Journal of Nuclear Medicine, published on January 26, 2017 as doi:10.2967/jnumed.116.188086

Variation in maximum count rates during myocardial blood flow quantification using Rubidium-82 PET

J.M.Renaud, J.Moody, R.A.deKemp

We thank the authors for their interest in our recent paper reporting the dynamic-range of current 3D PET systems, and the corresponding weight-based dose-limits (MBq/kg) for accurate measurement of tracer activity and myocardial blood flow (MBF). They suggest that the proposed translation of phantom-measured to patient-recommended dosing may lead to count-rates that exceed the recommended limits in some patients. We agree that the cardiac phantom scans are a simplified representation of patient imaging conditions, and that the phantom results should not be used alone without comparison to patient data confirming the weight-based dose-limit that allows accurate quantification of MBF on a particular scanner, as shown in our paper. In this regard the authors are commended for comparing their patient-measured count-rates (CR) to those obtained using the cardiac torso phantom. However, we note that their phantom-measured peak count-rate was obtained using a different method than we recommended, which is to determine the *instantaneous* total activity in the scanner field-of-view and the corresponding DTF (or prompt CR) at which quantitative accuracy is maintained with <10% bias. The measured or simulated phantom count-rates reported by van Dijk et al following injection of their standard dose of 740 MBq do not appear to have any relation to the 10% bias criteria recommended in our paper. Their phantom data does appear to us to be fully consistent with the spread of patient values around the lines-of-best-fit, although prediction bounds were not included in their figures.

To further clarify, our original methodology determined the maximum dead-time correction factor (DTF) with <10% bias in reconstructed activity (Appendix Figure 1A). These values are closely related to the prompt coincidence count-rate (Appendix Figure 1B), which can also be used to establish and confirm the dynamic range for accurate quantification. Comparative data from our Discovery 690 demonstrate a measured activity bias < 10-12% at CR < 5000-6000 kcps and DTF < 1.5-1.6 for this particular scanner. As illustrated in Appendix Figure 1C, our peak patient count-rates are in excellent agreement with the *instantaneous* phantom count-rate corresponding to an injected dose of 9-10 MBq/kg (and <10% activity bias). This dose used in our clinical practice is slightly lower than the 11.4 MBq/kg maximum value listed for the Discovery 690 scanner in the original paper, and accounts for the population variability in peak DTF and CR observed due to differences in patient height, body habitus, or other non-weight-based factors as we reported initially. The distribution of count-rates in our patient data is very similar to that reported by the authors, with a large percentage of patients having higher peak count-rates than observed in the phantom scan with equivalent injected dose. However, the authors should not assume that these higher count-rates are associated with inaccurate measured activity values, since they did not report the count-rate (or DTF) limit to maintain accuracy on their particular scanner. The lower peak count-rate observed in the 50-kg weight-equivalent phantom and in the smaller patients is a direct consequence of the recommended weight-based dosing. Although there is a clear trend to obtain higher count-rates in larger patients, the correlation did not reach statistical significance due to limited sample size. This is in sharp contrast to the normalized count-rate per activity (kcps/MBq) which shows a significant negative correlation with patient weight (Appendix Figure 1D), and is associated with higher count-rates and DTF (and possible inaccuracy) in smaller patients when injected with a standard activity (e.g. 740 MBq), which is the current practice in many centers.

The patient-scan revised vs phantom-scan predicted doses from the original paper are summarized below in Table 1, with the limited available data for the Gemini/Ingenuity TF scanners. The phantom-predicted and patient-revised values were quite similar for the first 2 scanners listed, whereas the phantom-predicted dose was substantially underestimated compared to the patient-revised value in the 3rd scanner. This highlights the

need to validate the final weight-based dosing using patient scans acquired on any given scanner. If the phantom peak count-rate of 2,000 kcps reported by van Dijk et al does represent the accuracy limit on the Ingenuity TF scanner, then indeed their patient data would suggest that the clinical dose should be reduced below 4.6 MBq/kg. Their scanner appears to have very high count-rate capability (>9,500 kcps); we recommend that they determine the dynamic-range of count-rates and weight-based doses that will maintain quantitative accuracy in their patients scans.

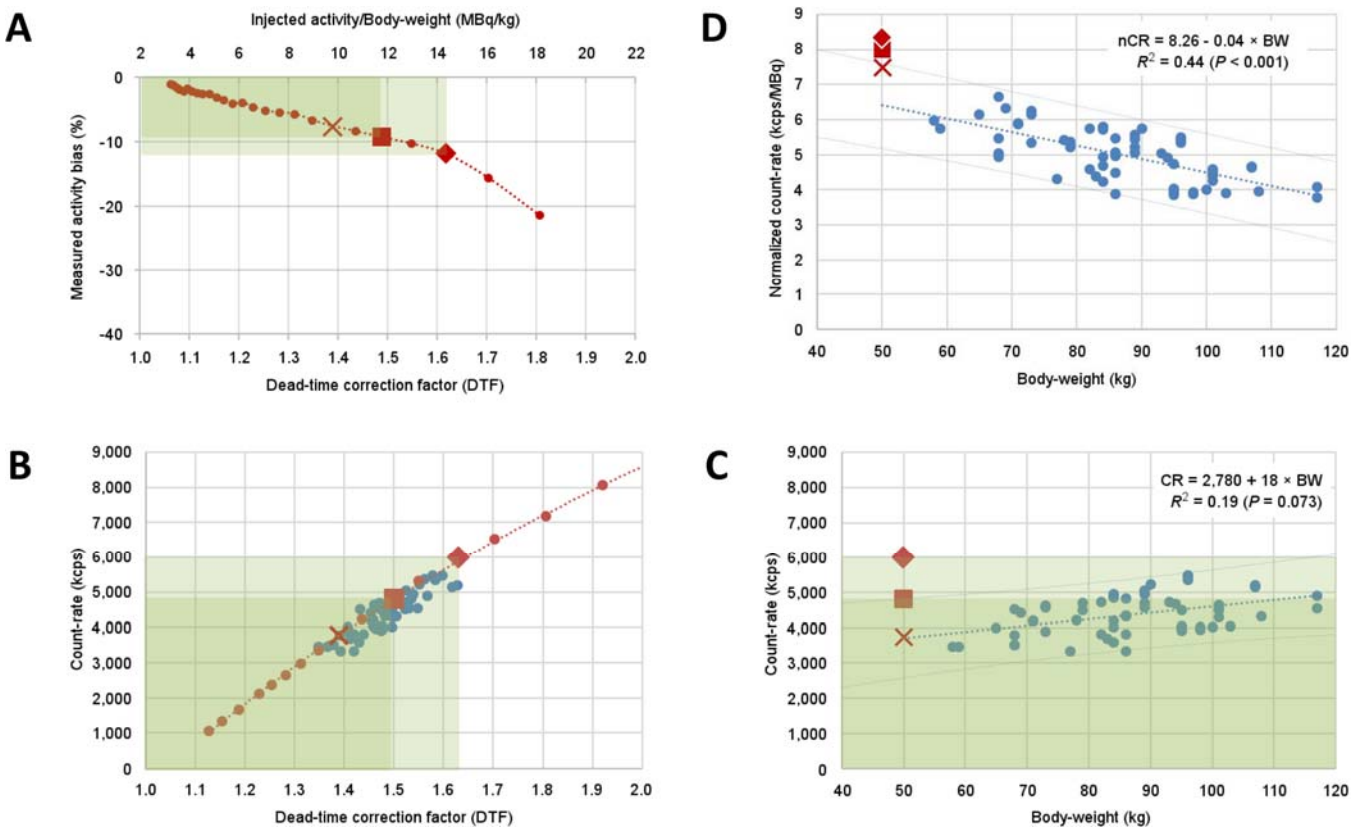

Figure 1. Activity bias in the decaying-phantom study is <10-12% (square & diamond markers and green shaded areas) with dead-time correction factors (DTF) <1.5-1.6 (A). Prompt count-rates (CR) are closely related to the DTF values in both phantom (red) and patient (blue) studies (B). 50-kg weight-equivalent phantom study (red X) is consistent with peak measured patient count-rates using 10 MBq/kg weight-based dosing (C). Normalized count-rates (nCR) per MBq injected activity decrease with body-weight (BW), therefore smaller patients will have higher peak count-rates and higher potential bias when using a standard injected activity regardless of body-weight (D).

Table 1. Approximate dead-time and prompt coincidence count-rate limits with <10% activity bias.

PET Scanner Model	Dead-time correction factor (dead-time%)	Prompt count-rate (kcps)	Maximum recommended dose (MBq/kg)	
			Phantom-scan predicted	Patient-scans revised
Discovery 690	1.5 (33%)	5,000	11.4	9
Discovery 600	2.1 (52%)	4,000	6.5	7.5
Scintron 3D	1.6 (38%)	1,500	2.7	6
Gemini/Ingenuity TF	?	2,000?	4.6	?