Abstract: Quality assurance metrics for routine clinical PET rubidium-82 myocardial blood flow quantification

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Topic(s):
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Citation:
Introduction: Rubidium-82 (Rb82) PET myocardial perfusion imaging (MPI) is becoming more widely used due to superior diagnostic accuracy and availability without an onsite cyclotron. For optimal myocardial blood flow (MBF) quantification with low test-retest variability, the injected Rb82 activity should be accurate, precise and delivered consistently over a short time interval. We evaluated PET MBF data obtained in a clinical setting using constant-activity-rate infusions from a new Rb82 elution system to identify useful quality assurance parameters and establish their normal limits.

Methods: 4,006 patients underwent rest-stress dynamic 3D PET imaging (8,012 scans) using 10 MBq/kg, 30s constant-activity-rate ‘square-wave’ infusions of Rb82 over a 2.5-year period (680 imaging days). To obtain regional MBF estimates, a 1-tissue-compartment model was fit to the dynamic image data from 0-6 min after injection. MBF image quality was determined from the model goodness-of-fit (R²) polar-maps and K1 SNR = mean/standard deviation (SD), and evaluated vs. patient weight. Reliability of the MBF estimates was assessed using two derived quality assurance metrics to identify outlier values: i) total rest+stress K1 coefficient-of-variation (COV = SD/mean), and ii) log(rest/stress K1 COV).

Results: Kinetic model R² values were excellent on average: 0.98 ± 0.2 at rest and 0.98 ± 0.3 at stress, indicating that there was high quality fitting of the model across the population sample. SNR values were excellent, with slightly higher image quality at rest vs. stress (61 ± 18 vs 47 ± 15, p<0.001). There was no correlation of image quality with weight, indicating that uniform image quality was maintained regardless of patient size. Total rest+stress K1 COV < 10% was determined to be a useful limit to identify outliers with potential modeling or image quality issues; 14 patients (0.35%) were outside the median ± 5×IQR range using this criterion. For the log(rest/stress K1 COV), the population median ± 3×IQR = [-1.65, 1.15] was found to be robust for identifying outliers, with only 0.27%, or 11 patients falling outside this range. QA evaluation of the outliers revealed that the majority of the dynamic images contained patient motion, suggesting that the resultant MBF (K1) values may not reliable in these cases.

Conclusion: A 1-compartment kinetic model applied to dynamic Rb82 PET data obtained with 30s constant-activity-rate ‘square-wave’ infusions results in uniformly high-quality estimates of K1 and MBF. With the weight-based 10 MBq/kg dosing, image quality is consistently high over a wide range of patient weights. Total rest+stress K1 COV < 10% and log(rest/stress K1 COV) in the range of [-1.65, 1.15] are useful quality assurance metrics to identify outliers requiring investigation of potential technical issues, including patient motion.
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Supporting Figure. (A) 1-compartment model (1TCM) goodness-of-fit ($R^2$) and (B) signal-to-noise ratio (SNR) from uptake rate constant $K_1$ mean/standard deviation for dynamic MBF images. No correlation was observed with any of the image quality metrics and patient weight, indicating that uniform image quality is maintained regardless of patient size with weight-based dosing. (C) Scatter plot of rest $K_1$ COV values vs. stress $K_1$ COV values showing the determined normal limit of 10% and 14 outliers beyond this threshold. (D) Histogram of the log(rest/stress $K_1$ COV) values for the patient population, demonstrating that 99.8% of the values fall within 3 x IQR of the median [-1.65, 1.15], suggesting that this is a useful normal limit for identifying outliers with this metric.