Baseline Left-Ventricular Function During Frequent Ventricular or Atrial Ectopic Beats: Concise Communication

V. Kalff, M. A. Rabinovitch, W. Chan, W. O'Neill, J. Stewart, J. Walton, B. Pitt, and J. H. Thrall

University of Michigan, Ann Arbor, Michigan

This radionuclide study demonstrates that the quantitative indices of left-ventricular function derived during sinus rhythm (such as ejection fraction, relative end-systolic volume, and relative end-diastolic volume) are not altered during frequent atrial ectopic beats, and are only minimally changed during frequent ventricular extrasystoles.

J Nucl Med 23: 1076–1079, 1982

Radionuclide ventriculography has become an important noninvasive tool for assessing various forms of heart disease (*1–4*). Although the various indices of ventricular function obtained by the equilibrium gated blood-pool technique have been validated for patients in sinus rhythm (*5*), one of the major problems with this technique has been the difficulty in assessing myocardial functions in the presence of frequent atrial or ventricular premature beats. It has been demonstrated that the underestimation of radionuclide ejection fraction caused by the inclusion of the ectopic-beat data, increase linearly as the frequency of ectopic beats increases (*6*). With the introduction of ECG-gated list-mode data aquisition (*7*) and off-line arrythmia-filtering algorithms (*8*), the sinus-beat data can now be separated from data derived from both the ectopic beats and those potentiated by following them, thereby allowing measurement of ventricular function during only the sinus beat. To be able to fully assess the significance of baseline ventricular function and its response to interventions such as exercise, it is important to establish that findings obtained during such arrythmias, ostensibly assessing base-line ventricular function, are not significantly different from those obtained when the patient is in sinus rhythm.

This study was therefore designed to examine the effect of frequent ventricular or atrial extrasystoles on the sinus-beat function by artificially inducing atrial or ventricular trigeminy and then comparing the quantitative measures of left-ventricular function obtained during these stimulation studies with those obtained from a preliminary radionuclide study with the patient in sinus rhythm.

Received April 27, 1982; revision accepted Aug. 4, 1982.

For reprints contact: James H. Thrall, MD, Dept. of Nucl. Med., University of Michigan, Ann Arbor, MI 48105.

METHODS

The protocol for this study was approved by the University of Michigan Hospital Ethics Committee. The population studied was taken from a series of patients who were to have cardiac catheterization as part of their cardiovascular evaluation. Five women and five men gave informed consent. The mean age of this group was 54 yr (range 36 to 68). The various diagnoses, and concurrent medications, are listed in Table 1. The patients on cardioactive drugs had these medications maintained until the time of study. The stimulation protocol commenced immediately following an uncomplicated cardiac catheterization. Two No. 4 French catheters were inserted into the venous access used for the cardiac study. One was advanced to the apex of the right ventricle, the other into a stable position somewhere in the right atrium. The patient was then intermittently paced through these electrodes to stimulate a trigeminal rhythm. This was first performed in the catheterization laboratory to ensure stable position of these electrodes and also to eliminate those patients who gave coupled premature beats induced by such stimulation. The coupling interval

TABLE 1. PATIENT DATA

Patient	Age	Sex	Disease	Therapy
1	54	male	CAD	N,B
2	47	male	none	—
3	58	male	CAD	N,B
4	50	female	CAD	N
5	68	female	CAD	N
6	45	male	CAD	N,B
7	53	female	MYO	N
8	61	male	CAD	—
9	63	female	none	N,B
10	36	female	none	—

CAD = coronary artery disease.
MYO = cardiomyopathy.
N = nitrates.
B = beta blockers.

of the ventricular premature beats, in particular, was chosen to be relatively long so as to avoid the possibility of inducing a sustained ventricular arrhythmia during the vulnerable period. Once stable capture was obtained from both pacing sites, the patient was transferred to the Nuclear Cardiology Suite. Each received an intravenous dose of stannous pyrophosphate and, 20 min later, an intravenous dose of 25 mCi of [Tc-99m] pertechnetate to label red blood cells in vivo. About one hour after the last contrast injection, standard two-minute, equilibrium-gated radionuclide angiography was performed in the modified left anterior oblique projection using a portable gamma camera with a high-sensitivity, low-energy, parallel-hole collimator. Radionuclide data were collected on a computer with a large multiplatter storage disk facility. A lead shield was used to reduce the scanning area to a region of interest 20 cm in diameter. This was done to reduce the contribution of extracardiac activity, since subsequent list-mode data aquisition requires a large amount of computer storage space and nontarget background is a limiting factor in such studies.

Following the preliminary equilibrium-gated radionuclide study, the patient was intermittently stimulated with a pacing apparatus to simulate a trigeminal rhythm for two periods of ten minutes, fifteen minutes apart. During one period, atrial trigeminy was stimulated, and during the other ventricular trigeminy with an identical coupling interval was stimulated. The order of stimulation was randomized to ensure elimination of any lingering effects of contrast ventriculography. During each period of stimulation, radionuclide ventriculographic data were collected in ECG-gated list mode, and the ECG was recorded for later assessment of R-R coupling intervals. The duration of stimulation was chosen such that there were at least 3 min of resumed sinus-beat data available for analysis. At the end of the stimulation period, the pacing wires were withdrawn and hemostasis obtained by application of constant pressure. No complications occurred as a result of this study; in particular, no sustained re-entry arrhythmias were induced.

RADIONUCLIDE DATA ANALYSIS

Each serial-mode study was reformatted after data collection to obtain an R-R histogram (Fig. 1). From its inspection the group of beats with the shortest R-R intervals were seen to represent the interrupted sinus beat. By setting the R-R limits around this group, the serial mode was then again reformatted to create a single composite cardiac cycle representing the interrupted sinus beat.

All data were then analyzed, blind, by an observer who calculated the ejection fraction and the end-systolic and end-diastolic left-ventricular counts for each study. A modified second-derivative edge method (*9*) was used to define the left-ventricular regions of interest for each frame of the cardiac study. The count data were corrected for frame duration and radioactive decay to calculate relative end-diastolic and end-systolic volumes for each study. These volumes were expressed as percentages of the respective baseline volumes (*10*).

The ECG monitor strips were analyzed to determine the R-R intervals of each type of beat obtained. For the purposes of this work, the R-R interval of the post-extrasystolic, potentiated beat in the trigeminal sequence was assumed to represent the intrinsic sinus rate for that study.

Statistical analysis was performed for all data groups using the paired t-test. All data are expressed as mean ± 1 standard deviation, except where indicated.

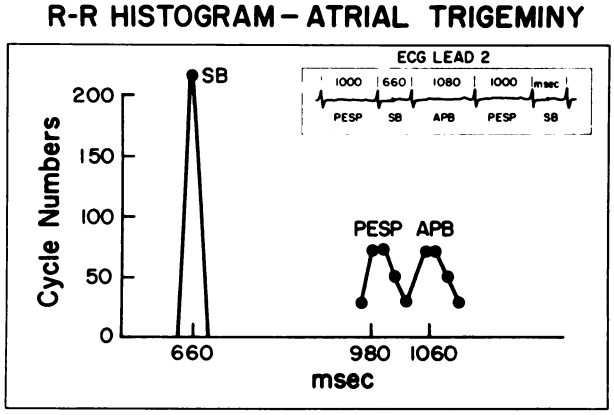

FIG. 1. R-R histogram derived from atrial-stimulation study of Patient 1 shows three groups of beats. From accompanying ECG rhythm strip it can be seen that the group with shortest R-R interval represents the interrupted sinus beat (SB), the group with longest R-R interval represents the atrial premature beat (APB) followed by its compensatory pause, and the group with intermediate R-R interval represents the post-extrasystolic potentiated beat (PESP). Intermediate R-R interval is used to define intrinsic heart rate.

TABLE 2. INDICES OF SINUS-BEAT LEFT-VENTRICULAR FUNCTION

Pt. No.	Ejection fraction (%) during			Relative EDV[X] during			Relative ESV[X] during			Intrinsic sinus rate R-R internal (msec)		
	Prelim study	Ventric stim	Atrial stim	Prelim study	Ventric stim	Atrial stim	Prelim study	Ventric stim	Atrial stim	Prelim study	Ventric stim	Atrial stim
1	65	66	67	—	125	131	—	111	113	1040	1016	1070
2	70	64	65	—	102	111	—	122	129	980	960	980
3*	69	69	66	—	106	90	—	93	108	1110	1030	1120
4	42	40	41	—	102	92	—	106	94	880	840	840
5*	63	54	57	—	86	83	—	110	98	980	890	980
6	40	39	34	—	99	98	—	101	108	720	690	750
7	27	28	33	—	119	100	—	127	104	560	530	550
8*	68	66	69	—	94	95	—	98	90	900	890	950
9*	57	58	60	—	125	111	—	123	104	950	930	960
10	60	60	64	—	93	91	—	93	82	770	730	810
Mean ± s.d.	56 ± 14	54 ± 14	56 ± 15	—	105 ± 14	100 ± 14	—	108 ± 12	103 ± 13	890 ± 100	850 ± 100	900 ± 17
P† =	—	N.S.	N.S.	—	N.S.	N.S.	—	P <0.05	N.S.	—	P <0.01	N.S.

* First stimulation study gave atrial trigeminy

† P = P value obtained from paired t-test comparing the values obtained from the preliminary study and those obtained from the stimulation study.

Ventric stim = ventricular-stimulation study.

EDV = end-diastolic volume.

Atrial stim = atrial-stimulation study.

ESV = end-systolic volume.

X = relative volumes expressed as percentage of volume obtained during preliminary (prelim) study.

RESULTS

Table 2 shows a comparison of the quantitative indices of sinus-beat left-ventricular function observed during the preliminary, atrial-, and ventricular-stimulation studies. Note that there was no significant difference in the ejection fractions for the sinus beats of each study, although the mean ejection fraction for the sinus beat of the ventricular premature stimulation study, (54 ± 14)%, was slightly lower than that obtained from the preliminary study, (56 ± 14)%, and from the sinus beat of the atrial-stimulation study, (56 ± 14)%. Similar findings occurred for the relative end-diastolic volumes. The values obtained from the sinus beat of the atrial-stimulation study, (100 ± 14)%, and preliminary study (100%) were the same; both appeared slightly smaller than the relative end-diastolic volumes obtained during the ventricular-stimulation study, (105 ± 14)%, but the differences were not statistically significant.

In contrast, the mean relative end-systolic volume of the sinus beat from the ventricular-stimulation study, (108 ± 12)%, was significantly greater ($p < 0.05$) than that obtained for the sinus beat of the preliminary study. However, although it also appeared greater than the relative end-systolic volume obtained during the sinus beat of the atrial-stimulation study, (103 ± 14)%, this did not quite reach statistical significance. The intrinsic R-R intervals did show significant differences between studies. While they were the same for the atrial-stimulation study (900 ± 170 msec) and the preliminary study (890 ± 160 msec), they were significantly longer ($p < 0.01$) than those obtained from the ventricular-stimulation study (850 ± 160 msec). Thus the intrinsic heart rate was significantly higher for a ventricular extrasystole.

DISCUSSION

This study demonstrates that quantitative sinus-beat left-ventricular function as measured by radionuclide ventriculography is not significantly altered by frequent atrial ectopic beats, and only minimally altered by frequent ventricular extrasystoles. An explanation for the sinus-beat changes induced by ventricular extrasystoles includes the possibility that it causes a greater reduction in cardiac output than atrial extrasystole, and the following post-extrasystolic, potentiated beats are unable to augment cardiac output sufficiently to compensate for this. This results in a baroreceptor-mediated compensatory increase in the heart rate. The mechanism for this increase almost certainly involves a decrease in overall vagal tone controlling the sinoatrial node, because there are no accompanying changes in ventricular contractility that would be expected if compensation was mediated through an alteration in sympathetic tone (*11*).

Although the premature beats in this study were induced artificially, they functionally mimic the atrial or ventricular extrasystoles commonly seen in clinical practice. Intermittent pacing allows the frequency of these ectopic beats to be increased to a rate that is the maximum for which list-mode radionuclide data acquisition can be made, thereby giving the best chance of inducing any alteration of ventricular function, should this occur.

Our results indicate that, under ECG-gated list-mode acquisition, sinus-beat left-ventricular function can be measured in the presence of frequent extrasystoles, and the quantitative values obtained in any individual patient are essentially the same as those where the patient is in sinus rhythm. Although it is true that there are group differences in some indices of function during ventricular extrasystoles, the changes in individual patients are less than the intrinsic variability of the techniques used.

ACKNOWLEDGMENTS

The authors thank Joanne Boldt for typing the manuscript.

Dr. Kalff is supported by an Australian Heart Foundation Travel Grant. Dr. Rabinovitch is supported by a Canadian Heart Foundation Grant.

REFERENCES

1. ZARET VL, STRAUS HW, HURLEY PM, et al: A noninvasive scintiphotographic method for detecting regional ventricular dysfunction in man. *N Engl J Med* 284:1165-1170, 1971
2. BERGER HJ, ZARET BL: Medical progress: Nuclear Cardiology Pt II. *N Engl J Med* 305:855-865, 1981
3. OKADA RD, BOUCHER CA, STRAUSS HW, et al: Exercise radionuclide imaging approaches to coronary artery disease. *Am J Cardiol* 46:1188-1204, 1980
4. THRALL JH, PITT B, BRADY JT: Radionuclide wall motion study and ejection fraction in clinical practice. *Med Clin N Am* 64:99-117, 1980
5. BACHARACH SL, GREEN MU, BORER JS, et al: Beat-to-beat validation of ECG gating. *J Nucl Med* 21:307-313, 1980
6. BRASH HM, WRAITH PK, HANNAN WJ, et al: The influence of ectopic heart beats in gated ventricular blood pool studies. *J Nucl Med* 21:391-393, 1980
7. BACHARACH SL, GREEN MV, BORER JS, et al: A real-time system for multi-image gated cardiac studies. *J Nucl Med* 18:79-84, 1977
8. KALFF V, CHAN W, RABINOVITCH MA, et al: Radionuclide evaluation of post-extrasystolic potentiation of left ventricular function induced by atrial and ventricular stimulation. *Am J Cardiol* (in press)
9. BRADY T, LO K, THRALL JH, et al: Exercise radionuclide ejection fraction: Correlation with exercise contrast ventriculograpy. *Radiology* 132:703-705, 1979
10. KALFF V, KELLY MJ, JENNINGS GL, et al: The radionuclide assessment of left ventricular function using graded exercise in normal subjects. *Aust and N Z J Med* 10:533-539, 1980
11. RANDALL WC: Neural regulation of the heart. New York, Oxford University Press, 1977, pp 43-157