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IMAGE QUALITY CRITERIA IN CARDIOLOGY

G. Bernardi[1,*], R. Padovani[2], L. Spedicato[1], W. Desmet[3], M. R. Malisan[2], J. D. Giannuleas[4], E. Neofotistou[5], A. Manginas[6], Z. Olivari[7], J. Cosgrave[8], F. Alfonso[9], H. Bosmans[10], A. Dowling[11] and E. Vano[12]
[1]Unità Operativa di Cardiologia, Az. Osp. S. Maria della Misericordia, Piazzale della Misericordia, 15, 33100 Udine, Italy
[2]Unità Operativa di Fisica Sanitaria, Az. Osp. S. Maria della Misericordia, Piazzale della Misericordia, 15, 33100 Udine, Italy
[3]Cardiology Department, Gasthuisberg University Hospital, Herestraat 49 B, 3000 Leuven, Belgium
[4]Cardiology Department, Athens General Regional Hospital, 154 Mesogion Avenue, 11527 Athens, Greece
[5]Medical Physics Department, Athens General Regional Hospital, 154 Mesogion Avenue, 11527 Athens, Greece
[6]Cardiology Department, Onassis Cardiac Surgery Center, 356 Sygrou Avenue, 17674 Athens, Greece
[7]Cardiology Department, Az. Osp. Ca Foncello, Piazza Ospedale 1, 31100 Treviso, Italy
[8]Cardiology Department, St James's Hospital, P.O. Box 580 James's Street, Dublin 8, Ireland
[9]Cardiology Department, San Carlos University Hospital, Complutense University, Madrid, 28040, Spain
[10]Medical Physics Department, Gasthuisberg University Hospital, Herestraat 49 B, 3000 Leuven, Belgium
[11]Medical Physics Department, St. James's Hospital, P.O. Box 580 James's Street, Dublin 8, Ireland
[12]Medical Physics Department, San Carlos University Hospital, Complutense University, Madrid, 28040, Spain

Image quality evaluation plays a key role in the process of optimisation in radiological procedures. Image quality criteria for cardiac cine-angiography were recently agreed as part of a European Research Project, and a scoring system based on these criteria has been developed to allow an 'objective' measurement of the quality of cardiac angiograms. Two studies aimed at the evaluation of the methodology have been completed, demonstrating that the method can be applied to cardiac images and translated into a scoring system that yields reproducible data. Based on the results of these studies, quality criteria have been further reviewed by DIMOND III panel and the updated version is presented in this paper.

INTRODUCTION

Quality of cardiac angiographic images is of paramount importance for clinical decision making, but is not always granted. Literature on this topic is scarce, but in a recent study performed in 29 New York State hospitals, major defects have been demonstrated in more than half of angiograms[1]. Even if Scientific Societies have published guidelines aimed to guarantee adequate levels of performance in invasive cardiology[2–6], the problem of achieving and maintaining high-quality standards in angiographic imaging is addressed in a vague manner and precise criteria have never been stated. Moreover, quality evaluation plays a pivotal role in the process of optimisation, as the radiation dose delivered to patients should follow the as low as reasonably achievable (ALARA) principle: nevertheless, a recent European survey[7] has demonstrated a wide variation of exposure parameters in common practice, and data derived from the DICOM header of 30 CD ROMs examined in a DIMOND III trial[8] showed a very different behaviour of interventionalists in terms of fluoroscopy time, number of series and frames, projection distribution, focus–detector mean distance and patient dose.

Several methods are used to evaluate image quality in clinical radiology: the performance of the imaging system is assessed by means of test objects or phantoms and objective parameters can be measured[9]. Nevertheless, the use of a correct methodology and technique of examination can be assessed only by evaluating the final images produced. This can be made by comparison with other images which represent 'gold standards' and these methods are extremely useful in clinical studies, as those performed to assess the acceptability of different levels of digital compression[10,11] or to compare performance of different equipments[12]. However, this requires the 'correct answer' to be known and is not applicable to routine activity. On the contrary, the method of image quality criteria[13] has proven to

*Corresponding author: guglbern@tin.it

be effective and relevant in clinical practice and for training purposes, at least for radiographic[14–17] and CT scan studies[18]. In this approach, quality of images is assessed in comparison to pre-specified criteria to comply with.

Recently, the European Concerted Action DIMOND Cardiology Group (Digital Imaging: Measures for Optimising Radiological Information Content and Dose) have set quality criteria on cardiac images[19]. Starting with these criteria, a method based on a scoring system has been developed to provide a tool to test quality in daily practice. Two studies were then undertaken to evaluate whether this method, derived from a model conceived for static radiological imaging, could be applied to the more complex cine-angiographic examinations[20–22]. In these studies, a total of 45 cardiac angiograms containing left ventriculography and left and right coronary angiography were examined by experienced cardiologists and 172 scores were obtained. The results indicate that the method of quality criteria can be applied to cardiac images and translated into a scoring system that yields reproducible data in most instances. After reviewing the data, DIMOND III panel agreed to incorporate some improvements to the quality criteria. Moreover, they have been separated in two sets (clinical criteria and technical criteria) and some 'Aspects of an optimised angiographic technique' have been added. These improvements have been extended to angiography of venous graft, of arterial free graft and mammary arteries *in situ*, even if they had not specifically tested in the studies.

The updated version of the quality criteria is presented in this paper. As previously stated[19], quality criteria are intended to give some guidelines regarding how an angiogram should appear provided that good equipment and correct angiographic techniques are used. They cannot be applied in all cases, and in some situations a lower level of image quality may be acceptable so that under no circumstances an image which fulfils all clinical requirements but does not meet all image criteria should be rejected. However, reasons for a 'suboptimal' procedure (such as renal failure or haemodynamic instability) should be recorded.

QUALITY CRITERIA FOR CARDIAC IMAGES

Description of terms

Clinical criteria are defined as the levels of visualisation of important anatomical features; the levels of visualisations are expressed using the following terms:

- *Visualisation*: 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).

Technical criteria are defined in terms of technical aspects and technical parameters of the procedure. Technical parameters taken into account are as follows: the frequency of image acquisition, the number of sequences per procedure, the number of images per sequence and the use of wedge filters. Other aspects of the procedure are as follows: acquisition in apnoea condition, use of panning and arm position.

Aspects of an optimised angiographic technique: these refer to the use of the wedge filter on bright peripheral areas, the number of sequences, the frame rate to be used and the average number of images per sequence (except for difficult cases or special settings).

LEFT CORONARY ANGIOGRAPHY (PROJECTION BASED ON OPERATOR'S CHOICE)

Clinical criteria

(1) Visually sharp reproduction of the origin, proximal, mid and distal portions of the left anterior descending and circumflex arteries, in at least two orthogonal views, with minimal foreshortening and overlap.
(2) Visually sharp reproduction of side branches $\geq$1.5 mm of the left anterior descending and circumflex arteries in at least two orthogonal views, with minimal foreshortening and overlap. The origin should be seen in at least one projection.
(3) Visually sharp reproduction of lesions in vessels $\geq$1.5 mm in at least two orthogonal views, with minimal foreshortening and overlap.
(4) Visualisation of collateral circulation when present.

Technical criteria

(1) Simultaneous and full opacification of the vessel lumen at least until the first flow-limiting lesion (in general ~90–95% by visual estimation).
(2) Performed at full inspiration, if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(3) Arms should be raised clear of the angiographic field.

(4) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(5) When clinical criteria 1–4 are fulfilled, avoid extra projections (mainly LAO semi-axial).

Aspects of an optimised angiographic technique

(1) Use of the wedge filter on bright peripheral areas.
(2) Three to five sequences (except for difficult anatomic details).
(3) 12.5–15 frames per second (25–30 only if heart rate exceeds 90–100 beats per minute or in paediatric patients).
(4) Sixty images per sequence at an average (12.5–15 frames per second) except if collaterals have to be imaged or in case of slow flow.

RIGHT CORONARY ANGIOGRAPHY (PROJECTION BASED ON OPERATOR'S CHOICE)

Clinical criteria

(1) Visually sharp reproduction of the origin, proximal, mid (especially the crux region) and distal portion in at least two orthogonal views, with minimal foreshortening and overlap.
(2) Visually sharp reproduction of side branches $\geq$1.5 mm in at least two orthogonal views, with minimal foreshortening and overlap. The origin should be seen in at least one projection.
(3) Visually sharp reproduction of lesions in vessels $\geq$1.5 mm in at least two orthogonal views, with minimal foreshortening and overlap.
(4) Visualisation of collateral circulation when present.

Technical criteria

(1) Simultaneous and full opacification of the vessel lumen at least until the first flow-limiting lesion (in general $\sim$90–95% by visual estimation).
(2) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(3) Arms should be raised clear of the angiographic field.
(4) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(5) When clinical criteria 1–4 have been fulfilled, avoid extra projections (mainly LAO semi-axial).

Aspects of an optimised angiographic technique

(1) Use of the wedge filter on bright peripheral areas.
(2) Two to three sequences (except for difficult anatomic details).
(3) 12.5–15 frames per second (25–30 only if heart rate exceeds 90–100 beats per minute or in paediatric patients).
(4) Sixty images per sequence at average (12.5–15 frames per second) except if collaterals have to be imaged or in case of slow flow.

LEFT VENTRICULOGRAPHY (RIGHT ANTERIOR OBLIQUE)

Clinical criteria

(1) Reproduction of the left ventricle in the longitudinal axis, selecting the proper angulation (25–35°) to see the typical ovoid shape.
(2) Visually sharp reproduction of ventricular walls in systole and diastole, without causing extra systole, which interferes with ejection fraction evaluation.
(3) Reproduction of mitral leaflets and visualisation of aortic leaflets.
(4) Visualisation of mitral regurgitation when present (left atrium framed).
(5) Reproduction of the ascending aorta in the proximal portion.

Technical criteria

(1) Performed at full inspiration apnoea, to avoid diaphragm superimposition.
(2) Arms should be raised clear of the angiographic field.
(3) No panning allowed.

Aspects of an optimised angiographic technique

(1) Use of the wedge filter on bright peripheral areas.
(2) Perform one sequence (except for congenital diseases).
(3) 12.5–15 frames per second (25–30 only if heart rate exceeds 90–100 beats per minute or in paediatric patients).
(4) Sixty images per sequence at average (12.5–15 frames per second).

ANGIOGRAPHY OF VENOUS GRAFT OR ARTERIAL FREE GRAFT (PROJECTION BASED ON OPERATOR'S CHOICE)

Clinical criteria

(1) Visually sharp reproduction of proximal and distal anastomoses, possibly in two

orthogonal views, with minimal foreshortening and overlap.
(2) Visually sharp reproduction of the origin, proximal, mid and distal portion in at least two orthogonal views, with minimal foreshortening and overlap.
(3) Visually sharp reproduction of the lesions in at least two orthogonal views, with minimal foreshortening and overlap.
(4) Visualisation of collateral circulation when present.

Technical criteria

(1) Simultaneous and full opacification of graft lumen at least until the first flow-limiting lesion (in general ~90–95% by visual estimation).
(2) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomic relationship (in apnoea in any case).
(3) Arms should be raised clear of the angiographic field and the spine should appear as little as possible.
(4) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(5) When clinical criteria 1–4 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

Aspects of an optimised angiographic technique

(1) Use of the wedge filter on bright peripheral areas.
(2) Three sequences (except for difficult anatomical details).
(3) 12.5–15 frames per second (25–30 only if heart rate exceeds 90–100 beats per minute or in paediatric patients).
(4) Eighty images per sequence at average (12.5–15 frames per second) except if collaterals have to be imaged or in case of slow flow.

ANGIOGRAPHY OF LEFT MAMMARY ARTERY *IN SITU* (PROJECTION BASED ON OPERATOR'S CHOICE)

Clinical criteria

(1) Visually sharp reproduction of the origin, proximal and mid portion in at least two orthogonal views, with minimal foreshortening and overlap.
(2) Visually sharp reproduction of the distal portion and distal anastomoses in at least two orthogonal views, with minimal foreshortening and overlap.
(3) Visually sharp reproduction of the lesions in at least two orthogonal views, with minimal foreshortening and overlap.
(4) Visualisation of collateral circulation when present.

Technical criteria

(1) Simultaneous and full opacification of graft lumen at least until the first flow-limiting lesion (in general ~90–95% by visual estimation).
(2) Performed at full inspiration if necessary to avoid diaphragm superimposition or to change anatomical relationship (in apnoea in any case).
(3) Arms should be raised clear of the angiographic field and the spine should appear as little as possible.
(4) Panning should be limited. If necessary, pan in steps rather than continuously, or make subsequent cine runs to record remote structures.
(5) When clinical criteria 1–4 have been fulfilled, avoid extra projections (mainly LAO semiaxial).

Aspects of an optimised angiographic technique

(1) Use of the wedge filter on bright peripheral areas.
(2) Three sequences (except for difficult anatomical details).
(3) 12.5–15 frames per second (25–30 only if heart rate exceeds 90–100 beats per minute or in paediatric patients).
(4) Eighty images per sequence at average (12.5–15 frames per second) except if collaterals have to be imaged or in case of slow flow.

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