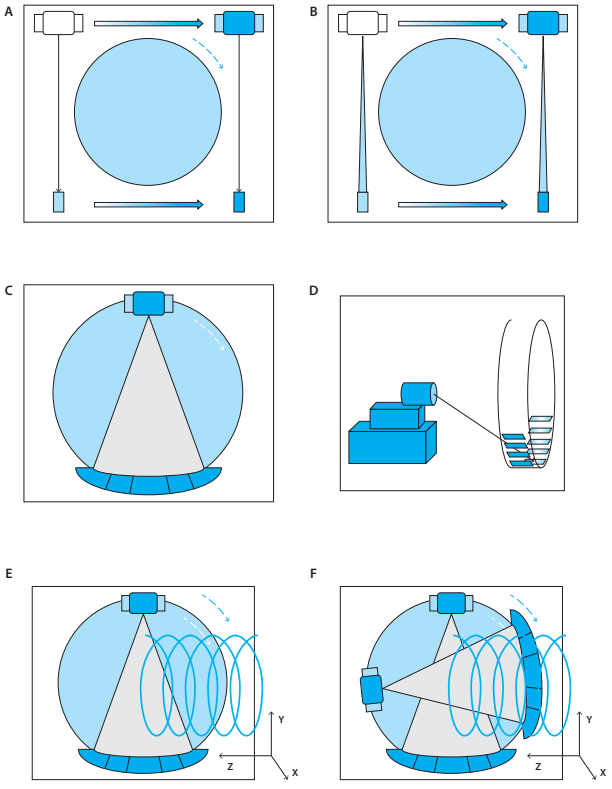


**Figure 1.** *Select generations of computed tomography (CT) scanners. A. The first-generation CT scanner in the 1970s used a translate-rotate design with a pencil-like x-ray beam. B. Differences between first- and second-generation scanners amounted to use of a narrow fan beam. C. The third-generation scanner used a wide fan beam incorporating a winding- and unwinding-gantry motion (x-ray tube and detector moved in unison). D. The electron beam CT scanner was the fifth-generation scanner. E. Subsequent CT designs restored third-generation geometry. Here, sixth-generation scanners incorporated the advent of slip ring technology (x-ray tube and receptor rotated in unison continuously) making spiral or helical scanning possible in the 1990s. F. Dual-source scanning was commercially introduced in 2006. Currently, dual-source and single-source scanners operate using single or dual energy sources. Images courtesy of the author.*

at the Mayo Clinic in Rochester, Minnesota. The DSR viewed many angles of the heart nearly simultaneously through a 160° arc of a circular gantry that rotated. The system recorded via 2-D projections, but data reconstruction rendered dynamic 3-D volumes.[6] Moreover, the accuracy of the DSR was superb for its time. For example, use of the machine for defining ventricular muscle volume in canines agreed to within 6% of postmortem evaluation.[7]

Capable of true 4-D imaging (ie, acquiring data from axial, coronal, and sagittal planes while using a time element), the DSR was a multiple-source, multiple-detector scanner initially containing 14 x-ray tubes (see **Figure 2**). Its power enabled 1 scan in 11 ms. Under cine mode, the DSR used less radiation than conventional cardiac angiography from that day.[6] The DSR created 300 volumes of 120 cross-sections each in 5 seconds while producing 4 to 5 R for a 4- to 5-second cine run to record several cardiac cycles. Conventional cardiac angiography from that era produced 5 to 10 times this level of radiation, with up to 100 R when employing cine.[6]

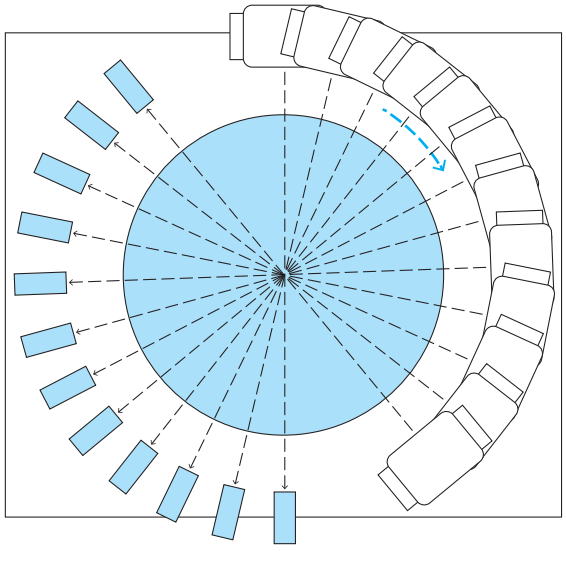

**Figure 2.** *Schematic of the dynamic spatial reconstructor, a multiple-source unit initially containing 14 x-ray tubes (later, 27 of them) that fired sequentially with matching detectors through a 160° arc in a circular gantry that rotated. Developed in the late 1970s at the Mayo Clinic in Rochester, Minnesota, this scanner enabled high-speed 3-D CT imaging of the heart. Image courtesy of the author.*

### *Coronary Artery Patency*

Hounsfield lauded the concept of CT-based coronary angiography, a remark that foreshadowed the development of CCTA to assess coronary artery disease. Preferential profiles for the scanners that emerged were multislice, multidetector CT systems using third-generation platforms.[8,9] A white paper released in 2010 by several societal and governing bodies in radiology and cardiology noted that CT scanners intended for cardiac imaging must be capable of simultaneously acquiring 64 slices covering the entire heart volume in a single breath hold ($\leq$ 20 seconds).[10] Further performance requirements included[10]:

- adequate tube capacity and maximum slice thickness of 1.5 mm
- spatial resolution of 0.5 mm or less in the xy-plane and 1.0 mm or less in the z-axis
- temporal resolution equal to 250 ms (or less)

## From Slip Ring Technology to Dual-Source Imaging

Currently, the predominant CT systems are those designed with multidetector arrays based on rotate-rotate, third-generation geometry. It was the advent of the slip ring by Varian Associates in 1976 that enabled rotate-rotate platforms.[3] Their system transferred high voltage to the scanner (unlike today's systems that transfer low voltage) using slip rings that allowed gantry rotational speeds of 3 seconds; half-second reconstructions promoted sub–3-second temporal resolution.[3] Moreover, in today's environment contemporary scanners cover the heart with 1 axial rotation, yet the slip ring remains the key to the design because a gantry must be revolving many times before applying x-rays for imaging to take place.[11]

State-of-the-art systems achieve submillimetric spatial resolution, whereas design schemes incorporating dual-source, dual-detector platforms permit temporal resolution of 66 ms via a gantry speed of 250 ms (eg, Force and Naeotom Alpha, Siemens Healthineers).[12-16] Furthermore, 1 single-source scanner (eg, Aquilion One, Canon) obtains up to 640 slices along the z-axis by employing an alternating focal spot to generate dual sampling through an array containing 320 detector rows, in which each detector element is 0.5 mm to

cover 160 mm of anatomy. This system accommodates a temporal resolution of 137 ms via gantry speeds at 275 ms.[10,17,18]

With respect to fulfilling radiation dose reduction strategies for CCTA, including sub–1-mSv outcomes, Richards and Obaid assumed 7 nontrivial points[19]:

- adequate detector width and longitudinal range, with maximum capacity (320 rows covering 160 mm of anatomy) in the current era achieving a mean effective radiation dose of as little as 0.88 mSv from a single axial scan
- application of prospective electrocardiographic gating
- combining data from 90° helical scanning using dual-source CT with ultra-high pitch (eg, 3.4 pitch) and prospective electrocardiographic gating to achieve as low as 0.9 ± 0.1 mSv to 2.04 ± 0.94 mSv
- heart rate ideally at 60 bpm or less unaided, or administration of beta blockers to acquire rate control
- optimal tube voltage that might attain 12.7 ± 1.7 mSv at 120 kV or 7.8 ± 2.0 mSv at 100 kV for patients weighing 85 kg or less
- postprocessing through iterative reconstruction to yield a 22% to 43% reduction in dose
- use of helical scan modes with 180° data plus beam angle, instead of 360° data

## Conventional Coronary Physiology Testing

Interventionalists evaluating coronary physiology seek to describe the functional outcome of a coronary artery lesion associated with 40% to 70% stenosis, instead of relying on anatomical and angiographic appearances, to determine whether treatment through percutaneous coronary intervention is needed (see **Figure 3**). Paradigms aimed at perfecting different methods became relevant from the outset of the first interventional coronary angioplasty procedure.[20] The pioneers in this field sought ways to minimize risks associated with revascularization procedures.[20-22]

Although attempts to fine-tune physiological methods began once an invasive flow-derived technique called *coronary flow reserve* was defined, the revolution in the science began after the introduction of fractional flow reserve (FFR), a pressure-derived index.[21,23] As an essential part of this cardiac catheterization technique, FFR integrates pharmacological-induced stress via intracoronary or intravenous administration of adenosine. Because adenosine is a vasoactive stressor, invasive FFR is a hyperemic pressure ratio.

### *Hyperemic Flow: FFR Defined*

Knowing that pressure is a surrogate for flow, and, importantly, with distal pressures measured 2 cm beyond the stenosis, the formula for hyperemic flow is as follows[21]:

$$FFR = \frac{Pd}{Pa}$$

This equation defines FFR with the stressor agent administered. Pd represents mean distal pressure, whereas Pa signifies mean aortic pressure. However, without the use of hyperemic stress, the right-hand component of the equation conveys resting Pd/Pa values (ie, nonstress physiological states recorded as raw data).

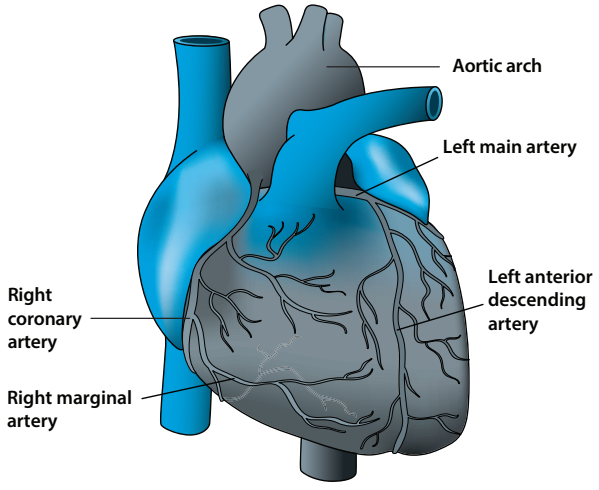


**Figure 3.** *The right coronary artery and the left main artery arise from the aorta and supply the heart with oxygen-rich blood. The left main artery divides into the circumflex artery (not depicted) and the left anterior descending artery. Arterial segments are named according to the region of the heart that they supply. © 2023 ASRT.*

To help illustrate FFR's derivation, technologists can imagine a guiding catheter placed at the coronary ostium with a pressure wire inserted into the coronary artery under investigation (see **Figure 4**). Pd is normalized to Pa before testing. During testing, if the resulting ratio is 0.81 or greater under hyperemic flow, the stricture is considered functionally sound, which means intervention might be deferred (see **Table 1**).

### *Examples of Nonhyperemic Pressure Ratios*

The mid-to-late 2010s brought several noninferior and nonstress flow indices (compared with FFR) to the catheterization laboratory. Most notable are the instantaneous wave-free ratio (Philips), the resting full-cycle ratio (RFR, Abbott), and the diastolic hyperemia-free ratio (Boston Scientific).[21,26-28] Because vasoactive dilators such as adenosine are not necessary, each index is categorized as a nonhyperemic pressure ratio meant for stable yet indeterminate coronary lesions (ie, those lesions with angiographic stenotic appearances of 40% to 70%).[29]

With patients at rest (ie, not stressed physiologically), the instantaneous wave-free ratio obtains pressure data during the cardiac cycle's wave-free periods encountered during diastole. Not only is the heart's motion less variable during diastole, but also coronary flow resistance is at a minimum during this phase. Both issues translate into best timing for the myocardium to receive oxygenated blood.[21] Moreover, instantaneous wave-free ratio became the first nonhyperemic pressure ratio released into the market, with the ADenosine Vasodilator Independent Stenosis Evaluation (ADVISE) trial establishing a clinical match between an instantaneous wave-free ratio cutoff value of 0.90 and the cutoff ratio of 0.81 for FFR.[30] For these ratio valuations, no intervention would be needed.

Furthermore, ADVISE found that a 0.75 FFR cutoff compared favorably with an instantaneous wave-free ratio value of 0.85 for optimal care (an 88% match), and thus, intervention is warranted. Finally, to account for the FFR gray zone of 0.75 to 0.80, the recommendations topped out at a 93% match, in which hybrid approaches incorporating FFR and instantaneous wave-free ratio were advised.[30] However, researchers from 2 large-scale randomized trials, the Instantaneous Wave-Free Ratio vs Fractional Flow Reserve in Patients with Stable Angina Pectoris or Acute Coronary Syndromes Study Powered by the Swedish Angiography and Angioplasty Registry (SwedeHEART) and the Define-Flair Study, concluded that instantaneous wave-free ratio is noninferior to FFR, which nullified the hybrid approach.[31,32]

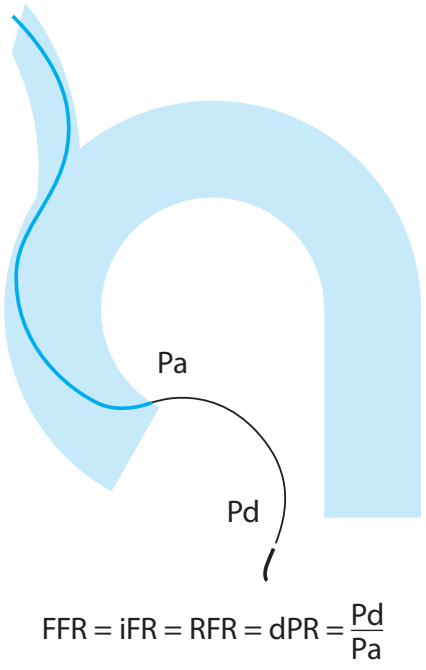


**Figure 4.** *Physiology-guided percutaneous coronary intervention schematic. Coronary physiology testing reflects the difference (ie, the ratios) in blood flow or pressure distal to a lesion (Pd, distal pressure) compared with that at the aorta and coronary ostium (Pa, aortic pressure). Aortic pressure is detected through the luminal opening at the catheter tip and transmitted via the fluid-filled column in the catheter, whereas distal pressures are recorded by a sensor (a micromanometer) located at the junction (as depicted, the small white gap along the wire length) of the radiopaque tip and radiolucent body of the wire. The distal pressures should be measured 2 cm beyond the anatomical area of stenosis, given that the sensor is 3 cm from the wire tip. Abbreviations: dPR, diastolic pressure ratio; FFR, fractional flow reserve; iFR, instantaneous wave-free ratio; RFR, resting full-cycle ratio. Image courtesy of the author.*

Table 1

**Hyperemic vs Sub- or Nonhyperemic Cutoff Values for Percutaneous Coronary Intervention**[21,24,25]

| Index | Proceed with treatment | Defer treatment |
|---|---|---|
| Fractional flow reserve[a] | ≤ 0.80 | ≥ 0.81 |
| Contrast-based fractional flow reserve[b] | ≤ 0.82 | ≥ 0.91 |
| Instantaneous wave-free ratio[c] | ≤ 0.89 | ≥ 0.90 |
| Resting full-cycle ratio (RFR)[c] | ≤ 0.89 | ≥ 0.90 |
| Diastolic hyperemia-free ratio[c] | ≤ 0.89 | ≥ 0.90 |

[a] *Hyperemic*
[b] *Subhyperemic*
[c] *Nonhyperemic*

RFR is another nonhyperemic pressure ratio associated with rest; it is equivalent to instantaneous wave-free ratio. However, unlike instantaneous wave-free ratio, this index is designed for collecting pressure information during diastole and systole (ie, the entire cardiac cycle).[21] In turn RFR might exhibit functional and clinical advantages, especially when evaluating the right coronary artery. Lesions in this artery can sometimes be challenging to examine because of an associated perfusion paradigm. From a physiological standpoint, because the right ventricular myocardium is not as thick as left ventricular myocardium, the dependence on delivery of oxygen-rich blood during diastole becomes less critical in the right chamber.[24]

A final nonhyperemic pressure ratio reviewed here is diastolic hyperemia-free ratio, which is one of the most recent resting indices on the market.[28] Diastolic hyperemia-free ratio was first tested against instantaneous wave-free ratio with subsequent outcomes compared to FFR. Because no significant differences were observed, the U.S. Food and Drug Administration marked diastolic hyperemia-free ratio as having substantial equivalence.[28] The diastolic hyperemia-free ratio algorithm produces a fully automated measurement that, like those for instantaneous wave-free ratio and RFR, is created in real-time.

## Clinical Studies Substantiating Coronary Physiology Testing

Two studies, Deferral of Percutaneous Coronary Intervention (DEFER) and Fractional Flow Reserve vs Angiography for Multivessel Evaluation (FAME), showed the importance of FFR, though several outcome-based studies demonstrated viability of the nonhyperemic pressure indices.[33,34] Whereas the ADVISE, Define-Flair, and SwedeHEART trials helped define instantaneous wave-free ratio's use, it was SwedeHEART that showcased instantaneous wave-free ratio's capacity to guide intervention. Moreover, the Validate and Revalidate trials showed RFR equivalence. As for diastolic hyperemia-free ratio, the Verify 2 trial supplied equivalency data.[34]

### *DEFER and FAME*

For FFR, the pivotal investigations were DEFER and FAME. As the first randomized controlled trial looking at the suitability of FFR-guided intervention, DEFER compared deferral of treatment vs intervention. The 2-year, 5-year, and 15-year follow-ups showed that patients with non-ischemia-producing coronary artery stenoses had excellent outcomes when medically managed (ie, no benefits were derived for intervention performed on such lesions).[35]

FAME's purpose was to examine 1-year differences in probabilities concerning major adverse cardiac events among patients receiving angiography-guided intervention vs those receiving FFR-guided intervention.[36] Out of a total of 1005 patients participating in the study, 498 were enrolled in the angiography-only group and 507 in the FFR group. The 1-year event rate was 18.3% vs 13.2% for the angiography vs FFR groups, respectively. Outcomes with respect to

angina-free lifestyles were 78% (n = 388 out of the 498 patients) in the angiography group vs 81% (n = 410 out of 507 patients) in the FFR group.[36]

### *SwedeHEART*

The open label, randomized SwedeHEART trial established the noninferiority of instantaneous wave-free ratio vs FFR for the capacity to guide intervention.[37] This study enrolled 2037 patients presenting with either stable angina or acute coronary syndromes, in which the primary endpoints were all-cause mortality, nonfatal myocardial infarction, and unplanned revascularization within 1 year. The 1-year event rate was 6.7% (n = 68 out of 1012 patients) for the instantaneous wave-free ratio group vs 6.1% (n = 61 out of 1007 patients) for the FFR group. Because chest pain and shortness of breath (or a rhythm disturbance known as *atrioventricular blockade*) often are associated with the hyperemic agent adenosine, the results indicated overwhelmingly that fewer of these procedurally dependent symptoms occurred (ie, 3.0% for the instantaneous wave-free ratio group [an adenosine-free procedure] compared with 68.3% for the FFR group [an adenosine-dependent procedure]).[37]

### *Validate-RFR and Revalidate-RFR*

Organized as a retrospective study design that reanalyzed instantaneous wave-free ratio waveforms from 651 patients who underwent intracoronary angiography, the Validate-RFR trial considered agreement between RFR and instantaneous wave-free ratio as its primary endpoint. Data demonstrated that RFR outcomes were highly correlated with those typical for instantaneous wave-free ratio.[38] In addition, RFR's diagnostic equivalence compared to instantaneous wave-free ratio fell to within 1.0%.[38]

With respect to trends concerning physiological detection, Validate-RFR found that prominent impairments occurred outside of diastole in 12.2% of all waveforms from all cardiac cycles. Moreover, when compared to instantaneous wave-free ratio, RFR was solely capable of finding physiologically limiting stenosis in 32.4% of the waveforms associated with the right coronary artery. This inflection point reiterated RFR's clinical relevance. Investigators surmised that RFR granted operators the ability to unmask physiologically significant coronary stenoses that would be missed by only assessing specific segments of the cardiac cycle, as occurs with instantaneous wave-free ratio.[38]

Capitalizing on RFR's capacity to capture important physiological data outside of diastole during intracoronary angiography, the Revalidate-RFR trial established a blinded comparison between FFR, RFR, and instantaneous wave-free ratio. This study prospectively examined 431 patients from 2 independent catheterization laboratories.[39] RFR was first compared to instantaneous wave-free ratio, then resulting outcomes were compared to FFR. RFR's performance and diagnostic equivalence were like those seen in the Validate trial (see **Table 2**).[39] Moreover, the Revalidate-RFR investigators agreed that RFR affords a viable alternative to FFR, and does so with less time, less cost, and potentially fewer adenosine-related adverse effects (ie, chest pain and shortness of breath or atrioventricular block).[39]

### *Verify 2 and CONTRAST*

Like instantaneous wave-free ratio, diastolic hyperemia-free ratio considers diastole only. Therefore, when planning diastolic hyperemia-free ratio, designers leveraged findings from the Verify 2 study, a 3-tiered prospective study first showing

Table 2

**Outcomes Data for the Validate-RFR and Revalidate-RFR Trials**[37,38]

| Trial name | Accuracy, % | Sensitivity, % | Specificity, % | PPV, % | NPV, % |
|---|---|---|---|---|---|
| Validate-RFR | 97.4 | 98.2 | 96.9 | 94.5 | 99.0 |
| Revalidate-RFR | 97.8 | 97.8 | 97.8 | 96.2 | 98.7 |

*Abbreviations: NPV, negative predictive value; PPV, positive predictive value.*

clinical comparisons between instantaneous wave-free ratio and resting Pd/Pa values; second, between instantaneous wave-free ratio and FFR; and, third, between instantaneous wave-free ratio and hyperemic instantaneous wave-free ratio.[33,34,40,41] What distinguishes diastolic hyperemia-free ratio, however, is that its algorithm works off 2 distinct diastolic features[40,41]:

- the moment when Pa is less than mean Pa
- the point marking a down-sloping Pa

To bring diastolic hyperemia-free ratio to market, information was compiled from Rapid Injection of Contrast Medium vs Nitroprusside or Adenosine in Intermediate Coronary Stenoses (CONTRAST), a novel study that tested the vasodilator-stress continuum in 763 patients enrolled through 12 international centers.[25] The continuum starts with resting states and spans 2 conditions: those using iodinated contrast media administration and traditional scenarios with adenosine hyperemia. CONTRAST was based on the principle that iodinated contrast media injected into the coronary arteries causes submaximal hyperemia for the arterial system under examination.[25,42] Paired and repeated assessments were made between instantaneous wave-free ratio, contrast-based FFR, and traditional FFR. Contrast volume was 8.0 ± 2.0 mL per recording.

CONTRAST results confirmed yet another means with which to curb negative patient experiences associated with adenosine administration (ie, associated chest pain and shortness of breath or possible atrioventricular block).[42] The investigators concluded that contrast-based FFR offers a universal technique capable of diagnostic performance superior to that of instantaneous wave-free ratio for predicting FFR-related information.[25] However, because the optimal match concerning diagnostic certainty reached only 86% under a ratio of 0.82 or less for treatment, methods that blend contrast-based FFR with instantaneous wave-free ratio or traditional FFR were suggested. When compared with traditional FFR directly, this technique might simplify traditional, invasive coronary physiology testing by using less adenosine per test.[25,42,43]

## Conclusion

Creative and historical innovations spurred the practicality of CT for aiding cardiac care. Chief among these advances were slip ring technology for swift and continuous gantry rotation, wide detectors capable of longitudinal coverage of the heart, and dual-source designs pressing the limits of temporal resolution. In addition, the advent of prospective electrocardiographic gating enabled identification of the phases of the heart, namely diastole. Invasive, conventional coronary physiology testing imparts functional assessment of coronary artery disease, whether by FFR or the nonstress flow indices that followed. These advances converged to instill the robustness of CCTA applications, including CT-based flow and pressure gradient estimates.

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*Kevin L Wininger, BS, BS, R.T.(R)(CT)(CI), is computed tomography technologist and cardiac interventional technologist at University Hospitals Samaritan Medical Center in Ashland, Ohio.*

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*This article is the first in a 3-part series reviewing coronary artery evaluation for computed tomography (CT) technologists. A follow-up article will spotlight the clinical implications of coronary CT angiography (CCTA), emphasizing important milestones driving acceptance of noninvasive pressure gradient and flow testing. A third installment will earmark engineering and design strategies that underscore cardiac CT's potential, with a focus on the benefits for CCTA and the promising results for structural heart assessments.*

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Building Professionals

# Treating Anxiety and Depression With Psilocybin Therapy

Amanda Paige Hanstein, MSHA, R.T.(T)
Chance Felchlin, R.T.(T)

Individuals who receive a life-threatening or terminal illness diagnosis often face difficult emotions and feelings, including anxiety and depression. The fear of death and the thought of no longer existing can induce extreme anxiety, and the idea of leaving a family behind can result in the development of considerable depression in patients. Although traditional pharmaceutical therapies are useful for many patients, there is promising research supporting psilocybin as a possible alternative for those with treatment-resistant depression.[1] Psilocybin is found in certain types of mushrooms and can induce dreamlike hallucinations, synesthesia, and an altered sense of time and thought.[2] Research shows that psilocybin effectively reduces anxiety and depression in those facing a life-threatening diagnosis, and it might be more effective than traditional pharmaceutical treatments.[2]

Currently, psilocybin is not legal in the United States, and it is not approved for therapeutic use by the U.S. Food and Drug Administration. However, several states and cities have added legislative protections for individuals in those locations, and as of 2024, psilocybin is in an international phase 3 trial for treatment-resistant depression. In 2018, the Right to Try Act made it legal for terminally ill patients to use medicines that are not currently approved but are in the phased trial process.[3,4]

## Method of Action

Psilocybin is a psychedelic compound primarily derived from several species of mushrooms that grow in the wild. After ingestion, the body converts psilocybin into its active form, psilocin, which acts as an agonist with serotonin receptors. Serotonin receptors are associated with the mediation of many emotions and moods such as anxiety and aggression, as well as cognition and other neurologic processes.[2] After the serotonin receptors are active, hyperfrontality, or acute activation of the prefrontal cortex, is induced, which mediates antidepressive and anxiolytic effects.[2]

## Current Research

A study by Ross et al described the beneficial role psilocybin can have in oncology patients who have depressive symptoms, including suicidal ideation and loss of meaning.[5] After 1 moderate-to-high dose of psilocybin coupled with psychotherapy, patients immediately showed a drastic drop in suicidal ideation and loss of meaning. The results also showed a sustained reduction in these areas after 6.5 months.[5] These results are important considering that those with a cancer diagnosis can be up to 4 times as likely to commit suicide compared with the general population, and the current drugs to combat this are not effective.[5] Research supporting the effectiveness of pharmaceutical therapy on suicidal ideation is limited.[5]

A systematic review of psychedelic research described the lasting effects psilocybin therapy can have regarding anxiety and depression. After 6 months, 60% of participants had decreased anxiety, and 80% had decreased depression.[6] Moreover, at 3- and 4-year follow-ups, more than half of patients showed sustained

significant reduction in anxiety and depression from the initial dose.[6] The lasting effects of 1 dose are substantial and show the potential for far-reaching clinical benefits in the areas of depression and anxiety.

Because each patient experiences anxiety and depression uniquely, quantitative data are limited. Therefore, narrative, or qualitative data, are needed for insight into patients' experiences with psilocybin. Because of psilocybin's drastic effect on consciousness, patients often experience deeper introspection and more pronounced emotional processing.[7] The induced hallucinogenic state can allow patients to better confront and work through emotions. Anecdotal data from these experiences can help researchers learn more about how anxiety and depression work and the role psilocybin plays.

One study assessed the personal experiences of 4 study participants and provided personal accounts of feelings they experienced during their psilocybin encounter.[8] All the patients had received a cancer diagnosis, and 2 of them were at a later stage of cancer.[8] One patient, a man in his 20s, stated that he had a spiritual guide for his psilocybin journey and that the guide escorted him through different emotions. He stated that he did not have a body and was simply an entity or soul that was shopping for a body. In the end, the only body that he could choose was his own. He went on to explain that this was a representation of him coming to terms with his illness and said, "I think that acceptance has been liberating."[8] Another patient, a woman in her 60s, also had a transformative experience. She stated that she felt as if she was outside of space and time but "in a way that was really. . .comforting and beautiful." She also believed she experienced her own death on 2 different occasions during her experience and was not afraid. At the end of her experience, she said, "maybe death is a beautiful thing."[8] These personal accounts are quite remarkable and thought-provoking, and they serve as valuable data in the ongoing research regarding psilocybin and the treatment of anxiety and depression.

## Conclusion

Current research on psilocybin shows it has promising potential as an option to treat anxiety and depression in patients with life-threatening and terminal illnesses. Quantitative data show reduced anxiety and depression that can last from months to years. Qualitative data provide more insight into how psilocybin might be working psychologically to relieve anxiety and depression. Despite favorable evidence so far, there is a need for much more in-depth research and data to determine whether psilocybin can legitimately and safely benefit patients with life-threatening and terminal illnesses.

*Amanda Paige Hanstein, MSHA, R.T.(T), works for the University of Oklahoma Health Sciences Center in Oklahoma City.*

*Chance Felchlin, R.T.(T), works for Texas Oncology in Dallas.*

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# Opportunities and Ethical Considerations of Social Media Use in Health Care

Lillian Amann, MSRS, R.T.(R)

Social media has caused a shift in the way people communicate and has affected the health care profession.[1] The amount of time people spend on social media platforms presents opportunities and challenges for the health care profession, including ethical considerations.

## Opportunities

There are several opportunities in which the health care profession can use social media, including empowering and educating patients, fostering a sense of community, disseminating health information quickly, promoting professional education and research, improving communication and networking among providers, and interprofessional collaboration.

### *Empowering and Educating Patients*

Social media offers an accessible and engaging platform for the public to get reliable medical information. Health care organizations and specialists can exchange instructional materials about illnesses, remedies, precautions, and healthy lifestyle habits.[2] Using this knowledge, patients can take an active role in making wise decisions regarding their health.

### *Fostering a Sense of Community and Helping Others*

Online support groups are gaining popularity on social media. These groups offer emotional support and a means to share experiences and helpful information, which helps patients feel connected and less isolated.[3]

### *Disseminating Health Information Quickly*

During public health emergencies or disease outbreaks, social media can be used to quickly disseminate important information to a large audience. With the combination of technology and social media, health care professionals can update the public about symptoms, preventive measures, and immunization programs to help them stay informed and take appropriate precautions in real time.[3]

### *Professional Education and Research*

Social media can be a valuable tool for health care professionals and students to continue education and professional development throughout their career.[3] It has given health care professionals a means to be informed about the latest research findings and scientific developments by participating in webinars, online conferences, discussion forums, and blogs on social media.[2]

### *Improved Communication, Knowledge Exchange, and Networking*

Social media platforms help facilitate communication between health care professionals, promoting collaboration and effective patient care.[2,3] Furthermore, social media can facilitate sharing medical knowledge, discussions on challenging cases, research discoveries, and best practices among health care professionals, promoting improved learning, career development, and more comprehensive

treatment strategies.[1,3] Social media also enables health care workers to expand their professional networks by connecting with specialists, exchanging experiences, and collaborating on research projects.[3]

## Challenges and Ethical Considerations

There are many challenges and ethical considerations when using social media in health care. Maintaining patient privacy and confidentiality are challenges because disclosing medical information or case specifics on social media can unintentionally violate patients' rights to confidentiality and privacy.[4] Health care professionals must exercise caution when sharing medical information on social media.[3] Informed consent requires health care workers to obtain explicit permission from patients or their legal representatives before sharing patient photographs, videos, or stories on social media.[3] Data security and Health Insurance Portability and Accountability Act (HIPAA) compliance are crucial when using social media.[1] Health care businesses must have strong security measures to strictly respect HIPAA standards and prevent unauthorized access to patient information.[1,4] In addition, misleading medical information can spread quickly on social media. Health care professionals can prevent this by sharing only evidence-based information and reliable sources with patients.[3]

Health care professionals must maintain professional integrity on social media by avoiding conflicts, refraining from giving medical advice without a patient-provider connection, and upholding acceptable limits.[3] They also should avoid unprofessional or disparaging content that could negatively affect their reputation or their company's reputation.[4] Health care professionals using social media should be mindful of how personal beliefs and affiliations could affect their professional identity and the organization's reputation.[4] Maintaining appropriate boundaries with patients during online interactions and avoiding behavior that blurs the line between personal and professional relationships are important ethical considerations.[4] There can be potential damage to the professional reputation of health care professionals and organizations through their use of social media.[3] Therefore, it is important to maintain a professional image online by adhering to policies and guidelines set by health care institutions. These policies focus on patient privacy, specify acceptable behavior, and offer instructions on responsible social media use to uphold professionalism and safeguard patient privacy.

Health care professionals should use caution when using social media on the job. Excessive social media use at work can distract health care professionals from their duties, jeopardizing patient safety and care quality. Prioritizing workload and abstaining from personal interests while on the job is crucial. In addition, there are ethical concerns with personal use of social media during work hours.

Screening social media accounts can assist with candidate evaluation during the hiring process, but a balance between respecting candidates' privacy and avoiding prejudices that might result from seeing private information on social media platforms is necessary.[3]

## Social Media Use in Health Care Education

Radiography students use social media for various educational reasons, but there are a few ethical concerns. One of the most important concerns is a breach of patient confidentiality and privacy. HIPAA violations might occur because of students unintentionally sharing pictures, videos, or information about patients on social networking platforms.[2] As a result, there might be legal ramifications for the student and the institution.[2] Students using social media might also face challenges related to academic integrity. Ethical issues arise when students seek help online without citing sources or share exam questions or answers with their peers. This could affect the quality of their education and damage the reputation of their program. Institutions need to ensure that clear guidelines are established regarding social media use by health care workers and students to mitigate these concerns.[2] These guidelines should include rules on patient privacy and confidentiality, professional conduct, and academic integrity. Students should be educated on these guidelines during orientation and periodically reminded of them throughout their program.[2]

## Conclusion

Social media in health care can be effective and useful. It supports communication, sharing knowledge,

professional development, and continuing education. On the other hand, it also might cause ethical concerns regarding patient privacy, confidentiality, and online professionalism. Therefore, health care workers should be cautious when using social media while at work and adhere to organizational policies. Maintaining a balance between the responsible use of social media for professional purposes and prioritizing patient care is important. If there is any ambiguity, professionals should refer to their organization's policies or consult with the legal department or a supervisor to ensure compliance and appropriate ethical conduct. Health care organizations can navigate these challenges and harness the benefits of social media responsibly by establishing comprehensive social media guidelines and policies, creating an environment that fosters effective communication while upholding the highest ethical standards. Overall, health care professionals should be cautious when using social media.

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*Lillian Amann, MSRS, R.T.(R), is adjunct lecturer and chapter director for the New York Zeta Chapter, Lambda Nu National Honor Society for radiologic and imaging sciences at City University of New York College of Technology in Brooklyn. She is a doctoral candidate studying education in the health care professions at Nova Southeastern University in Fort Lauderdale, Florida.*

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# Choosing and Narrowing a Research Topic

Laurie Coburn, EdD, R.P.A., R.R.A., R.T.(R)(CV)

Research opens new possibilities, allowing exploration of the unknown and expansion of knowledge. Learning something new can be fulfilling, especially for those who enjoy intellectual challenges, critical thinking, and problem-solving. Discovering and synthesizing information, and subsequently explaining findings, is gratifying. Research also can lead to groundbreaking technologies, new medications, theories, improved processes, and methodologies that drive society forward. Being an active participant in this process can be incredibly rewarding. Often, aspiring researchers wonder about the best way to find research topics, how to navigate the research process, and where to access available resources. Uncertainty can hinder engagement in research projects. This article encourages participation in research by highlighting the first step of beginning a research project—choosing and refining a suitable research topic.

## Defining Research

Research is an academic examination and a diligent search; it is collecting information on a chosen topic. Specifically, research is an "investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws."[1]

Preliminary research development is critical for the entire project's success. Choosing a topic and developing the problem statement and hypothesis guide the entire research process. After the topic has been defined, researchers use a literature search to gain deeper understanding. With this information, a research topic can be developed and finalized.

## Choosing a Topic

Determining purpose of research is important when considering topics. This can be accomplished by exploring a primary idea and then addressing specific subcategorical questions. The initial idea can stem from various sources, such as identifying a problem in a clinical setting, personal interests, or a passion for a particular topic. In addition, ideas for research can originate from colleagues, mentors, or leaders in a profession.

Determining importance of the research also is considered during the process of choosing a research topic. First, determine the audience by questioning who will be reading the research and why it is important to them. Consider whether a process or knowledge base will change based on the research presented. Next, consider the importance of the subject. Reading and learning about the potential research subject makes it easier to determine whether gaps in current understanding need to be filled. This step should ensure that the research adds to the existing body of knowledge.

Regardless of the method used to discover the topic, researchers must begin the investigation with a broad perspective and gradually narrow the focus to enhance the research effort, which is crucial. Several methods

aid in exploring topics for research. Free writing, 3 perspectives, concept mapping, and PICO (Population, Intervention, Comparison, and Outcome) framework stimulate the thought process for topic development.

### *Free Writing*

Free writing is a technique used to engage in uninterrupted, continuous writing. During free writing, the writer disregards grammar, spelling, and punctuation. Because of this, free writing acts as a form of brainstorming, allowing the writer to freely jot down thoughts, ideas, and any related associations that come to mind. It encourages the exploration of creativity and provides a platform for expressing ideas.[2,3] A time limit can be predetermined when free writing, but the critical point is there is no initial judgment of ideas. After free writing, the writer reviews the words and ideas generated, sorts through the information, and searches for emerging topics or insights.

### *Three Perspectives*

The 3-perspective method of writing and analysis takes into consideration multiple perspectives to gain an understanding of a topic or issue then looks for interesting relationships or mismatches.[4] This method recognizes that different perspectives can provide valuable insights and contribute to a wide-ranging analysis. This method might analyze facts and ideas in the context of description, historical perspective, and relationships to develop a research topic. To use this strategy, the researcher answers questions from 3 perspectives[4]:

- describe it – Describe the subject in detail. What is the topic? What are its components? What are its interesting and distinguishing features? Distinguish the subject from those that are similar to it. How is the subject unlike others?
- trace it – What is the history of the subject? How has it changed throughout time? Why has it changed throughout time? What are the important events that have influenced the subject?
- map it – To what is the subject related? By what is it influenced, and how? What does it influence, and how? Who has a stake in the topic, and why? What fields are consulted for the study of the subject, and why? How have others approached the subject? How is their work related to the current interest?

### *Concept Mapping*

Concept maps provide a framework for organizing and representing knowledge on a particular topic (see **Figure 1**). They visually represent the relationships between concepts, helping researchers identify key constructs and understand the theory and concepts related to research. The construction of a concept map should follow several stages. First, in the center of the map is the general topic. Next, in separate arms, labels describe the main concepts supporting the main topic. These arms could include similarities, differences, cause and effect, correlations, or outcomes. Putting these concepts in hierarchical order from general to the most specific is important. After this step, links are added between concepts with phrases that describe relationships. Finally, cross-links and relationships between concepts in different subdomains are identified and labeled.[5] After this process is complete, critical concepts will be identified along with gaps in information related to the topic, allowing for the identification of themes related to the topic.

### *PICO Framework*

Researchers commonly use the PICO framework to formulate research questions and keywords to guide the literature search.[6] In the acronym, the P refers to the population or the group of people that is the research focus. It includes a specific patient population, age groups, or individuals with a particular condition or characteristic. The I represents the intervention or treatments under study. The C stands for comparison, which refers to the alternative or a control group compared with the intervention group. Finally, the O refers to the outcome or the desired effect expected from the intervention.[6] The PICO framework helps the researcher define research questions and identify relevant elements to consider in the study design and literature search.[6]

## Searching for Information

After a topic has been defined, the next step is to explore what is already known about it and what

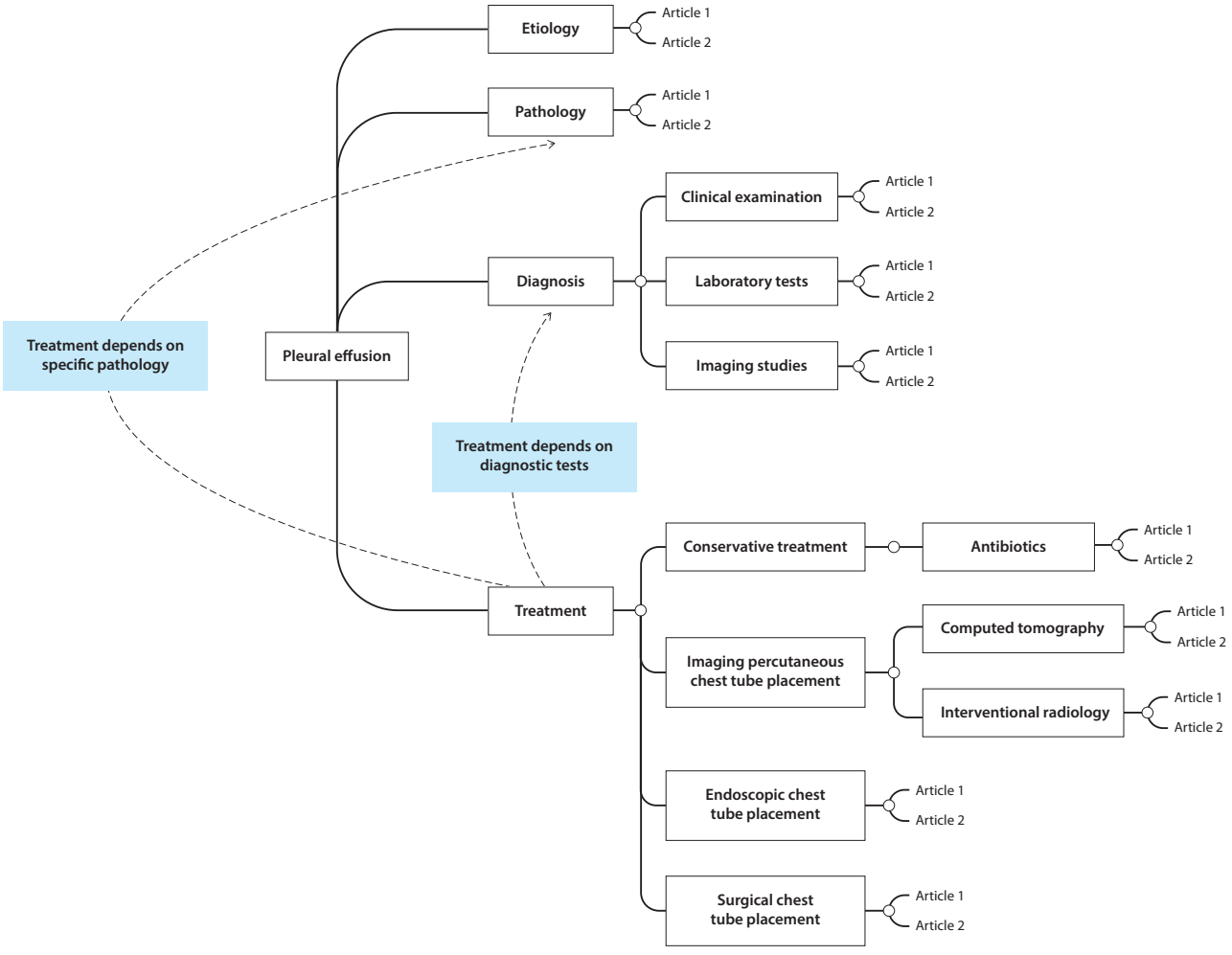


**Figure 1.** *Example of concept mapping for the topic pleural effusion. Figure courtesy of author.*

remains unknown. Concept maps can assist in generating ideas about what the investigator already knows about the topic. However, acknowledging that there might be gaps in knowledge is essential; these gaps can be in the researcher's understanding and in the overall understanding of the topic. The primary objective of the search is to find published information and assess it to identify whether any gaps are evident in the current understanding. Several sources and methods are available to discover information that can validate what is known and identify what is still unknown.

### *Search Engines*

Search engines are instruments used to search for information electronically. Open-source search engines are a way to learn, study, and master search technology.[7] There are several types of search engines[8]:

- chatbots
- crawler-based search engines
- human-powered directories
- hybrid search engines
- meta-search engines
- question-answering systems

Crawler-based search engines, such as Google, Microsoft Bing, and Yahoo!,[9] are also known as *web crawlers* or *spiders*. They are automated programs that systematically browse the web, following links and indexing web pages for retrieval. They use algorithms to analyze and rank web pages based on relevance to search queries.[10]

Human-powered directories rely on human editors to manually review and categorize websites. These directories organize websites into specific categories and subcategories, making navigating and finding relevant information easier for users. Examples of human-powered directories include the Open Directory Project (DMOZ) and the Internet Public Library.

Hybrid search engines combine the features of crawler-based search engines and human-powered directories. They use automated crawling and indexing techniques and incorporate human editorial input to refine search results and improve relevance.[11] Question-answering systems, dialogue systems, and chatbots are designed to interact with users conversationally, answer specific questions, or engage in dialogue.

Preliminary searches using engines like Google, Yahoo!, or Microsoft Bing provide a variety of credible sources, such as books, journals, and websites. The researcher can ascertain whether the body of knowledge is substantial or there is a gap in the literature for which original research is welcomed and desired. Depending on the information required, the user might require services beyond general search engines like Google.

### *Databases*

A bibliographic database is a structured collection of detailed descriptions of publications such as books, articles, conference papers, and reports. These databases are storehouses of bibliographic information, including author names, publication titles, journal names, abstracts, keywords, and sometimes full-text content. A bibliographic database, such as Medline, PubMed, Education Resources Information Center (ERIC), or EBSCOhost, is an important starting point to search for topics related to biomedicine and health sciences, allowing users to stay informed about the latest research and developments. The U.S. National Library of Medicine (NLM) database is a vital medical and health care research resource. Supported by the National Institutes of Health, the NLM offers a broad range of information and research services dedicated to biomedicine and health care.

Bibliographic databases also support evidence-based practice and research by facilitating identification of relevant studies for systematic reviews and meta-analyses. As such, bibliographic databases have important roles in advancing knowledge and improving health care outcomes in the evolving landscape of biomedicine and health sciences.[12] Databases typically are available through a college, university, or public library. Researchers can retrieve relevant articles and gain insights into current trends and topics by searching for specific keywords or subject areas.

### *Types of Searches*

The keywords input into the search engine are critical to gathering viable, useful resources. The researcher might begin with a basic structured search using simple keywords such as *leukemia*; however, mixing search topic terms might aid in including all relevant publications. An example of a mixed search term is *pediatric leukemia*. Researchers might conduct simple topic searches, as well as advanced searches that help explore different aspects of a topic and identify key concepts, types of evidence, and research gaps.

Using a simple topic search, researchers look for documents that are directly related to the general topic of interest. A simple search might produce an abundance of material that would take time to sift through for relevant, informative items. In simple searches, browsing, rather than focused searching, is performed. A topic search focuses on finding information relevant to the overall theme or subject of the research topic and is important for choosing references.[13]

An advanced search uses techniques like filtering to refine the search. For example, the search time frame could be refined by adding a filter to select only research from the previous 5 years. Another type of advanced search uses Medical Subject Headings (MeSH), the NLM controlled vocabulary thesaurus, to categorize and organize biomedical literature in the NLM databases. The purpose of an advanced search

typically is to limit the search to a manageable amount of information that pertains to the topic.

An exploratory search is used to understand the nature of the research topic better. Exploratory searches help researchers find different perspectives, theories, and approaches related to the topic. These searches often are conducted at the beginning of the research process to develop and refine research questions and hypotheses.[14]

Finally, systematic searching is another important type of search. It aims to identify all relevant information sources in a transparent and reproducible manner. Systematic searching involves using specific search methods and search systems with advanced functionalities to ensure comprehensive coverage of the literature.[14]

### Boolean Operators

Boolean operators are used to connect and define the relationship between the words used in a search. For example, a list of keywords with the conjunction *and* qualifies that all terms provided in the search must be contained in the results. The database or search engine retrieves only items containing all words entered. If the conjunction *or* is entered between keywords, the search stipulates that any, but not necessarily all, of the words entered must appear in the search results. Using *or* is a method of searching for synonymous or related terms when there are multiple words for the same concept.

### Nesting

Nesting is a way to search for multiple terms related to the same topic simultaneously. Grouping similar terms in parentheses is called *nesting* because multiple terms relating to the same idea are clustered together. To nest in a search, multiple similar terms and the Boolean operator *or*, which is used to connect the similar terms, are placed in parentheses. An example of nesting could be inputting terms like *(lung cancer or 'lung carcinoma')* and *('genetic markers' or genetics)*. The apostrophe signals that you are looking for both terms together.

### Plus and Minus Signs

Most general search engines allow users to enter plus or minus signs before a particular word. Entering a plus sign before a word (eg, +cancer) stipulates that the word must appear in the search results. A minus sign before a word (eg, –lung) stipulates that the word should not appear in the results. Because some search engines might use the plus and minus signs as substitutes for Boolean operators, understanding what is unique to each website and using the correct modifiers is important.[15]

### Truncation

Truncation symbols permit the researcher to search various sources with the use of a symbol. The purpose of truncation is to broaden search results. By using a truncation symbol, usually an asterisk (*), at the root word, the search tool searches all word variations after the asterisk. In the case of radiology, the use of * with *radiol* (ie, radiol*) will retrieve radiology, radiologic technology, and Radiol B-R (an antibacterial jelly for horses). Depending on the root word and placement of the asterisk, truncation can retrieve some irrelevant results. Truncation symbols are unique to each database, and sometimes a question mark (?) or exclamation mark (!) is used instead of an asterisk.[16]

### Wildcard Symbols

Wildcards are characters used to assist a search for information. Wildcards are used to represent 1 character or letter in a word. Wildcards are especially useful when the user needs clarification on the correct spelling of a word. There are variations in the use of American and British spellings for medical terms. The most used wildcard is a question mark (?). An example is *col?r*, yielding color and colour.[16]

### Proximity Operators

Proximity operators are symbols, typically *w* for within and *n* for near, that allow the location of 1 word within a certain distance of another word when applied in a search. These operators allow researchers to specify the distance between words (eg, n4, n5, w8) and retrieve results that meet the specified proximity criteria.[17] For example, n2 will find terms within 2 words of each other. The query *lung cancer n2 smoking* might produce results related to lung cancer and smoking or indicate a causal relationship between smoking and

lung cancer. In comparison, using the w operator, the query *Wilhelm w2 Roentgen* might produce results that include variations of Wilhelm Roentgen's name but not the reverse order (ie, Roentgen Wilhelm).

### *Limiters*

Limiters can be used when narrowing a broad topic. A limiter refers to a specific criterion or condition such as year, document type, or journal name, which is applied to narrow down the search results and focus on a specific subset of information. Limiters help ensure the retrieved articles meet certain predetermined criteria. Limiters should be justified and based on the research question or objectives.

#### Medical Subject Headings

Terms from the MeSH thesaurus (ie, limiters) are used when searching the NLM databases (eg, PubMed, MEDLINE). For example, if a researcher was interested in the effects of exercise on mental health, they would conduct a MeSH query using the MeSH term *exercise*, the operator *and*, and the MeSH term *mental health* to identify articles that focus specifically on the intersection of exercise and mental health.

#### Organizing Information from Keyword Search

After completing the search for information, organizing the compiled information is crucial. A research topic or question is likely becoming apparent. It might be the final research topic, or it might be modified throughout the research process. There are several ways to organize the information, but a systematic review of the literature is efficient.

## Documentation of Search Strategies

Research requires reviewing a large amount of information. As search strategies are implemented to narrow a research topic, documenting every search and its usefulness to guide future search strategies is important. Organizing the information in a way that helps track searches, provides easy access to documents, provides a summary of information, and consolidates the information is needed to progress through the research process.[18]

The matrix method, developed by Judith Garrard, is a system that consists of several digital folders, including a paper trail folder, a documents folder, a review matrix folder, and a synthesis folder.[18] Each of these digital folders serves an important purpose during the research process. Every time the literature is searched, the date, the database searched, and the main search terms should be documented, as well as the limiters or filters used. For example, if a search was limited to the past 5 years or a certain patient population, such as pediatric patients, it should be noted. By recording the limiters, determining whether a limiter excessively decreased the number of results is easier. This search log would be stored in the paper trail folder of the matrix system. Further, if other ways of gathering information were used, such as interviews or help from a librarian, this information also would be noted in the paper trail folder.[18] The paper trail folder serves 2 main purposes; it allows the researcher to review and refine search results, and it documents the searches used that must be discussed in the final research paper.

### *PRISMA Flowchart*

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) is a set of guidelines for evaluating health interventions that uses a defined flowchart to help report systematic reviews transparently and completely.[19] By including this flowchart in health care systematic review articles, authors show the process used to review information regarding the research topic.

A systematic review is a review of scientific evidence in medical literature identifying information such as etiology, diagnosis, prognosis, and treatment of various conditions.[18] Systematic reviews are important as they comprehensively summarize available published information.[19] Meta-analyses provide a quantitative estimate for the effect of a treatment intervention or exposure.

The PRISMA guidelines include 27 items researchers should include in reporting systematic reviews.[20] Information in the PRISMA flowchart includes the research question, publication dates of documents included in the search, the search strategy, and data analysis (see **Figure 2**). By following and including these guidelines in a systematic review, authors make it easier for readers to evaluate and understand the findings.[20] Page et al have outlined the PRISMA

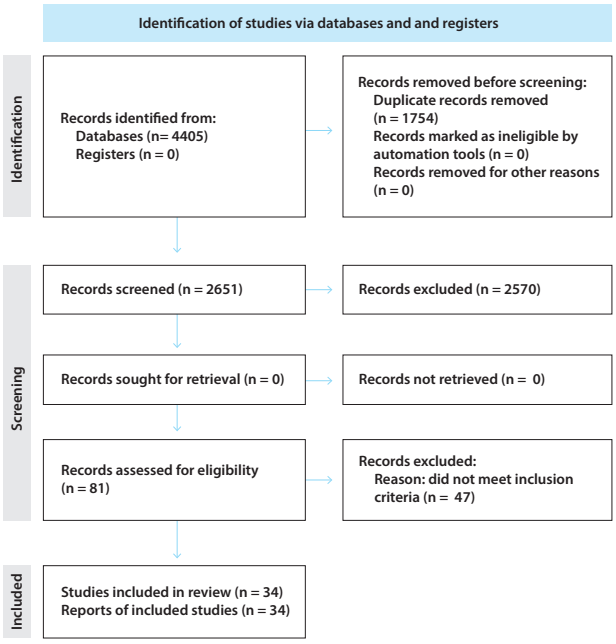


**Figure 2.** *Example of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. © 2023 American Society of Radiologic Technologists. Kortbawi M, Heuer A, Reid-Hector J, Ghajar M. Effect of Simulation-Based Learning Strategies on Undergraduate Radiologic Science Students.* Radiol Technol. *2023;95(2):125-133.*

flowchart.[20] It provides a template for researchers to include in their systematic reviews. An initial PRISMA flowchart should also be stored in the paper trail folder during organization of research searches.[18]

## Selecting Relevant Articles

When conducting research, there needs to be a method for selecting articles relevant to the chosen topic. A 3-stage review process ensures each article is applicable to the topic of research. The first level of the process is a review of the title and the date of publication. If the article's title appears relevant to the current research, it should be added to a citation manager, which will help track the sources and facilitate the citation process later. A citation manager helps organize and keep a record of all sources used in a project. The sources might be viewed as a list and often provide a link to the reference. As the paper is written, citation managers help the author insert citations from references into the document. Common citation managers include:

- BibTeX
- Citavi (Lumivero)
- EasyBib
- EndNote (Clarivate)
- Mendeley (Elsevier Ltd)
- Papers (Digital Science Research and Solutions Inc)
- ReadCube (Digital Science Research and Solutions Inc)
- RefWorks (ProQuest LLC)
- Zotero

Numerous options are available for free; they are open-source software and function as browser extensions. If an article is related to the research topic based on its title, it also should be saved in the digital document folder of the matrix system.[18]

After the articles are screened based on titles, the abstracts are reviewed. The abstract contains information about each study's purpose, methodology, and findings. It provides the opportunity for further scrutiny of the article as it relates to the research topic, allowing for decisions to include or exclude the article from the references used in the research.

The final step in screening for relevant articles is a review of the entire article. If, after reading the article, it is found to be very relevant to the research topic, further review of the article's reference list is also valuable. Journal article references offer more information that might be useful for the research project. In addition, some authors are experts on the subject, and conducting a search using the author's name might identify other publications related to the topic.[21]

## Organizing Information from Selected Articles

After following the steps to extensively search the literature and select relevant articles, analyzing the information is essential. One of the best ways to organize information is through a literature review matrix. The review matrix is a spreadsheet that lists a topic at the top of each column and presents information for each reference by row.[18] The column topics are not set,

and might be different for each research project. For example, if comparing the methodologies used in various research papers is essential, the review matrix might look like **Table 1**. If the researcher wanted to highlight various themes identified during the literature review, the column headings would still include journal article reference and year, but the other columns would be labeled with themes found during the research. The goal is for the organization of the review matrix to meet the objective(s) of the researcher. Other column topics that might be beneficial are (listed in order of the review process)[21]:

- problem being addressed
- central purpose of the study
- information about the sample, population, or subjects
- review of results
- gaps identified
- technical flaws of the study

The review matrix should be updated continually with new reference entries. The topics in the columns might be modified throughout the research process as new information is added. Copies of all versions of the review matrix should be kept. Saving the previous versions makes it easy to follow the timeline of work, which might be necessary.[18] The review matrix is typically stored in a digital format. If the matrix method is used, the review matrix will be stored in the matrix folder.[18]

### *Thematic Concept Map*

Thematic concept mapping is also a valuable tool in the research process. It allows researchers to visually organize and analyze complex information, identify relationships between concepts, and facilitate the generation of theories and hypotheses. Thematic concept maps are diagrams or graphical tools that help researchers visualize emerging ideas from data, clarify relationships, communicate the developing theory, and demonstrate analytical thinking.[22,23] A thematic concept map helps organize data into themes that might be turned into an outline for the study. A thematic concept map can take many forms. For example, it might be organized in the form of a table. Tables can be constructed with columns labeled *Theme* and *Supporting research*, and rows listing the theme and the supporting articles, or the themes might be listed in columns across the top, and the article information and an X indicating inclusion in the theme listed in rows (see **Tables 2** and **3**). Some articles will be associated with more than 1 theme. This is common because 1 report often includes many themes. During a review of each article, each theme supported should be noted, and any newly identified themes added. In addition, when listing articles that support themes, page numbers should be included. This aids in quickly accessing the relevant information later when outlining and writing the paper.

Alternatively, thematic concept mapping can be accomplished using a diagram with the central topic listed in circles or boxes and the supporting themes structured hierarchically. Ideas are then connected using lines or arrows to identify relationships. These connectors are labeled to specify how the concepts are related (see **Figure 3**). Again, this diagram provides the same information as the thematic concept tables but also adds relationships. Every researcher should employ the method, whether tables or diagrams, that best aligns

Table 1

**Example of Review Matrix Highlighting Topic and Methodology**

| Journal article reference | Year | Topic | Methodology |
|---|---|---|---|
| Naylor S, Foulkes D. Diagnostic radiographers working in the operating theatre: an action research project. *Radiography*. 2018;24(1):9-14. | 2018 | Interprofessional education | Action research |
| Olson R, Bialocerkowski A. Interprofessional education in allied health: a systematic review. *Med Educ*. 2014;48(3):236-246. | 2014 | Interprofessional education | Systematic review |

Table 2

**Example 1 of Thematic Concept Map Table: Factors That Affect Faculty Use of Technology**

| Theme | Article supporting research |
|---|---|
| Theme 1 (eg, gender) | Article 1 and page number<br>Article 2 and page number |
| Theme 2 (eg, training) | Article 3 and page number |
| Theme 3 (eg, institution type) | Article 2 and page number<br>Article 3 and page number |
| Theme 4 (eg, institution size) | Article 1 and page number |

Table 3

**Example 2 of Thematic Concept Map Table: Factors That Affect Faculty Use of Technology**

| Article supporting research | Theme 1 (eg, gender) | Theme 2 (eg, training) | Theme 3 (eg, institution type) | Theme 4 (eg, institution size) |
|---|---|---|---|---|
| Article 1 | X | | | X |
| Article 2 | X | | X | |
| Article 3 | | X | X | |

with their analysis of themes and data extracted from the literature.

### *Gap Map*

Although the thematic concept map helps abstract information and outlines the article's key themes, gap maps also are important. The aim of a gap map is to identify gaps in the existing literature on a research topic. A gap map also visually represents the current state of knowledge by mapping out the existing knowledge and highlighting areas where further research is needed.[24] Some benefits of a gap map include identifying research priorities, avoiding duplication of studies, and providing a visual representation of gaps in knowledge. As articles are studied in the concept map, the rows are typically used to abstract each paper. However, when the goal is to integrate the information, concentration shifts to the themes in columns.[18] When reviewing, the themes in each column should be reviewed to identify what is missing in each study. For example, a specific population might be poorly represented, or the sample size might be too small. Often this information is easily identified in each article's limitation or future research sections. Finally, essential elements that the article should have addressed might be missing. When the thematic concept map incorporates these limitations, it essentially creates a type of gap map that helps identify the areas in the literature where information or research is lacking.[18]

## Conclusion

Conducting a systematic review to narrow down a research topic is essential. The matrix system is a way to perform this evaluation. The first step is to document all search strategies by tracking and recording each time the literature is reviewed. The next step is to narrow the documents included in the research, accomplished by a review of the title, abstract, and finally, the whole article, including references. During article inspection, it is essential to file the documents used and to keep a review matrix to organize and abstract the information found in each piece. Some crucial components of the review matrix include the full citation of the article; the problem addressed; the central purpose or focus of the study; information about the sample, population, or subjects; a review of

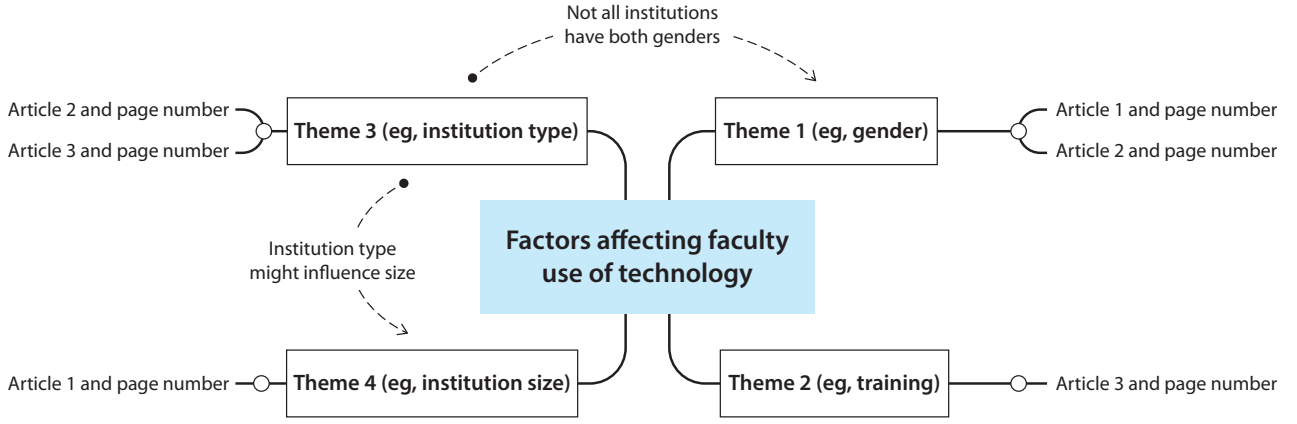


**Figure 3.** *Example of thematic concept map diagram. Figure courtesy of the author.*

key results related to the research; the methodology of the study; any technical or methodological flaws that are evident; and themes.

Researchers review the summaries and create a thematic concept map with gaps. The thematic concept map aids in analyzing published information and categorizes it into subtopics. When creating the thematic concept map, researchers should consider identifying gaps in the literature. The purpose is to narrow the research topic and to ensure the research will add to the current body of literature. Performing this analysis accomplishes the final step of outlining the research question or topic. Researchers can then formulate well-defined research questions by applying the PICO framework, focusing on specific populations, interventions, comparisons, and outcomes. By following these systematic procedures, researchers can ensure that their work contributes meaningfully to the current body of knowledge.

*Laurie Coburn, EdD, R.P.A., R.R.A., R.T.(R)(CV), is assistant professor at Weber State University in Ogden, Utah, and serves on the* Radiologic Technology *Editorial Review Board.*

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# Integrating Pranayama in Allied Health Education for Student Well-Being

Agata Stelmark, BS, RN, CCRN, E-RYT 200, RYT 500, YACEP
Jarek Stelmark, MBA, R.T.(R)(CT)(MR)(CV)(QM)(BD)(VI)

After the COVID-19 pandemic, stress levels among allied health students were at unprecedented levels. The challenges brought on by the global health crisis intensified existing pressures, leaving students feeling overwhelmed from long hours of study and clinical work at understaffed clinical education centers. Pursuing a career in allied health requires resilience and dedication, but the landscape after the pandemic added new dimensions to the stress experienced by these students.

After the pandemic, allied health students faced additional stressors. Because of the shift to online learning during the pandemic and the necessity to keep up with rapidly evolving health care guidelines, allied health students faced increased academic pressure.[1] Adapting to virtual classrooms and managing the demands of rigorous coursework contributed to elevated stress levels. The pandemic disrupted allied health students' clinical rotations and hands-on training. Limited access to clinical sites and the need for additional safety measures affected their learning experiences, potentially leaving them feeling less prepared for future health care roles. As students observed the consequences of the pandemic on patients and health care professionals, they might have experienced emotional distress and compassion fatigue. Witnessing the emotional and physical effects of COVID-19 can take a toll on mental well-being. Finally, the pandemic led to staffing shortages in health care facilities, placing added responsibilities on allied health students during their clinical rotations.[1]

In response to these concerns, educators and institutions must address allied health students' mental and emotional well-being. One promising method to ease stress and improve overall wellness is incorporating pranayama techniques in the classroom.

## Pranayama Techniques and Benefits

Incorporating pranayama techniques in the classroom can bolster allied health students' mental, emotional, and physical well-being (see **Table**). Pranayama is rooted in the art of yogic breath control and is an ancient practice that has shown efficacy in reducing stress, promoting relaxation, and enhancing focus.[4] Derived from Sanskrit, pranayama combines *prāna*, life force or vital energy, and *āyāma*, control or extension. In the context of yoga, pranayama involves conscious breath control during which individuals regulate their breathing patterns to harness and manipulate the flow of *prāna* in the body.

By engaging in specific pranayama techniques, practitioners aim to optimize their physical, mental, and spiritual well-being, and ultimately achieve a harmonious balance between the body and mind.[2,3,5] Through consistent practice, allied health students can potentially develop effective coping mechanisms and resilience to challenges. By integrating pranayama in the classroom, educators encourage students to embrace stress reduction, relaxation, and enhanced focus, and empower them on their wellness journey. As students engage in specific pranayama practices, they understand the

Table

**Pranayama Techniques**[2,3]

| Technique | Description | Benefits |
|---|---|---|
| Deep abdominal breathing (or diaphragmatic breathing) | A foundational pranayama technique. Individuals inhale deeply through the nose, expanding their diaphragm and allowing the belly to rise. They then exhale slowly and evenly, encouraging the diaphragm to relax and the belly to fall. | Nurtures relaxation, stimulates the parasympathetic nervous system, and enhances oxygenation. |
| *Nādī shodhana* (alternate nostril breathing) | Individuals use the thumb and ring finger to close and open alternate nostrils while breathing. | Harmonizes the brain's 2 hemispheres, promoting mental clarity, and reducing stress and anxiety. Renews a sense of focus and mental equilibrium. Serves as a balancing and cleansing pranayama technique. |
| *Bhrāmarī* pranayama (humming bee breath) | Entails inhaling deeply through the nose and exhaling while producing a humming sound similar to a bee. | Calms the mind, alleviates tension, and reduces anxiety. The gentle vibrations created are believed to soothe the nervous system, making it an effective technique for stress reduction. |
| *Ujjayi* pranayama (victorious breath) | Involves the gentle constriction of the back of the throat to create a soft, whispering sound during inhalation and exhalation. | Assists in anchoring the mind, deepening concentration, and fostering a meditative state. Empowers the individual with mental clarity and presence. |
| *Śītalā* pranayama (cooling breath) | Entails inhaling through the mouth while rolling the tongue into a tubelike shape and exhaling through the nose. | Reduces body heat, calms the mind, and alleviates stress and irritability. |

mind-body connection, cultivating a sense of harmony in themselves.

Pranayama is not only beneficial for students but also for teachers. The practice of pranayama offers educators a valuable tool for managing their own stress, cultivating a balanced work-life dynamic, and promoting self-care to their students. By embracing pranayama in their personal and professional lives, teachers can lead by example and create a harmonious learning environment that prioritizes the well-being of everyone involved.[6]

With its diverse breathing exercises, pranayama offers benefits to individuals seeking to enhance their overall wellness, including stress reduction and emotional well-being, mitigation of burnout and fatigue, improved focus and concentration, enhanced self-care, and building resilience.

### *Stress Reduction and Emotional Well-Being*

Pranayama techniques, such as *nādī shodhana* (alternate nostril breathing) and *bhrāmarī* pranayama (humming bee breath), have been shown to activate the parasympathetic nervous system, reducing the production of stress hormones.[7] As students engage in these practices, they can experience a sense of calmness and emotional balance, enabling them to cope with the stresses of academic rigor and pandemic-induced challenges.

### *Mitigating Burnout and Fatigue*

After the COVID-19 pandemic, allied health students were at a higher risk of burnout and fatigue due to extended hours and increased responsibilities. Pranayama enhances oxygenation and energy levels, providing students with a natural and sustainable method to combat exhaustion and maintain well-being.[8]

### *Cultivating Focus and Concentration*

The pandemic's disruptions made it challenging for students to maintain focus during lectures and clinical practice. Pranayama techniques foster mindfulness, improving attention spans and enabling students to be fully present in their studies and interactions with patients.[9]

### *Enhancing Self-Care Practices*

Incorporating pranayama in the classroom emphasizes the importance of self-care, encouraging students to prioritize well-being amid demanding schedules. By internalizing these practices, students can develop healthy habits that extend beyond their academic years and into their professional lives.[10]

### *Building Resilience Against Future Challenges*

The health care landscape after the pandemic is still adjusting, and allied health professionals will continue to face challenges such as adapting to new protocols, managing increased patient volumes, addressing mental health needs, and navigating evolving health care policies. Including pranayama techniques in education programs equips students with valuable skills that enable them to adapt to unforeseen circumstances with composure and determination.

There are practical steps to introduce and integrate pranayama techniques into the classroom. Instructors should begin by introducing the concept of pranayama to the students. Explain the meaning and benefits of pranayama and how conscious breath control can positively affect mental, emotional, and physical health. Next, familiarize students with techniques such as deep abdominal breathing and *nādī shodhana*, as well as *bhrāmarī*, *ujjayi*, and *śītalā* pranayama. Provide brief descriptions of each technique and their respective benefits. Show students how to perform each pranayama technique correctly. Demonstrate the breathing patterns, hand placements, and other specific instructions. Encourage students to observe the demonstration.

Next, conduct group practice sessions with students in the classroom. Lead them through guided pranayama sessions, ensuring they understand and follow the techniques correctly. Start with simple techniques like deep abdominal breathing and gradually progress to more advanced ones. Incorporate short pranayama breaks during longer classes or study sessions. Pause the class for a few minutes to lead students through a brief pranayama practice, allowing them to refresh and reenergize. Invite yoga or meditation instructors to lead pranayama sessions in class occasionally. Exposure to different teaching styles can enrich the students' understanding and experience of pranayama. In addition, encourage students to practice pranayama regularly outside of class. Emphasize that consistency is vital to experiencing the full benefits of these techniques. Provide resources or hyperlinks to guided pranayama videos or mobile applications students can use for self-practice (see **Box**).

Integrate the practice of breath control in yoga with mindfulness exercises by guiding students through a brief mindfulness meditation after a pranayama session. Mindfulness is a mental state and the practice of being fully present and aware of the present moment, without judgment or attachment to thoughts, feelings, or external stimuli.[11] This combination enhances students' awareness and presence, fostering a deeper connection with the present moment and their inner experiences.[1,2,8]

Create an open and supportive environment in which students can discuss challenges or concerns during pranayama practice. Encourage students to journal or share their experiences with pranayama practice. Ask them to reflect on changes they notice in their stress levels, focus, and emotional state. Provide modifications or alternatives for students with physical limitations or medical conditions. Finally, discuss how pranayama can benefit their future roles as allied health professionals. Emphasize how stress reduction and emotional regulation can positively affect patient care and well-being.

To ensure safety and effectiveness, a certified yoga instructor should conduct pranayama sessions in the classroom. Faculty interested in leading these sessions should undergo appropriate training, such as

Box

**Examples of Guided Pranayama Videos**

- Mindfulness exercise: emotional freedom technique (Policy Research Associates, Inc)
  youtube.com/watch?v=S1U3cl2QxHw
- Mindfulness exercise: vagus nerve reset (Policy Research Associates, Inc)
  youtube.com/watch?v=TONw4nCjb84
- 10-Minute traditional pranayama techniques (The Yoga Institute)
  youtube.com/watch?v=3BPIBxe6mVs
- 5-minute pranayama (The Yoga Institute)
  youtube.com/watch?v=YFLGvOl479Y

obtaining a 200-hour yoga teacher training certification (Registered Yoga Teacher [RYT 200]). This certification is a standardized program for yoga instructors provided by the respected Yoga Alliance organization, which establishes guidelines and standards for yoga teacher training worldwide. Certified instructors possess the necessary skills to guide students safely through pranayama practices, offering personalized alignment cues and modifications as needed. With their expertise in the mind-body connection, they create a conducive environment for students to experience the full benefits of pranayama. Integrating pranayama into allied health education under the guidance of certified instructors upholds professional standards and ethical practices, ensuring a positive and enriching experience for students as they navigate their academic and health care careers.[12]

## Conclusion

As allied health students navigate the health care profession after the pandemic, they might experience stress and mental fatigue. Educators and institutions have a vital role in alleviating these pressures and supporting the overall well-being of their students. By recognizing the unique challenges faced by allied health students, the integration of pranayama techniques in the classroom emerges as a potent solution. The practice of pranayama has been shown to reduce stress levels, promote emotional balance, improve focus, and increase resilience. These benefits make it an important tool for the health and success of future health care professionals. Incorporating pranayama techniques in the classroom to reduce stress among allied health students holds tremendous potential for fostering a positive and balanced learning environment. The integration of pranayama, with the guidance of certified yoga instructors, empowers students to navigate challenges with resilience and tranquility. The practice of pranayama not only alleviates stress and burnout among students, but also enhances their emotional well-being, focus, and self-care practices. By combining pranayama with mindfulness exercises, educators can create a comprehensive approach to support their students' mental and emotional health.

*Agata Stelmark, BS, RN, CCRN, E-RYT 200, RYT 500, YACEP, is yoga instructor for Allied Health in River Edge, New Jersey.*

*Jarek Stelmark, MBA, R.T.(R)(CT)(MR)(CV)(QM)(BD)(VI), works for Hostos Community College in the Bronx, New York, and Agahatha Yoga in River Edge, New Jersey.*

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# The Peer-Review Publication Process

Kendall C Youngman, MSRS, R.T.(R)(CT)(MR)
Cheryl O DuBose, EdD, R.T.(R)(MR)(CT)(QM), MRSO, FASRT

According to the Census Bureau's 2019 American Community Survey, the health care industry is composed of 22 million workers, accounting for 14% of all U.S. workers.[1] A more staggering statistic is that only 1% of the 22 million health care workers submit original research or publish in peer-reviewed journals. Health care is changing constantly and publishing new knowledge in peer-reviewed journals is essential to advancing the field and informing other professionals.[2] This research must be communicated effectively to a variety of audiences (eg, physicians, nurses, patients, pharmaceutical regulators), and if health care workers do not provide this information, individuals who are not in health care will fill this void and become the written voice for health care professions, including radiology. Practicing imaging technologists and therapists are highly skilled professionals who can publish invaluable knowledge and experiences or review manuscripts submitted for publication. Peer reviewers are an important part of the publication process, not only for their expertise but also as gatekeepers who ensure high ethical standards in publications.

## Methods

A literature review was conducted by searching databases at Arkansas State University using the key words *publication process*, which generated 956 092 results. The search was refined to peer-reviewed articles published in the past 10 years, which reduced the results to 225 846 articles. The first 27 articles were used to create an outline of topics. Google was used to identify current practices and formats promoted by educational institutions and professional societies to bridge gaps in the selected peer-reviewed literature. PubMed, Google, and Inside Higher Ed were searched for recent ethical case studies and information on research report formats.

## The Publication Process

Publishing peer-reviewed academic books or manuscripts is a methodical process. Authors must[3]:

- investigate a topic
- choose the preferred publication venue
- follow author guidelines and instructions of the selected publication when writing the manuscript
- submit the manuscript to the publication venue
- respond and edit the manuscript based on reviewer feedback
- resubmit to the editor with the requested edits

### *Investigate a Topic*

Research and writing for peer-reviewed publication starts with an idea. Potential authors want to share information, such as clinical, patient care, or academic techniques that can help someone else be more successful or improve quality outcomes. Manuscript topics can be an individual's original thought, a continuation of research discussed in a previous peer-reviewed publication, or the repeat of a previously conducted experiment or study.

### *Prepare the Manuscript*

Once a topic has been decided, the author must decide which type of article is best suited for the topic. Full original research articles distribute completed research findings. The 5 main components of original research articles are introduction (purpose), methods, results, discussion, and conclusion.[4] If submitting a case report, a type of original research article, authors generally include an introduction (background), case description, discussion, and conclusion.[5] A literature or systematic review is a critical synthesis of a particular topic or idea citing numerous references with opposing viewpoints.[4] No original research is offered for a literature review. Instead, a literature review is a means of writing to compare different ideologies about a topic or weigh the pros and cons of a particular process. Another type of article is short communications such as editorials or blogs.[4] This style is more informal, might not be peer-reviewed, and can be a good place to start for new authors to learn about the publication process.

For original research and literature review manuscripts, the peer-review process assesses the quality of articles. When writing a peer-reviewed manuscript, a framework guiding methodologies, prioritizing the right questions, and constructing logical sequences is crucial. There are multiple frameworks to format research, case reporting, or literature reviews. Implementing a framework early on aids an author in the manuscript process to formulate clear, solid, and useful concepts (see **Table**).[7] Frameworks can be detailed in the publication's author guidelines, or an author might have their own preference.

Table

**List of Publication Guidelines[6]**

| Type of research study | Recommended framework |
|---|---|
| Case reports | CARE |
| Randomized trials | CONSORT |
| Original research | IMRaD; PICO |
| Formulating research questions | FINER |
| Systematic reviews | PRISMA |
| Quality improvement | SQUIRE |
| Qualitative research | SRQR |

#### IMRaD Format

The introduction, methods, results, and discussion (IMRaD) structure is the most used format in scientific writing.[8] IMRaD outlines the basic sections of a research report, providing concise internal organization that allows readers to scan for specific information and permits editors to validate findings easily.[9] Because of its simplicity and popularity, the IMRaD structure is the format taught by most universities and other institutions to introduce students to the realm of research and peer-reviewed writing.[9] Once students graduate from academia and become more comfortable researchers, other research formats or structures are available to them.

#### PICO Framework

Population, intervention, comparison, and outcomes (PICO) is a popular method to assist researchers in selecting a topic and formulating their research question.[10] Commonly used in evidence-based research to answer clinical and health care-related questions, the PICO approach encourages researchers to focus on using background information to develop foreground questions that analyze causes or risk factors, compare diagnostic tests, identify treatment options, and discuss outcomes of treatments.[11] In addition, PICO has the potential to be hybridized with the feasible, interesting, novel, ethical, relevant (FINER) method.[12] This hybrid method is another means to encourage authors to focus on research questions that add to an existing body of knowledge.[11]

PICO has evolved beyond the clinical setting and arguably has become a universally accepted technique in multiple research venues.[12] However, PICO has its detractors. A research study by Schiavenato and Chu found that nursing students confuse PICO with evidence-based practice. These authors caution educators against incorporating PICO into the classroom as the sole research methodology.[13]

#### FINER Framework

The FINER framework covers the "so what?" aspect of professional writing and is an excellent complement

to other writing formats. FINER allows the author to ask objective questions about the research concept they want to explore, such as what new evidence the research will provide to the profession, whether the research methodology follows current standards for ethical behavior, and whether the information produced by the research affects clinical practice. Such questions allow the author to determine whether their research idea is new, objective, needed, and moral.[9]

#### CARE Standards

The CAse REport (CARE) standards were developed by 27 international authors with previously published articles who had an interest in improving the quality, transparency, and replicability of case reports.[14] Originally published in 2013, the CARE standards consist of 13 items developed to assist authors as they submit for publication in medical journals around the world. These guidelines focus on supporting the measurement of clinician-patient outcomes, clinical practice effectiveness, and return on investment.[15] The CARE case report guidelines website also provides authors access to CARE-writer, an online application used to help authors organize and format their information.

#### CONSORT Protocol

Consolidated standards of reporting trials (CONSORT) is a protocol that assists researchers in developing and reporting data obtained during randomized controlled trials.[15,16] CONSORT consists of a 25-item checklist detailing how the trial was designed, analyzed, and interpreted, as well as the presence of a flow diagram for easy protocol analysis by readers. Following the CONSORT model allows clinical practitioners to assess the quality of the evidence provided and to determine whether to implement the presented methods into their own clinical practice.[15]

#### PRISMA Standards

Used more in literature reviews, preferred reporting items for systematic reviews and meta-analyses (PRISMA) standards were originally published in 2009 to improve the quality of these manuscripts. PRISMA assists authors during the systematic review and meta-analysis process by charting a road map to help authors portray what has been done, what has been found, and what is planned.[17] Updated in 2020, the latest PRISMA document consists of a 27-item checklist for the systematic review or meta-analysis, an abstract checklist, and revised flow diagrams for original and updated reviews.

#### SQUIRE Guidelines

In 2008, the standards for quality improvement reporting excellence (SQUIRE) 1.0 was published as a resource for those attempting to publish work related to the quality improvements in health care. Until this point, there was no reliable and consistent way to publish these reports.[18] Gradually, health care continued to change, and SQUIRE 2.0 was developed between 2012 and 2015 to account for these changes.

#### SRQR Guidelines

Departing from quantitative research reporting objective numbers, qualitative research attempts to investigate findings of social phenomena in a research participant's natural setting. The standards for reporting qualitative research (SRQR) was designed by researchers and physicians and outlines 21 items considered essential for complete and transparent qualitative research reporting.[19] Published in 2014, guidelines for this style of reporting were deemed necessary to assist authors, editors, and reviewers with qualitative research reporting.

### *Choose a Publication Venue*

Deciding on the publication platform is an important part of the publication process. It is the responsibility of authors to research and identify the most appropriate publication venue for their manuscript. Authors might choose to submit to:

- blogs
- books
- magazines
- online journals
- printed journals
- various other platforms

The platform should be selected based on article type and the narrative of the project. In peer-reviewed

publication venues, formal requirements are enforced, which can include a particular writing style (eg, American Psychological Association [APA], American Medical Association [AMA], or Modern Language Association [MLA]) and avoiding first-person pronouns. Peer-reviewed publications require third-person narratives that avoid the use of pronouns or other aspects of informal writing.

After an author has determined the desired narrative and writing style, he or she must determine the target audience of interest. Case studies, systematic reviews, and original research, in general, are published in professional journals directed toward a particular professional audience. *Radiologic Technology* is published by the American Society of Radiologic Technologists and is geared toward all medical imaging and radiation therapy professionals, especially those in the United States. The *Journal of the American College of Radiology* focuses on areas of health care, clinical practice, training, and management of relevance and interest to radiologists and other physicians.

Along with considering the targeted audience, researching a publication venue's desired influence from a local to international scale is beneficial. One measurement of influence is a journal's impact factor. The impact factor signifies the relative importance of a journal to its field and is calculated based on the number of citations generated for its published articles over a 2-year period.[20] This number can be misleading for a variety of reasons. The foremost concern is that impact factor does not account for the quality of the peer-reviewed articles.[20] Another argument is the process of calculating impact factor: the number of times its articles are cited in indexed journals is divided by all available citable articles in the journal for a 2-year period. The impact factor of a journal might be unfairly skewed based on infrequently produced publications or if the intended audience is restricted to members of a group, thereby decreasing public access to its articles. Authors should carefully investigate a journal's influence and determine whether the audience and professional quality are appropriate.

Once an author selects the best publication venue and type of manuscript, he or she must carefully review and follow the author guidelines available on the publication website. Formatting, font, margin sizes, and manuscript structure might be mandated by the publisher. Authors can maximize their publication success by strictly following the venue's specified guidelines for publications. Publishing guidelines include but are not limited to using the correct writing style (eg, AMA, APA, MLA), uploading a cover letter, labeling and uploading associated tables and images appropriately, and including the author's biographical information. Authors should be aware of publication fees associated with the selected journal and be prepared to pay the fees during the submission process if necessary.[21]

### *Submission of Manuscripts and Peer-Review Process*

After the publication venue is selected, the author is ready to submit the manuscript and enter the peer-review process. After submission, the manuscript might be immediately rejected by the editor or editorial review board chair or forwarded to 2 or more peer reviewers. A manuscript might face immediate rejection if it:

- does not fill a gap or void in the existing body of knowledge
- does not introduce a new or novel perspective on existing literature
- does not meet the rigor required for a peer-reviewed publication
- is not deemed a fit for the journal's audience

If a manuscript is immediately rejected, it is not an indication of a manuscript's worth. Each journal has its acceptance guidelines and rates, and journals with higher impact factor have a lower acceptance rate for original research. The *Radiology* journal published by the Radiological Society of North America had a 12% original research acceptance rate in 2021.[22] Authors should determine whether a specific criterion has not been met. Authors can choose to resubmit the manuscript in its original form or with modifications to another publication venue.

If the manuscript is sent forward, it undergoes an initial quality control review by an editor or editorial review board chair. Many journals follow the double-blind process in which the reviewers do not know the identity of the author, and the author does not

know the identity of the reviewers. This double-blind process is intended to minimize the possibility of bias.[23,24] The reviewers provide feedback that includes whether the topic is suitable for publication in the journal and whether the manuscript has the potential to contribute to professional knowledge. Authors must then decide whether to continue in the peer-review publication process or pull their manuscript from the queue.

Authors who decide to resubmit must address the suggestions of the reviewers before resubmission.[3,25] Authors, reviewers, and editors work together to develop the best possible version of the manuscript before publication. Once the authors and editors finalize all changes to the manuscript, the manuscript begins the editorial process for journal layout and archiving. Authors should be prepared for the editorial process to take a few months or more than a year. Once the editorial process is complete, the manuscript is ready for publication.

## Ethical Considerations

Ethical integrity is essential to writing and publishing, and when integrity is questioned, repercussions resonate throughout the professional community. In 2012, Hyung-in Moon admitted to subverting the peer-review process by submitting peer reviews on his own work. His admission resulted in the retraction of 28 articles published by Informa, as well as the resignation of an editor.[26-28] In 2013, it was discovered that Peter Chen, an engineer in Taiwan who was coauthor on 60 publications, had created a similar racket to subvert the peer-review process.[26,27] This discovery led to the retraction of the 60 articles in July 2014. Both authors were able to submit fake peer reviews of their own work because the journal publishers allowed authors to recommend reviewers. This recommendation option might be offered by journals publishing manuscripts in highly specialized areas with multinational submissions or if editors have difficulty finding peer reviewers who are willing to review in a timely manner.[27] Authors are not the only ones tempted to bypass the peer-review process. The publisher Hindawi discovered that 3 of its editors were responsible for providing fake peer reviews, resulting in 32 retracted articles.[27]

Ethical standards aim to promote honesty, transparency, and accountability among authors, editors, and publishers.[29] Major ethical dilemmas include[30-33]:

- collaborator permission
- conflicts of interest
- copyright concerns
- duplicate publication
- falsification of data
- patient permission
- plagiarism

Ethical dilemmas such as these tend to be perpetuated by researchers who need publications to obtain tenure or promotion, or who want to generate funding for research.[32] The peer-review process is integral to reducing publications of unethical research and is the gatekeeper for publishers and the scientific community.[29,32]

### *Plagiarism*

Plagiarism is when 2 or more papers share exact information. With plagiarism, authors misrepresent, intentionally or unintentionally, another's work as their own. In 2021, Johnny He submitted 4 research grant applications and 1 research record to the National Institutes of Health (NIH). On investigation, it was discovered that he plagiarized research data and text from 4 published papers and 1 preprint manuscript. He entered into a voluntary agreement with the NIH that required 3 years of research supervision.[32]

### *Duplicate Publication*

When authors self-plagiarize to increase publication numbers and inflate their resume, this is termed duplicate publication.[29] Duplicate submissions occur when authors use the same text, images, or manuscripts with different titles.[29]

### *Collaborator Permission*

Collaborators assist authors by providing expertise for a research project. Failure to obtain a collaborator's permission to publish their findings results in an ethical dilemma.[34] Patient consent for inclusion in a study is required. A recent institutional review board investigation at the University of Maryland discovered the lack of patient consent from psychotherapy clients referenced in the study. This ethical breach resulted in

the immediate retraction of 8 published papers, with an anticipated eventual retraction of 17 papers across 3 journals.[33]

### *Falsification of Data*

Reports regarding the publication of falsified data (ie, fraud, manipulation, or fabrication of data or images) are taken seriously and result in immediate investigations.[29] The Office of Research Integrity is a branch of the U.S. Department of Health and Human Services that oversees research integrity for studies supporting all federal grants except those provided by the Food and Drug Administration.[32] This includes grants provided by the NIH and the Centers for Disease Control and Prevention. Misconduct case summaries are listed on the Office of Research Integrity website for researchers who have violated ethical research standards.[32] A more recent example is the 2021 case of Yiorgos Laliotis, a postdoctoral fellow who fabricated data related to his cancer research. This discovery affected 3 published papers, 2 unpublished papers, and 2 NIH grant applications.[35] As a result, Laliotis was terminated from his postdoctoral position at The Ohio State University and resigned from his postdoctoral position at Johns Hopkins University.[35] Another data falsification case involved Stanford University President Marc Tessier-Lavigne. Although he was cleared of wrongdoing, Tessier-Lavigne chose to relinquish his administrative position after claims of data manipulation by his coauthors that resulted in the withdrawal of 3 publications and robust corrections of 2 publications.[31]

### *Conflicts of Interest*

Conflicts of interest occur when an author or researcher must contend with competing concerns, such as honest reporting, making a profit, or retaining funding.[36] Researchers working for institutions that receive federal grants must disclose any potential conflicts of interest to avoid violating statute 18 USC § 1001, which prohibits lying to the federal government in association with economic espionage.[27,37] Feng "Franklin" Tao, a chemist at the University of Kansas, failed to disclose that he also was employed by China's Fuzhou University. Tao was arrested and charged with 3 counts of wire fraud and 1 count of making false statements. On January 18, 2023, Tao was sentenced to time served and cleared of espionage charges.[37,38]

### *Copyright Concerns*

Copyright is founded on the principle that authors own the rights to their intellectual creations and determine what conditions in which their work can be used.[39] Although the intellectual property initially belongs to the author, some publication venues might require a copyright transfer agreement. When an author signs a copyright transfer agreement, ownership of the manuscript is transferred to a journal or publisher. Authors who want to republish images, artist renderings, tables, or other copyrighted works must obtain permission from the original authors or publisher before use.

## Promoting Publishing

Once published, it is worthwhile for authors to promote their publication. Authors can use social media platforms to interact online with other professionals to spark conversation and discussion. Presenting research findings at conferences is another approach to inform colleagues of new information. Promotions through social media and in-person interactions allow engagement in the scholarly community and for the possibility for future collaborations in research and publishing.

In an editorial to its readers, 1 journal outlined the important role that peer reviewers have in the publication process. It stated that peer reviewers are a necessary component because they[40]:

- "advise the editors whether the manuscript content is important and appropriate for the journal"
- "evaluate the quality of the manuscript, including adequacy and accuracy of the content"
- "provide a constructive critique and specific recommendations that can help the author improve the manuscript"

## Conclusion

Practicing radiologic technologists and therapists are capable researchers and authors who offer unique experiences and insights that they can share by publishing in peer-reviewed journals. Without radiologic technologists' perspective in peer-reviewed publications, the

radiology profession could experience a deficiency of relevant and quality research related to the field, and this research is necessary to keep the profession moving forward. Publishing also is essential for the professional growth and career development of radiologic technologists. The publication process can be daunting, but publication venues provide guidelines and helpful resources for authors.

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*Kendall C Youngman, MSRS, R.T.(R)(CT)(MR), is assistant professor and magnetic resonance imaging program director of Medical Imaging and Radiation Sciences for Arkansas State University.*

*Cheryl O DuBose, EdD, R.T.(R)(MR)(CT)(QM), MRSO, FASRT, is a professor and department chair of Medical Imaging and Radiation Sciences for Arkansas State University.*

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# Radiation Exposure in Fluoroscopy-Guided Procedures

Christian B Dyess
Kristi G Moore, PhD, R.T.(R)(CT)

More than a century ago, physicist Wilhelm Roentgen discovered a different type of ray while experimenting with a cathode ray tube; this ray, the x-ray, could pass through human tissue, creating a lasting image. As word spread of Roentgen's discovery, scientists and physicists all over the world began trying to replicate his discovery. Along with this great discovery came debilitating injuries due to radiation exposure.[1] Today, as the advances in medicine have driven medical imaging to evolve rapidly, physicians, staff, and patients still are being exposed to radiation and are at risk for injury. In the United States, more than half of the population's radiation exposure is due to medical radiation.[2] With the growing popularity of minimally invasive procedures using fluoroscopy, the number of procedures, complexity, and radiation exposure time is increasing.[1] Although fluoroscopy-guided procedures have advantages, the consequences of prolonged radiation exposure are a considerable disadvantage.

## Fluoroscopy-Guided Minimally Invasive Procedures

The number of fluoroscopy-guided procedures performed by interventional radiologists and surgeons is increasing, including radiological, neuroradiological, vascular, urologic, cardiological, and orthopedic procedures.[1] Fluoroscopy-guided procedures decrease the invasiveness of certain operations, resulting in decreased patient morbidity.[3] Because of the complexity of these interventions, the radiation exposure time to the radiologist or surgeon and the patient also is increasing.[4] However, because the surgeon, staff, and patient are exposed to substantial levels of radiation during these complex procedures, precise positioning of instrumentation using intraoperative imaging is imperative.[4]

## Radiation Exposure

Minimally invasive fluoroscopy-guided surgeries and interventions increase the risk of radiation exposure to the surgeon, staff, and patient. *Radiation exposure* is defined as the measure of radiation required to produce a specific amount of ionization of air at standard temperature and pressure.[5] When physicians and patients are exposed to radiation, some of it is absorbed into the body. Most of this radiation to the operator is secondary radiation that is the result of scatter radiation and leakage.[5] As the level of radiation exposure and the number of procedures performed increase, the risk of harmful biological effects increases exponentially.[3]

The amount of radiation surgeons receive while performing routine fluoroscopy-guided procedures has been analyzed. In one study, orthopedic surgeons were evaluated because of the vast number of procedures they perform that include the use of fluoroscopy or C-arm guidance.[3] The researchers found that although some surgeons overuse radiation protective measures, other surgeons underuse them. They also found that several surgeons lacked education on and awareness of how

much of their body is exposed to radiation during the procedure.[3] Research showed that although the level of radiation the whole body received was well within recommended levels, certain body parts that were near the patient were repeatedly exposed to ionizing radiation.[3]

In 1 study, radiation exposure during fluoroscopy-guided intradiskal ozone therapy for treatment of disk herniation was measured and compared using fluoroscopy and computed tomography (CT)-guided techniques. Surgeons perform minimally invasive procedures to inject ozone into herniated disks to alleviate a patient's pain or to avoid open surgery completely. The researchers concluded that both CT and fluoroscopy provided the surgeon with equally good visualization of the area.[6] The level of radiation during the use of both machines also was measured. They directly compared the radiation dose (dose area product for fluoroscopy and dose length product for CT guidance) to the effective dose. Both techniques had optimal outcomes of being 100% effective. They found that fluoroscopy exposed the patients to lower levels of radiation than did CT guidance; exposure to staff was not explicitly addressed.[6]

Radiation exposure during the use of fluoroscopy in endoscopic retrograde cholangiopancreatography has been previously monitored. A study conducted to evaluate how much formal fluoroscopic and radiation training endoscopists receive found that although 61% of the endoscopists confirmed that they controlled their own fluoroscopy, most (56.6%) had not received any formal training on operating the fluoroscopy equipment. Only a small number of endoscopists attempted to decrease radiation exposure to patients by using techniques such as pulse fluoroscopy, frame rate modification, and collimation. Furthermore, although most used personal radiation protection, few used dosimeters.[2]

One study went a step further and instead of measuring the level of radiation exposure as a whole, researchers measured the amount of radiation exposure to each body part of the interventionist or surgeon performing a fluoroscopy-guided spinal epidural injection. One group used anteroposterior real-time fluoroscopy, and the other group used lateral real-time fluoroscopy.[5] They placed dosimeters on the chest (outside and inside the lead apron), neck (outside and inside the thyroid collar), groin, lead gloves, and rim of glasses of the physicians in both groups. Results showed that the cumulative dose equivalent in all sites was lower in the group that used the anteroposterior position except for the groin location.[5] Exposure to secondary radiation during fluoroscopic procedures is of utmost concern for physicians; therefore, best practices in radiation protection should be employed. Some of the recommended methods of decreasing exposure to physicians include increasing their distance to at least 1 m from the x-ray tube; placing the x-ray tube under the operating table; collimating; employing pulsed-mode fluoroscopy; and limiting beam-on time.[5]

## Biological Risks

Chronic exposure to low-level radiation carries a risk of cancer to physician interventionalists, radiologist interventionalists, and radiologic technologists. Research has shown that these physicians and technologists are at an increased risk for developing brain tumors and melanoma due to radiation exposure.[1] Research has indicated that surgeons performing fluoroscopy-guided procedures had the greatest risk of radiation exposure to their extremities, head, and neck. This finding is related to the biologic effects reportedly occurring in the form of cataracts, skin cancers, and thyroid conditions.[3] Researchers found exposure time and exposure dose were contributing factors of biologic damage.[3] Fluoroscopy-guided procedures are instrumental for patient diagnosis. However, the biological risks from radiation exposure cannot be eliminated. By adhering to the International Commission on Radiological Protection (ICRP) Publication 139 ("Occupational Radiological Protection in Interventional Procedures")[7] and using the as low as reasonably achievable (ALARA) principle, physicians can greatly reduce the amount of radiation exposure.[3,8]

## Factors That Reduce Radiation Exposure

Multiple methods can be used to reduce radiation exposure when working in fluoroscopy. Imaging staff can wear personal protection and use equipment-based protection. Adequate training also has been shown to reduce radiation exposure. Reducing exposure times

during procedures also decreases radiation exposure to the patient and staff.

### *Personal Protection*

Medical personnel, including the interventionalist, should wear radiation protection during fluoroscopy-guided procedures. This commonly comprises a lead apron and lead thyroid collar. Research has shown that lead aprons that wrap around from back to front provide 5 times the protection compared with those that just cover the front of the body.[1] All personnel should wear personal dosimeters that are monitored regularly.[3] Some interventionalists wear extra protection, such as radiation caps, protective glasses, and gloves, depending on the type of procedure being performed.[1]

### *Equipment-Based Protection*

Lead glass screens often are used to shield personnel from radiation exposure. Depending on its position, research has shown that a screen can decrease exposure by 90% to 98%.[1] When interventionalists and surgeons use CT or fluoroscopy during surgery, scatter radiation is the biggest concern, especially under the examination or operating room table. Undertable shielding can reduce scatter and exposure to the surgeon's lower extremities by as much as 64%.[1]

### *Trained Personnel*

The interventionalist or surgeon should be adequately trained to perform the procedure. Research has shown that the more experienced the interventionalist, the lower the level of radiation exposure during the procedure.[3] In addition, support personnel involved in the procedure should be trained on the importance of proper radiation protection.[3] The radiation equipment should be maintained properly to ensure the amount of radiation delivered is correct.[3]

### *Best Practices*

When fluoroscopy is used, it should be delivered in short 3-second bursts; therefore, continuous fluoroscopy should be avoided.[3] To avoid exposing a patient to needless radiation, image capture and memory storage should be used so the image can be studied again later.[3] Because of the position of the x-ray tube and detector on a C-arm, the surgeon receives most of the scatter radiation when it is used in the horizonal position, so every attempt should be made to change the position. Collimation also should be used to decrease radiation exposure to the surgeon and staff.[3]

## Artificial Intelligence in Radiation Protection

Medical imaging is constantly evolving because of technological advancements. Artificial intelligence can be used to improve workflow efficiency by aiding in scanning, planning, and positioning the patient in CT procedures. The use of artificial intelligence algorithms can ensure patients are centered on the isocenter and that the entire region of interest is obtained. This can assist the operator in reducing potential manual errors and ensuring proper radiation doses are applied.[9] An artificial intelligence system can benefit the patient by reducing the number of positioning errors by the technologist, which reduces the number of repeat images.[9] This system allows the radiologic technologist to minimize the radiation dose to the patient for medical imaging procedures. In fluoroscopy-guided procedures, an artificial intelligence system can produce high-quality images with reduced radiation exposure for the patient and the interventionalist. The latest technology discovered by researchers is called *FluoroShield* (Omega Medical Imaging). This system is embedded with technology to aid in radiation protection by using ultrafast collimation to reduce radiation exposure to patients and staff.[9] Systems, such as FluoroShield, can lead to better quality of care for the patient and a safer environment for all radiologic personnel.

## Conclusion

For more than 100 years, scientists have known that radiation exposure is harmful. Although using radiation to produce medical images of the body is essential to the diagnosis and treatment of many diseases, radiation emitted during the examination can damage human tissue of the patient, the interventionalist or surgeon, and other staff who are present. With minimally invasive fluoroscopy-guided procedures becoming more advanced, the risk of radiation exposure and serious injuries has become a greater concern. Overexposure

and unnecessary exposure to radiation during certain procedures can result in cancer, genetic mutations, and cataracts. Radiation protection measures should be employed and monitored. Interventionalists, surgeons, radiologic technologists, and other personnel should have adequate training and continuing education to stay abreast of the latest advancements in the field, such as the application of artificial intelligence systems in radiation protection efforts. The safety hazards related to medical imaging and radiation exposure can be minimized by using established radiation safety practices.

*Christian B Dyess is a radiologic sciences student at the University of Mississippi Medical Center in Jackson.*

*Kristi G Moore, PhD, R.T.(R)(CT), is chair and professor for the Department of Radiologic Sciences at the University of Mississippi Medical Center in Jackson and former chair of the American Society of Radiologic Technologists Board of Directors.*

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This symbol honors students who contribute to the profession's body of knowledge.

# Symbiotic Relationship of Educational Programs and Clinical Settings

Judy Wood, MBA-HCM, R.T.(R)(MR)

Clinical education is a critical component of any allied health program, including medical imaging and therapeutic sciences. Clinical education can be defined as, "Health care education conducted in health care facilities, outpatient clinics, emergency centers, hospitals, or private offices, under the supervision of a qualified practitioner or teaching staff."[1] Clinical education is incorporated into the American Society of Radiologic Technologists curricula, the American Registry of Radiologic Technologists clinical competencies, and the Joint Review Committee on Education in Radiologic Technology (JRCERT) Standards for an Accredited Educational Program. Discussions regarding the role clinical settings have in educating these professionals and their relationship with educational programs is vital.

Clinical education is the cornerstone of developing professionals. It gives students the opportunity to develop and perfect professional skills while under the supervision of practitioners. According to Tay et al, "clinical placement is crucial to develop knowledge and skills acquired theoretically—allowing students to consolidate knowledge, socialising into the radiographer role, and acquiring values."[2]

The clinical education component can be undervalued, but it requires a symbiotic relationship between the educational program and clinical settings. Both entities are equal partners in the development of students, as well as potential employees.

## JRCERT Standards and Clinical Education

The JRCERT values clinical education, and it is interwoven throughout the Standards for an Accredited Educational Program.[3] Standard 3, Objectives 3.1, 3.2, and 3.3 address the need and minimum requirements for clinical staff and clinical preceptors. Standard 4, Objectives 4.3, 4.4, and 4.5 discuss the need for clinical settings to be recognized by the JRCERT as well as have appropriate, educationally valid learning experiences for the students, including access to advanced imaging and therapeutic technologies. Student and patient safety, as well as supervision of students, is incorporated throughout Standard 5.[3]

## Challenges in Procuring Clinical Settings

Health care in the 21st century is confronted by numerous challenges, including an aging population that requires substantial health care resources, limited health care resources due to efficiency measures necessitated by budgetary constraints, chronic shortage of health care professionals especially in rural and regional areas, and an increasing focus on care where the consumer is much more user oriented.[4]

There also are challenges in locating clinical settings. One challenge is the consolidation of medical facilities. With the issue of limited resources, smaller medical facilities have been purchased by larger institutions, potentially reducing the number of clinical settings. In addition, new educational programs are being started and student enrollments might be increased to combat the workforce shortage, resulting in an increased competition for these valuable clinical settings.

## Benefits of Clinical Education

There are many benefits of clinical education that benefit educational programs, students, and clinical settings.

### *Educational Programs and Students*

Educational programs would not be in existence without clinical settings. In addition to this main benefit, a clinical setting brings other attributes to the program and its students. In the clinical setting,

students enhance the technical and professional skills learned in the classroom and laboratory. Students are learning in a setting of patients and scenarios, thus being exposed to a variety of cases and situations. These diverse situations permit students to develop and enhance their critical-thinking skills while still being supervised so patient care is not compromised.

Another benefit of clinical education for the students is networking opportunities, which can lead to professional prospects. Spending an extended period in the clinical setting also helps the student and future graduate determine if this would be a viable employment opportunity. The student can determine if the clinical setting will be a good fit professionally.

### *Clinical Settings*

A clinical setting should take on the additional role of serving as an educational setting for a program and students. Although there can be challenges associated with providing clinical education for students, there are several benefits that outweigh the challenges (see **Table**). Although students are not to be used in place of qualified staff,[3] students can assist in increasing productivity. A Kumar et al research study in 2017 focuses on the implications for students with changing health care and found students are beneficial in the clinical setting.[4] "Commonly, it is perceived that engaging with students increases staff workload and impacts negatively on their productivity. However, findings from the literature suggest the opposite to be true."[4]

A benefit of hosting students from an educational program is increasing an employee pool of potential future applicants. With the recent workforce shortage, today's students are tomorrow's employees. Students can be placed at a clinical setting from a few weeks to a year or 2, so the clinical setting administrators have an opportunity to observe and become better acquainted with the student. The process serves as an informal interview for both parties.

Finally, another benefit is keeping clinical staff competent and current with professional development opportunities. "Clinical supervisors and staff too benefit through access to ongoing professional development, ready access to cutting-edge resources, and exposure to inter-sectoral collaboration."[4] Kumar et al also found that engaging with students resulted in the development of clinical knowledge and reasoning skills as well as prompting clinical staff to keep up with the latest evidence-based practice.[4]

Table

**Benefits of Clinical Education**[4]

| Benefits for program and students | Benefits for clinical setting |
|---|---|
| Develop technical and professional skills | Professional development, which keeps staff current and competent |
| Exposure to various patients and cases | Potential increased productivity |
| Potential future employer | Potential employee pool |
| Networking opportunities | Ability to screen potential employees |

## Important Attributes When Developing a Relationship

Networking in medical imaging and therapeutic sciences is important when building relationships and partnerships with other entities. An educational program might approach a clinical setting to inquire about taking students, or perhaps the clinical setting decides to become involved with an educational program to increase its employee pool. Regardless of who initiates the communication, the relationship between these 2 agencies is important and needs to be nurtured by those involved.

There are some key attributes that should be followed for a successful relationship. An important aspect is communicating clear expectations from those involved. Programs should communicate what they expect from the clinical setting, particularly, clinical preceptors and staff. Conversely, clinical settings, for whom students are guests, need to clearly communicate their expectations as well. These expectations might include affiliation agreements, student and employee handbooks, and various policies and procedures.

Meeting regularly to discuss policies and procedures and issues that might arise is a good practice. In addition, documenting meeting minutes assists in archiving

important decisions or discussions. This documentation also is beneficial to the clinical staff who might not be directly involved in these meetings and to the educational program when it is time to submit evidence for a self-study report or an interim report.

If a clinical setting determines there are issues involving the educational program, professional behavior would be to communicate these to the program officials, whether that be the clinical preceptor, clinical coordinator, or program director.

## Conclusion

The role clinical settings have in clinical education is extremely valuable and required for any educational program in health care. When everyone remembers that the benefits of clinical education outweigh any potential negative effects, the student and, ultimately, the profession succeed.

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*Judy Wood, MBA-HCM, R.T.(R)(MR), serves on the Joint Review Committee on Education in Radiologic Technology board of directors and is executive director of Imaging Services at Stanford Health Care in California.*

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# (Re)Introducing Image Wisely

Eric Gingold, PhD, FAAPM, FACR
Melissa Culp, MEd, R.T.(R)(MR)

In 2009, a radiology patient in southern California began noticing patchy hair loss a few days after a computed tomography (CT) brain perfusion scan.[1] Because the hair loss had an unusual pattern, a ring around the patient's head just above the ears, the patient realized that there might be a connection between the hair loss and the recent CT scan. The patient reported the issue to the imaging facility where the scan was performed. The facility looked carefully at this patient's imaging study and realized that the default protocol for CT brain perfusion on 1 of its scanners had been altered and indeed was delivering excessive radiation dose, not the typical dose for this examination. It eventually was determined that 8 times the typical dose was delivered to 206 patients who underwent CT brain perfusion scanning during an 18-month period on 1 CT scanner.[1] Approximately 40% of those patients reported that they experienced patchy hair loss. During the next year, a few other imaging facilities across the United States received similar reports of hair loss after CT. Reports of these incidents were in local and eventually national news media.

## What Is Image Wisely?

There was a consensus in the imaging community that action was needed to address safety incidents and to disseminate recommendations to prevent them from reoccurring. To that end, the Image Wisely initiative was formed jointly by the American Society of Radiologic Technologists, the American Association of Physicists in Medicine, the American College of Radiology, and the Radiological Society of North America (RSNA). Image Wisely raises awareness and provides educational resources to radiology professionals and referring clinicians about the safe use of adult medical imaging for treatment. The original mission of the initiative was to promote safety when using ionizing radiation. The scope has expanded recently to include magnetic resonance (MR) imaging and contrast media safety topics. Image Wisely focuses on adult medical imaging because it has a sister program, Image Gently, that promotes safety exclusively in pediatric imaging.

## What Can Image Wisely Do for Me and My Patients?

Most of the Image Wisely resources are accessible on its website.[2] Image Wisely offers a variety of educational materials, with something for everyone. Examples include[2]:

- articles – Brief modality-oriented articles on topics in CT, fluoroscopy, nuclear medicine, MR imaging, and contrast media safety LinkedIn quizzes based on current monthly RSNA exhibit
- links to current literature and news items on topics related to Image Wisely's mission
- radiation safety cases – Free case studies that offer continuing education credit
- RSNA exhibits – Selected educational posters from the previous year's RSNA annual meeting (1 new exhibit each month)
- videos – Presentations, conversations, interviews, and webinars on topics of interest

Most of the content relates to modalities that use ionizing radiation. However, look for material about MR imaging and contrast media coming later in 2024 as Image Wisely expands its focus.

## How Can I Contribute to Image Wisely?

Image Wisely is always looking for new content to educate the imaging community about safety in adult medical imaging. This content can take the form of articles, safety cases, videos, and stories of personal

experiences where Image Wisely principles are being practiced. Medical imaging and radiation therapy professionals have valuable insights and contributions to share as patient safety advocates. If you have an idea for new educational content or a tip to share about how you and your colleagues image wisely, share it with Image Wisely at imagewisely@acr.org.

Medical imaging technologists and radiation therapists are educated professionals who advocate for patient care and safety every day on the frontline of medicine. Be part of the Image Wisely community by taking the annual pledge, and encourage your coworkers and associates to do the same. The pledge is accessible at the top of the Image Wisely website.[2] Take the pledge today!

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*Eric Gingold, PhD, FAAPM, FACR, is co-chair of the Image Wisely Executive Committee.*

*Melissa Culp, MEd, R.T.(R)(MR), is executive vice president of member engagement at the American Society of Radiologic Technologists.*

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# Author Information


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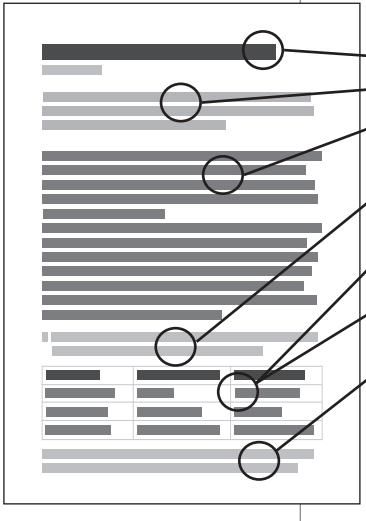

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- ☐ **References** – listed in the order in which they appear in the manuscript and following AMA style
- ☐ **Tables** (optional) – use to summarize, organize, and condense complex or detailed data that supports statements in the text
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