Gated blood pool SPECT: The estimation of right ventricular volume and function is algorithm dependent in a clinical setting

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Background. **Gated blood pool SPECT (GBPS) requires further validation for the assessment of the right ventricle (RV). This study evaluated three algorithms: BP-SPECT, QBS, and TOMPOOL (results are referred using this order). We compared (1) their ''quantitative-accuracy'': estimation of RV ejection fraction (EF), end-diastolic volume (EDV), and cardiac output (CO); (2) their ''qualitative-accuracy'': threshold values allowing diagnosing an impairment of the RV function; (3) their reproducibility: inter-observer relative variability (IOV).**

Methods and Results. **Forty-eight consecutive patients underwent GBPS. Recommended reference standards were used: cardiac magnetic resonance imaging (CMR) (EDV, EF, n = 48), catheter measurements from thermodilution (TD) (CO, n = 25). (1) ''Quantitative-accuracy'': r = 0.42, 0.30, 0.42 for RVEF (CMR); r = 0.69, 0.77, 0.53 for RVEDV (CMR); 0.32, 0.36, 0.52 for RCO (TD). (2) ''Qualitative-accuracy'': optimal thresholds were 54.7%, 38.5%, 45.2% (AUC: 0.83, 0.80, 0.79) for RVEF; 229, 180, 94 mL (AUC: 0.83, 0.81, 0.81) for RVEDV; 4.1, 4.4, 2.6 L·minute^{-1} (AUC: 0.73, 0.77, 0.80) for RCO. (3) Reproducibility: IOV was 5% ± 6%, 8% ± 12%, 17% ± 18% for RVEF; 6% ± 8%, 4% ± 4%, 21% ± 18% for RVEDV; 8% ± 8%, 11% ± 15%, 24% ± 20% for RCO.**

Conclusion. **Diagnostic accuracies are similar. A CMR-based calibration is required for a quantitative-analysis (cautious interpretation) or an accurate qualitative analysis (thresholds must be adjusted). Automatic procedures (BP-SPECT, QBS) offer the best compromise accuracy/reproducibility. (J Nucl Cardiol 2015)**

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INTRODUCTION

Tomographic equilibrium radionuclide ventriculography (T-ERNV) allows for simultaneous assessment of bi-ventricular function but its validation is restricted to the analysis of the left ventricle. The availability of numerous imaging alternatives that provide additional information such as strain (echocardiography) or wall thickening (MPS)[1,2] proves that ''LVEF'' is nowadays ''not enough'' in order to stay competitive. Furthermore, the proof that T-ERNV is accurate for the assessment of the function of the right ventricle (RV) might improve the management of patient. Indeed, the estimation of RV function is clinically relevant because it can independently determine prognosis, treatment, and follow-up in a wide range of indications.[3,4] In addition, there is no reliable alternative to tomography for the radionuclide ventriculography of the RV: planar ERNV is not recommended to measure RVEF and first-pass RNV requires a perfect bolus and is therefore operator dependent.[3,4]

Imaging the RV is a challenge. T-ERNV algorithms use two different approaches: count-based or gradient-based approach. The main difficulties are the modeling of the shape of the RV, the delineation of the outflow tract, and the delineation of the valve planes. BP-SPECT (count-based) is designed for the analysis of markedly abnormal RV. It was reported to be the only algorithm without any significant trend in calculations of volumes[5] and to be the most accurate in order to assess the RV volume and function.[3,6-12] QBS was reported to include less of the RV toward the pulmonary outflow tract and toward the RV apex[5,8] due to its gradient-based approach but the newest version is a count-based method. TOMPOOL (count-based) is a semi-automatic algorithm[13-18] in which the operator defines manually the septal and valvular (aortico-mitral) planes, as well as the position of the pulmonary infundibulum (upper limit of the right ventricle). Theoretically, it should be more appropriate and reliable.

An evaluation of the accuracy of existing algorithms is required[3,4] because there are no optimal threshold values, which can be implemented, in routine clinical work. It is mandatory in order to diagnose a dilatation of the RV, an impairment of the right ventricular ejection fraction (EF) or of the right cardiac output (CO). The absence of existing threshold value is due to differences between protocols and procedures used in the literature (automatic or semi-automatic or manual correction) and since CMR was not systematically used as the reference standard[3] (thus, CMR is the missing step from evaluation on phantom or planar ERNV to introduction into clinical routine).

This report evaluated the intrinsic performance of each algorithm using the most automatic method of measurement available. The main objective was to assess the inter-observer relative variability (IOV) and the diagnostic accuracy of BP-SPECT (version 1.1), QBS (version 2009), and TOMPOOL. The reference standards were CMR for the estimation of the EF and end-diastolic volume (EDV) in 48 patients and right heart catheter measurements using thermodilution technique (TD) for the evaluation of CO in 25 patients. The second objective was to determine the optimal threshold values in order to diagnose an impairment of the RV function (EDV, EF, CO).

MATERIALS AND METHODS

Patient Recruitment

Patients referred for ERNV to the Department of Nuclear Medicine of the University Hospital, Toulouse, France, were included prospectively and consecutively from May 2012 to April 2013. Patients were excluded if the time elapsed between the performance of T-ERNV and CMR (time delay) was superior to 60 days; the time delay between T-ERNV and TD pressure was superior to 14 days; patients were not in sinus rhythm during either radionuclide or CMR data acquisitions (patients with arrhythmia were asymptomatic during the days preceding the acquisition); patients reported acute symptoms, significant cardiac event, or change in therapy (medical or surgical) between ERNV and CMR. Diagnosis, clinical indications of ERNV, CMR, or RV pressure monitoring by TD, and patients' follow-up were established and supervised by a cardiologist. The majority of the procedures were performed in the framework of standard clinical management, and not with a bias, selecting patients for this particular study. The patients underwent both T-ERNV and CMR and most of them both T-ERNV and thermodilution according to the local protocol used in clinical routine in our institution. Some patients underwent T-ERNV and thermodilution strictly for research purposes. The study was approved by the Institutional Review Board of CHU Toulouse. Informed consent was obtained from all patients.

T-ERNV Procedure

All examinations were performed according to the EANM/ESC guidelines for radionuclide imaging of cardiac function[3] using in vivo labeling of red blood cells. The activity

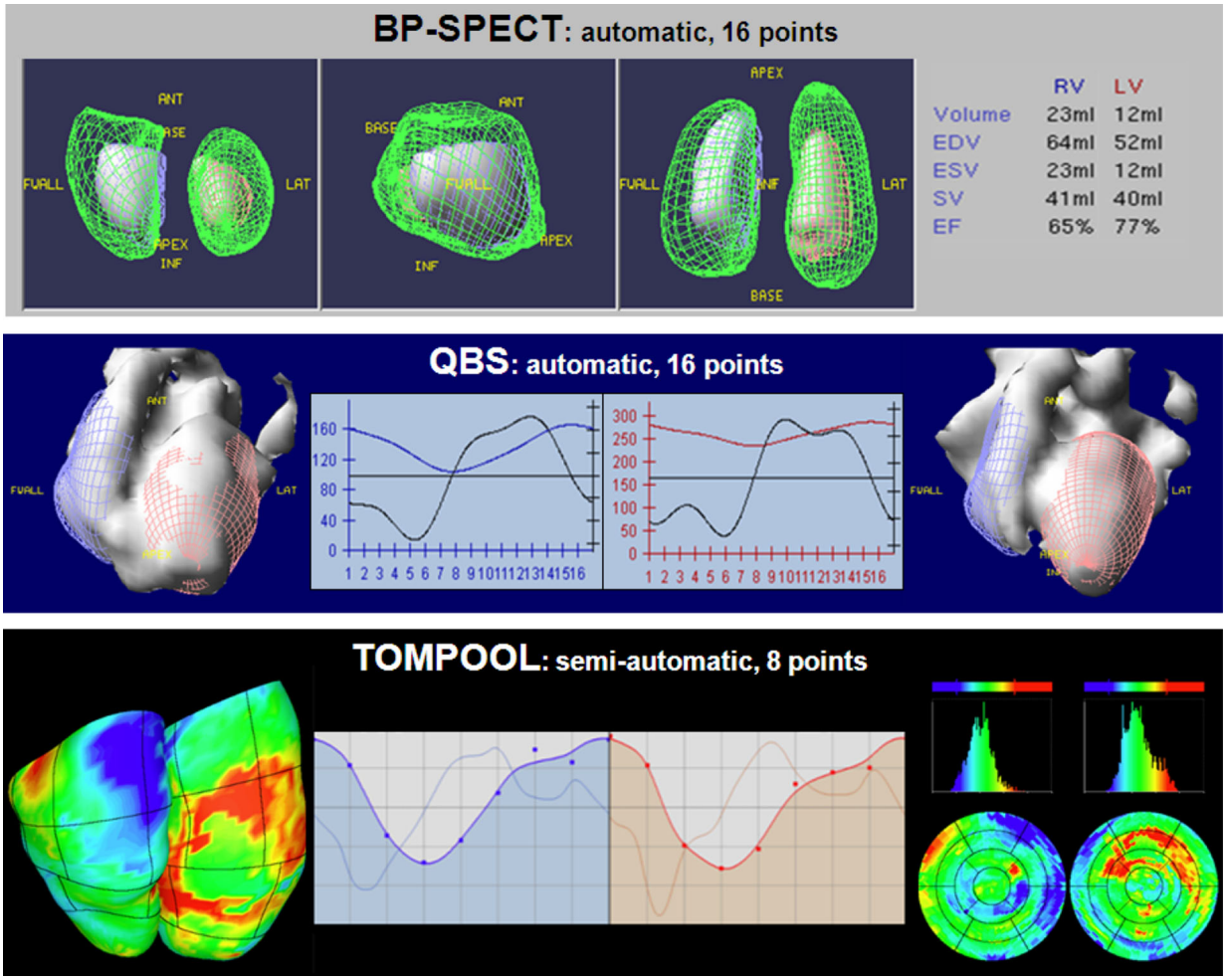

Figure 1. Modeling the shape of the right ventricle by T-ERNV. Representation of the outlines and time-activity curves according to TOMPOOL, QBS, and BP-SPECT. Right ventricle (*blue*) and left ventricle (*red*).

of injected radiopharmaceuticals was 920 MBq. Planar ERNV was performed first, immediately followed by T-ERNV acquired using a dual-head gamma camera (GE Healthcare Medical Systems) with parallel hole low-energy and high-resolution collimator. The acquisition parameters were 32 steps over 180° by each head of the gamma camera, 60-second acquisition per step, 20% R-R interval acceptance window, 16 gated intervals, matrix size: 64 × 64 pixels, and zoom 2.6 for T-ERNV. Projection data were pre-filtered using a Butterworth filter (cutoff frequency = 0.5 cycles·cm^{-1}; order = 5.0) for gated tomograms followed by Ramp filtering. There was no scatter or attenuation correction. Two experimented nuclear medicine physicians performed the calculations of global function parameters (EF, EDV, CO) with each algorithm. They were blinded to any clinical information and to knowledge of other measurement values. The mean of 2 measures on T-ERNV was compared to the mean of 2 measures on CMR. A representation of the RV (blue) and of the left ventricle (red) outlines and time-activity curves according to the three algorithms is shown in Figure 1.

Supplemental Figure 1 illustrates the automatic delineation of the endocardial contour by BP-SPECT. Supplemental Figure 2 shows horizontal long-axis views of the ventricles as seen in TOMPOOL. In T-ERNV, the characteristics of the image acquisition in a sample of 20 patients revealed that the mean counts were as follows: 464 counts per pixel in the RV in a time interval (16/cycle, the voxel dimensions of the reconstructed slices were 6.09 × 6.09 × 6.09 mm), 172,400 counts in the image, and 115,710 counts in the heart cavities.

Processing by BP-SPECT, QBS, and TOMPOOL

See Supplemental material Table 1.

CMR Measurement

The parameters of acquisition and the processing are described in Supplemental Material Table 2. CMR imaging

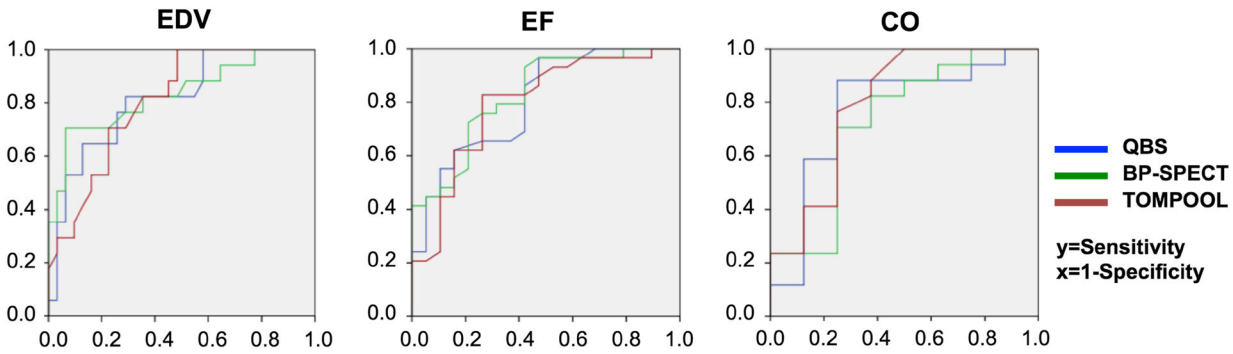

Figure 2. Qualitative accuracy of QBS (*blue*), BP-SPECT (*green*), and TOMPOOL (*red*). Area under the ROC curve for the diagnosis of an alteration of the EF (EF $\leq$ 45% in CMR), of an enlargement of the RV (EDV $\geq$ 167 mL), and of an alteration of the right cardiac output (CO $<$ 4 L·minute^{-1}).

was performed according to CMR guidelines and using the optimal pulse sequences. Images were acquired on two 1.5-T scanners (Magnetom Avanto 1.5 T, Siemens; Ingenia 1.5 T, Philips) with multiplane localizers.

Qualitative Analysis

The threshold values for the best parameters in order to diagnose a dilatation of the RV or an impairment of the right function were calculated and compared to the normal values described in previous studies on MRI (EDV $>$ 88 mL·m^{-2}, EF $\leq$ 45%, CO $<$ 4 L·minute^{-1}).[19,20] The threshold value for EDV enlargement was defined as superior to 167 mL. If there was discordance between GBPS and MRI and an echocardiography was performed with less than 1 week of interval with the GBPS and showed the presence of the absence of either an enlargement of the right ventricle or an alteration of the ejection fraction, the reference standard was switched from CMR to echocardiography.

Thermodilution Measurements in RV

A Swan-Ganz flow-directed monitoring catheter (size 7F) was introduced via the femoral vein after local anesthesia and placed in the pulmonary artery. The RCO was calculated from a temperature-time curve and determined as the mean of repeated measurements using the thermal indicator method described by Ganz: a cold thermal indicator is injected rapidly via one port of the catheter which ends at a side hole into the right side of the heart and mixes with the blood in the right atrium and ventricle before passing into the pulmonary artery where the fall in temperature is sensed by a thermistor.

Statistical Analysis

Data and results were summarized using frequencies and percentages for nominal data and using mean, SD, median, and range for continuous data. Correlation (r) was established using the Spearman's rank correlation coefficient or Spearman's rho. Normality was tested using Skewness and Kurtosis test. The IOV was obtained as the difference between the two calculated measurements normalized to their average and expressed as a percentage. All tests were two tailed. An ROC curve calculated the optimal threshold values, their sensitivity, and specificity. $P < .05$ was considered to indicate statistical significance. All statistical analyses were done with SPSS software (IBM, SPSS 22) (Figure 2).

RESULTS

Study

Forty-eight consecutive patients were included. Characteristics of the patients and of the reasons for referral are summarized in Table 1. Forty-eight CMR and 25 TD measurements were included and carried out within a mean interval (between T-ERNV and reference standard examinations) of 22 ± 22 and 2 ± 3 days, respectively. The minimal processing time was 2 minutes for BP-SPECT, 3 minutes for QBS, and 7 minutes for TOMPOOL.

Accuracy and IOV

The accuracy of the three algorithms is summarized in Table 2. The mean EF differed from CMR for BP-SPECT and QBS. The mean EDV differed from CMR for the three algorithms. The mean CO differed from TD for BP-SPECT and TOMPOOL. However, the three algorithms showed similar correlation with CMR and TD. The area under the curve was not different in order to diagnose an enlargement of the EDV or impairment of the EF or of the CO (Table 2). The thresholds and the results were highly algorithm dependent. Nine patients performed T-ERNV, MRI, and catheter measurement the same day. In this sample, the correlation coefficients (not statistically significant trends) with TD for RCO were

Table 1. Patient characteristics in the two groups: CMR (n = 48) and TD (n = 25)

	CMR	Thermodilution
Delay with GBPS (days)	22 ± 22	2 ± 3
Parameters assessed	EF, EDV	CO
n	48	25
Age (years)	54 ± 13	61.7 ± 9
Male	79%	80%
BMI ($kg \cdot m^{-2}$)	26 ± 4	26 ± 4
BSA (m^2)	2.5 ± 0.2	1.9 ± 0.2
Systolic BP	13 ± 2	13 ± 2
Diastolic BP	8 ± 1	7 ± 1
Heart rate ($beats \cdot minute^{-1}$)	68 ± 13	75 ± 14
Smoking	63%	76%
Hypertension	35%	36%
Diabetes	15%	24%
Hyperlipidemia	30%	36%
Left valve regurgitation	31%	16%
Right valve regurgitation	15%	12%
Referral: heart disease		
Dilated non-ischemic	14 (29%)	3 (12%)
Ischemic	9 (19%)	6 (24%)
Ventricular arrhythmia	11 (23%)	0
Other	14 (29%)	16 (64%)

Qualitative values are expressed as n (%), quantitative value as median (range). Values are expressed as Mean ± SD or n (%).

Table 2. Accuracy of BP-SPECT, TOMPOOL, and QBS in comparison with the reference standards

					ROC curves			
Variable	**n**	**Mean ± SD (range)**	**Linear regression**	***r***	**AUC**	**Threshold**	**Se**	**Spe**
RVEF (%)								
CMR	48	50.3 ± 14.9 (15:80)						
BP-SPECT	48	54.6 ± 15.8 (27:87)*	$y = 0.40x + 34$	0.42	0.83 (0.71-0.94)	54.7	72	79
QBS	48	43.7 ± 11.6 (22:66)*	$y = 0.22x + 32$	0.30	0.80 (0.68-0.93)	38.5	86	58
TOMPOOL	48	49.8 ± 15.3 (20:89)	$y = 0.34x + 33$	0.42	0.79 (0.66-0.93)	45.2	83	74
RVEDV (mL)								
CMR	48	154.4 ± 50.2 (47:271)						
BP-SPECT	48	236.5 ± 98.2 (72:563)*	$y = 1.30x + 36$	0.69	0.83 (0.70-0.96)	229	82	65
QBS	48	182.6 ± 57.1 (72:318)*	$y = 0.83x + 54$	0.77	0.81 (0.69-0.94)	180	82	71
TOMPOOL	48	96.8 ± 29.5 (40:148)*	$y = 0.31x + 49$	0.53	0.81 (0.69-0.93)	94	83	65
RCO ($L \cdot min^{-1}$)								
TD	25	5.8 ± 2.1 (2.5:10.0)						
BP-SPECT	25	4.5 ± 1.8 (2.0:9.6)*	$y = 0.73x + 2.2$	0.32	0.73 (0.49-0.96)	4.1	71	75
QBS	25	5.5 ± 1.8 (3.0:10.2)	$y = 0.72x + 3.2$	0.36	0.77 (0.55-0.99)	4.4	88	75
TOMPOOL	25	3.9 ± 1.7 (1.3:7.6)*	$y = 0.85x + 1.2$	0.52	0.80 (0.58-1.00)	2.6	88	63

r, Spearman's rho; *AUC*, area under the curve; Se, sensitivity of the threshold value; Spe, specificity of the threshold value.
* Mean statistically different from the reference standard.

Table 3. Comparison of the IOV of the measures: comparison of BP-SPECT, TOMPOOL, QBS, and MRI (n = 48)

Variable	IOV (%)
EF (%)	
CMR	11 ± 16 (67)
BP-SPECT	5 ± 6 (35)
QBS	8 ± 12 (77)
TOMPOOL	17 ± 18 (88)
EDV (mL)	
CMR	10 ± 12 (57)
BP-SPECT	6 ± 8 (44)
QBS	4 ± 4 (15)
TOMPOOL	21 ± 18 (71)
CO ($L \cdot min^{-1}$)	
CMR	18 ± 17 (75)
BP-SPECT	8 ± 8 (43)
QBS	11 ± 15 (91)
TOMPOOL	24 ± 20 (71)

Values are expressed as mean ± standard deviation (maximum).

calculated for CMR ($r = 0.55$), BP-SPECT ($r = 0.49$), QBS ($r = 0.61$), and TOMPOOL ($r = 0.27$).

The IOV of the measures was compared to CMR (Table 3). The less variable algorithm was BP-SPECT for the measure of EF and CO whereas it was QBS for EDV. The semi-automatic procedure of TOMPOOL leads to a greater IOV than CMR.

DISCUSSION

Previous studies reported correlation coefficients and mean differences in comparison with heterogeneous reference standard having a variable methodology. The rationale of this study is that in clinical routine, a good algorithm should be reproducible (follow-up) and should permit to diagnose an enlargement of the RV or an impairment of the EF and of CO. A qualitative analysis is needed in most case and a quantitative measure is not always required. Therefore, it is crucial to establish threshold values for the above parameters (with optimal sensitivity and specificity) in a population with a wide range of cardiac diseases and a high percentage of right ventricular dysfunctions. The conclusion is that the diagnostic performance of the three algorithms (AUC, sensitivity, specificity) is similar with different threshold values (described in Table 2). In this study, the correlation coefficients of BP-SPECT, QBS, and TOMPOOL with CMR for the estimation of RVEF were similar. The correlation is lower than some previous studies but can be explained by patients with severe ventricular dysfunction (dilatation, hypokinesis, hyperkinesis, valve insufficiency were frequently encountered), a blind analysis, the time delay, the inaccuracy of the ESV measurement on CMR, and the fact that the most automatic procedure of measurement was used (in order to correlate to clinical practice).

BP-SPECT is designed for markedly abnormal RV, is fully automatic, uses 16 frames per R-R intervals and a third-order harmonics fits. This study shows that the common notion that it is the most accurate algorithm for RV function assessment[3,5,7-11] and does not show any significant trend in volume calculations[5] is questionable since EDV was underestimated. Visual assessment confirmed that BP-SPECT rigorously included distal parts of the RV outflow tract (to delineate a larger RV ventricle) and does not include atrial activity (as shown previously on phantom models[5,7]). The low IOV of BP-SPECT, which was previously proved for all the parameters of both ventricles[11] is confirmed.

QBS used to be gradient and surface based. It also used to truncate a portion of the RV in an attempt to define the pulmonary valve plane.[5] In the new version, the algorithm is count based, and the ability to turn off RV truncation has been added. The intention was to improve repeatability, accuracy, and reproducibility. Thus, results from previous version are not applicable to the newest version. QBS was reported to be less accurate than BP-SPECT, in a phantom model (16 frames per R-R), for the measurement of the RV volumes (QBS: $r = 0.93$, mean difference = −41 mL; BP-SPECT: $r = 0.97$, md = −13 mL), or of the RVEF (QBS: $r = 0.84$; BP-SPECT: $r = 0.94$).[5] However, the clinical transposition of validation from a physical phantom is questionable because in an MRI and phantom study (8 frames per R-R),[8] QBS showed significantly worse results in comparison with the phantom than in comparison with CMR, whereas the correlation with either physical phantom or CMR was similar for BP-SPECT. In a specific population of Tetralogy of Fallot or Pulmonary Artery Hypertension,[8] QBS showed higher RVEF, lower RVEDV, and lower correlation than BP-SPECT (BP-SPECT: $r = 0.81$ for RVEF and $r = 0.83$ for RVEDV; QBS: $r = 0.47$ for RVEF, and $r = 0.71$ for RVEDV). In patients with dilated cardiomyopathy (n = 32, 8 frames per R-R), in comparison with CMR, correlations were good but RVEF was overestimated ($r = 0.62$), and RVEDV was underestimated ($r = 0.86$). It was reported that QBS is less accurate because it includes less of the RV toward the pulmonary outflow tract and toward the RV apex.[5,8] Indeed, it used to be a gradient method, and at ED there is rarely an identifiable pulmonary valve plane: RV and PA appear to be continuous, whereas by observing the evolution of counts RV is distinguished from PA. However, when the RV is narrow, the partial

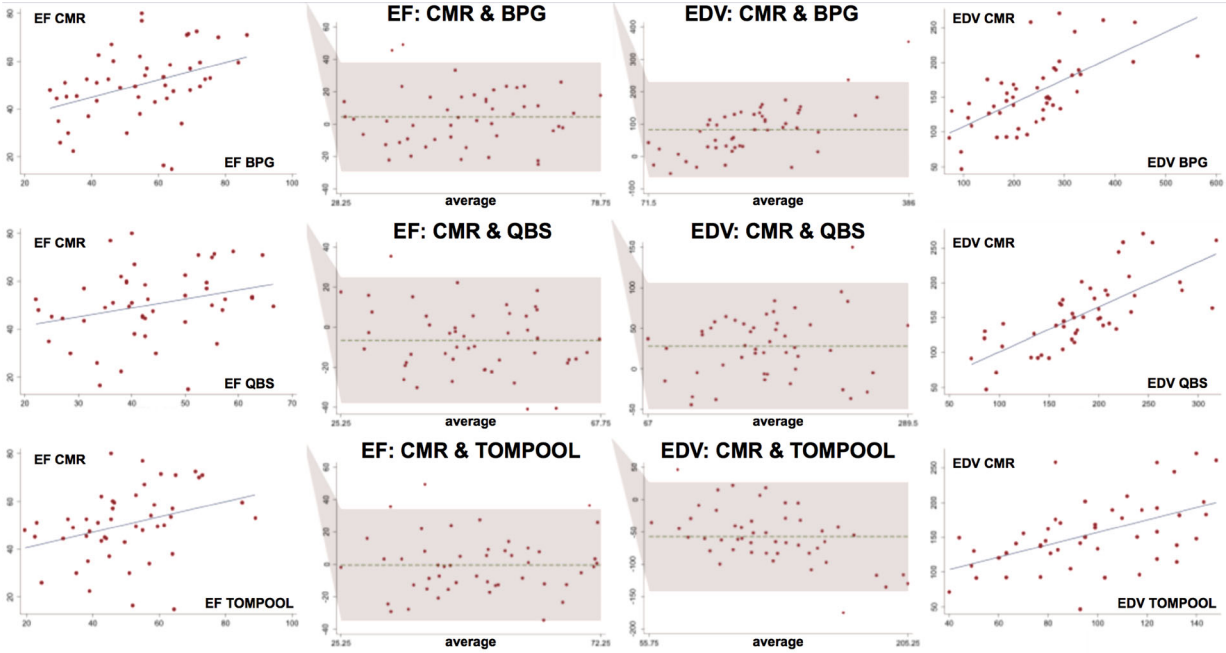

Figure 3. Comparison of CMR and GBPS: linear regression (with fitted value) and Bland and Altman graphes.

volume effect compromises gradient- and count-based method because apical RV counts are misperceived. This study also confirmed the low IOV (inter-observer correlation: $r = 0.96$ for RVEDV and $r = 0.95$ for RVEF[21]) (Figure 3).

TOMPOOL uses a semi-automatic procedure (localization of valve plane by the operator), a down-sampling on 8 frames per R-R intervals and a template-based method for the generation of time-activity curve. Its performance for the analysis of the RV has never been compared to BP-SPECT and QBS,[8-10,12,18,22-26] and this study broadens its evaluation to a larger population with new types of heart diseases.[14-18] It confirms the underestimation of EDV[18] and CO.[17] Finally, the operator delineation of the valve plane leads to an IOV greater than CMR which is not counterbalanced by an increased accuracy.

However, it should not be forgotten that reference standard modalities have pitfalls. This study showed that the IOV of automatic T-ERNV algorithm was twice lower than that of CMR, whereas a semi-automatic procedure showed similar IOV. Indeed, CMR is not based on a geometrical model, thus delineation of volumes is more accurate but it involves operator dependence in terms of experience dependence, time-consuming data processing, and decreased reproducibility with significant intra-observer,[27] inter-observer,[27] and inter-study[28] variability. However, steady-state precession sequences such as True FISP have improved contrast and endocardial delineation,[29] accuracy, and reproducibility.[30] It was reported that the geometrical model may not lead to statistically significant differences for EF evaluation[31] as a contrary to endocardial drawing[32] and slice orientation.[33,34] Higher differences between CMR and T-ERNV in ESV[18] are explained by an inaccurate estimation of ESV by CMR: trabeculation and papillary muscles are included in drawing endocardial contours and it accounts for a larger percentage of cavity volume in ESV than in EDV; their exclusion will give increased accuracy but decreased reproducibility.[32] Similarly, there is a significant inter-estimation variability[17] of measure of the CO in Thermodilution which is the mean of numerous estimations.

T-ERNV is simple, reproducible, and accurate but could be challenging. The first problem stems from the compensation of degrading factors which introduces artifacts, so that T-ERNV has to cope with motion, detector response, attenuation, scatter, and iterative reconstruction. The second challenge for algorithms is the delineation of the valve plane: self-attenuation by the blood pool induces decreased basal counts[23]; tomographic sections (as opposed with planar ERNV) lead to a reduced count densities[8]; the RV shape is the most complex part because the RV outflow tract is irregular and relatively hypokinetic and it is difficult to delineate the pulmonary valve. As a result, statistically different EFs are observed with automatic algorithm when the LV

is dilated and the RV is smaller. Indeed, RVEF may be overestimated when RV partially emerges into the LV at ES (due to limited spatial resolution of SPECT)[21] and RVEF may be underestimated because self-attenuation may be more significant for RVEDV rather than for RVESV (in case of a dilated LVEDV, RV is deeper).[21] On the contrary, enlarged RV facilitates the separation of left and right ventricles with thicker septa by a count-threshold approach.[9] The last challenge is the underestimation of RVEDV observed in most algorithms because of the self-attenuation by the blood pool which affects predominantly larger volume.[3,18] The other explanation for the underestimation of volumes/RVEF/CO are acquisition with 180° orbit vs 360°,[35] the temporal resolution lower than that of CMR (16 frames per cycle vs 35, even if with 16 frames additional information are obtained on filling and emptying but may not be routinely achieved due to lower frame count statistics[14]; 8-frame T-ERNV does not lead to systematic underestimation of EF.[18,36-38]

NEW KNOWLEDGE GAINED

1. BP-SPECT, QBS, and TOMPOOL, are ''qualitatively accurate'' in order to diagnose an impairment of the RVEF but ''quantitatively inaccurate'' for the measurements of EDV, EF, and CO (right ventricle).
2. Automatic procedures (BP-SPECT, QBS) are twice more reproducible than CMR or semi-automatic procedure (TOMPOOL).
3. The valve plane delineation remains a challenge that may be partially overcome using a semi-automatic procedure but the penalty is increased variability of the measurement that is not counterbalanced by an increased accuracy.
4. In order to diagnose right ventricular dysfunction, thresholds must be adjusted: a highly significant inter-algorithm difference was demonstrated.

CONCLUSION

A highly significant inter-algorithm difference was demonstrated in clinical routine. The normal limits and threshold values are algorithm dependant for the diagnosis of a dilatation of the RV, an impairment of the RVEF or of the RCO. The RV valve plane delineation remains a challenge that may be partially overcome using a semi-automatic procedure but the penalty is an increased variability of the measurement. As a result, in this population with a wide range of right ventricular dysfunction, results lead us to recommend considering that none of the three programs work well enough to guide clinical decision making for the estimation of volume, EF, and cardiac output in a clinical setting. Indeed, the method is not perfectly accurate and quantitative measures of right ventricular function and volume based on T-ERNV are not yet ready for clinical use. However, they are efficient in order to diagnose an impairment of the right ventricle function: enlargement, impaired ejection fraction. Thus, a qualitative analysis, presence or absence of enlargement, normal, or impaired EF, shows a good diagnostic performance. The condition is to train the physician to an algorithm and that each laboratory should calibrate the SPECT programs against CMR prior to its use in clinical routine. The implication is that the conclusions obtained with one algorithm are not applicable to all the algorithms or to T-ERNV and that each department should perform a CMR-based calibration. The good IOV may encourage the use of this technique for the follow-up of RVEF and the monitoring of the efficacy of treatment. The potential interest of a semi-automatic algorithm with manual delineation of the endocardial border is a failure of the automatic algorithm due to a small and dyskinetic right ventricle. All these results should be confirmed by a multicentric study with a bigger sample size.

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Disclosures

There is no conflict of interest to declare.

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