THE QUALITY OF THE IMAGE IN TELE-ECHOCARDIOGRAPHY: THE ROLE OF THE ISS IN AN ITALIAN PROJECT

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Abstract: In order to investigate the image quality in tele-ecocardiography the ISS (Italian National Health Institute) defined a novel methodology based on objective, subjective and partially objective /subjective measurements. In particular the methodology based also on the recovery of the experience in X-Ray imaging was based on :
1 simulations performed by means of Matlab R12 (The Mathworks,USA)
2. Critical cases selection
3. Optimal indexes for images choosing
4. ROC analysis
5. Phantoms adoption
6. Detail-contrast curves building
At the moment the preclinical stage has been terminated and the procedures are ready for exploiting the clinical images

Introduction

The imaging diagnostics, whatever the acquisition technique may be [1, 2], must be always supported by the evaluation of the medical images quality [3], in order to assure a reliable diagnostic accuracy. The image processing techniques adopted for this aim, often exploit determined transformations to produce variously balanced edges and contrast detail [4, 5]. Furthermore, both the benefits of edge and contrast emphasis are required simultaneously to avoid recognition missing of morphological and/or functional details and thus misdiagnosis. Unfortunately, the anatomic features, highlighted by edges and contrast, are corrupted by many compression algorithms, commonly used in digital registration of the medical images and in telemedicine. In echocardiography also studies on the evaluation of the visualization and diagnostic content of the images were performed [6-8].

In addition, studies on the reliability and the goodness of the diagnosis in the using digital echocardiography versus traditional videotape showed a good reliability of the digital echocardiography [9-14] and the possibility thus of using it in telemedicine [15-24]. Some studies however reported a little discrepancies occurred in the diagnosis of particular diseases and/or in the assessment of certain morpho-functional parameters. For instance, cases of some uncertain or incorrect diagnosis regarded valvular heart disease [21] and the identification of mild ventricular dysfunctions [24].

The images quality evaluation reported in the abovementioned studies were accomplished by both human assessment (subjective evaluation) and quantitative assessment (objective evaluation). Although the human assessment remains the gold standard method to assess image quality, the objective assessment is however useful, especially in order to validate any automatic and/or semi-automatic estimation of morpho-functional parameters [14].

Actions of standardization in image quality were accomplished in order to define what constitutes image quality from a diagnostic perspective [25]. In addition, objective measurements, using statistic parameters of the images, were performed on different types of medical images to compute the image degradation and the features preservation [26-28]. Also the human visual task efficacy was examined and the comparison with the model observer, using the ensemble statistics of the images, was inspected in order to investigate on the anatomical variability deriving by the degraded images [29, 30]. The most commonly used quantitative parameters are the Peak Signal to Noise Ratio (PSNR) and/or the Mean Squared Error (MSE) and the measurements were carried out for many image patterns and for different methods of compression and whatever may be the cause of degradation.

To carry out a deeper investigation on the degrade in the using digital echocardiography for telemedicine, the authors' paper started a feasibility study on the diagnostic accuracy of the tele-echocardiography, that involves the evaluation of objective and subjective parameters of image quality. In this manner all aspects affecting the diagnosis could be taken into account.

To define what is the best criteria for assessing the image quality, with especial regard to the diagnosis and in particular to the tele-echocardiography, we studied and compared the existing techniques of both objective measures and subjective measures, such as visual observation and visual computations on the images.

Similar experiences in the evaluation of the tele-echocardiography were performed [31, 35]. The studies

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assessed the feasibility and the goodness of the medical images on the basis both of objective and subjective measures. No exhaustive study was presented, that investigated on all aspects of the image quality, either human assessment or quantitative assessment. This shows the complexity of the problem in defining standard criteria for the image quality especially in terms of diagnosis accuracy. Beside the quantitative metrics for the image quality assessment, we retain thus that, also and always, the visual inspections by experts should be applied to validate the diagnosis accuracy.

Unfortunately, today there are more some factors that limit the applications of tele-echocardiography, such as costs, time-consuming (especially for routine clinical studies), high bandwidth. However the obvious advantages deriving by tele-echocardiography are evident especially in the areas lacking of specialized centers. In these cases the visual inspection by experts is the immediate clinical evaluation for deciding a potential transport of the patient to the specialized center.

In order to take account all aspects of these practical needs, a feasibility study on the tele-echocardiography on field engaged the authors' paper.

In this paper we described the first stages of the project in which the authors' paper were involved, the project "Tele-Ecocardiografia sul territorio:studio di fattibilità, accuratezza diagnostica e analisi del rapporto costo/efficacia" funded by the Ministry of the Health. The role of the Istituto Superiore di Sanità (National Institute of the Health) in the project was to build and set up a quality control system for the imaging diagnostics in tele-echocardiography.

Materials and Methods

The beginning stage of the project was dedicated to the set-up and the validation of the feasibility study on the quality assessment of the images in tele-echocardiography.

Figure 1 shows the ensemble of the activities involved in this first stage.

Simulations

The first action was the interaction with the clinicians and technicians partners for defining the "simulation of the scenario of the expected quality".

We examined thus different software development tools in order to individuate the more appropriate functions and algorithms to be applied to the echocardiographic images. The Image Processing and the Signal Processing tools of the Matlab (The MathWorks) scientific language offered many tools for computing statistics measurements and then we adopted this language to accomplish quantitative measurements in our data.

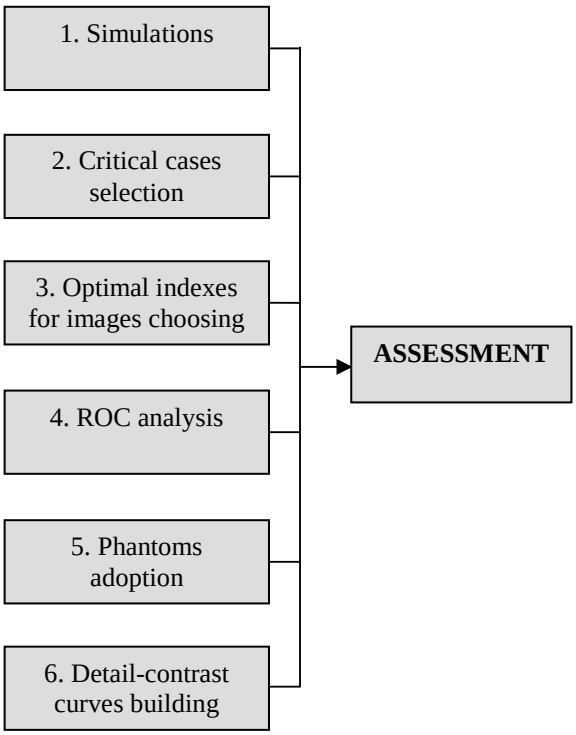

Figure 1: The set-up of the quality control of the image in tele-ecocardiography

Critical case selection

We carried out an interaction with the clinicians partners for individuating a set of "clinical-critical-cases" in order to obtain a set of reference images. The case were selected on the basis of the diagnosis difficulty and/or significant for the incidence of the pathology.

Optimal indexes for images choosing

In the choosing the optimal indexes, we took into account either objective evaluations or subjective evaluations and considered also and applied a preliminary mixed evaluation for the video quality assessment [36], using simulated subjective estimations [37, 38].

The individuation of "optimal indexes for the objective quality of images" comprehended the following activities:

a) evaluation of quality indexes of the received images by the echocardiograph. For example, the accuracy and the spatial linear resolution assessment, the spatial resolution, the contrast resolution, the focalization, the sensibility, uniformity, the dynamic range and so on
b) evaluation of different methodologies. For example the optical transfer function, the Wiener method, the methods used to obtain the contrast-detail curves based on the Rose-model.

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Quantitative measurements

Among objective measures of image quality, two commonly used measures are Mean-Squared Error and Peak Signal-to-Noise Ratio. The mean-squared error (MSE) between two images g(x,y) and g'(x,y) is:

$$e_{MSE} = \frac{1}{M \cdot N} \sum_{n=1}^{M} \sum_{m=1}^{N} [g'(n,m) - g(n,m)]^2 \quad (1)$$

But the mean-squared error depends strongly on the image intensity scaling. To avoid this, the most used parameter of quality is the Peak Signal-to-Noise Ratio (PSNR), that avoids this problem by scaling the MSE according to the image range:

$$PSNR = 10 \log_{10} \frac{S^2}{MSE} \quad (2)$$

where S is the maximum pixel value. PSNR is measured in decibels (dB). The PSNR measure is also not ideal, but it is in common use. Its main failing is that the signal strength is estimated as S^2, rather than the actual signal strength for the image. PSNR is commonly used as a good measure for comparing restoration results for the same image and we retain thus that it is also a good measure to investigate on the information loss in the medical images.

Subjective measurements

Subjective measurements were employed and were based on the visual inspection of the clinical operators. We adopted a qualitative scoring on the goodness of the image quality, assigned by expert clinicians with the diagnostic accuracy perspective. The selected indexes, assigned to the received video and/or images, should be dichotomic or not, such as a "YES/NO" judgment on the capacity of making reliable diagnosis or a different degree of goodness assignment.

ROC analysis

We individuated some quality indexes focused on the clinical operator: the Receiver Operating Characteristics (ROC) for the determination of the so called TFP and FPF-ROC curves concerning the medical decisions.

Phantoms adoption

Other quality indexes were based on "tissue-equivalent-ecocardiographical-fantoms", commonly used in the echocardiography.

Detail-contrast curves building

In addition, using similar approaches commonly followed in the quality control in the X-rays field, we used phantoms in order to build the detail-contrast curves.

Results

At moment we accomplished the set up of the feasibility study and individuated and defined the operative procedures to build a quality control for the tele-echocardiography images in terms of diagnostic accuracy.

Preliminary studies were carried out in the evaluating some video clip assessed by expert echocardiographysts by visual inspection, in order to test the feasibility of the tele-echocardiography on the areas involved in the project, especially in terms of transmission times and required bandwidth. In addition a preliminary study on the video clip quality assessment was accomplished: we applied an algorithm adopted in television quality, that uses both objective and subjective measurements.

In order to test the images quality by means of the detail-contrast curves method, a software simulated phantom was developed. This phantom was constitute of some filled elements different in shape and gray scale, with the smallest element corresponding to the resolution of the system. The original phantom image will be used to generate different MPEG compressed images, that is with different compression levels. At moment a dedicated group of observers is analyzing these images to obtain the abovementioned curves.

Discussion and Conclusion

The final goal of the ISS role in the project was to compare results from different methodologies adopted for assessing the images quality, with both objective and subjective measurements. At the moment, the preclinical stage with the complete definition of the methodologies and procedures has terminated.

The next stages thus will be focused on the mixed objective and subjective analysis performed on a statistical suitable samples of images and observed by a set statistically significant of expert clinicians in echocardiography.

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