Advances in image reconstruction software in nuclear cardiology: Is all that glitters gold?

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The cornerstone results of nuclear cardiology in the last 25 years were obtained with the Filtered Back Projection as the preferred reconstruction method for tomographic studies. Recently, evolution of the OSEM iterative reconstruction algorithms was implemented by different vendors. The value and limitations of the new methods are briefly addressed.

Key Words: Gated-SPECT • iterative algorithms • image reconstruction

Myocardial perfusion imaging with radionuclide tracers is the most worldwide used non-invasive imaging technique for the diagnostic evaluation and risk stratification of patients with known or suspected coronary heart disease.[1–4] It accurately stratifies the risk in a variety of sub-populations including women, patients with diabetes, previous myocardial infarction, or coronary revascularization procedures.

The major, well consolidated, strengths of nuclear cardiology are the unique capability of assessing perfusion and function in the same session, the very low event rate in subjects with a normal MPI (<1%/year, comparable to that observed in the general population), and a close correlation between the amount of extent and severity of perfusion defects or the amount of left ventricular dysfunction with the adverse events rate.

All these pivotal results were obtained with the instrumentation invented by Hal Anger back in the ‘50 and the Filtered Back Projection (FBP) as the preferred reconstruction method for tomographic studies. This methodology was the basis of nuclear cardiology up to the ‘90, when iterative methods entered the nuclear medicine field.

Unlike analytical methods (e.g., FBP), the iterative reconstruction methods, besides taking into account the probabilistic nature of the radiation detection phenomenon, allow the definition of a more realistic model of the whole tomographic system. The Maximum Likelihood Expectation Maximization algorithm (MLEM) is the most popular statistical reconstruction method; rigorous mathematical demonstrations indicate that MLEM convergences to the real image but, at the same time, is greatly limited by its slowness of convergence and by the computational resources request.[5] The Ordered Subsets Expectation Maximization (OSEM) iterative algorithm was introduced in 1994 by Hudson and Larkin with the aim of reduce the reconstruction time typical of the conventional MLEM.[6] OSEM algorithm divides the acquired projections in N subsets and, starting from the first subset, applies the MLEM algorithm to each subgroup of projection using the result of the previous subset as input for the next subset. In this way, it is possible to obtain an acceleration proportional to N. However, it must be considered that, despite being based on the MLEM, it is not guaranteed that OSEM converges to the same ML solution; moreover, at the increase in the number of subsets, there is an increment in the image noise suggesting that this parameter represents a critical point of the algorithm that has to be modified carefully. Despite these limitations,

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due to its speed, the OSEM algorithm quickly became the reconstruction method of choice in nuclear medicine.

More recently, some advanced iterative reconstruction algorithms based on OSEM method were implemented with resolution recovery and noise suppression techniques (IRR). The major differences between IRR and FBP are clearly summarized in this issue by Olga et al[7]; in summary, IRR algorithms employ an iterative reconstruction process that compensates for the non-stationarity of the collimator's response (''beam spread function'' effect), take into consideration the statistical behavior of the emission and noise, which may vary from one application to the other, and correct for the variation in the detector-to-patient distance according to a fixed or variable type of orbit. All these points play a role in the better resolution of IRR over conventional FBP reconstruction, and in the superior image contrast, and allow reconstruction of images with low counts statistics, obtained either with shorter acquisition time or lower radionuclide activity.

The pathway of implementation of the IRR in the clinical practice includes the following:

(1) *Experimental phantom studies*: they documented that the new IRR algorithms resulted in better resolution when compared to conventional FBP and OSEM.[8–10] In addition, in an anthropomorphic cardiac phantom, WBR showed a comparable performance with respect to conventional FBP, either in half-time SPECT with a standard dose or with SPECT acquired at a standard time/frame but with half isotope activity.[10]
(2) *Single-center clinical studies*: they documented that the image quality and the interpretation of half-time or half-dose gated-SPECT reconstructed with the new algorithms were comparable respectively to that of a standard-time or standard-dose gated-SPECT acquisition reconstructed with conventional FBP.[11–16]
(3) *Clinical validation* diagnosis and prognosis. Most of the published studies comparing new IRR with conventional FBP focused on demonstrating the ''non inferiority'' of IRR images in terms of image quality and the ''equivalence'' in terms of image interpretation and perfusion defect quantification.[17–21] A recent report by Patil et al, documented in 93 patients a sensitivity of 92% and specificity of 87% in the detection of significant coronary artery disease.[19] Gutstein et al, in a larger group of 290 patients reported sensitivity and a specificity values of 89% and 75%, respectively.[20] Moreover, the utilization of IRR increased the diagnostic interpretation of equivocal studies, reducing the need of further testing.[21] These accuracy values favorably compare with that reported in the literature using gated-SPECT acquisitions reconstructed with the conventional FBP.[2,4] More recently, the prognostic value of MPI with the new softwares was also demonstrated.[22]

Finally, the new IRR softwares are able to provide the physicians high-quality SPECT images, with shorter acquisition time or lower study tracer activities, hampering patients' and staff's exposition.

Is this a sort of Holy Grail of nuclear cardiology?

Several pitfalls should be taken into account.

Most manufacturers have implemented their own version of IRR algorithms into conventional softwares for OSEM iterative reconstruction, optimized for their own specific camera. As result, the recommended reconstruction parameters vary widely between systems, making the comparison a difficult task.[23]

The performances of the different coupled hardware-software systems available in the market have been investigated in a experimental phantom study.[24] It was demonstrated that there is an effective dependence of the image quality indexes from the scanner/software combination, which is not univocal but also depends on the image quality index considered. This could be due to the fact that the different manufacturers seem to emphasize different aspects of the myocardial image quality.[24] As a matter of fact, the experimental results obtained in phantom studies show that IRR algorithms produce better results than conventional FBP and OSEM in terms of lesion contrast, wall thickness and noise indices, independently from the scanner/software combination considered.[24] Moreover, the best results are obtained applying attenuation and scatter corrections, a practice still performed by the minority of laboratories. As a final point, also the polar maps obtained by these different models are significantly different; consequently, normal reference databases must be specifically implemented for each algorithm and system used.[25]

All the above-mentioned observations are related to the effect of the IRR on the perfusion pattern. Several concerns also affect the left ventricular volumes and ejection fraction measurements. As correctly emphasized by Dendy and Tilkemeier in this issue, in addition to the perfusion values, the functional parameters obtained by gated SPECT studies as well are strongly dependent on the patient's characteristics and the reconstruction model used.[23] The values obtained with the new IRR algorithms are critically related to the scanner/software combination used. This issue, however, is well known: volumetric quantification values in gated-SPECT acquisitions are strongly dependent on the quantification package used.[26]

As a consequence, normal reference limits specific for each scanner/software combination should be considered, either for polar maps quantification or left ventricular volumes and ejection fraction values.

Conclusions The new iterative reconstruction softwares are able to provide images of good quality from low count density acquisitions, allowing a significant reduction in acquisition time and/or dose/radiation, providing clinical information comparable to conventional FBP images reconstruction. Images interpretation, however, should take into account the differences between the different software/hardware packages.

Although we are still far from the numbers provided by the last 25 years of nuclear cardiology literature with conventional reconstruction methods, giving experimental and clinical studies available so far, the use of the new IRR to reduce the radiation burden to patients and operators,[27] without losing diagnostic and prognostic accuracy, should be encouraged.

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