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Original Article

A practical background correction method for an immediately repeated first-pass radionuclide angiography

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Abstract

Background: A satisfactory bolus injection is essential for a successful first-pass radionuclide angiography (FPRNA). Rescheduling the FPRNA study is usually needed due to high background interference caused by an unsatisfactory bolus injection. We developed a protocol to correct the pre-existing background activity subsequent to immediately repeating the study.

Methods: Seventy-four consecutive patients who had their bone scan and FPRNA scheduled on the same day were included for analysis. The initial 51 cases constituted the "validation-only" group. In the other 23 cases, the "validation plus clearance constants" group, a 5-min dynamic acquisition was performed during the 5-min equilibrium to obtain the background clearance curve and the clearance constants. For all included 74 cases ejection fraction (EF) analysis was proceeded using the images from the first injection, second injection, and second injection with the corrected background to yield EF1, EF2, and EF2′, respectively. EF2 and EF2′ were then compared to the ejection fraction without background interference, the EF1.

Results: For the LV, the mean difference between the EF1 and the uncorrected EF2 (|LVEF1-LVEF2| in mean ± SD) was 3.1 ± 2.0% and the difference between the EF1 and the corrected EF2′ (|LVEF1-LVEF2′|) was 1.6 ± 2.1%, while the mean differences for RV are 2.2 ± 1.9% and 1.8 ± 1.8%, respectively. A significant difference ($p < 0.05$) was observed between the uncorrected and the corrected data for both the LV and RV.

Conclusion: In FPRNA, when a bolus injection is immediately readministered, both LVEF and RVEF can be underestimated. With our correction method, the results are superior to those without correction.

Keywords: Background correction; Background interference; Background subtraction; Ejection fraction; First-pass radionuclide angiography; Image processing

1. Introduction

Despite many nuclear medicine techniques for evaluation of heart function such as gated myocardial perfusion scan, gated cardiac blood pool imaging, and gated cardiac positron emission tomography, first-pass radionuclide angiography (FPRNA) remains the simplest and the least expensive method. It provides rapid evaluation of both right and left ventricular ejection fractions (RVEF and LVEF), ventricular wall motion of the imaging plane, and quantification of the left-to-right shunt.

In FPRNA, a satisfactory bolus injection is crucial for a good quality study and accurate results. If the bolus is unsatisfactory, guidelines indicate that the image should not be analyzed further, and the study should be repeated on another day to avoid background interference from the failed injection.[1−3] It is well known that an incorrect background selection may result in inaccurate ejection fractions (EF) in a single-injection FPRNA, but to the best of our knowledge, there has not been a study

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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discussing the impact of a pre-existing background on the RVEF and LVEF.[4]

However, even with experienced hand and very careful procedure, failure of bolus injection happens at an incidence rate, with conservative estimation at, around 3−5%, that is, almost an every-day-event in a high throughput laboratory with 20−30 cases of FPRNA a day. Rescheduling the study on another day not only causes inconveniences both to the patients and the clinicians but also causes a delay in diagnosis and treatment. Repeating study immediately avoids these inconveniences but the issue of the pre-existing background interference needs to be handled properly.

The purpose of our study is two-fold: first, to determine the effect of a pre-existing background on an ejection fraction if a study is repeated immediately after the first injection and second, to assess whether the EFs can be corrected with our technologically advanced background correction method.

2. Methods

2.1. Patient population

Consecutive patients, who had their bone scan and FPRNA study scheduled on the same day, referred to our department by the clinicians were eligible. We prospectively included these patients from August 14, 2012, to July 16, 2013. The study was approved by the Institutional Review Board of Taipei Veterans General Hospital. All included patients were well informed about the study and completed a written informed consent.

We explained our study protocol to a total of 117 patients and 83 patients agreed to participate in the study. Fifty-five patients were in the “validation-only” group and the other 28 patients were in the “validation plus clearance constants” group (Fig. 1).

A total of nine patients' data was excluded due to prolonged superior vena cava mean transit time (SMTT) (four patients), prolonged pulmonary mean transit time (PMTT) (three patients), and inadequate data acquisition (two patients). This made the actual patient number in the “validation-only” group to be 51 and the patient number in the “validation plus clearance constants” group to be 23 (Fig. 1).

The SMTT and PMTT are important quality control (QC) indexes in an FPRNA which respectively guarantee a successful bolus injection and concentrated pulmonary transit. Acceptable transit times, i.e. SMTT less than 4 s and PMTT less than 8 s, constitute the basis of an accurate EF results. With prolonged SMTT and/or PMTT, the temporal separation of the RV phase and LV phase is lost and the accuracy of the LVEF and RVEF will be hampered. Therefore, those cases with prolonged QC indexes were excluded.

2.2. First-pass radionuclide angiography acquisition

A single head gamma camera (Siemens Symbia E ®, single head) with a low-energy, all-purpose collimator is used for FPRNA studies. Patients are in a supine position with the detector positioned in the right anterior oblique 30° on the anterior chest of the patient. A bolus injection of 370 MBq (10 mCi) of Tc-99m MDP was given through a 21-gauge venous cannula in the external jugular vein or the anterior cubital vein if the neck veins are difficult to access. Data acquisition for a total of 60 s in a frame mode with a frame time of 0.05 s was started immediately after injection.

2.3. Validation of the correction method

The 83 patients involved in this part of the study were constituted by the 55 patients in the “validation-only” group and the other 28 patients in the “validation plus clearance constants” group, received a total dose of 740 MBq (20 mCi) of Tc-99m MDP that was split into two doses, 370 MBq (10 mCi) each, to accommodate two FPRNA studies per patient without hampering the patients' imaging quality or increasing the patients' radiation burden. The split doses were highly concentrated with their volume less than one milliliter, which is essential to facilitate bolus injection. A 1-min dynamic acquisition was done after a bolus injection of the first dose of 370 MBq (10 mCi) of Tc-99m MDP. The acquisition parameters were described in section 2.2. This was followed by a 5-min rest period for the 55 patients in “validation-only” group having no data acquisition during the 5-min rest period (protocol A) and the remaining 28 patients in the “validation plus clearance constants” group having data acquisition using frame mode at a rate of 10 s per frame for a total of 5 min (protocol B). The purpose of the 5-min data acquisition was explained later in section 2.4. Then, in both groups, a 30-s static frame was obtained for background correction. The second dose of 370 MBq (10 mCi) of Tc-99m MDP was given via the same intravenous cannula and followed by another 1-min dynamic acquisition with the same parameters as the acquisition after the first dose of 10 mCi Tc-99m MDP. A schematic summary of the study design was in Fig. 1.

2.4. Obtaining average clearance constants

Because activity changes with time and changes differently in each ROI, after the first injection, a single 30-s static frame at 5 min post first injection cannot represent the exact background distribution during the second injection phase. So, we replaced the 5-min rest period with a 5-min dynamic acquisition with a frame time of 10 s in 28 cases leaving the other 55 cases with no data acquisition during the 5-min rest period (Fig. 1).

Time-activity curves (TAC) for the LV, the right ventricle (RV) and the pericardiac background regions of interest (ROI) from the 5-min acquisition were derived and fitted with simple exponential clearance functions to get the average clearance constants for the RV ROI, the LV ROI, and the pericardiac background ROIs.

2.5. Background correction and ejection fraction analysis

All images, including the FPRNAs and bone scans, were reviewed to exclude overt tracer infiltration and no overt infiltration was noted in all included 74 cases. Background

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