The effect of ventricular pacing on measurements of left ventricular function: A comparison between echocardiographic methods and with radionuclide ventriculography

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\textbf{KEYWORDS}

Pacemaker; Echocardiography; Heart failure

\abstract

\textbf{Aims}: Different methods exist for measuring left ventricular function echocardiographically; each may be error prone due to the abnormal pattern of ventricular activation during pacing.

\textbf{Methods and results}: Echocardiography was undertaken on 307 patients with permanent pacemakers; a subset of 57 underwent radionuclide ventriculography. Intrinsic and paced beats were analysed for left ventricular function by: Simpson's bi-plane, Teicholz M-mode, wall-motion scoring and 'eyeball' assessment. Agreement between techniques and with radionuclide ventriculography were compared according to intrinsic or paced beats. Echocardiographic measures of ejection fraction give mean values 5% higher than radionuclide ventriculography (Simpson's 30±9\% vs. Teicholz 30±13\% vs. radionuclide ventriculography 25±9\%, \(p=0.03\)). Agreement between Simpson's, Teicholz and radionuclide ventriculography by Bland–Altman analysis showed poor agreement (Simpson's vs. Teicholz range (4×SD) = 57\%, Simpson's vs. radionuclide ventriculography = 36\%, Teicholz vs. radionuclide ventriculography = 46\%, \(p=0.02\)), the level of agreement deteriorates with ventricular pacing (Simpson's vs. Teicholz range = 61\%, Simpson's vs. radionuclide ventriculography = 34\%, Teicholz vs. radionuclide ventriculography = 47\%, \(p=0.02\)). The correlation between wall motion analysis and radionuclide

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Ventriculography is moderately poor (all subjects $r=0.58$, ventricular pacing $r=0.52$, not pacing $r=0.66$).

**Conclusion:** Echocardiography and radionuclide ventriculography are the only non-invasive techniques to assess left ventricular function in the paced population. Results are poorly interchangeable and the accuracy of any comparison dependent on the underlying rhythm.

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**Introduction**

Permanent cardiac pacemakers are widely used in modern cardiological practice, with implant rates ranging from 250 to 800 per million of the population per annum, leading to 1000–3000 patients undergoing regular follow up in a typical pacemaker centre. Heart failure, symptoms of heart failure and cardiac co-morbidities are common in these patients leading to frequent requests for echocardiography, often to assess left ventricular function. Methods of reporting left ventricular function vary widely. The commonest used are:

1. Subjective ‘eyeball’ assessment of left ventricular function, often graded in a range from normal, mild, moderate through to severe impairment.
2. M mode measurements of the left ventricle to derive fractional shortening and ejection fraction utilising Teicholz formula.
3. Regional wall motion index scoring using 9 or 16 segment models of the left ventricle.
4. 2D echocardiography employing Simpson’s bi-plane method to determine left ventricular volumes and ejection fraction.

Existing data from non-paced subjects have shown differing levels of agreement between the main imaging modalities of echocardiography, radionuclide ventriculography and cardiovascular magnetic resonance imaging when assessing left ventricular function. There are also significant differences depending on which echo technique is used, with Simpson’s bi-plane method along with radionuclide ventriculography showing better agreement with the ‘gold standard’ of MRI than M-mode based measurements. In the paced population, such differences may be accentuated by the abnormal pattern of left ventricular activation imposed by right ventricular pacing. This may lead to systematic under or over reporting of left ventricular function based on some echocardiographic techniques. To compound this, the high prevalence of left ventricular systolic dysfunction and associated left ventricular dilatation in the paced population also makes unsafe many of the geometric assumptions that M mode echo is based on.

**Methods**

**Patient selection**

Three hundred and seventeen patients with permanent cardiac pacemakers were selected sequentially from a pacemaker follow up clinic, with 307 (97%) agreeing to participate. These patients underwent a detailed transthoracic echo. A subset of 57 (19%) underwent radionuclide ventriculography. Written informed consent was obtained from all patients. The local research ethics committee approved the study.

**Echocardiographic studies**

All studies were conducted within 14 days of entry into the study using commercially available equipment (Vingmed ‘Vivid’ V with a 3.4 MHz electronic transducer, GE industries, USA). M-mode atrial and ventricular variables were measured according to the recommendations of the American Society of Echocardiography. Simultaneous electrocardiographic recording allowed each digitised cardiac cycle loop to be categorised as an intrinsic beat (i.e. one that corresponded with that patient’s pre-paced or non-paced QRS segment morphology) or a paced beat. Data from each patient was either intrinsic rhythm or paced rhythm, there were no mixed data sets and patients could only contribute data to one set or the other. If a patient’s rhythm fluctuated between the two, then the first three beats after the transition were discarded. Echo analyses were performed by two experienced observers (ST and NN). The images were evaluated in random order with the observers blinded to the patient’s identity and were analysed by means of a fully digital offline system (Echopac, GE Vingmed Ultrasound). Differences of greater than 5% or one category between the two observers were reconciled by a third observer (KW) with the mean of the
three readings taken. Left ventricular function was assessed in four different ways:

(1) Based on a Simpson’s bi-plane method of discs calculation from an apical four-chamber view and two-chamber view at end systole and end diastole. Endocardial tracings were made manually, giving left ventricular end-systolic volumes, left ventricular end-diastolic volumes and left ventricular ejection fraction.

(2) Using Teicholz formula applied to M-mode images resulting in left ventricular ejection fraction (end-diastolic volume = \(7/(2.4 + \text{end-diastolic diameter}) \times (\text{end diastolic diameter})\), and end systolic volume = \(7/(2.4 + \text{end-systolic diameter}) \times (\text{end systolic diameter})\).

(3) Using a nine segment averaged regional wall motion score, with a score per segment of −1 for dyskinesia, 0 for akinesia, 1 for hypokinesis, 2 for normokinesia and 3 for hyperkinesis. The lower the overall average score the greater the number of regional wall motion abnormalities. A score of 2 is normal.

(4) An ‘eyeball’ assessment of left ventricular function with descriptors ranging from no impairment, trivial, mild, mild to moderate, moderate, moderate to severe and severe impairment of left ventricular function.

Radionuclide studies

A subset of 57 patients underwent gated radionuclide ventriculography, 47 of these to confirm the suspicion of left ventricular systolic dysfunction on echo, and 10 selected at random. Studies were performed at a separate session within 28 days of the echocardiogram, giving left ventricular end systolic volumes, left ventricular end-diastolic volumes and left ventricular ejection fraction. In order to reduce variation, the same person (GW) analysed all radionuclide ventriculography studies, blinded to all other patient information. Intravenous administration of stannous agent (Amersham Health, Buckinghamshire, UK) was followed 20 min later by 800 MBq of \(^{99m}\text{Tc}-\text{pertechnetate}. A left anterior oblique best-septal view, gated to the electrocardiogram, was acquired for a duration of 600 s. Sixteen frames per cardiac cycle were acquired. Midway through the acquisition, a 5 ml blood sample was withdrawn from the patient, using the opposite arm to that used to administer the \(^{99m}\text{Tc}-\text{pertechnetate}. After the acquisition was completed, but before moving the gamma camera, a small point source of \(^{99m}\text{Tc}\) was attached to the chest of the patient superimposed over the middle of the left ventricle. The persistence display of the gamma camera was used to aid in positioning. An electrocardiogram-gated anterior view was then acquired for 600 s. Following completion of the patient images, the blood sample was imaged for 600 s. All images were acquired using an ADAC Forte dual headed gamma camera (Philips Medical Systems, Eindhoven, Netherlands). The images were transferred to a Link Medical MAPS 10,000 computing system (Link Medical, Hampshire, UK) for analysis. Ejection fraction was calculated from the left anterior oblique best-septal image. Left ventricular volumes were calculated using the anterior marker view to estimate the required attenuation correction and the blood sample image to convert the left ventricular counts to volumes, as described by Link.

Data analysis

All analyses used commercially available software (SPSS\textsuperscript{®}). Two main analyses were undertaken, those with echo data \((n=307)\), and those with echo and radionuclide ventriculography data \((n=57)\). These two sets were further subdivided into studies taken during ventricular pacing vs. an intrinsic rhythm activation (sinus rhythm, atrial paced with intrinsic ventricular activation or atrial fibrillation). To test the hypothesis that abnormal left ventricular geometry associated with ventricular dilation or left ventricular systolic dysfunction would make M-mode data unreliable when compared to Simpson’s or radionuclide ventriculography ejection fraction, the groups were further analysed according to left ventricular end-diastolic diameter (above or below 60 mm) and ejection fraction (above or below 40%).

Ejection fraction derived from Simpson’s and Teicholz methods were compared with each other and with radionuclide ventriculography ejection fraction using Bland—Altman analysis,\textsuperscript{20} comparison between wall motion scoring and Simpson’s, Teicholz and radionuclide ventriculography ejection fraction used Pearsons’ correlation coefficient.

Bland—Altman plots are a scatter plot of the mean of two paired values on the x-axis (for instance the Simpson’s and Teicholz ejection in a subject) plotted against the difference of the two values. Multiple subjects allow a mean and ranges to be included. The upper limit being \(1.96 \times \text{the standard deviation, the lower limit is } -1.96 \times \text{standard deviation. The difference between the upper and lower limits represents the } \text{range of the Bland—Altman test; the narrower the range, in general terms, the better the level of agreement between observations. The scatter of} \)
the points also gives some inference of the type of error between the two values.

**Analysis of ‘eyeball’ LV function data**

The visual assessment and categorization of left ventricular function is a measure of the ability of the operator to group patients with similar degrees of reduction in ejection fraction into broadly similar categories. We hypothesised that the presence of septal dyssynchrony during pacing introduces discrepancy between the visual assessment of left ventricular function and the ejection fraction by Simpson’s technique or radionuclide ventriculography. To assess this we analysed the mean ejection fraction values in each category of eyeball assessment (none through to severe) and compared between pacing and intrinsic studies. Differences in the mean values would suggest over- or under-interpretation of left ventricular function. Mean values were compared using an independent sample $t$-test; a $p$ value of $<0.05$ was taken as statistically significant.

**Results**

M-mode echo quality was adequate in 96% of subjects and poor in 4%, two-dimensional echo quality was adequate in 93% and poor in 7%. Images were obtained from 160 (52%) patients in an intrinsic rhythm and 126 (41%) patients who were in a paced rhythm. Table 1 shows the mean ejection fraction or wall motion score for each technique. The radionuclide ventriculography data demonstrates the subset contained primarily patients with left ventricular systolic dysfunction. Simpson’s and Teicholz echo techniques gave mean values for ejection fraction 5% higher than radionuclide ventriculography ($p=0.003$).

**Comparison of echocardiographic techniques**

Despite similar averages and reasonable correlations, Bland–Altman analysis (Fig. 1) shows poor agreement between Simpson’s and Teicholz ejection fractions (Table 2). The Bland–Altman range (the ejection fraction % between the lower limit of agreement ($-1.96$ standard deviation) and the upper limit of agreement ($+1.96$ standard deviation)) comparing these techniques is wide at 56%, with a worsening of the level of agreement in the presence of pacing (intrinsic rhythm 52% vs. 61% ventricular pacing, $p=0.001$). In all subgroups the presence of ventricular pacing causes the Bland–Altman range to widen, suggesting reduced agreement between Simpson’s and Teicholz ejection fraction, most significantly in those with 'preserved' left ventricular function (ejection fraction $\geq 40\%$, $n=203$; intrinsic rhythm 52% vs. ventricular pacing 63%, $p=0.001$) and normal left ventricular diameters (left ventricular

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean $\pm$ SD for left ventricular ejection fraction (%) or wall motion assessment for each technique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All subjects with echocardiographic data ($n=307$)</td>
</tr>
<tr>
<td>Simpson’s bi-plane method (%)</td>
<td>46 $\pm$ 12.8 ($n=286$)</td>
</tr>
<tr>
<td>Teicholz method (%)</td>
<td>46 $\pm$ 17.2 ($n=295$)</td>
</tr>
<tr>
<td>Wall motion score</td>
<td>1.7 $\pm$ 0.4 ($n=239$)</td>
</tr>
<tr>
<td>RNV (%)</td>
<td></td>
</tr>
<tr>
<td>Intrinsic rhythm during study</td>
<td></td>
</tr>
<tr>
<td>Simpson’s bi-plane method (%)</td>
<td>47 $\pm$ 12 ($n=160$)</td>
</tr>
<tr>
<td>Teicholz method (%)</td>
<td>46 $\pm$ 17 ($n=164$)</td>
</tr>
<tr>
<td>Wall motion score</td>
<td>1.7 $\pm$ 0.4 ($n=133$)</td>
</tr>
<tr>
<td>RNV (%)</td>
<td></td>
</tr>
<tr>
<td>Paced during study</td>
<td></td>
</tr>
<tr>
<td>Simpson’s bi-plane method (%)</td>
<td>45 $\pm$ 14 ($n=126$)</td>
</tr>
<tr>
<td>Teicholz method (%)</td>
<td>46 $\pm$ 18 ($n=131$)</td>
</tr>
<tr>
<td>Wall motion score</td>
<td>1.7 $\pm$ 0.4 ($n=106$)</td>
</tr>
<tr>
<td>RNV (%)</td>
<td></td>
</tr>
</tbody>
</table>

The first column are patients with echocardiographic data, the second column those with echocardiographic and radionuclide ventriculography (RNV) data (predominantly patients with suspected left ventricular systolic dysfunction). * $p<0.05$.  


end-diastolic diameters < 60 mm, n = 235; intrinsic rhythm 53% vs. ventricular pacing 64%, \( p < 0.001 \)). In those with dilated left ventricles (end diastolic diameter \( \geq 60 \) mm, \( n = 61 \)), the Bland–Altman range was narrowest (48%), but still significantly poorer during paced beats (intrinsic rhythm 36% vs. ventricular pacing 52%, \( p < 0.001 \)). Analysis of those with dilated and impaired left ventricles improves the Bland–Altman range agreement to 40% (intrinsic rhythm 36% vs. 44% ventricular pacing, \( p = 0.04 \)), but represents only 37 (12%) of the original sample.

Wall motion index showed better correlation with Simpson’s than with Teicholz (\( r = 0.75 \) vs. 0.52
Effect of ventricular pacing

Table 2  The comparison of Simpson’s and Teicholz echocardiographic ejection fraction estimates

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean difference (%)</th>
<th>p value</th>
<th>r</th>
<th>Bland–Altman limits (%)</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.3</td>
<td>ns</td>
<td>0.58</td>
<td>28.5 to 27.8</td>
<td>56</td>
</tr>
<tr>
<td>Intrinsic rhythm</td>
<td>1.4</td>
<td>ns</td>
<td>0.63</td>
<td>27.4 to 24.7</td>
<td>52</td>
</tr>
<tr>
<td>Paced rhythm</td>
<td>−0.8</td>
<td>ns</td>
<td>0.5</td>
<td>29.8 to 31.4</td>
<td>61</td>
</tr>
</tbody>
</table>

**Stratified by left ventricular ejection fraction (LVEF)**

All subjects
- LVEF ≤ 40%: −1.8, ns, 0.36, 25.5 to 29.1, 55
- LVEF ≥ 40%: 1.3, ns, 0.3, 29.8 to 27.1, 56

Intrinsic rhythm
- LVEF ≤ 40%: 0.5, ns, 0.5, 26.6 to 25.5, 52
- LVEF ≥ 40%: 1.6, ns, 0.35, 27.7 to 24.5, 52

Paced rhythm
- LVEF ≤ 40%: 4.5, 0.04, 0.28, 23.6 to 32.6, 56
- LVEF ≥ 40%: 0.9, ns, 0.23, 32.3 to 30.6, 63

**Stratified by left ventricular end-diastolic diameter (LVEDD)**

All subjects
- LVEDD ≤ 60 mm: −0.9, ns, 0.6, 27.9 to 29.7, 58
- LVEDD > 60 mm: 5.0, 0.02, 0.63, 28.8 to 18.9, 48

Intrinsic rhythm
- LVEDD ≤ 60 mm: −0.6, ns, 0.53, 25.7 to 26.9, 53
- LVEDD > 60 mm: −8.9, < 0.001, 0.76, 27.6 to 8.9, 36

Paced rhythm
- LVEDD ≤ 60 mm: −1.4, ns, 0.5, 30.7 to 33.4, 64
- LVEDD > 60 mm: 0.5, ns, 0.6, 26.5 to 25.5, 52

The mean difference between the two techniques, correlation coefficient, Bland–Altman limits of agreement and range (equal to 2×1.96 standard deviations) for the comparison of left ventricular ejection fraction between Simpson’s and Teicholz methods in all subjects, ventricularly paced subjects, intrinsically activated subjects, impaired systolic function (ejection fraction ≥ 40%) and dilated/non-dilated left ventricle (end-diastolic diameter > or ≤ 60 mm) during the study.

in all subjects), in paced (r = 0.66 vs. 0.52) and intrinsic rhythm subgroups (r = 0.83 vs. 0.66). From the 160 patients with images taken in intrinsic rhythm, 35 (22%) have a QRS duration of > 120 ms on their ECG. Subgroup analysis of these patients with the remaining patients from the intrinsic rhythm group showed no statistically significant differences between different types of ejection fraction measurement.

**Comparison with radionuclide ventriculography**

Wall motion index showed the highest correlation with radionuclide ventriculography (all, r = 0.58; intrinsic rhythm, r = 0.66; ventricular pacing, r = 0.52) followed by Simpson’s ejection fraction (all, r = 0.52; intrinsic rhythm, r = 0.53; ventricular pacing, r = 0.57) then Teicholz ejection fraction (all, r = 0.49; intrinsic rhythm, r = 0.49; ventricular pacing, 0.56), the correlation between wall motion index and radionuclide ventriculography ejection fraction reducing in the presence of ventricular pacing. Bland–Altman plots (Fig. 1) show the narrower range for Simpson’s ejection fraction vs. radionuclide ventriculography ejection fraction (22.5% to −13.6%, 4× standard deviation = 36%), compared to Teicholz ejection fraction vs.
radionuclide ventriculography ejection fraction (18.4% to −27.4%, 4× standard deviation=46%, \( p=0.02 \)). The agreement between Simpson’s ejection fraction and radionuclide ventriculography ejection fraction by Bland–Altman is relatively unaffected by pacing (intrinsic rhythm 17.8% to −15.4%=33% vs. ventricular pacing 24% to −10%=34%, \( p=\text{ns} \)) compared to Teicholz ejection fraction and radionuclide ventriculography ejection fraction (intrinsic rhythm 21% to −21%=42% vs. ventricular pacing 33% to −14%=47%, \( p=0.04 \)).

**Discussion**

In patients with pacemakers, heart failure or suspected heart failure is common\(^4\); consequently, the need to assess left ventricular function initially

<table>
<thead>
<tr>
<th>Table 3</th>
<th>The mean ejection fraction±1 standard deviation by Simpson’s echocardiographic method and radionuclide ventriculography for each category of LV impairment by ‘eyeball’ estimate of LV function (radionuclide ventriculography (RNV) groups with less than five subjects is not shown)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (%)</td>
<td>IR (%)</td>
</tr>
<tr>
<td>None ((n=118))</td>
<td>55±8</td>
</tr>
<tr>
<td>Trivial ((n=51))</td>
<td>51±6</td>
</tr>
<tr>
<td>Mild ((n=33))</td>
<td>47±8</td>
</tr>
<tr>
<td>Mild/moderate ((n=35))</td>
<td>37±7</td>
</tr>
<tr>
<td>Moderate ((n=38))</td>
<td>33±7</td>
</tr>
<tr>
<td>Moderate/severe ((n=12))</td>
<td>27±9</td>
</tr>
<tr>
<td>Severe ((n=13))</td>
<td>21±7</td>
</tr>
<tr>
<td>MILD/moderate RNV ((n=12))</td>
<td>31±9</td>
</tr>
<tr>
<td>Moderate RNV ((n=19))</td>
<td>29±7</td>
</tr>
<tr>
<td>Moderate/severe RNV ((n=10))</td>
<td>25±8</td>
</tr>
<tr>
<td>Severe ((n=13)) RNV ((n=13))</td>
<td>15±5</td>
</tr>
</tbody>
</table>

Mean difference and \( p \) value is between intrinsic rhythm (IR) and ventricularly paced rhythm (VP).
and repeatedly often arises. Identification or exclusion of systolic dysfunction as a cause of symptoms has important prognostic and therapeutic implications. Usually cardiac function is assessed by echo or radionuclide ventriculography, as MRI is contra-indicated for routine use due to the ferromagnetic pacemaker. It is important to know how interchangeable the results from each technique are, and how each is influenced by the presence of ventricular pacing and the resultant inter- and intra-ventricular dysynchrony.

Simpson’s and Teicholz M-mode echo techniques for calculating ejection fraction show similar means, both slightly higher than radionuclide ventriculography, but show poor agreement with each other on Bland—Altman analysis. The level of agreement deteriorates significantly in the presence of ventricular pacing, particularly in those with a non-dilated or well-preserved left ventricular function. Septal paradoxical motion due to pacing is likely to be the cause for this, making M-mode point measurements taken from the septum very unrepresentative of the whole of the left ventricle. In those with dilated poorly functioning ventricles overall movement is less, so the error between the two techniques is less, but still considerable. Simpson’s method showed better agreement with radionuclide ventriculography than Teicholz, particularly in the context of pacing, with little increase in the Bland—Altman range for Simpson’s with pacing, but a significant increase with Teicholz. The ranges seen are very consistent with other studies on non-paced subjects, which have shown better agreement between radionuclide ventriculography and MRI than echo and MRI. These data show that the ejection fraction by 2D Simpson’s matches more closely the ejection fraction from radionuclide ventriculography than the ejection fraction from M-mode Teicholz, and is less prone to error in the presence of ventricular pacing. Wall motion scoring potentially is less prone to error due to septal paradoxical motion as each segment is analysed separately, the data however show that despite reasonable correlation with radionuclide ventriculography the technique still loses some correlation in subjects who are pacing.

The accuracy of ‘eyeball’ assessment of ventricular function by virtue of being subjective is difficult to gauge. The mean ejection fraction in each successive group is lower, as expected, and in those with preserved left ventricular function is well matched whether pacing or non-pacing. In the groups with moderate or greater degrees of left ventricular impairment on ‘eyeball’, differences in the mean ejection fraction values arise with the presence of ventricular pacing, with a significant difference in the severely impaired group. The data show that in the groups with significant ventricular impairment, for a given ejection fraction an observer will tend to appoint a lesser degree of left ventricular impairment on ‘eyeball’ when a subject is pacing. As this effect is only present in those with marked degrees of left ventricular impairment in practice this is unlikely to have much clinical significance. The large spread of ejection fraction within each group measured by echo or radionuclide ventriculography shows the difficulty of even an experienced operator to broadly group similarly impaired ventricles, suggesting the technique is too imprecise to be relied upon solely, with or without ventricular pacing.

The results show that assessment of ejection fraction by the main techniques available in paced subjects are poorly interchangeable, with the two most commonly used echocardiographic methods of deriving the ejection fraction giving values higher than radionuclide ventriculography. In addition, all of the echocardiographic techniques studied appear to lose accuracy in comparison with radionuclide ventriculography in the presence of ventricular pacing. This has important implications, making less safe decisions based on studies performed during ventricular pacing, and making follow up studies in the same patient very difficult to compare if taken in different rhythms. The data show that particularly if M-mode estimates of the ejection fraction are used then differences in the calculated ejection fraction, depending on the rhythm, can be sufficiently large to be clinically very relevant. Simpson’s bi-plane method from 2D echo shows the best agreement with radionuclide ventriculography with or without ventricular pacing. A very high proportion of patients in this study gave images of sufficient quality to allow the accurate endocardial border delineation necessary for Simpson’s method. This high proportion is in contrast to other studies comparing these techniques and likely due to the fully digital acquisition and analysis of images avoiding the loss of clarity inherent in videotape.

Left ventricular ejection fraction, measured by the techniques routinely available in this important group of patients are poorly interchangeable. Each echocardiographic technique is subject to additional error introduced by the presence of ventricular pacing particularly if M-mode techniques are used, Simpson’s 2D method appears less vulnerable. When appraising echocardiographic data in paced subjects consideration should be given to not only the technique employed, but also the underlying rhythm at the time of the study.
Limitations

The radionuclide ventriculography subset contained primarily patients with LV systolic dysfunction, selected to confirm the clinical and echocardiographic suspicion of LV systolic dysfunction. These patients were not a representative random sample of the study population, however, as this is very often the target for an echo, we feel that comparison between radionuclide ventriculography and echo is valid. Echo and nuclear studies were not performed on the same day, possibly leading to a small amount of day to day variation. There is also the possibility that the RNVG projections used may slightly underestimate posterior wall dyskinesia, however, in the authors’ practice this is rare.

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