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POSITION PAPER

Reporting nuclear cardiology: a joint position paper by the European Association of Nuclear Medicine (EANM) and the European Association of Cardiovascular Imaging (EACVI)

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The report of an imaging procedure is a critical component of an examination, being the final and often the only communication from the interpreting physician to the referring or treating physician. Very limited evidence and few recommendations or guidelines on reporting imaging studies are available; therefore, an European position statement on how to report nuclear cardiology might be useful. The current paper combines the limited existing evidence with expert consensus, previously published recommendations as well as current clinical practices. For all the applications discussed in this paper (myocardial perfusion, viability, innervation, and function as acquired by single photon emission computed tomography and positron emission tomography or hybrid imaging), headings cover laboratory and patient demographics, clinical indication, tracer administration and image acquisition, findings, and conclusion of the report. The statement also discusses recommended terminology in nuclear cardiology, image display, and preliminary reports. It is hoped that this statement may lead to more attention to create well-written and standardized nuclear cardiology reports and eventually lead to improved clinical outcome.

Keywords Cardiac imaging • Nuclear cardiology • Nuclear medicine reports • Practice guidelines

Preamble

This position paper on reporting nuclear cardiology examinations has been developed under the auspices of the Cardiovascular Committee of the European Association of Nuclear Medicine (EANM) and the Section on Nuclear Cardiology and Cardiac Computed Tomography of the European Association of Cardiovascular Imaging (EACVI) of the European Society of Cardiology (ESC), highlighting the importance for close collaboration and bridging between the two specialties.

In the daily routine, this collaboration is particularly obvious in two areas: referral for the nuclear cardiology examination and the communication of the outcome of the examination. The former has more recently received a lot of attention with discussions of appropriate use criteria, classes of indications of the examinations, and varying reimbursement in some European countries, etc. In contrast, the communication of the results has received much less attention, though of equal significance. It is therefore important that, by reading the report, the results of the examination are understood as closely and accurately as possible reflecting the interpretation of

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the nuclear medicine physician. Ideally, the information presented should be uniform and independent of individual physician's preferences or patient-specific parameters.

The information presented below is specifically adapted to European practice. A significant limitation of our recommendations is the lack of evidence from original scientific studies on the influence of the report on the use of the results of the examination. Another important limitation for the present, English written, paper is related to the great variations within Europe both regarding national traditions and regulations, and the differences in the languages. With those limitations, the authors wish to give some recommendations regarding structure and standards for the nuclear cardiology report: the goal of the report must be to transfer from the interpreting physician to the referring physician a message that in a coherent clinically relevant and predictable format[1] and in an easily readable way that concisely reflects the nuclear medicine interpretation of the examination.

Introduction

'The report of an imaging procedure is often the only communication from the interpreting physician to the caregiver, and is the final and perhaps the most critical component of an imaging procedure'.[1] It may occasionally also may become legal evidence.[2] In a way, nuclear cardiology studies undergo two interpretations: the first one being performed by the physicians who make a report based on the analyses and interpretation of the images, stress data, etc. The second is the interpretation made by the physician who reads the report and from this reading draws his or her conclusions for further clinical action. Although sometimes the referring and image report making person are the same, the information in the report should be uniform and as accurately possible reflecting the interpretation. Guidelines on reporting imaging procedures in nuclear cardiology, to optimize the communication of the information from reporter to reader, are essential.

Ideally, guidelines should be based on evidence from clinical studies,[3] but in practice mostly on expert opinions. Owing to a lack of published evidence, all available recommendations on reporting nuclear cardiology are largely or totally based on expert opinions. Fortunately, there is wide consensus on most of the issues,[4–6] including the critical need of structured reporting, as opposed to free text descriptions, so that key report components and data elements are not omitted. Increased standardization would facilitate the reading of reports.[1] Terminology must be accurate, but always expressed in a reader friendly style.

The present paper combines existing evidence with expert opinions and previously published guidelines and recommendations[1,4–11] with current clinical practices. This joint expert statement focuses on:

(i) Myocardial perfusion imaging (MPI) with single photon emission computed tomography (SPECT) or positron emission tomography (PET).
(ii) Equilibrium radionuclide ventriculography (ERNV).
(iii) Viability imaging evaluated by ^{18}F-fluoro-deoxyglucose (FDG) PET/MPI.
(iv) Hybrid imaging with coronary artery calcium score (CACS) and/or coronary CT angiography (CCTA) and MPI.
(v) ^{123}I-metaiodobenzylguanidine (MIBG) imaging.

The paper also includes discussion of terminology, use of preliminary reports, and the selection of images accompanying the report. In concordance with the previously published guidelines,[10] three levels of importance are used, including 'must' (information required in the report), 'should' (information highly recommended), and 'may' (optional information).

The minimum information recommended to be included in the report appears as 'must' and encompasses unequivocal identification of patient, study, date, and signature (often digital), as well as a description of findings, whether normal, abnormal or inconclusive, and finally a conclusion presenting the clinical interpretation of the findings. The remaining data that can be added in the report depend on a number of factors, including national and local traditions and 'culture', national legislation, and relation between the referring and reporting physicians and/or institutions. Examples of reports are presented that include both 'must' and 'should' information to present the level recommended by the authors, i.e. in-between the minimum ('must') and, 'may' be included information. Reports must include sufficient data of relevant detailed elements to describe the findings, but too lengthy reports should be avoided. Compared with US guidelines,[1,10] those presented in this statement allow for more degrees of freedom, which is related to European vs. US traditions, the national variations within European countries, and possibly also related to the more common use of medical legal litigating in the USA and thereby the related over-completeness/defensive medicine.

It is hoped this paper may lead to improvement in the clinical value of nuclear cardiology for patients and physicians as well as to facilitate and improve research in nuclear cardiology.[12] However, recommendations presented are neither infallible nor substitute for good clinical judgment.

Terminology in the report

It is crucial that the referring or treating physician understands the report as intended by the interpreter of the images. This implies careful attention to the terminology used in the report.

Regarding general language, it is strongly recommended that:

(i) The report is written in a simple way, if possible, without the use of technical terms.
(ii) The use of abbreviations and technical information not important for the referring physician should be avoided or extremely limited.
(iii) Qualitative descriptions (e.g. small, medium-sized, large or slightly, moderately, severely reduced) should be replaced, if possible, by quantified data since qualitative words are used and understood differently.[13]
(iv) Protective expressions (e.g. is likely, cannot be excluded) are used as little as possible. However, relevant doubt about the clinical implication of the interpretation must be communicated.

The report must cover clinically relevant information, but not technically irrelevant details. Terms should be used that are widely recognized and approved both in nuclear medicine and in cardiology. The section on *findings* must give a precise description of the images. Some expressions may appear equally good: a perfusion defect can be

reversible (stress-induced) or irreversible (non-reversible, fixed, and permanent). Depending on the context, one expression may appear more correct than another one. In the description of SPECT *findings*, an ischaemic perfusion defect is less accurate than a reversible or stress-induced perfusion defect, but is more relevant in the clinical *conclusion* of the study. Likewise, in the *conclusion*, an expression like a fixed or permanent perfusion defect, relevant in the section on *findings*, should be translated to infarction or scar tissue, provided that viable tissue is unlikely. The more standardized format of accurate and relevant information is provided, the better the reader's interpretation will be minimizing misunderstandings of the report leading to subsequent better clinical decisions.

The preliminary report

In communications other than the final report, the preliminary report is the most important type of message given about an imaging study. Preliminary reports, typically given in order to direct immediate patient management, may be written, transmitted electronically, or given verbally. It is not expected to include all information of the final report.[14] The person responsible for the preliminary communication must assure the receipt of it. The preliminary report should be reproduced into a permanent format and archived as a preliminary communication, since clinical decisions may very well be based on a preliminary report. Subsequently, it must be documented in the final report. The documentation is important, as recently shown for pulmonary scintigraphy.[15] If it has been given as a person-to-person communication, it must specifically name the person to whom the communication was delivered. If the message of the final report deviates from that of the preliminary report, this discrepancy should be clearly stated in the final report. Immediate transfer of a preliminary report has been shown in radiology to result in a small, but important number of adverse outcomes. However, if edited in the final report, the benefits of rapid information transmission may outweigh the additional risks.[16]

Oral communications

Sometimes other forms of communication may occur, e.g. during a clinical conference or by a verbal comment to an outside study. Occasionally, such an interpretation does not result in a 'formal' report. That type of communication carries an inherent risk by missing comparison with previous studies, adequate patient history, etc., and is therefore not recommended. Ideally, discussion in multidisciplinary meetings (i.e. more than one medical specialty present) and the subsequent clinical decisions should be reported in a separate report.

The structured nuclear cardiology report

A structured report, in contrast to free text, with adequate headings should be used, since a well-structured report is more easily accessible for the referring or treating physician.[1,4] In the present paper, a number of headings have been used to describe the different aspects of the report. They were chosen since they are widely used in clinical imaging practice and recommended for nuclear cardiology by others as well.[7,9] Headings may differ between different institutions and different countries due to local tradition and legislation. The headings used here include: demographics; clinical indication; tracer administration and image acquisition; findings; conclusion; as well as date and signature. *Figures 1* and *2* show examples of

Demographics
<Site administrative data, contact information>
<Patient name, identification number/date of birth, gender>

Clinical indication
Suspicion of coronary artery disease.

Stress testing data
Adenosine stress testing was performed with low-level exercise (50W) during adenosine infusion (6 min). No other medication was given.

Tracer administration
600 MBq ^{99m}Tc-Tetrofosmin was injected after 4 min of infusion, and images were acquired 45 min after tracer injection.

Findings
Homogeneous tracer distribution throughout the myocardium at stress. LV ejection fraction: 70% (normal > 60%). Normal LV volumes and normal wall motion and wall thickening.
No rest study was performed.

Conclusion
No stress induced ischemia. No myocardial infarction. Normal LV function.

Figure 1 Example of the contents that should (including must) be provided in a report of a normal MPI.

Demographics
<Site administrative data, contact information>
<Patient name, identification number/date of birth, gender>

Clinical indication
Suspicion of coronary artery disease.

Stress testing data
The patient performed a bicycle exercise test. Maximum workload 125 W (4METs). Heart rate increased from 72 to maximum 153 beats/min (92% of maximum predicted heart rate). Blood pressure increased from 145/95 mmHg to maximum 195/- mmHg. The patient experienced moderate chest pain during peak exercise. The test was terminated due to fatigue and dyspnoea. During exercise 2 mm ST-depression was observed in leads V_4-V_6. No medications were administered.

Tracer administration
600 MBq ^{99m}Tc-Sestamibi at peak exercise and 600 MBq at rest (2-day protocol). Images were acquired 45 min after the tracer injections.

Findings
Rest study: Homogeneous tracer distribution throughout the myocardium.
Stress study: Severely decreased tracer uptake in a large area of the left ventricle including the whole anterior wall, apex and apical lateral region (segments 1, 7, 13, 16, 17).
Gated SPECT imaging showed normal myocardial thickening and wall motion at rest. LVEF was 65% (normal > 60%), but decreased during stress to 55%. Moderate hypokinesia and moderately decreased antero-lateral wall thickening during stress. Normal LV volumes both at rest and after stress.

Conclusion
Severe, stress-induced ischaemia in the whole anterior wall, apex and apical lateral region, approx 25% of the LV. No sign of myocardial infarction.
Global and regional LV systolic function was normal at rest, but EF decreased significantly after exercise, and regional systolic function was reduced after exercise.

Figure 2 Example of the contents that should (including must) be provided in a report of an abnormal MPI.

reports from a normal and from an abnormal MPI, with information that 'should' (including 'must') be included in the report.

Demographics

Site administrative data (physical address), contact information, as well as name and affiliation of the referring physician must be provided, as well as patient name, unique identification number (date of birth, etc.), and gender.

Clinical indication(s)

The clinical indication for the study should be reported, both to show the appropriateness of the study and to focus the examination and the report. Cardiac history and symptoms and prior cardiac investigations may be summarized, active medications may be noted, and pre-test probability of coronary artery disease may be calculated.

Tracer administration

The tracer administered and amount of radioactivity should be reported. According to legislation in some countries, the amount of radioactivity must be reported. For ^{99m}Tc-labelled tracers, it should be noted if a 1-day or a 2-day protocol is followed. The timing in relation to termination of a stress test procedure and the time interval between tracer injection and image acquisition should be noted.

For an FDG study, blood glucose at the time of FDG injection must be reported in diabetic patients; in other patients, it may be noted. Oral glucose load, insulin–glucose clamp, acipimox administration etc., must also be reported.

Image acquisition

If the routine procedure is followed, it should not be described in the report. If the default procedure has not been chosen, the reason must be presented, e.g. changes from the usual protocol regarding rotation, position of patient, gating, or attenuation/scatter correction problems, etc.

Findings

Myocardial perfusion imaging

The stress testing procedure and findings must be briefly described, also if the stress test is normal (*Table 1*). The perfusion distribution is the key information: Does the activity distribution in the myocardium appear normal, abnormal only at stress or also at rest, or is the study non-diagnostic? The findings should be described as shown in *Table 2*.

Table 1 Findings related to the stress test in the report of an myocardial perfusion SPECT study

Stress test type	Must be included	Should be included	May be included
Symptom limited exercise test	Reason for termination of test	Exercise capacity (MET), peak HR, and BP, changes vs. rest. Stress-induced symptoms and abnormal ECG findings (rest and stress-induced)	Type of protocol: Bruce, modified Bruce, etc.
Pharmacological stress ± exercise	Vasodilators or dobutamine (± atropine). Reason for premature termination. Other drugs including doses administered during the test (anti-anginal, etc.)	Dose of stress agent and timing of administration	Symptoms and ECG changes. HR and BP baseline/peak

BP, blood pressure; HR, heart rate; METs, metabolic equivalents.

Table 2 Findings of tracer distribution in the report of a gated myocardial perfusion SPECT study

Tracer distribution	Must be included	Should be included	May be included
Normal	Brief description		
Abnormal	Presence of defect(s)		Other comments to perfusion distribution abnormalities
Location of defect(s)	Relation to LV segments, relation to the patient's coronary artery distribution if known	Preferably using the 17-segment model.[9] Suggestion of single- or MV disease	Relation to standard coronary anatomy with reservations regarding anatomy variations
Extent of defect(s)	Description of defect size(s). 'Large', 'small', etc. is a minimum	Quantification as percentage or a percentage interval of the LV[a]; alternatively in summed scores	
Severity of defect(s)	Description of defect severity. 'Mild', 'severe', etc. is a minimum	Quantified in summed stress/rest/difference scores[b]	
Reversibility of defect(s)	Reversible (stress-induced), fixed (permanent and irreversible), or mixed (partially reversible) defect(s)	Quantified in summed difference scores[b]	
Quantification of regional perfusion in PET		Absolute values in ml/min/g tissue at rest/during hyperaemia, including reference values. Coronary flow reserve in units	
Other abnormalities	Incidental extracardiac findings	Deviations in tracer distribution (locally increased/decreased uptake, LV cavity dimensions)	
Non-diagnostic study	Describe the reason		

LV, left ventricular; MV, multivessel.
[a]A reversible defect >10% of the LV has prognostic information.[17,18]
[b]Scores vary with software systems used.[19]

Left ventricular function

If gated studies have been acquired (rest and/or stress), left ventricular (LV) function data should be reported, as also shown in *Table 3*. Reference values of LV ejection fraction (EF) should accompany the report, either as values from the department (preferable) or as values referred from the literature obtained with similar technique and software tools. Possible discrepancies between regional perfusion and regional myocardial functional data must be discussed.

Equilibrium radionuclide ventriculography

LVEF must be presented (*Table 4*), and reference values of LVEF should accompany the report, either as values from the department (preferable) or as values referred from the literature obtained with similar technique and software tools. It should be noted (cf. section on reference values in ref. [8]) that LVEF values differ between men and women and between gated MPI and ERNV.

Viability with FDG in combination with MPI (by PET or SPECT)

Regional FDG uptake must be described in relation to reduced regional perfusion (SPECT or PET): is FDG uptake reduced (*match* between reduced metabolism and reduced perfusion), or is it normal or enhanced (*mismatch* in relation to reduced regional perfusion)? The evaluation compares the uptake in the hypoperfused myocardial region with that in the remote myocardium. Quantification of mismatch is recommended.

Table 3 Findings of LV function in the report of a gated myocardial perfusion SPECT study

LV function	Must be included	Should be included
LVEF	Numerical values	Reference values
LV volumes		Numerical values (with reference values) Presence of TID (visual evaluation and/or quantified)
WM		Visual evaluation: normal, hypokinesia (mild, moderate, and severe), akinesia, or dyskinesia
WT		Visual evaluation: normal, decreased (mild, moderate, and severe), or absent
Phase analysis		Dyssynchrony
Differences between stress and rest global and regional LV function	Stress-induced LV dilatation (TID)	Comment on differences
Findings that may reduce the accuracy of the assessment of LV function		Other comments (i.e. cardiac arrhythmias)
Local perfusion/WM or WT relationship		A comment
Non-diagnostic study	Describe the reason	

LV, left ventricular; EF, ejection fraction; TID, transient ischaemic dilatation; WM, wall motion; WT, wall thickening.

Table 4 Findings in the report of an ERNV

Must be included	Should be included	May be included
LV functional evaluation		
LVEF value	Reference values, either as values from the department (preferable) or as values referred from the literature obtained with similar technique and software tools[a]	Regional LV function and volumes, if relevant (e.g. suspicion of ischaemic aetiology of a cardiomyopathy). Description of a very dilated or a very small LV cavity in qualitative terms. An artificially high LVEF value (>70%) may be related to a small LV
LVEF monitoring		
Add comment on a significant change for LVEF determination (if applicable)		
RV function[b]		
		Presence of a large RV or tricuspid regurgitation into the splanchnic area

ERNV, equilibrium radionuclide ventriculography; LVEF, left ventricular ejection fraction; RVEF, right ventricular ejection fraction.
[a]LVEF values differ between men and women and between gated myocardial perfusion SPECT and ERNV.
[b]RVEF can be determined accurately only from a tomographic ERNV or by a first-pass technique (not discussed in this paper).

Hybrid imaging with CACS and/or CCTA

The description of MPI is similar to the stand-alone study. The additional information obtained from CACS or CCTA must be reported and integrated with the MPI results. With CCTA, reporting should follow the recommendations of stand-alone CCTA, as described in detail in part B of the guidelines of the Society of Cardiovascular Computed Tomography.[20] The severity of a stenosis can be assessed in qualitative terms (minimal, mild, moderate, severe, and occluded), or the length and luminal reduction may be quantified. The location and severity of detected lesions must be set in relation to the regional MPI findings, and a conclusion drawn regarding agreement or disagreement between findings by the two modalities. The clinical interpretation must be discussed in case of a possible disagreement, e.g. is a stenosis detected by CCTA hardly of haemodynamic significance since stress perfusion is normal in that region; or could the perfusion findings be falsely normal, maybe due to balanced ischaemia in multivessel coronary disease? Further diagnostic examinations or invasive angiography may be recommended.

^{123}I-metaiodobenzylguanidine

Normal or reduced ^{123}I-MIBG cardiac uptake must be described, and comment on the clinical significance should be included (*Table 5*). If available, possible perfusion/innervation mismatch should be discussed.

Table 5 Findings in the report of a cardiac ^{123}I-MIBG study

Cardiac images	Must be included	Should be included	May be included
Planar	Visual description (normal, abnormal, or non-diagnostic study)	Quantified in early and late H/M ratios and washout rate, with reference to normal values	Prognostic information
SPECT	Description of regional defects regarding location, extent, and severity	Relation to perfusion when MPI is available[a]	

H/M, heart-to-mediastinum ratio.
[a]Cf. *Table 2* for the findings to include in the report regarding the gated MPI part of the study. ^{123}I-MIBG uptake should follow the same nomenclature.

Table 6 Conclusions in the report of nuclear cardiology study types

	Must be included	Should be included	May be included
Myocardial perfusion SPECT	Defect suggesting stress-induced ischaemia or scar tissue. Location and extension/severity	*Defect:* Extent and severity quantified. Relation of defect to coronary anatomy and/or stenosis if reported/available	
Functional data from gated myocardial perfusion SPECT	Stress and rest (if available) LVEF and change from rest to stress. Reference values for LVEF. LV dilatation, TID. Concordances and discrepancies between perfusion and wall motion, if observed	LV volumes and regional function. Synchrony	Other quantitative values
ERNV	LVEF value with reference values. Significant change from a previous EF value	LV volumes	Regional LV abnormalities
Viability imaging	Viable or non-viable tissue. Summary of the location and extent of viable tissue (% of LV)	Extracardiac FDG accumulations	LV function
Hybrid imaging	Integration of both imaging modalities. Otherwise similar to stand-alone studies	Comparison between quantified stenosis and quantified stress-induced perfusion defect. Integrated risk stratification	
^{123}I-MIBG	Normal or reduced ^{123}I-MIBG uptake. Significantly abnormal H/M ratios and/or washout rate. Possible perfusion/innervation mismatch		Prognostic information (if relevant)

EF, ejection fraction; ERNV, equilibrium radionuclide ventriculography; FDG, ^{18}F-fluoro-deoxyglucose; LV, left ventricular; TID, transient ischaemic dilatation.

Conclusion of the report

The conclusion must address and as clearly as possible answer the clinical question from the indication. A statement must be given whether the study is normal, abnormal, or inconclusive. Results from the present study should be compared with previous studies if available. Information about technical errors, sub-optimal quality, or abnormal extracardiac tracer uptake should be mentioned. Further diagnostic investigation may be suggested, dependent on the relationship between the referring and interpreting physician and based on the extent and severity of present perfusion and functional abnormalities.

For the different study types, specific points are presented in *Table 6*.

Images in the report

Images accompanying the report must illustrate and support the conclusion. Care should be taken not to present images that may cast doubt on the interpretation of the study (e.g. images with artefacts, reported as normal). If not, they can be confusing or even lead to misinterpretation for the clinical reader of the report. Technical images (a raw image from a screen capture of a cine loop, etc.) and text (matrix, filter information, etc.) are superfluous and should not be included. Several colour scales are available in current reporting environments. It is important to use the same, standardized scale for each type of study[9] and to present a limited number of images since the referring physician rarely wants to look at too many images.

Gated MPI

Images showing both tomograms (stress and rest slices correctly aligned) and polar plots are recommended. An image display has been discussed in further detail in the European procedure guidelines on myocardial perfusion.[9]

Equilibrium radionuclide ventriculography

A printer/reader friendly screen capture can be used showing 'best septal' separation of the LV in end-diastole and end-systole with regions of interest superimposed (including background) with an LV time/activity curve. Parametric amplitude and phase images (the latter with its histogram) may be included.[8]

Viability imaging

Relevant slices or polar plot images (cf. above under MPI images) showing perfusion and FDG images should be shown side by side, correctly aligned.

Hybrid imaging

Perfusion images are displayed as discussed above. The CCTA images should be analysed and displayed according to the standard methodology for CCTA. Specific software tools for hybrid displays are currently not yet standardized. The general aim, however, is that the perfusion distribution is overlaid with individual coronary vasculature to allow precise localization of perfusion abnormalities with coronary anatomy.

^{123}I-MIBG cardiac imaging

Anterior, planar, early, and late images should be presented.[21] In case SPECT or PET images are presented, the display should follow the same rules for slice presentation and polar plots as described for MPI.[9] Images showing ROIs may be added to show the quality of quantified data.

Conclusion

Over the years, a lot has been done to achieve optimal data and images by the best protocols, tracers, and cameras, and to improve their interpretation by training and the use of sophisticated hardware and software tools. However, little attention has been paid to the transmission of the image information from the reporting physician to the referring physician: the creation of the good report. Efforts must be made to improve the report by increased standardization and by an appropriate written communication, using simple, clinically relevant, and accurate terminology. In general, the reports should be brief. Information that is of little value for the referring physician should be omitted and the use of protective expressions limited to the doubt in interpretation that sometimes must be communicated.

The present joint paper may hopefully lead institutions and teachers of nuclear cardiology to better recognize, underwrite, and instruct the importance of a good report. In addition, this joint expert statement may trigger studies on the effect of different reporting manners and systems on clinical decision-making, thereby generating scientific evidence on this final, important component of nuclear cardiology examinations.

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