The Effects of Gating Delays on Ejection Estimates: Concise Communication

Thomas A. Powers, Robert D. Bowen, Ronald R. Price, and James A. Patton

Veterans Administration Medical Center and Vanderbilt University Hospital, Nashville, Tennessee

We have examined the effects of gating delays on the left-ventricular ejection fraction as measured by gated blood-pool studies. Patients with normal ventricular function were shown to have greater errors introduced by gate delays than those with poor function. The magnitude of the error depends on the shape of the ventricular time-activity curve. Actual delay measurements were performed on several commercial gates.

J Nucl Med 23: 15–16, 1982

Although not generally appreciated, all EKG gating devices have an intrinsic delay between the time that the R wave is sensed and the time that the gating signal occurs. Preliminary testing has revealed gating delays of up to 100 msec between the time the R wave occurs and the time computer acquisition begins. In a phantom study, Wery et al. determined that delays of this magnitude can decrease the calculated ejection fraction by up to 14% at heart rates of 160 per minute.* We undertook to extend this study to humans and to test several commercially available devices.

MATERIALS AND METHODS

Clinical studies. Gating delays in nine human subjects were simulated by collecting radionuclide ventriculograms in list mode and reformatting the data into 40-msec frames, omitting the first 10, 20, 30, 40, and 50 msec of data following the R wave. These studies were performed using a gating device whose delay had previously been determined to be 2 msec at a heart rate of 180/min. Four of the patients had ejection fractions less than 0.50 (range 0.27–0.46) and five had ejection fractions greater than 0.50 (range 0.61–0.80). Of the five with normal ejection fractions, three were exercise studies.

Gate measurements. Four commercial EKG gating devices were studied: Hewlett-Packard Model 1505A, American Optical, Brattle, and Electronics for Medicine. An EKG simulator† was used to trigger the gate being tested. Outputs from the simulator and the gate were displayed simultaneously on a dual-channel oscilloscope, which permitted measurement of any delay introduced by the gate. Each gate was tested at simulated heart rates of 60, 120, 180, and 240 per minute.

RESULTS

Patient study. Table 1 shows the experimental results in the human study. In none of the four patients with ejection fractions less than 0.50 was the absolute difference between 0 delay and 50 msec delay greater than 0.04. In the two patients studied at rest with ejection fractions greater than 0.60, this difference was 0.01 and 0.10, respectively, at 50 msec. Two of the three exercise studies had differences of 0.15 and 0.17, while the third had only 0.05 at 50 msec delay.

When the 10-msec delay is examined, the greatest difference in any of the six rest studies was 0.02. In the three exercise studies the maximum error was 0.04.

Gate measurements. Table 2 summarizes the results of the gate measurements. At clinically attainable heart rates, only the American Optical gate exhibited delays of greater than 2 msec. The Electronics for Medicine gate apparently triggers on the upslope of the R wave, thus accounting for its occurrence before the peak of the R wave.

Received Mar. 24, 1981; revision accepted Sep. 4, 1981.

For reprints contact: T. A. Powers, Nuclear Medicine Service, Veterans Administration Medical Center, 1310 24th Avenue South, Nashville, TN 37203.

TABLE 1. PATIENT EJECTION FRACTIONS

Patient	Heart rate	Gate delay (msec) 0	10	20	30	40	50
GR	75	0.27	0.27	0.26	0.25	0.25	0.25
IR	62	0.27	0.27	0.26	0.25	0.25	0.24
WB	77	0.38	0.37	0.36	0.36	0.36	0.35
KH	62	0.46	0.46	0.45	0.43	0.42	0.42
RC	73	0.67	0.68	0.67	0.65	0.65	0.66
RS	73	0.68	0.66	0.64	0.63	0.61	0.58
RB*	128	0.61	0.58	0.55	0.52	0.48	0.44
BG*	130	0.69	0.65	0.62	0.60	0.57	0.54
LS*	120	0.80	0.79	0.78	0.77	0.76	0.75

* Exercise studies.

TABLE 2. GATE DELAYS (msec)

Manufacturer	Simulated heart rates 60	120	180	240
Hewlett-Packard	0	0	0	4
Brattle	0	2	2	5
American Optical	9	9	9	40
Electronics for Medicine	−2	−2	−2	−2

DISCUSSION

Radionuclide ventriculography has become an important, noninvasive technique for the assessment of cardiac function. Implicit in the assumptions of this method is the constant relationship between the R wave and end-diastole. Delay between the actual electrical event and its detection by the computer will result in a shift of the perceived R wave from its actual location. Since the maximum counts in the left ventricle are then artifactually decreased, the calculated ejection fraction will be lower than the actual ejection fraction. It is intuitively apparent that the magnitude of this error depends on the slope of the volume curve in early systole. That is, the more rapidly the ventricle empties, the greater will be the effect of gate delay. This is illustrated by Patient BG whose time-activity curve is shown in Fig. 1. Even with a delay as short as 10 msec there is a significant drop in ejection fraction (0.69 → 0.65) in this patient with normal ventricular function. This is especially pronounced at higher heart rates, e.g., during exercise as in this patient. Conversely, patients with poor ventricular function will have less pronounced effects related to gate delays. This is demonstrated by Patient GR, whose time-activity curve is shown in Fig. 2. Even with a delay as long as 50 msec there is very little change in ejection fraction (0.27 → 0.25).

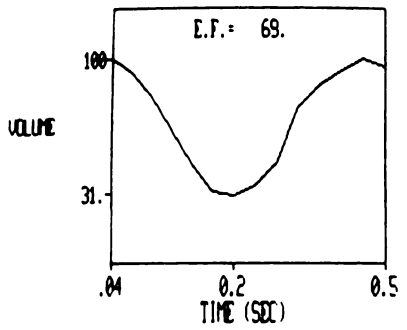

FIG. 1. Computer-generated time-activity curve of Patient BG. Notice relatively steep slope of curve in early systole.

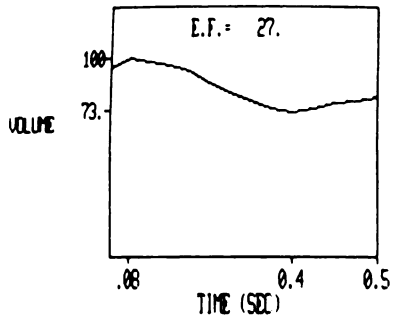

FIG. 2. Computer-generated time-activity curve of Patient GR. Notice relatively flat slope of curve in early systole.

In summary, gating delays will cause the greatest artifactual depression of ejection fraction in patients with normal ventricular function. These effects will be most pronounced at rapid heart rates, as during exercise studies. Each laboratory performing cardiac blood-pool studies should determine the delay introduced by its own gate.

FOOTNOTES

* R Wery, HJ Dworkin, JC Hill: Reduced calculated ejection fraction in multiple gated acquisition techniques due to ECG gating delay. Scientific exhibit, 27th Annual Meeting, Society of Nuclear Medicine.

† ECG Performance Tester, Model EH-5D, Biohio Systems Co., Columbus, OH.