Radiation Protection Dosimetry
Vol. 94, Nos 1–2, pp. 167–172 (2001)
Nuclear Technology Publishing

A METHOD BASED ON DIMOND QUALITY CRITERIA TO EVALUATE IMAGING IN DIAGNOSTIC AND INTERVENTIONAL CARDIOLOGY

G. Bernardi[1], R. Padovani[2], G. Morocutti[1], L. Spedicato[1], J. D. Giannuleas[4], E. Neofotistou[5], A. Maginas[6], J. C. Goicolea[7], J. McNeill[8] and E. Vañó[3]
[1]Unità Operativa di Cardiologia and [2]Unità Operativa di Fisica Sanitaria
Az. Osp. S. Maria della Misericordia, Udine, Italy
[3]Catedra de Fisica Medica, Facultad de Mecidina Univ. Complutense, Madrid , Spain
[4]Cardiology Dept. and [5]Physics Dept, Athens General Regional Hospital, Athens, Greece
[6]Cardiology Dept, Onassis Cardiac Surgery Centre, Athens, Greece
[7]Cardiology Dept, Hospital Meixoeiro, Vigo, Spain
[8]Royal Brompton Hospital, London, UK

Abstract — Image quality criteria (IQC) for cine-angiography were recently settled. The aim of this study was to test whether these criteria allow a measurement of the quality of cine-angiograms. A questionnaire was derived from IQC where a binary response was required regarding the degree of visibility of anatomic or pathologic structures. Scores were given on a ranking scale. Two quality scores were defined (total score and minimum score) and standard deviation (SD) was assumed to be an indicator of the method's reproducibility. Data of the total score are presented for the first nine angiograms. Six experts obtained thirty-nine readings. The total scores ranged between 83 and 99% (SD 0.8–18.7%); 89% of the readings were within 4% of SD. This preliminary experience indicates that quality criteria can be translated into a scoring system that yields reproducible data in most instances. The analysis of the remaining angiograms will help in understanding how to improve these results.

INTRODUCTION

Scientific societies have implemented guidelines to guarantee an adequate level of performance in invasive cardiology: these generally refer to the training of operators, to quantitative standards[1–3] and to quality assurance programmes[4–5]. Recently, the Italian Society of Invasive Cardiology (GISE) and the Italian Society of Physics in Medicine have set quality criteria to give some more precise guidelines about how an angiogram should appear, provided that good equipment and a correct angiographic technique are used[6]. These criteria have been reviewed by the European Concerted Action DIMOND Cardiology Group (Digital Imaging: Measures for Optimizing Radiological Information Content and Dose) and translated into a questionnaire to provide cardiologists with a method to assess quality of cine-angiographic examinations. A pilot study was then started to evaluate whether this method, derived from a model conceived for static radiological imaging, could be applied to these more complex procedures, to give a reproducible measurement of image quality and to further progress the optimisation of image quality and patient dose in cardiology. The method and some preliminary data are presented here.

MATERIALS, METHODS AND PRELIMINARY RESULTS

A series of 15 angiograms performed in three centres in Italy, Spain and Greece, containing left ventriculography (LV), left and right coronary angiography (LCA, RCA) were examined by six experienced cardiologists. The five Spanish angiograms were recorded on CD-ROM according to DICOM standards, whereas the Italian and Greek images were on 35 mm film. The CD-ROM images were displayed on a colour PC monitor with a Viper graphic card and the quality of the images was similar to those on the 35 mm film. The matrix size was 512×512 as stated by DICOM standards for cardiac images and the resolution of the monitor was 800×600 pixels. The participating centres perform a minimum of 1200 diagnostic and 500 interventional procedures per year.

The films, together with images recorded on CD-ROM, were circulated among the experts in these three countries. The readings of the angiograms were done according to the method proposed by the DIMOND Group. Based on the quality criteria, a questionnaire was set, where a binary response was required from the observer, regarding the degree of visibility of anatomic or pathologic structures. Scores were given on a ranking scale, depending on the importance of these structures and were based on a consensus reached by the DIMOND experts. If a given situation did not apply (i.e. a vessel or a stenosis were not present), it was cancelled, as was the indicated score. An example of application of the scoring system to a real case is given in Table 1 for a RCA: all the branches which are not present or do not reach the size of 1.5 mm, are cancelled and a score of 0 to 2 is given, based on the fulfilment of the criteria. A similar form is completed for LCA and LV. The

* Contact author E-mail: guglbern@tin.it

questionnaires allow for a subjective difference in evaluating the anatomy without causing a relevant variation in the final score. For example, it will make little difference erasing a single postero-lateral branch regarding it as less than 1.5 mm in size and no difference at all considering a vessel as a posterior descending instead of a postero-lateral branch.

The maximum possible score (MPS) of the single parts and of the whole examination is that obtained if all the quality criteria are met, having cancelled all non-applicable points. The actual score (AS) may equalise the MPS or be lower to a variable degree. Quality scores are expressed as percentages of the AS over MPS. In Table 1 the AS is 19.5 and MPS 21: the mean quality score for that RCA is then 93%.

Two quality scores were defined: the total quality score, derived from the whole examination and the minimum quality score which could be obtained either in LV, LCA or RCA. The scores were computed using an electronic sheet and finally reported as mean and standard deviation of each reading.

The cardiologists were also asked to give a subjective opinion on quality, which was compared to the scores. This was defined as good (minimal or no defects), acceptable (major defects with sufficient clinical information), unacceptable (major defects, insufficient

Table 1. Example of the questionnaire and of the calculation of the quality score for the Right Coronary Artery. PD = Posterior Descending; PL1 = First Postero-Lateral; PL2 = Second Postero-Lateral; PL3 = Third Postero-Lateral; QS = Quality Score.

			score			score
1. arms superimposition	yes	□	0	no	■	0.5
2. apnoea	yes	□	0.5	no	■	0
3. full opacification of the vessel lumen:	yes	■	1	no	□	0
4. Panning	absent or limited	■	1	excessive	□	0

Visually sharp reproduction in two orthogonal views without superimposition of other vessels of: (score: yes = 2, no = 0)

5. origin	yes	■	no	□
6. proximal	yes	■	no	□
7. mid	yes	■	no	□
8. distal (pre-crux)	yes	■	no	□

Visually sharp reproduction of the side branches > 1.5 mm in two orthogonal views (score: yes = 1, no = 0)

9. PD	yes	■	no	□
10. PL1	yes	■	no	□
11. PL2	yes	■	no	□
12. PL3	yes	□	no	□
13. Other	yes	□	no	□

Visually sharp reproduction of origin of side branches > 1.5 mm in one projection. (score: yes = 1, no = 0)

14. PD	yes	■	no	□
15. PL1	yes	■	no	□
16. PL2	yes	□	no	■
17. PL3	yes	□	no	□
18. Other	yes	□	no	□

Visually sharp reproduction of lesions ≥ 50% in vessels > 1.5 mm in at least two orthogonal views (score: yes = 2, no = 0)

Main vessel:

19. origin	yes	□	no	□
20. proximal	yes	□	no	□
21. mid	yes	■	no	□
22. distal (pre-crux)	yes	□	no	□
23. PD	yes	□	no	□
24. PL1	yes	□	no	□
25. PL2	yes	□	no	□
26. PL3	yes	□	no	□
27. Other	yes	□	no	□

Visualization of collateral circulation in two ortogonal views

28. Good	□	2	poor	□ 0

imaging redundance

29.	no or moderate ■	2	excessive	□ 0

Max possible score = 21
Actual Score = 19.5
21/19.5% = 93 QS

clinical information). The subjective opinion was then compared to the scores. The range of standard deviation of the mean was assumed to be an indicator of inter-observer variability for the total and minimum scores.

The preliminary results of the total score are reported in Figures 1 and 2. For the first nine angiograms, a total of 39 readings, minimum four, maximum five were obtained. Figure 1 shows the data expressed as the mean of the four (or five) readings. They ranged between 83% and 99% and standard deviation between 0.8% and 18.7%. Eighty-nine per cent of the readings were found to be within 4% of the standard deviation.

Figure 2 shows the comparison between the scores and the subjective opinion given by the examiners. In two cases the subjective opinion was lacking and they were not considered in this analysis. All angiograms were considered good or acceptable, none was deemed unacceptable, but a great variability was seen; in one case only (GRE 1) the examiners agreed completely, whereas the subjective opinion did not match the high score given in a relevant number of examinations.

DISCUSSION

The goal of radiological techniques is to provide images which help the clinician in decision making. Quality evaluation of these images is of paramount importance and always implies a variable degree of subjectivity depending on the method used[7]. The method used in this study is that of image quality criteria[8] and has already proven to be effective in clinical practice for adult[9,10] and paediatric[11] radiographic images and CT scans[12]. These preliminary data support the hypothesis that this method, initially developed for static radiology, can be applied to cine-angiography with a good level of reproducibility between independent experts. In fact, as much as 89% of the total score readings were within 4% of the standard deviation (Figure 1); this was assumed to represent the inter-observer variability and, as a consequence, the reproducibility of the scores. One of the causes for the observed differences, could have been the absolute binary definitions of the scoring system that did not allow any intermediate evaluation. As the vision threshold, or the decision threshold, can be variable, the inclusion of the possibility to graduate the level of visibility of a stenosis or vessel walls might improve operators agreement. However, a certain degree of subjectivity is inevitable.

The scores applied in the form used in this study were on a ranking scale, presuming that the ultimate information required is the clear visualisation of lesions and of the anatomy of the coronary vessels. It is probably necessary to score coronary anatomy and lesions visibility a little higher and to include both in the same section of the form. This will widen the range of the final scores and will simplify the readings: the time actually necessary to fill a form is, in fact, about 20 min.

Some considerations can be made observing the subjective opinions expressed by the cardiologists before being aware of the scores. There is an evident discrepancy (Figure 2) between the high total scores given in almost all the cases (>90% in 6/7) and the subjective opinion which one would expect to be good to the same extent. It is possible that the scores might have been able to measure only the level of clinical acceptability rather than discriminate the excellence of the images.

One of the limitations of this pilot study is that, even though no pre-selection of the angiograms had been made, none of them had been deemed unacceptable and, as a consequence, no evaluation of the scoring system in clinically unacceptable cases could be made. Nevertheless, it should be noticed that film rejection is a rare event, at least in high volume centres like those involved in this study, and probably in all centres, because repeating a procedure carries adjunctive risk and discomfort to the patient. One angiogram could be deemed unacceptable because a few but important details were lack-

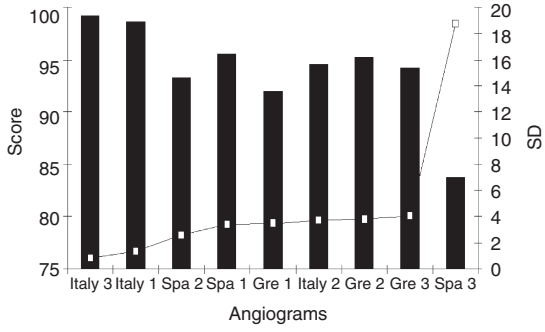

Figure 1. Total score (left axis) and standard deviation (SD, right axis). Each bar represents the mean score of 4 to 5 readings obtained by one single angiogram. The dots and the line represent the standard deviation.

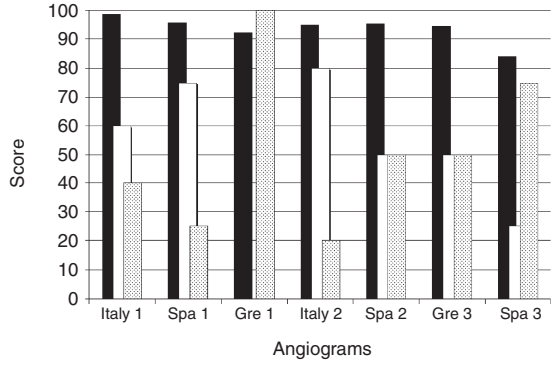

Figure 2. Total score compared to subjective opinion. Black bars represent the mean readings, white bars the subjective opinion = good and grey bars the subjective opinion = acceptable. The cases are 7 instead of 9 because some opinions were lacking.

ing in the evaluation of coronary anatomy. On the other hand, even if LV were suboptimal or not performed, the examination would not be rejected, in the majority of cases, because the same information could be obtained by other means. These drawbacks can be overcome by increasing some of the scores, as already pointed out, and omitting the score obtained in LV.

In conclusion, this very preliminary experience indicates that quality criteria methodology can be applied to cardiac images and they can be translated into a scoring system that yields reproducible data in most instances. The analysis of the remaining angiograms will help to understand how to improve and simplify the forms before undertaking a larger trial.

ACKNOWLEDGEMENTS

The authors are grateful to Mrs Laura Pilotto and Mrs Cristina Bernardi for the valuable help in reviewing this manuscript.

REFERENCES

1. Pepine, C. J., Babb, J. D., Brinker, J. A., Douglas, J. S. Jr, Jacobs, A. K., Johnson, W. L. Jr and Vetrovec, G. W. *Guidelines for Training in Adult Cardiovascular Medicine. Core Cardiology Training Symposium (COCATS). Task Force 3: Training in Cardiac Catheterization and Interventional Cardiology.* J. Am. Coll. Cardiol. **14**, 6 (1995).
2. Miller, R. M., O'Neill, B., Johnstone, D. and Rae, J. R. *Standards for Training in Adult Cardiac Catheterization and Angiography. Canadian Cardiovascular Society Committee*. Can. J. Cardiol. **12**, 470–2 (1996).
3. Cowley, M. J., Faxon, D. P. and Holmes, D. R. Jr *Guidelines for Training, Credentialing, and Maintenance of Competence for the Performance of Coronary Angioplasty: a Report from the Interventional Cardiology Committee and the Training Program Standards Committee of the Society for Cardiac Angiography and Interventions.* Cathet. Cardiovasc. Diagn. **30**, 1–4 (1993).
4. Heupler, F. A. Jr, al-Hani, A. J. and Dear, W. E. *Guidelines for Continuous Quality Improvement in the Cardiac Catheterization Laboratory. Laboratory Performance Standards Committee of the Society for Cardiac Angiography & Interventions.* Cathet. Cardiovasc. Diagn. **30**, 191–200 (1993).
5. Scanlon, P. J. and 19 others *ACC/AHA Guidelines for Coronary Angiography. A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Coronary Angiography). Developed in Collaboration with the Society for Cardiac Angiography and Interventions.* J. Am. Coll. Cardiol. **33**, 1756–1824 (1999).
6. Gruppo di studio: 'Assicurazione della Qualità nelle Procedure Radiologiche Invasive ed Interventistiche di Cardiologia'. *Ottimizzazione delle Immagini e Radioprotezione nel Laboratorio di Emodinamia e Cardiologia Interventistica*. Emodinamica **10**(Suppl.) (1997).
7. Martin, C. J., Sharp, P. F. and Sutton, D. G. *Measurement of Image Quality in Diagnostic Radiology.* Appl. Radiat. Isot. **50**, 21–38 (1999).
8. Commission of the European Communities (CEC). *European Guidelines and Quality Criteria for Diagnostic Radiographic Images.* EUR 16260 EN (Brussels: CEC) (1996).
9. Maccia, C., Ariche-Cohen, M., Nadau, X. and Severo, C. *The 1991 CEC Trial on Quality Criteria for Diagnostic Radiographic Images.* Radiat. Prot. Dosim. **57**, 111–117 (1995).
10. Vañò, E., Guibelalde, E., Morillo, A., Alvarez-Pedrosa, C. S. and Fernandez, J. M. *Evaluation of European Image Quality Criteria for Chest Examination.* Br. J. Radiol. **68**, 1349–1455 (1995).
11. Perlmutter, N., Arthur, R. J., Beluffi, G., Cook, V., Horwitz, E. A., Kramer, P., Montagne, J. P., Thomas P. S. and Schneider, K. *The Quality Criteria for Diagnostic Radiographic Images in Paediatrics.* Radiat. Prot. Dosim. **80**, 45–48 (1998).
12. Calzado, A., Rodríguez, R. and Muñoz, A. *Quality Criteria Implementation for Brain Computed Tomography Examinations.* Radiat. Prot. Dosim. **80**, 65–68 (1998).

APPENDIX

List of quality criteria for diagnostic and interventional cardiology images set by the Italian Society of Invasive Cardiology (GISE) and the Italian Society of Physics in Medicine (AIFM) as reviewed by the European Concerted Action DIMOND Cardiology Group (Digital Imaging: Measures for Optimizing Radiological Information Content and Dose).

DESCRIPTION OF TERMS

Visualization: characteristic features are detectable, but **details are not fully reproduced** (features just visible).
Reproduction: **details of anatomical structures are visible, but not necessarily clearly defined** (details emerging).
Visually sharp reproduction: **anatomical details are clearly defined** (details clear).

LEFT VENTRICULOGRAPHY

RAO 25°-35° Projection

(1) Performed at full inspiration to avoid diaphragm superimposition.
(2) Reproduction of the left ventricle in the longitudinal axis (select the proper angulation to see the typical ovoid shape).
(3) Visually sharp reproduction of ventricular walls in systole and in diastole, without causing extrasystole which interfere with EF evaluation.
(4) Reproduction of mitral and aortic leaflets.
(5) Visualisation of mitral regurgitation when present.
(6) Reproduction of the ascending aorta in the proximal portion.

LAO 40°-60° Projection

(If indicated after performing RAO view and preferably, after coronary angiography.)

(1) Performed at full inspiration to avoid diaphragm superimposition.
(2) Arms should be raised clear of the angiographic field.
(3) Reproduction of the left ventricle in the cross-sectional axis (grossly circular shape), avoiding superimposition of the spine.
(4) Visually sharp reproduction of ventricular walls in systole and in diastole.
(5) Reproduction of mitral and aortic leaflets.
(6) Visualisation of mitral regurgitation when present.
(7) Reproduction of the ascending aorta in the proximal portion.

LEFT CORONARY ANGIOGRAPHY

(Projection based on operator's choice.)

(1) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(2) Arms should be raised clear of the angiographic field.
(3) Visually sharp reproduction of vessel walls.
(4) Simultaneous and full opacification of the vessel lumen at least until the first critical lesion (= 70% by visual estimation).
(5) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(6) Visually sharp reproduction of the origin, proximal, mid and distal portion of the Left Anterior Descending and Circumflex arteries, in at least two orthogonal views.
(7) Visually sharp reproduction of the side branches >1.5 mm of the Left Anterior Descending and Circumflex arteries in at least two orthogonal views; the origin should be seen in at least one projection.
(8) Visually sharp reproduction of the lesions in vessels >1.5 in at least two orthogonal views.
(9) Visualisation of collateral circulation when present.
(10) When criteria 6–9 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

RIGHT CORONARY ANGIOGRAPHY

(Projection based on operator's choice.)

(1) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(2) Arms should be raised clear of the angiographic field and the spine should appear as little as possible.
(3) Visually sharp reproduction of vessel walls.
(4) Simultaneous and full opacification of the vessel lumen at least until the first critical lesion (= 70% by visual estimation).
(5) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(6) Visually sharp reproduction of the origin, proximal, mid (especially the crux region) and distal portion in at least two orthogonal views.

(7) Visually sharp reproduction of the side branches >1.5 mm in at least two orthogonal views; the origin should be seen in at least one projection.
(8) Visually sharp reproduction of the lesions in vessels >1.5 in at least two orthogonal views.
(9) Visualisation of collateral circulation when present.
(10) When criteria 6–9 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

ANGIOGRAPHY OF VENOUS GRAFTS OR ARTERIAL FREE GRAFTS

(Projection based on operator's choice.)

(1) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(2) Arms should be raised clear of the angiographic field and the spine should appear as little as possible.
(3) Visually sharp reproduction of graft walls.
(4) Simultaneous and full opacification of graft lumen at least until the first critical lesion (= 70% by visual estimation).
(5) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(6) Visually sharp reproduction of proximal and distal(s) anastomosis possibly in two orthogonal views.
(7) Visually sharp reproduction of the origin, proximal, mid and distal portion in at least two orthogonal views.
(8) Visually sharp reproduction of the lesions in at least two orthogonal views.
(9) Visualisation of collateral circulation when present.
(10) When criteria 6–9 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

ANGIOGRAPHY OF LEFT MAMMARY ARTERY *IN SITU*

(Projection based on operator's choice.)

(1) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(2) Arms should be raised clear of the angiographic field and the spine should appear as little as possible.
(3) Visually sharp reproduction of graft walls.
(4) Simultaneous and full opacification of graft lumen at least until the first critical lesion (= 70% by visual estimation).
(5) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(6) Visually sharp reproduction of the origin, proximal and mid portion in at least two orthogonal views.
(7) Visually sharp reproduction of the distal portion and distal(s) anastomosis in at least two orthogonal views.
(8) Visually sharp reproduction of the lesions in at least two orthogonal views.
(9) Visualisation of collateral circulation when present.
(10) When criteria 6–9 have been fulfilled, avoid extra projections (mainly LAO semiaxial).