Proposed volume-based methods for correcting the shift in left ventricular ejection fraction from blood-pool gated SPECT

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When compared with planar radionuclide angiography (RNA) or with other cardiac imaging methods, SPECT-RNA is currently associated with an overestimation of left ventricular ejection fractions (EF) setting in the normal range.[1–4] EFs above the 80% level are far from being uncommon and thereby undermine the confidence in SPECT-RNA results. This observation is likely related to an underestimation of end-systolic counts relative to end-diastolic counts, presumably due to differences between systole and diastole in partial volume effects, in photon attenuation and/or in the inner workings of the contour detection algorithms. In a study published in the present issue of the Journal of Nuclear Cardiology,[5] we used a general method of count-calibration on planar radionuclide angiographic data for correcting this relative underestimation of end-systolic counts. This calibration could be obtained with increasing volume values of an inflated balloon placed in a diffusing environment, but also with a comparison of SPECT- and planar-RNA data in a relatively small patient sample.

(1) For the first method, SPECT and planar counts are put in correspondence for **various volumes of a balloon** filled with a technetium-99m solution of approximately 0.25 MBq.mL^{-1} and placed at the center of the camera fields-of-view, within a cylindrical container of 20.4 cm diameter and 20 cm height enclosing a technetium-99m solution with a four-fold lower activity concentration than that of the balloon (see Figure 1A). The presence of this radioactive environment around the balloon is required in order to better match the clinical conditions of RNA recording and to prevent against a Gibbs effect on the balloon border.
SPECT and planar recordings must be performed with a sufficiently long recording time ($\geq$ 2 min for the smallest balloon volumes) and with an ECG simulator in order to obtain 16 interval-frames. The methods used to record, treat, and reconstruct the planar and SPECT images must be exactly the same as those used in patients (voxel size, reconstruction algorithm, filters, etc.). The sampling of balloon volumes should preferentially cover the large range of LV volumes documented in patients, ideally from 10 to 400 ml. However, the contouring of the smallest balloon volumes is difficult to obtain with the current software dedicated to SPECT-RNA. With the QBS software,[6] we found such contouring to be impossible for balloon volumes less than 32 ml, and a somewhat lengthy procedure of modulations of the contouring limits was often required to achieve the contouring of the entire balloon volumes.[5]
LV counts need to be extracted with well validated software for planar-RNA, with background subtraction, as well as for SPECT-RNA. Thereafter, a calibration curve may be built, expressing planar counts relative to SPECT counts at the same volume values, with an additional count normalization assigning similar total counts at the highest volume point for both planar and SPECT images (400 mL in our experiments[5]). The counts from the highest volumes are indeed likely to be the least affected by interfering factors, especially the imperfections in

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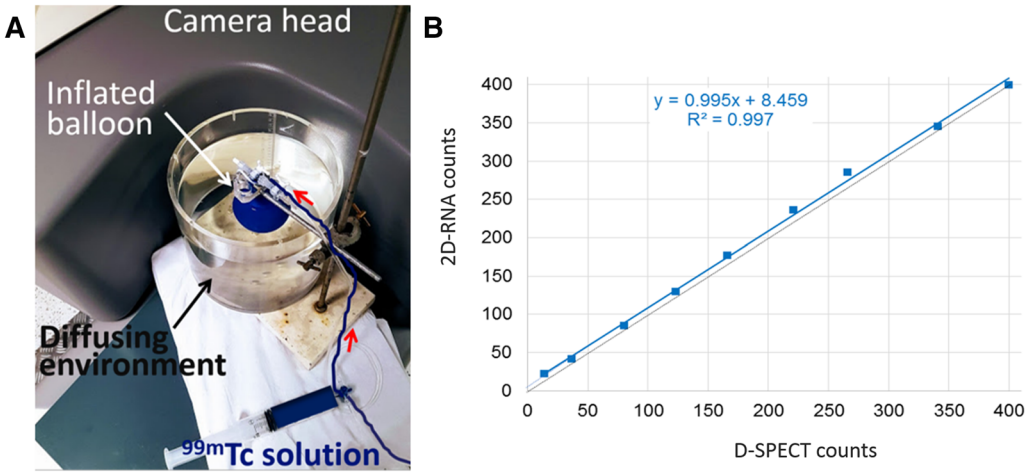

Figure 1. A Experimental set-up used for the balloon experiments and **B** linear relationship of planar- relative to SPECT counts at the same balloon volumes and after normalization at 1 count unit per mL at the 400 mL volume point (and thus with the same absolute values for counts and volume at this volume point).

the determination of background counts for 2D-RNA and in the delineation of cavity boundaries (algorithms of contour detection, partial volume effects, etc.). This normalization was applied at one unit per mL for the higher volume, such that the relative underestimation of the SPECT counts from smaller volumes could also be expressed as a volume underestimation.[5]

In our experimental conditions, depending on camera type as well as on recording and reconstruction parameters, this approach yielded evidence of a constant underestimation of SPECT counts corresponding to 8.5 mL of cavity volumes (Figure 1B). Furthermore, this magnitude of volume shift could be confirmed on end-systolic LV volumes recorded from patients.[5]

(2) This volume shift may also be estimated through **a simple comparison of the end-systolic volumes estimated with the EF from SPECT- and planar-RNA** in a small patient sample.

Figure 2 represents the end-systolic volumes determined with the EF values extracted from planar and SPECT images in 12 patients with presumably normal LV function (the initial 12 patients referred to RNA prior to any chemotherapy and in the absence of any history of cardiovascular disease in our study [5]). These end-systolic volumes were obtained with the formula: (1-EF) x EDV, where EF is calculated with planar or SPECT acquisitions and EDV is the end-diastolic volume estimated by the geometric surface-based method of the QBS software.[6] The volume shift was estimated in this

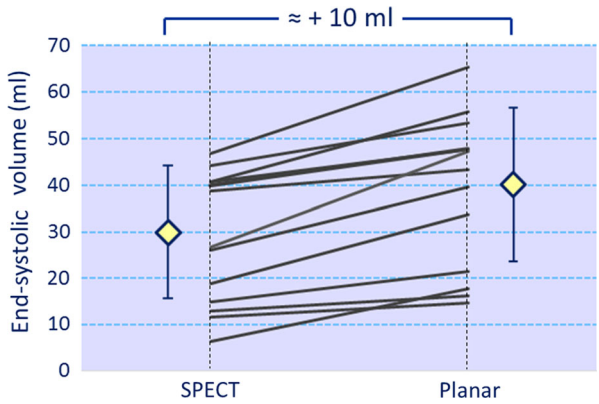

Figure 2. Comparison of the end-systolic volumes calculated with the EF from planar- (left) or SPECT images (right) in twelve presumably normal patients, yielding evidence of an averaged volume shift of almost 10 mL between the 2 techniques (see methodological details in the text).

instance at 10 mL (Figure 2), close to the 8.5 mL documented with the balloon curve. Thereafter, any EF may be corrected with the formula (EDV-ESV)/EDV where EDV is the end-diastolic volume from the surface-based method and ESV, the end-systolic volume obtained after having added the 10 mL of volume shift.

Although the surface-based method only provides an approximation of end-diastolic LV volumes,[7,8] a highly accurate estimate of this volume is not required here. As an illustration, for end-diastolic volumes of 160 and 140 mL, which are clearly but not markedly different, the corrected values of an uncorrected native EF value of 60% would be very

close: 54% and 53%, respectively. By contrast, for a much smaller end-diastolic volume of 80 mL, this corrected EF value would be of 47% and thus clearly different.

Finally, since the EF shift that needs to be corrected is strongly dependent of the level of LV volume, it is likely that the present volume-based method of EF correction is more appropriate than a correction directly applied on EF values (i.e., a calibration of the SPECT EF through the relationship with the planar EF from the same patients).

Disclosure

Pierre-Yves Marie and Laetitia Imbert declare that they have no conflict of interest.

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