RESEARCH LETTERS

Radiation Safety in Nuclear Cardiology—Current Knowledge and Practice: Results From the 2011 American Society of Nuclear Cardiology Member Survey

Nuclear stress testing is well recognized as an effective technique for diagnosing coronary disease, predicting patient outcomes, and guiding management. Numerous evidence-based appropriate indications and practice guideline recommendations have been published regarding accepted uses of nuclear stress tests (NSTs) across a wide spectrum of patients with known or suspected coronary disease. However, the approximate 10 million NSTs performed annually account for greater than 10% of the entire ionizing radiation burden to the US population.[1] One recent study, while pointing out that cancer risk from a single NST is small, projected on a population level that NSTs may result in thousands of radiation-attributable cancers annually,[2] partially offsetting their benefits.

See Editor's Note at end of letter

As in all areas of medical radiological protection, fundamental principles of justification (ensuring imaging is clinically necessary) and optimization (ensuring best-available technique) are central to ensuring patient protection. Appropriate use criteria (AUC)[3] are essential tools for ensuring justification, and numerous dose-reduction methods have been studied and implemented in clinical practice for optimization,[4,5] including protocol-,[6] software-, and hardware-based approaches.[7] For example, most NSTs are performed with initial imaging obtained with the patient at rest, followed by additional images obtained after injection of a radiopharmaceutical near peak exercise or pharmacologic stress ("rest-stress" protocol). Radiation exposure can be decreased by 75% using a protocol whereby stress imaging is performed first ("stress first"), with rest imaging eliminated in patients with normal stress images ("stress only"). Dual-isotope protocols involving both thallium 201 for rest imaging and a technetium (Tc)-99m–based radiopharmaceutical for stress imaging are associated with considerably higher radiation doses. Newer image reconstruction algorithms available for all scanners improve on traditional "filtered back-projection" and enable reducing the amount of radiopharmaceutical administered while preserving image quality. However, few data describe current clinical practices impacting patients' radiation exposure. To address this, we conducted a survey of NST protocols, radiation safety practices, and practitioners' knowledge.

Methods. We conducted a stratified random sample survey of American Society of Nuclear Cardiology (ASNC) members in 2011, including several questions addressing radiation. The survey (eAppendix; http://www.jamainternalmed.com) was developed by an expert panel and implemented using SurveyMonkey software. A 10% random sampling method, stratified geographically, was used to ensure that respondents would be geographically representative of ASNC membership. Sampling was based on proportional representation by state, and where groups of physicians reported the same zip code, city, or institution or practice, they were coded as a block, of which only 1 was available for sampling. Of approximately 4700 ASNC members, 374 were selected to receive the survey. Nonrespondents received up to 3 follow-up requests, conducted by staff trained in performing scripted interviews. Categorical variables were compared using the Fisher exact test. Protocol volumes were estimated multiplying total laboratory volume by percentage of studies performed using a given protocol. Low-, medium-, and high-volume sites were defined based on tertile of annual procedure volumes.

Results. A total of 73 survey responses (19.5%) were received (46 physicians, 23 technologists, and 4 other), reflecting practices of 202 physicians and 177 technologists. The median annual number of NSTs performed for the 59 respondents reporting nonzero volume was 1200 (intertertile range, 900-2000).

Protocols. Forty-five respondents reported both laboratory volume and percentage of studies performed using each imaging protocol. Among these respondents, rest-stress Tc-99m was most popular, used in 58% of studies and 40 laboratories (89%), followed by dual-isotope imaging, used in 15.6% of studies and 10 laboratories (22%) (**Table**). Low-dose stress-first imaging constituted only 7.3% of studies, all reported by 6 respondents (13%), with 4 from high-volume laboratories.

Dose Reduction Approaches. Thirty-seven respondents (51%) reported using 1 or more approach to reduce radiation exposure. No single approach was reported to be used in more than 30% of studies (eTable 1). The most commonly reported approach was reducing injected radiopharmaceutical while increasing imaging time, claimed by 24 respondents (33%), followed by the use of stress-only imaging (23%), newer camera systems (20.5%), and changing radiopharmaceuticals (19.2%). In terms of specific methods, no single method

Table. Summary of Distribution of Protocols

Protocol	Total Estimated Procedures per Year[a]	Mean Procedures per Year per Facility	Procedures, %[b]	Laboratories Performing at Least 1 Study
1-Day protocols				
Low-dose Tc-99m rest imaging followed by standard-dose Tc-99m stress imaging	52 693	1171.0	58.1	40
Low-dose Tc-99m stress imaging followed by standard-dose Tc-99m rest imaging	3650	81.1	4.0	5
Low-dose Tc-99m stress imaging with no rest imaging	2880	64.0	3.2	6
Standard-dose Tc-99m stress imaging with no rest imaging	3620	80.4	4.0	9
Tc-99m rest imaging only	637	14.2	0.7	11
Tl-201 single injection, injected at stress	192	4.3	0.2	2
Tl-201 single injection, injected at rest	269	6.0	0.3	4
Tl-201 double injection (stress and redistribution injections)	70	1.6	0.1	2
Tl-201 double injection (rest and redistribution injections)	59	1.3	0.1	2
Dual-isotope: Tl-201 rest imaging followed by standard-dose Tc-99m stress imaging	14 152	314.5	15.6	10
Dual-isotope: Tl-201 rest imaging followed by low-dose Tc-99m stress imaging	0	0.0	0.0	0
Other single-day protocol	7685	170.8	8.5	3
2-Day protocols				
2-Day standard-dose Tc-99m: rest imaging performed on earlier day than stress imaging	1986	44.1	2.2	10
2-Day low-dose Tc-99m: rest imaging performed on earlier day than stress imaging	64	1.4	0.1	1
2-Day standard-dose Tc-99m: stress imaging performed on earlier day than rest imaging	2662	59.2	2.9	12
2-Day low-dose Tc-99m: stress imaging performed on earlier day than rest imaging	64	1.4	0.1	1
Tl-201 rest imaging performed on earlier day than standard-dose Tc-99m stress imaging	0	0.0	0.0	0
Tl-201 rest imaging performed on earlier day than low-dose Tc-99m stress imaging	0	0.0	0.0	0
Tl-201 rest imaging performed on later day than standard-dose Tc-99m stress imaging	0	0.0	0.0	0
Tl-201 rest imaging performed on later day than low-dose Tc-99m stress imaging	0	0.0	0.0	0
Other 2-day protocol	0	0.0	0.0	0
Total	**90 683**	**2015.3**	**100.0**	

Abbreviations: Tl-201, thallium 201; Tc-99m, technetium 99m.
[a]Estimated by multiplying volume per year by percentage of procedures.
[b]Percentages do not total 100 because of rounding.

was reported to be used in more than 13% of studies in the previous week or in more than 15% of laboratories (eTable 2).

AUC. Twenty-four of 48 respondents answering reported that their practice uses AUC to track appropriate use. There were no differences among type of practices ($P = .76$) or practice NST volume tertiles ($P = .66$).

Professional Knowledge. Of 46 respondents, 40 (87%) reported having read at least 1 ASNC statement on radiation safety. Of the 73 individuals completing the survey, 36 responded to the question asking how many posteroanterior chest x-ray examinations would be equivalent to a single-day, rest-stress Tc-99m nuclear stress test. We considered a range of 350 to 650 x-ray examinations (ie, 7-13 mSv, assuming the standard estimate of 0.02-mSv effective dose for a posteroanterior chest x-ray examination[8,9]) to be a reasonable correct answer. Of these 36 respondents, 25 underestimated the dose. Twenty-two physicians omitted answering this question; among the 24 physicians responding, answers ranged from 1 to 1050 x-ray examinations. Seventeen physicians (71%) underestimated the dose (including 14 replying ≤166 x-ray examinations), 3 overestimated, and only 4 answered correctly (17% of respondents—9% of all physicians surveyed).

Discussion. Over the past decade, important advances in nuclear cardiology have allowed for high-quality studies at substantially reduced radiation exposure. This survey provides initial data describing current US NST practices, identifying that dose-reduction approaches have largely not been assimilated into everyday practice. Multiple reports evaluating more than 20 000 patients have demonstrated safety of stress-only imaging compared with traditional rest-stress imaging.[6] Given that most NSTs find no abnormalities, the 7.2% rate of stress-only imaging represents a missed opportunity to skip unneeded rest imaging in many patients. The 15.6% rate of dual-isotope testing is unacceptably high. Very few sites used scanner hardware such as cameras using multiple solid-state detectors or improved image reconstruction software to reduce radiation doses. Although 93% of physicians reported having read statements pertaining to radiation safety, only 9% could correctly characterize the radiation burden to patients from the most common NST protocol, a figure sizably lower than the proportion of imaging physicians correctly describing radiation in other contexts.[10]

Our study has several limitations. Most significant is its modest sample size. While the response rate was similar to other recent practice-based surveys,[11] it is uncertain what differences exist between respondents and nonrespondents. Not all respondents answered every question, although it is reasonable to expect those omitting a question are more likely to have suboptimal practices than those answering, suggesting that our data may reflect a bias toward *underestimating* actual underutilization of radiation protection approaches. Another limitation is that our findings are not based on data collected of actual protocols used and activities (millicuries) administered, but rather respondents' estimates and recall. These may be subject to bias, as illustrated by the observed discordance between actual vs professed use of stress-only imaging.

Nevertheless, our findings suggest significant opportunities for improving radiation safety for the 10 million US patients undergoing NSTs annually. Specific goals should include the following: (1) bridging gaps between physicians' exposure to radiation safety literature and actual knowledge; (2) increasing use of low-dose stress-first imaging, while decreasing dual-isotope imaging; (3) promoting wider integration of AUC into clinical practice, and (4) fostering validation, use, and affordability of advanced technologies permitting reduced administered activity.

Thus, contemporary US nuclear cardiology practice is characterized by underuse of existing approaches to ensure justification and optimization of ionizing radiation use and by gaps in practitioners' knowledge pertaining to radiation safety. Targeted educational programs are needed to better disseminate patient-centered radiation safety practices and effectively incorporate these principles into clinical practice.

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