Nuclear cardiology practice in Spain

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Background. **In Spain, nuclear cardiology (NC) procedures represent the second most frequently performed studies in nuclear medicine (NM) centers.**

Methods. **The NC Working Group of the Spanish Society of Nuclear Medicine and Molecular Imaging invited NM departments across the country to answer an online questionnaire regarding 2014 activity.**

Results. **Data on 40,161 patients from 42 centers were collected. The responding public centers served 39% of Spaińs population. The estimated NC activity for public hospitals was 2 studies/1,000 population/year. Of all the NC procedures, 69% were SPECT myocardial perfusion imaging (MPI), 17% equilibrium ventriculography, 12% ^{18}F-FDG PET, 1.3% first pass ventriculography, and <1% innervation and amyloidosis imaging, respectively. The most frequent NC study was a ^{99m}Tc tracer, exercise, 2-day MPI ECG-gated SPECT ordered by a cardiologist for diagnosis in an outpatient with 21 days of mean waiting time, the stress phase being supervised by both a cardiologist and a NM physician, with a NM physician writing a complete report.**

Conclusions. **A major challenge for NC in Spain is the gradual adoption of high-sensitivity, low-dose-dedicated cardiac SPECT cameras and the broadening of cardiac PET utilization with more cameras, and the availability of MPI tracers alongside the viability/inflammation setup.**

Key Words: Nuclear cardiology • myocardial perfusion imaging • SPECT • survey • Spain

Abbreviations	
NC	Nuclear cardiology
NM	Nuclear medicine
MPI	Myocardial perfusion imaging
SPECT	Single-photon emission computed tomography
PET	Positron emission tomography
CT	Computed tomography
ECG	Electrocardiogram
FDG	Fluorodeoxyglucose
MIBG	Iodine-123-metaiodobenzylguanidine
DPD	3,3-diphosphono-1,2-propanodicarboxylic acid

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INTRODUCTION

Nuclear cardiology has emerged over the past 30 years as a well validated, noninvasive imaging modality with a cost-effective and central role in the diagnosis and risk assessment of patients with known or suspected coronary artery disease[1,2] as well as in outcomes prediction[3] and guiding patient management.[4]

Nuclear cardiology continues to advance alongside other noninvasive imaging techniques, and despite the expansion of perfusion echocardiography, CT coronary angiography, calcium score, and magnetic resonance imaging,[5,6] its use is increasing worldwide.[3] Nuclear cardiology with SPECT or PET is widely used for noninvasive assessment of myocardial perfusion, viability, and left ventricular function.[4]

In Spain, nuclear cardiology procedures represent the second most frequently performed studies after ^{99m}Tc-diphosphonate bone scintigraphy and ahead of oncologic ^{18}F-FDG PET imaging, as reported in 2013 by the DOMNES project,[7] the spanish contribution to the european DOSE DATAMED 2 (DDM2)[8] study, which estimated nuclear medicine activity at 13.4 studies/1000 population/year.

MATERIALS AND METHODS

In order to obtain information on current nuclear cardiology practice in Spain, in 2015, the Nuclear Cardiology Working Group of the Spanish Society of Nuclear Medicine and Molecular Imaging (SEMNIM) projected an online questionnaire and invited nuclear medicine (NM) departments across the country to answer it regarding the 2014 activity. Participating NM departments were those in a list provided by SEMNIM which included both public and private centers. The survey contained 45 questions concerning equipment, patients, and nuclear cardiology practice (Appendix) and was approved by the Institutional Review Board of the core lab hospital. Data were presented as the mean ± SD for continuous variables and frequencies (proportions) for categoric variables.

RESULTS

Replies with useful information were received from 42 departments located in the following Spanish regions: nine in Andalucia, seven in Madrid, seven in Catalunya, six in Comunidad Valenciana, four in Castilla Leon, two in Aragon, two in Castilla La Mancha, two in Galicia, one in Cantabria, one in Canarias, and one in Pais Vasco. Centers were 10 private practices and 32 public hospitals, with 25 of them being university hospitals. The responding public centers served 39% of Spaińs population. The population served for nuclear cardiology studies in public hospitals ranged from 214,000 to 1,910,000 (mean 511,942 ± 327,390): 60% serving less than 500,000 population and the remaining 40% serving between 500,000 and 1,910,000. The number of beds ranged from 250 to 1,671 (mean 753, ± 335).

The total number of general nuclear medicine studies reported was 276,046, and the number of nuclear cardiology patients was 40,161, representing 15% of the total. The estimated nuclear cardiology activity for public hospitals was 2 studies/1,000 population/year.

Equipment

Sixty-one percent of departments belonged to a diagnostic imaging unit. All responding departments had at least one multiheaded gamma camera. Thirty-eight percent of departments had two gamma cameras, of which 64% were multiheaded SPECT cameras; 24% had three cameras, 83% of which were multiheaded; 19% had four cameras, of which 92% were multiheaded; and 16% had a single multiheaded camera (Figure 1). One center had five cameras, four of them multiheaded; and one center had a dedicated cardiac detector. Eleven centers (26%) used PET/CT scanners for nuclear cardiology.

Activity

Of all the nuclear cardiology procedures, 69% were SPECT myocardial perfusion imaging (MPI), 17% equilibrium ventriculography, 12% 18F-FDG PET, 1.3% first pass ventriculography, and less than 1% innervation and amyloidosis imaging, respectively (Figure 2). The mean MPI patients per center was 745 ± 753 ranging from 26 to 2727. Twenty-six percent of centers performed fewer than 250 patients, 45% performed between 251 and 1000, and 29% performed more than 1000 patients (Figure 3). Equilibrium ventriculography was performed mainly for evaluation of cardiac toxicity in oncologic patients. ^{18}F-FDG PET for viability/inflammation was performed in 11 centers. Innervation studies, for heart failure and Parkinson's disease, used ^{123}I-MIBG; and amyloidosis imaging mainly used ^{99m}Tc-DPD.

Myocardial Perfusion Imaging

All centers used ^{99m}Tc perfusion tracers and 16% of them additionally used ^{201}Tl in singular settings. Gated SPECT was performed both at stress and rest in 68% and exclusively at stress or at rest in 16% each. Attenuation correction was performed in 50% of departments, by means of CT in all cases. Prone imaging was used in obese patients by 10% of centers accounting for 8% of their studies. Image processing involved the use of well known, widely available state-of-the-art quantitative

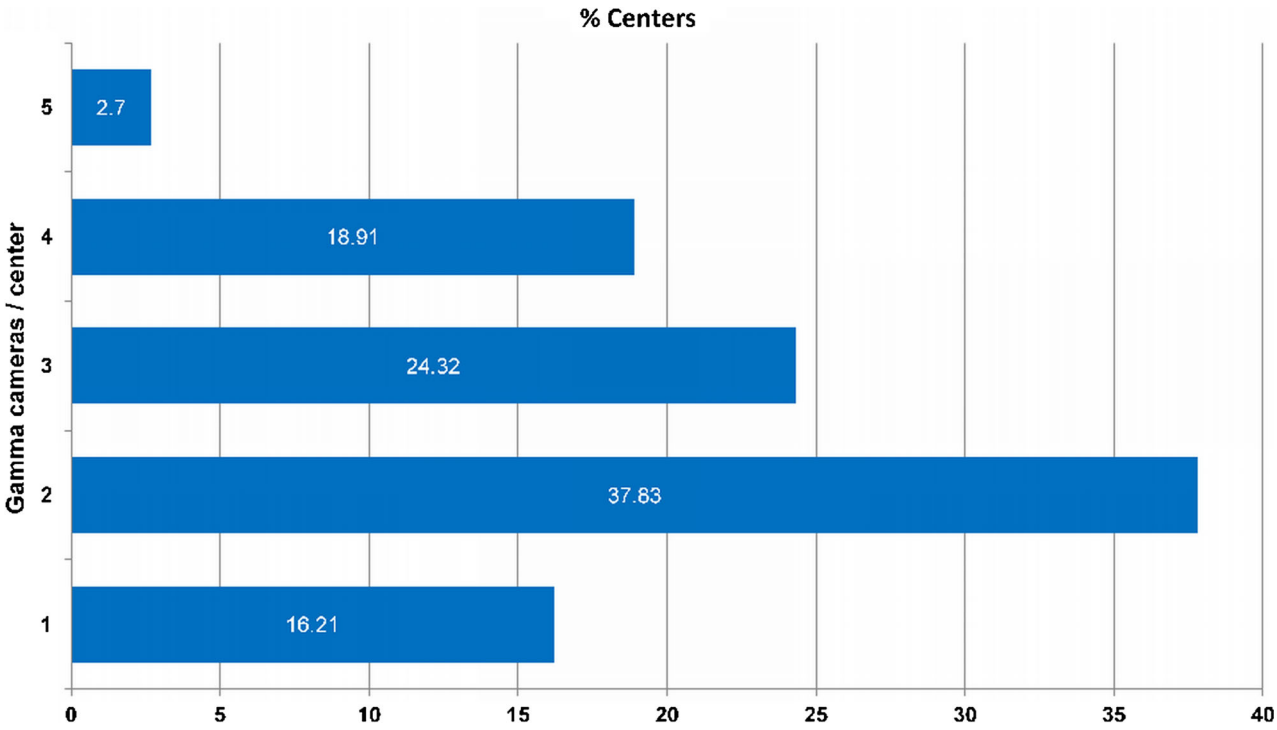

Figure 1. Percentages of centers according to number of gamma cameras in Spain.

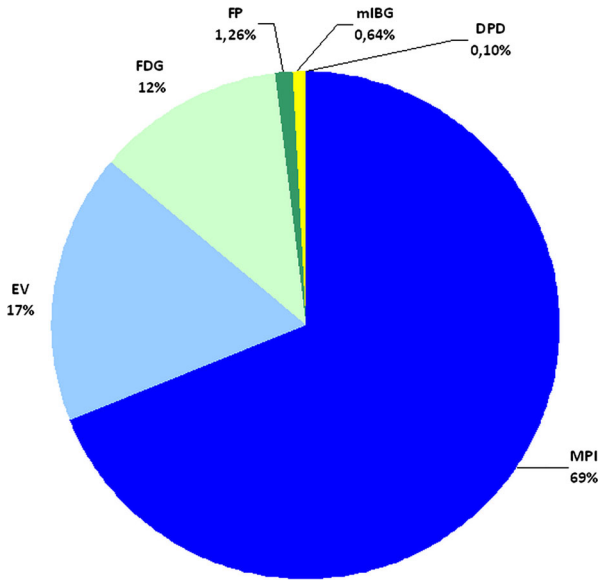

Figure 2. Percentages of studies performed according to type of nuclear cardiology procedure in Spain. *MPI* myocardial perfusion imaging, *EV* equilibrium ventriculography, *FDG* fluoro-deoxyglucose PET, *FP* first pass ventriculography, *mIBG* meta-iodobenzylguanidine, *DPD* diphosphono-propan-odicarboxylic acid.

software packages in all centers, 86% of them using the same particular package. Motion correction was performed by 40% accounting for 11% of their studies. Processing of images by the technologist was reported only in 16% of departments, with final supervision by the physician in all cases. A 2-day stress/rest protocol was used in 63% of centers; the remaining 37% using 1-day stress/rest or rest/stress protocols. Stress-only imaging was performed by 60%. ^{99m}Tc perfusion tracer doses were 7-10 mCi for the first injection and 20-25 for the second in 1-day protocols and 15-25 mCi for each injection in 2-day protocols. Thirty percent of centers reported weight-based dosing for technetium but this figure may be higher as weight dosing was not independently addressed in the questionnaire.

Stress Techniques

Cardiac stress was exercise, pharmacologic or combined in 48%, 43% and 9% of reported studies respectively (Figure 4). Eighty-six percent of centers used either exercise or pharmacologic stress (tailored to the patient's situation), of which 35% performed pharmacologic stress combined with low-level exercise. The remaining 14% exclusively performed exercise or pharmacologic stress to their patients. Dipyridamole, adenosine and dobutamine were the exclusively used stress agent in 30%, 11% and 5% of centers respectively; all other using more than one stress agent of which 8% used regadenoson. Regadenoson was licensed

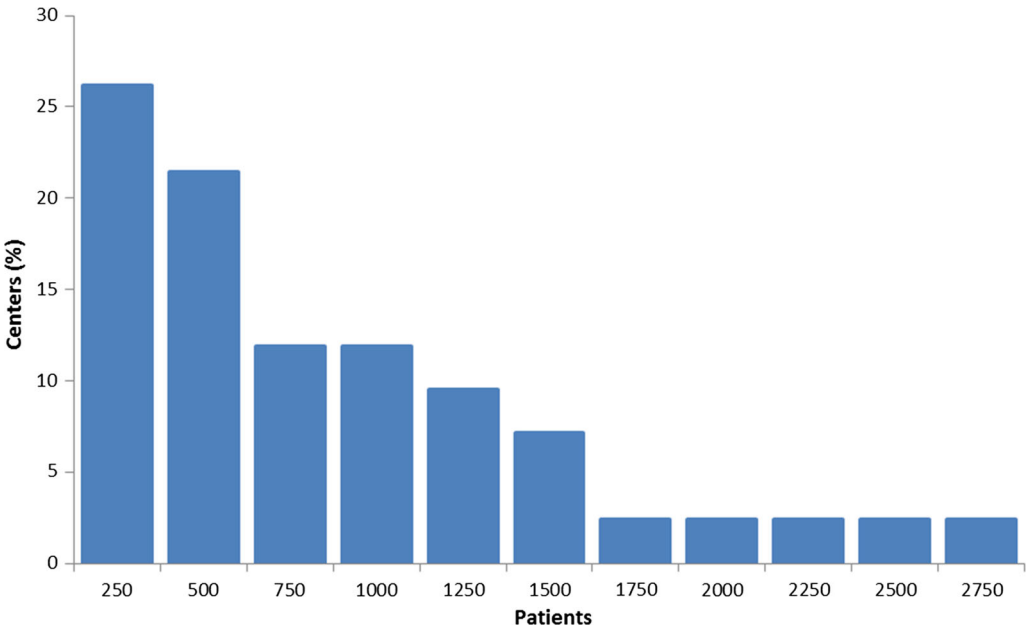

Figure 3. Frequency *histogram* showing percentage of centers according to number of annual MPI studies performed in Spain.

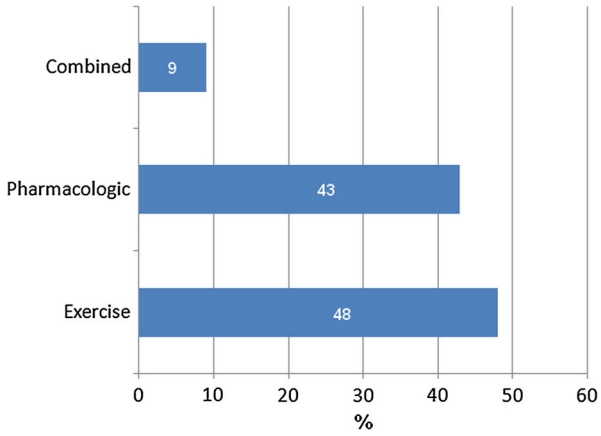

Figure 4. Choice of stress protocols in Spain. Exercise was the most commonly used protocol, closely followed by pharmacologic stress.

in Spain in 2014 although it has been used at single centers since 2010 as a foreign drug.

Stress procedures were supervised by a cardiologist, a NM physician or both in 33%, 21% and 46% of departments respectively. Supervision by a cardiologist was required only for ergometry or dobutamine in 19% of centers. The supervising cardiologist was appointed on a rotating basis in 77% of centers while the NM physician was always the same person in 57%. In all cases, at least one nurse was present during the procedure and 30% of centers had two nurses.

Referrals

The mean waiting time was 1.9 ± 1.7 days for inpatients and 21 ± 19.6 days for ambulatory patients. Eighty-six percent of MPS studies were performed on outpatients and 14% on inpatients. Thirty-four percent of referrals were from centers other than the site performing MPI. Eighty-eight percent of referrals were from cardiologists, 8% from internal medicine physicians, and 2% from cardiac surgeons and primary care physicians respectively. The purpose of MPI was diagnosis in 74%, prognostic assessment in 21% and viability/hibernation in 5%.

Reporting

The MPI report was written by a NM physician alone or in collaboration with a cardiologist in 70% and 30% of departments respectively, and comprised a detailed description of findings and a clear conclusion in all centers. Clinical data and description of the stress phase including adverse events were included in the report in 91% and 83% of centers respectively.

Consistent data on ECG treadmill tests, stress echocardiograms, cardiac magnetic resonance scans, CT coronary angiograms, CT calcium score, coronary angiograms, percutaneous interventions and coronary bypass graft operations performed at the center hosting the nuclear cardiology practice is lacking as these questions were not obligatory and therefore not answered by all respondents.

DISCUSSION

This survey portrays an overview of the practice of nuclear cardiology in Spain. Although the population covered by the responding centers is 39% of the countrýs population, it encompasses a broad range of users and centers distributed across the Spanish geography.

The estimated nuclear cardiology activity for public hospitals of 2 studies/1,000/year in 2014 represents a moderate utilization index [9] and is lower than the global 2.6 MPI studies/1000/year reported for Germany in 2012[10] which is between a moderate and a moderate-high index; but is higher than the 1.1 MPI studies/1000/year estimated for Spain in a 2007 European survey.[11] In 1998, nuclear cardiology was the third most frequently performed NM procedure after bone scintigraphy and endocrine studies.[12] The DOMNES study[7] in 2013 revealed a shift of nuclear cardiology to the second place after bone scintigraphy and ahead of the ever increasing oncologic PET. Therefore, we may consider nuclear cardiology in the last two decades to be on the rise in Spain.

The study underlines a nuclear cardiology practice according to international standards. All current nuclear cardiology procedures except PET for perfusion are provided, although ^{18}F-FDG PET is not widely available. All MPI studies are performed as gated SPECT, and half the centers use CT attenuation correction. The administered activity of 15-25 mCi for 2-day protocols is slightly superior to levels recommended by the European guidelines,[13] but significantly superior to the more recent ASNC recommendations,[14] largely reflecting the almost complete absence of dedicated cardiac detectors and the aging of standard cameras. On the other hand, most of the eight best practices developed by the IAEA for optimization of radiation protection[2,3] are fulfilled, with scarce thallium use; stress-only imaging performed by as many as 60% of centers; use of camera based dose reduction strategies whenever possible; and avoidance of inappropriate dosing leading to ''shine through'' artifact. In addition, weight-based dosing was performed by at least 30% of centers.

Dynamic exercise is the most common stress test and dipyridamole the most common pharmacologic stress, similar to the results of a 2007 European survey,[11] followed by adenosine, regadenoson and dobutamine. As many as 35% of centers performed vasodilator pharmacologic stress combined with low-level exercise, a recommended practice that significantly reduces the incidence and severity of side effects and improves image quality.[15] The use of regadenoson has increased steadily after our survey was finished and has recently rallied due to a national shortage of dipyridamole. Physician stress supervision by at least one physician in all cases, and the percentage of cardiologists involved is similar to a 2005 European report: 79% vs 77%[5], although the percentage of NM physicians; 67% vs 88% is lower, reflecting local preferences favoring the clinician.

The mean waiting time of a couple of days for inpatients and three weeks for ambulatory patients is well within the upper limits of 6 weeks for routine studies and 1 week for urgent studies as recommended by a 2004 British consensus[16] and the sixfold higher proportion of ambulatory to inpatients is similar to previous reports from European countries.[5,17] Likewise, the major referral group is represented by the cardiologists, and the most common indication for MPI is diagnosis of coronary artery disease. MPI reporting is similar to previous European data[11] with most reports being written by a NM physician and with the involvement of a cardiologist in $\leq$30% of reports. Finally, the structure and content of MPI reports adhere to recommended standards.[18]

We herein conclude that in Spain, the most frequent nuclear cardiology study was a 2-day myocardial perfusion-gated SPECT with exercise and a ^{99m}Tc tracer, ordered by a cardiologist for diagnostic assessment in an outpatient patient with a mean waiting time of 21 days, with the stress phase supervised by both a cardiologist and a NM physician—and the MPI report written by a NM physician addressing all aspects of the procedure.

A major challenge for nuclear cardiology in Spain is the gradual adoption of high-sensitivity-, low-dose-dedicated cardiac SPECT cameras and the broadening of cardiac PET utilization with more cameras and the availability of myocardial perfusion tracers alongside the viability/inflammation setup.

NEW KNOWLEDGE GAINED

An overview of nuclear cardiology practice in Spain has been obtained, revealing a practice according to international standards and the need for high-sensitivity-dedicated cameras and wider PET availability.

Disclosure

The authors declares that they have no conflict of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

APPENDIX

Nuclear cardiology practice questionnaire 2014

1. Contact name:
2. Specialty
3. E-mail address:
4. Telephone number:
5. Institution name and address
6. Size of population served for nuclear cardiology:
7. Number of beds in hospital or center:
8. Number (in year 2014) of:

ECG treadmill tests
Stress echocardiograms
Cardiac magnetic resonance scans
CT coronary angiograms
CT calcium score scans
Coronary angiograms
Percutaneous coronary interventions
Coronary bypass graft operations

9. Does your department belong to a Diagnostic Imaging Unit?
10. Number of gamma cameras in your department

Single head general purpose SPECT:
Multihead general purpose SPECT:
Dedicated cardiac SPECT:

11. Name of the camera that performs nuclear cardiology:
12. Do you perform nuclear cardiology PET studies? and for what indications?
13. Do you perform ECG-gated acquisition?

☐ Poststress and rest
☐ Poststress
☐ Rest
☐ Not performed

14. Do you perform attenuation correction?

☐ Always
☐ Occasionally
☐ Not performed

15. What software is used?

☐ QGS quantitative gated SPECT
☐ ECTB Emory cardiac toolbox
☐ 4D-MSPECT
☐ Other

16. Percentage of SPECT studies performed with prone imaging:
17. Percentage of SPECT studies performed with motion correction:
18. Does the technologist process the studies?

☐ Always
☐ In some situations
☐ Never

Describe the role of the technologist if the answer to the above question was positive

19. Total number of general nuclear medicine studies in 2014:
20. Number of SPECT myocardial perfusion studies in 2014:
21. Number of PET myocardial perfusion studies in 2014:
22. Number of 18F-FDG PET studies in 2014:
23. Number of myocardial innervation studies in 2014:
24. Number of equilibrium radionuclide ventriculograms in 2014:
25. Number of first pass radionuclide ventriculograms in 2014:
26. What other nuclear cardiology procedures did your department perform in 2014?
27. Percentages of inpatients and outpatients studied:

Outpatients:
Inpatients:

28. Percentage of referrals from your own or from other hospitals:

Your hospital:
Other hospitals:

29. Percentage of referrals according to specialty:

Cardiologist:
Internal medicine physician:
Cardiac surgeon:
Primary care physician:

30. Percentage indications for myocardial perfusion imaging:

Diagnosis of coronary disease:
Prognostic assessment in patient with known coronary disease:
Assessment of hibernation or viability:

31. Average waiting time for outpatient myocardial perfusion imaging:
32. Average waiting time for inpatient myocardial perfusion imaging
33. Does a cardiologist supervise the stress test?

If answer is positive:

☐ Always the same cardiologist
☐ Several cardiologists on a rotating basis

34. Does a nuclear medicine physician supervise the stress test?

If answer is positive:

☐ Always the nuclear medicine physician
☐ Several nuclear medicine physicians on a rotating basis

35. Do a cardiologist and a nuclear physician supervise the stress test together?

☐ Yes
☐ No

36. If the cardiologist supervises only certain types of stress tests please describe them:

37. How many nurses are present during the stress test?

☐ 1
☐ 2

38. Percentage of patients with each type of stress:
Treadmill:
Cycle ergometer:
Pharmacologic:
Pharmacologic combined with low-level exercise:

39. Percentage of patients with each type of pharmacologic stress:
Adenosine:
Dipyridamole:
Regadenoson:
Dobutamine:

40. Do you perform stress-only imaging if the stress study is normal?

☐ Yes
☐ No

If the answer to the above question is positive, what percentage do the stress-only studies represent?

41. What radiopharmaceutical protocols are used?

☐ MIBI 1-day stress/rest
☐ MIBI 1-day rest/stress
☐ MIBI 2-day
☐ Tetrofosmin 1-day stress/rest
☐ Tetrofosmin 1-day rest/stress
☐ Tetrofosmin 2-day
☐ Thallium
☐ Dual isotope
☐ Other

42. Stress dose in mCi:

43. Rest dose in mCi:

44. Who writes the myocardial perfusion report?

☐ Cardiologist
☐ Nuclear physician
☐ Cardiologist and nuclear physician in collaboration

45. Mark which of the following sections are addressed in myocardial perfusion report

☐ Clinical data and indication for the procedure
☐ Thorough description of the stress phase
☐ Side effects during the stress phase
☐ Image findings
☐ Overall impression with clear conclusion

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