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A STUDY TO VALIDATE THE METHOD BASED ON DIMOND QUALITY CRITERIA FOR CARDIAC ANGIOGRAPHIC IMAGES

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A method based on image quality criteria (QC) for cine-angiography was developed to measure the quality of cine-angiograms (CA). A series of 30 CA for left ventriculography (LV) and left and right coronary angiography (LCA, RCA) have been scored and 172 readings were obtained. Standard deviation of quality scores indicated the reproducibility of the method. Each part of CA was examined separately, giving scores for LV, LCA and RCA and a total score (TS), with clinical (C) and technical (T) criteria defined and examined separately. In 83% of the studies TS was >0.8 and with standard deviation from 0.02 to 0.21. In general, LV had a lower score and greater disagreement compared with RCA and LCA. Disagreement was greater in T, compared with C. In conclusion, these results indicate that QC, translated into a scoring system, yields reproducible data on the quality of cardiac images.

INTRODUCTION

Acceptable quality cardiac cine-angiographic images are a prerequisite to good clinical decision-making, but guidelines of scientific societies[1–5] address the problem in a vague manner and established methods are lacking.

Recently, the cardiology study group within the European Research Project DIMOND (Digital Imaging: Measures for Optimising Radiological Information Content and Dose) has developed a method based on image quality criteria (QC)[6,7] to provide a tool to test the quality of routine cardiac cine-angiographic images. In this method, quality criteria had been translated into a questionnaire, where a graded response was required from the observer regarding the degree of visibility of anatomic or pathologic structures of left ventriculography (LV) and of left and right coronary angiography (LCA, RCA). A pilot study was undertaken[7,8] to evaluate whether this method, derived from a model conceived for static radiological imaging, could be applied to the more complex cine-angiographic examinations. As a result of this study, some improvements have been made to the methods. The forms have been simplified by eliminating redundant questions, decreasing them from 51 to 27 for LCA, from 29 to 16 for RCA and from 19 to 8 for LV. An example is given in Figure 1 (the complete questionnaire can be found at the web site www.dimond3.org/workpackage5R.htm, European Trial of Image Quality Criteria). Criteria were then separated in two groups, clinical (C) and technical

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RIGHT CORONARY ANGIOGRAPHY

Technical criteria

1.	arms outside the x-ray beam	yes	☐ 2	no	☐ 0		
2.	apnoea[4]	yes	☐ 5	no	☐ 0		
3.	full opacification of the vessel lumen[5] :	yes	☐ 10	no	☐ 0		
4.	Panning	present	☐ 0	absent	☐ 5		

Final evaluation: cine runs have been performed in a way which is:

5.	insufficient	☐ 0	sufficient	☐ 10	redundant[6]	☐ 0	

Clinical criteria

Grade of visualization of vessels walls and/or stenosis with minimal foreshortening and overlap (consider two projections):

		visualization	reproduction	visually sharp reproduction	not applicable
6.	origin	☐ 1	☐ 5	☐ 10	☐
7.	proximal	☐ 1	☐ 5	☐ 10	☐
8.	mid	☐ 1	☐ 5	☐ 10	☐
9.	distal (pre-crux)	☐ 1	☐ 5	☐ 10	☐

Grade of visualization of vessels walls and/or stenosis with minimal foreshortening and overlap of the side branches ≥ 1.5 mm and/or stenosis (without superimposition of others) including the origin:

		visualization	reproduction	visually sharp reproduction	not applicable
10.	PD	☐ 1	☐ 4	☐ 8	☐
11.	PL1	☐ 1	☐ 4	☐ 8	☐
12.	PL2	☐ 1	☐ 4	☐ 8	☐
13.	PL3	☐ 1	☐ 4	☐ 8	☐
14.	AM	☐ 1	☐ 4	☐ 8	☐
15.	Others	☐ 1	☐ 4	☐ 8	☐

Visualization of collateral circulation in two orthogonal views[5]

5.	good	☐ 10	poor	☐ 0	not applicable	☐	

Figure 1. Form used to score right coronary angiography.

(T): the C group includes the important anatomical information that should be available in an angiogram of good quality, the T group helps to assess the technical quality of the procedure with features that do not necessarily impair the clinical information content. Grading the level of visibility of a stenosis or vessel wall has been included in order to widen the range of the scores and to simplify the readings. Finally, the definition of terms has been reassessed in order to further improve agreement.

In the present study the revised DIMOND criteria have been tested on a larger basis and results are presented.

MATERIALS AND METHODS

A series of 30 angiograms performed in 2001 in six centres in Italy, Spain, Belgium, Ireland and Greece, for LV and LCA and RCA were examined by seven experienced cardiologists. These centres were performing a minimum of 1400 diagnostic and 600 interventional procedures per year. Selection criteria for the angiograms were left to local cardiologists, who were asked to provide examples of their standard practice. The X-ray systems used were as follows: Hintegris HM 3000 and 5000, Hintegris+ DCI and Polydiagnost C (Philips, Eindhoven, The Netherlands) and Polydoros Bicor and Coroskop (Siemens AG, Erlangen, Germany).

All angiograms were recorded on a CD-ROM according to DICOM standards (matrix size 512 × 512). The framing rate was 12.5 or 25 frames s^{-1}. The images recorded on CD-ROM were registered with software from different manufacturers: Vepro, Philips and Siemens. All CDs could be visualised with work stations adapted for cardiology and also with freely available software. The CD-ROMs were circulated among the experts in these five countries. Images were viewed on PC monitors at a resolution of 800 × 600 pixels or higher. The software used was

either that provided by the various manufacturers or OSIRIS (version 3.1, Hopitaux Universitaries de Geneve, Geneve 1996). Viewing conditions (lighting, film examination order and controls of the display monitor to optimise the imaging) were left to the examiners' choice.

The readings of the angiograms were done according to the method proposed by the DIMOND Group[7] with the aforementioned improvements. Briefly, quality criteria were translated into a threefold questionnaire, where a graded response was required from the observer regarding the degree of visibility of anatomic or pathologic structures of LV, LCA and RCA. The examiners were unaware of the weighting factors of the scores of each proposed question, as these were given *a posteriori* during a consensus meeting of the DIMOND Group in September 2002. Higher scores were given to the visualisation of vessel walls of main coronary branches. For most of the items, it was possible to graduate the fulfilment of the criteria assigning only part of the score (for example 1, 5 and 10 or 1, 4 and 8). Scores were summed for each part of the examination (LV, LCA and RCA) and quality scores were expressed as a fraction of the maximum score which could be obtained if all the criteria were met. They were computed for each reading and finally reported as mean and standard deviation for each angiogram. Total score (TS) was defined as the weighted mean score of the whole examination. Moreover, C and T scores of LCA and RCA were considered separately, to investigate if there were any differences on the level of agreement between different examiners.

No specific training on this method was planned for the examiners and non-compliance tests were not performed, but it must be recognised that the majority had been participating in the previous trial[7,8].

The range of standard deviation of the mean was assumed as an indicator of inter-observer variability for the scores.

RESULTS

A total of 172 readings of the 30 angiograms were obtained. The time needed to score a study ranged from 5 to 15 min. Figure 2 reports the mean TS (including all three parts of the questionnaire: LCA, RCA, LV). In most of the studies, scores were >0.8 and standard deviation ranged from 0.1 to 0.2, indicating that in some studies the disagreement in the evaluation of the quality was relevant. In Figures 3, 4 and 5, the mean scores for LCA, RCA and LV are reported together with the standard deviation of the scores. In general, LV had a lower score and higher disagreement compared with RCA and LCA. But the high maximum TS assigned to LCA, as compared with RCA and LV, is driving the final TS and relative standard deviation.

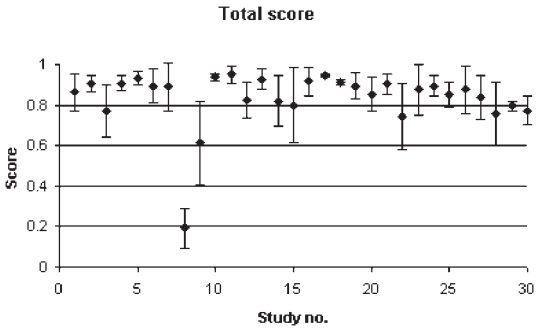

Figure 2. Total score evaluated for the coronary angiography procedures in the trial averaged on the total scores derived from all readers. Standard deviation of scores for each study is reported as an indication of the inter-observer agreement of the quality of each study.

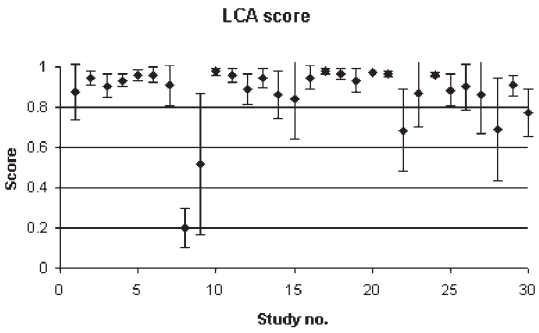

Figure 3. Score evaluated for the LCA part of a study averaged on the scores derived from all readers. Standard deviation of scores for each study is reported as an indication of the inter-observer agreement of the quality of the different studies.

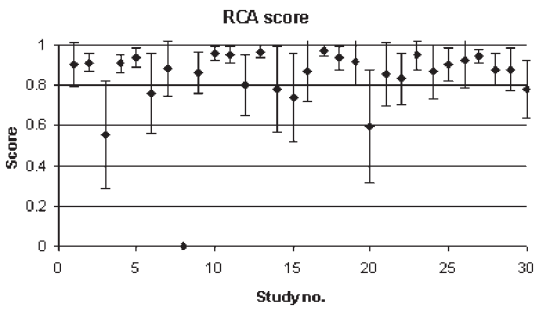

Figure 4. Score evaluated for the RCA part of a study averaged on the scores derived from all readers. Standard deviation of scores for each study is reported as an indication of the inter-observer agreement of the quality of the different studies.

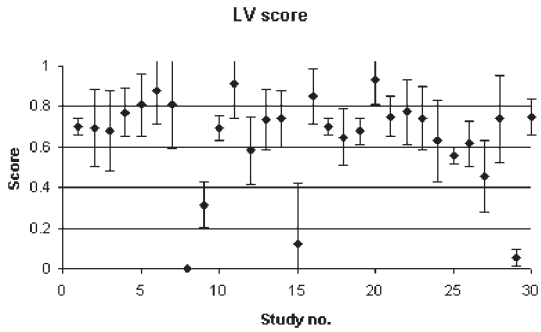

Figure 5. Score evaluated for the LV part of a study averaged on the scores derived from all readers. Standard deviation of scores for each study is reported as an indication of the inter-observer agreement of the quality of the different studies.

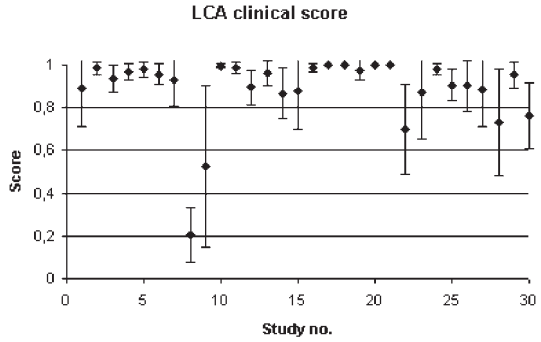

Figure 6. Mean partial score evaluated for the clinical quality aspects of LCA.

A more detailed analysis on LCA and RCA includes the mean partial scores for the clinical and technical parts of the criteria (Figures 6–9). Mean score for clinical criteria for LCA and RCA were 0.89 and 0.89, with a mean standard deviation of 0.09 and 0.14, respectively. For T factors, the mean scores for LCA and RCA were 0.77 and 0.78 with SD 0.15 and 0.14, respectively. In general, the disagreement between readers on technical criteria was higher as compared with evaluation of clinical information of images as estimated by clinical criteria.

For LV the mean score of all studies was 0.64 with a mean standard deviation of 0.13. LV showed the lowest score and the highest mean standard deviation.

In four studies, disagreement was particularly high regarding evaluation of apnoea, full opacification of vessel lumen, diaphragm superimposition, ascending aorta reproduction, the concepts of redundance, panning and the evaluation of the three grades of visualisation of vessels and stenosis.

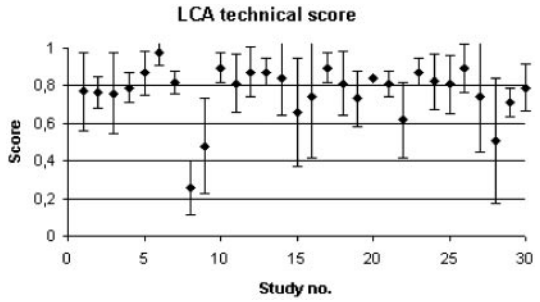

Figure 7. Mean partial score evaluated for the technical quality aspects of LCA.

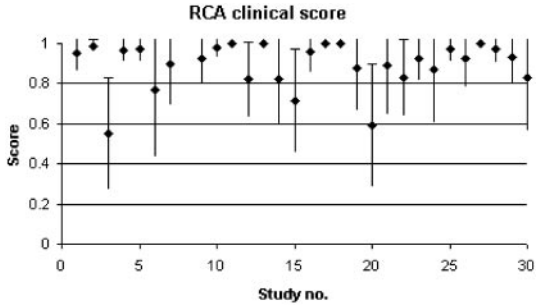

Figure 8. Mean partial score evaluated for the clinical quality aspects of RCA.

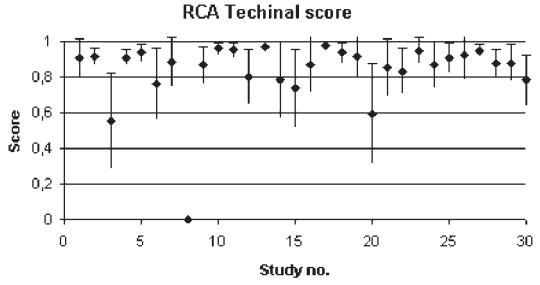

Figure 9. Mean partial score evaluated for the technical quality aspects of RCA.

DISCUSSION

The major problem in subjective analysis of clinical radiological images appears to be the lack of reproducibility or, in other words, the wide range of inter-observer variability[9]. Few studies in cardiology literature have dealt with the issue of image quality and established methods are lacking. Khoukaz *et al.*[10] used a scoring system to assess quality of angiograms performed either by an automatic pump or manual injection. They graded angiograms on a scale from 1 to 5 based on completely subjective judgement (1 = poor, 3 = marginally diagnostic

and 5 = optimal). Intra-observer ($10 \pm 3\%$) and inter-observer variabilities ($18 \pm 25\%$) were determined on 10 angiograms only and no statistical analysis was reported. Leape *et al.*[11] used six quality criteria, which was agreed in the Core Laboratory of Duke's University, and the angiograms were examined by a panel of three experts. Nevertheless they did not perform a study on the reproducibility of their method and its applicability to other settings by single or less-experienced readers may be questionable.

Some key issues for image criteria had been outlined: they should be unambiguous, mutually exclusive and as objective as possible, in order to warrant maximal agreement and reproducibility among experts[12]. The method used in this study is based on criteria obtained by consensus of a wide panel of experts of different institutions[6]. The within-patient variability observed in the scores was low, indicating a homogeneous rating behaviour of examiners. These figures compare favourably with those of static radiology[12–14] and support the hypothesis that the method can be applied to cine-angiography with a good level of inter-observer reproducibility.

The level of agreement obtained is even more remarkable if one considers that no run-in test was made for the examiners and single rather than panel readings were performed at different hospitals. It is well known that a certain amount of training may improve performance among both less-experienced and well-experienced operators[15] and that panel readings improve agreement[16,17]. This means that the method is quite simple to assimilate and the questionnaire, presented as a checklist, is easy to fill up.

The analysis of the four studies with the highest disagreement between readers allowed to identify criteria that were not well expressed or were difficult to apply in a homogeneous manner. They were mainly T criteria: apnoea, full opacification of vessel lumen and diaphragm superimposition. A better definition of terms is warranted, because they were probably too generic. The concept of 'redundancy' and evaluation of 'panning' may have been influenced by the individual behaviour of the cardiologist in performing angiography, as the different centres operate in different ways, using larger or smaller fields of view. In the latter case, panning may be necessary to record the entire coronary tree and may be perceived as a necessity, instead of a defect. Individual habits may also have influenced evaluation of the three grades of visualisation of vessels: visualisation, reproduction and visually sharp reproduction may have been estimated in a different way due to the typical image quality the reader is costumed. The one used to evaluate noisy images will give higher scores even to poor quality or noisy images.

In conclusion, this experience indicates 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. The set of criteria allows the detection of the quality of the studies and the disagreement observed in some is not to be considered a limiting factor to the use of this tool in clinical practice. In fact this was noted mainly on criteria regarding technical aspects of procedure and not on that describing important clinical information. Disagreements in general could be explained by the different image quality given by the angiographic systems used in the study and from the differences in the technical protocols used in the various centres. In order to harmonise technical protocols used in European centres, a set of technical recommendations should be added to the method of quality criteria.

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