The Left Ventricular Ejection Time in Elderly Subjects

By Jos L. Willems, M.D., Jos Roelandt, M.D., Hilaire De Geest, M.D., Hugo Kesteloot, M.D., and Jozef V. Joossens, M.D.

SUMMARY
The left ventricular ejection time (LVET) was studied by means of the carotid artery tracing in 512 elderly subjects (205 male and 307 female) who were between 60 and 90 years old (mean age, 70.5 years). A highly significant correlation was found between heart rate (HR) and LVET. The data on these aged subjects were compared and analyzed with the results previously reported concerning young and middle-aged adults. A small but significant increase of LVET with aging, independent of changes in HR and blood pressure, could be demonstrated by multiple regression analysis. A statistically significant difference existed between the sexes. The influence on LVET of parameters other than HR was small.

Additional Indexing Words:
Aging
Afterload
Ischemic heart disease
Carotid artery pulse
Phonocardiography

STUDIES concerning the relationship between left ventricular ejection time (LVET) and heart rate (HR) in older subjects are relatively scarce, and contradictory results have been reported on the influence of aging on LVET. 1-5

Until now no LVET data on a large number of healthy elderly persons, living in normal conditions, have been reported in the literature. Since the mean age of the ordinary hospital population is above age 60 and since it is especially at this age that atraumatic and simple methods for cardiac evaluation are needed, our study is mainly intended to be a source of data on ejection times in the older age group.

Regression formulae and regression lines for the prediction of normal ejection times were presented by several authors. 1, 2, 6-11 The purpose of the present study was to examine if these regression lines, based on the study of young and middle-aged adults, are also valid for older subjects. The influence of other factors besides HR on LVET was also analyzed.

Methods

The present investigation was part of an epidemiologic study of 515 middle-class elderly persons, all over age 60, living under normal conditions at home. One patient with complete heart block was excluded, and the carotid tracings of two subjects were not available. The final group studied consisted of 512 subjects, 205 men with a mean age of 71.8 (SD, 5.0) and 307 women with a mean age of 69.8 (SD, 5.4) years.

The questionnaire about cardiovascular symptoms and smoking habits designed and tested at the London School of Hygiene and Tropical Medicine was used. 12 Additional information was obtained about social and living conditions, other diseases, and medication. Digitalis was taken by

From the Division of Cardiology, Department of Medicine, and The Department of Epidemiology, School of Public Health, University of Leuven, Belgium.

Supported in part by grants from the Ministry of Health, the F. W. G. O., Brussels, and by World Health Organization Research Training Grant M8/181.

Address for reprints: J. V. Joossens, M.D., Chief, Cardiology Division, Academic Hospital, Capucijnenvoer, 35, Leuven, Belgium.

Received December 29, 1969; revision accepted for publication March 17, 1970.

Circulation, Volume XLII, July 1970
Table 1
Relationship Between Heart Rate (HR) and Left Ventricular Ejection Time (LVET) in the Total Group

<table>
<thead>
<tr>
<th></th>
<th>Mean HR Number (beats/min)</th>
<th>Mean LVET (msec)</th>
<th>Regression equation</th>
<th>r</th>
<th>SEv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>512</td>
<td>74.7</td>
<td>299.0 (13.7)</td>
<td>-0.75</td>
<td>19.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(28.7)</td>
<td>LVET = 416 - 1.56 HR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>205</td>
<td>69.4</td>
<td>300.6 (11.8)</td>
<td>-0.78</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(28.9)</td>
<td>LVET = 434 - 1.93 HR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>307</td>
<td>78.3</td>
<td>297.0 (13.8)</td>
<td>-0.77</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(28.5)</td>
<td>LVET = 422 - 1.58 HR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The values in parentheses represent standard deviations.
Abbreviations: r = correlation coefficient; SEv = standard error of estimate of LVET.

8.4% of the subjects (10.2% of the males and 7.1% of the females), and 13.8% of the subjects (9.2% of males and 16.8% of the females) received antihypertensive drugs or diuretics.

All subjects underwent a complete physical examination. Six men and three women presented clinical signs of heart failure. Recommendations of the WHO were followed for the measurement of blood pressure in the supine position. The mean systolic blood pressure was 158.1 (sd, 27.3) mm Hg in males and 170.1 (sd, 30.9) mm Hg in women. The diastolic blood pressure, phase five, amounted to 86.7 (sd, 12.7) mm Hg in men and 90.1 (sd, 14.2) mm Hg in women.

Magnesium sulfate was used to measure the arm-to-tongue circulation time (CT). The maximal transverse heart diameter and cardiothoracic ratio were measured on standard chest x-rays. The electrocardiograms, recorded by a direct-writing Elema-Mingograph 31-B recorder, were interpreted using the Minnesota code. Atrial fibrillation was present in seven men and in six women and left bundle-branch block in three males and in two females. The mean P-R interval of subjects in sinus rhythm was in the normal range.

The duration of the left ventricular ejection was derived from the indirect carotid artery tracing. LVET was defined as the interval between the beginning of the upstroke and the trough of the incisura. The pulse signals were recorded between 10 a.m. and 12:30 p.m. by means of an Elema plethysmograph with a time constant of 1.2 sec, the subjects being in the supine position and with held respiration. The paper speed was 100 mm/sec. In each case, the mean of at least five consecutive measurements was calculated. All intervals were measured to the nearest 0.005 sec. The intervals are expressed in milliseconds and the HR in beats per minute.

All the data were fed into an IBM 360-40 computer. Statistical calculations and Student's t-tests were performed according to Snedecor. Standard terminology is used. Differences between regression lines were tested according to Hald.

Results

Relationship Between Heart Rate and Left Ventricular Ejection Time

The mean values and standard deviations for LVET and the corresponding HR for the total group and for men and women separately are represented in table 1. The regression equations relating LVET to HR are shown in the same table.

A highly significant correlation was found between HR and LVET. The slopes of the linear regression equations for men and women were statistically different (P < 0.01).

![Figure 1](http://circ.ahajournals.org/)

The linear regression lines relating left ventricular ejection time (LVET) to heart rate in young and old subjects.
Table 2

Multiple Regression Analysis of LVET (Y) in Function of Heart Rate (HR), Age (A), and Systolic Blood Pressure (SP) in the Combined Group of Young and Old Subjects

<table>
<thead>
<tr>
<th>No.</th>
<th>Y = 374 - 1.497 HR + 0.205 A + 0.147 SP</th>
<th>r</th>
<th>se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>742</td>
<td>(0.052)</td>
<td>(0.042)</td>
</tr>
<tr>
<td>Men</td>
<td>399</td>
<td>T = 392 - 1.539 HR + 0.156 A + 0.038 SP</td>
<td>(0.064)</td>
</tr>
<tr>
<td>Women</td>
<td>343</td>
<td>Y = 370 - 1.494 HR + 0.276 A + 0.153 SP</td>
<td>(0.057)</td>
</tr>
</tbody>
</table>

At all heart rates, LVET was statistically longer in women than in men (P < 0.001). The difference between the ejection time of both sexes at the mean HR of the total group (74 beats/min) was 12.9 msec, which is 4% of the observed LVET at that HR.

Effect of Age

The LVET of the elderly subjects was compared to that previously published for 218 normal young men, with a mean age of 34 (sd, 10) years and mean HR of 72, and 70 normal young women with a mean age of 23.5 (sd, 4.5) years and mean HR of 87.10. As heart failure and digitalis are well known causes of shortening of LVET, elderly subjects with clinically manifest heart failure and those who used digitalis were excluded for this comparison. The calculated regression lines of these younger and older subjects are depicted in figure 1. The coefficients of the regression lines relating LVET to HR in the younger and elderly subjects were statistically different. At heart rates up to 85/min, the mean LVET of the older group was statistically longer than that of the younger group. At heart rates over 90/min the mean LVET of the elderly group seemed to be shorter; this difference, however, was not significant. Only 18% of the total population, 9% of the male and 24% of the female, had heart rates over 90/min. Furthermore it is likely that any subjects with subclinical heart failure would be found in the high HR group.

To rule out the influence of blood pressure, which was significantly higher in old than in young subjects, 158/87 mm Hg versus 132/80 in men and 170/90 mm Hg versus 126/76 in women, multiple regression analysis was performed on the pooled data of both groups (table 2). Taking into account the difference in blood pressure between old and young subjects, a statistically significant influence of age alone on LVET could be demonstrated independent of changes in HR. The partial correlation coefficient between LVET and age was +0.26, which is highly significant (P < 0.0001) in view of the large number (n = 742) of subjects involved, ranging in age from 18 to 90 years.

Effect of Some Other Factors on LVET

In old people, the influence on LVET of other factors, independent of changes in HR, was small, as could be demonstrated by multiple stepwise regression analysis (table 3). There was a small, positive, significant correlation between LVET and systolic blood pressure (r = 0.24; P < 0.001), independent of changes in HR. The partial regression coefficient of LVET on systolic blood pressure was +0.134 (sd, 0.030) in the total group of old subjects (n = 512). LVET was also significantly, but negatively, correlated with the arm-to-tongue circulation time (r = -0.21; P < 0.001), with the transverse diameter of the heart (r = -0.12; P < 0.01), and with the blood hemoglobin content (r = -0.17; P < 0.001). The total explained variation of the regression including LVET and heart rate, circulation time, heart diameter, hemoglobin, and systolic blood pressure was 62.2% (table 3). The explained variation by heart rate alone was 56.2%. No correlation could be found between LVET as the dependent variable and
Table 3

Multiple Regression Equation Relating LVET (Y) to Various Parameters in the Total Group (N = 512) of Old Subjects*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>SE</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y = 465 - 1.71 HR - 0.53 CT† - 0.25 THD†</td>
<td>(0.07)</td>
<td>(0.22)</td>
<td>0.09</td>
</tr>
<tr>
<td>+ 0.13 SP† - 1.89 Hgb†</td>
<td>(0.03)</td>
<td>(0.64)</td>
<td></td>
</tr>
<tr>
<td>R = 0.79†</td>
<td>seY = 17.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*As the regression coefficients calculated separately for men and women proved to be not statistically different, regression analysis on the pooled data has been performed.

†CT = circulation time in sec; THD = transverse heart diameter in mm; SP = systolic blood pressure in mm Hg; Hgb = hemoglobin in g/100 ml.

The partial correlation coefficients are given in the text.

LVET in Subjects With and Without Ischemic Heart Disease

Subjects with a typical history of angina pectoris or with electrocardiographic changes indicating previous myocardial infarction were considered to suffer from definite ischemic heart disease (IHD). Ischemic heart disease was thought to be probably present in subjects with atypical history of angina, lone left bundle-branch block, or atrial fibrillation. After correction for changes in height, weight, or QRS duration as the independent variables.

Table 4

Linear Regression Equations Relating Heart Rate (HR) and LVET (Y) in Subjects Without (group 1) or With (group 2) Ischemic Heart Disease

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Regression equation</th>
<th>( \beta_Y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1</td>
<td>Y = 415 - 1.54 HR (0.08)</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>2*</td>
<td>Y = 414 - 1.56 HR (0.11)</td>
<td>21.2</td>
</tr>
<tr>
<td>Men</td>
<td>1</td>
<td>Y = 428 - 1.79 HR (0.16)</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>2*</td>
<td>Y = 435 - 1.90 HR (0.18)</td>
<td>18.4</td>
</tr>
<tr>
<td>Women</td>
<td>1</td>
<td>Y = 421 - 1.57 HR (0.09)</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>2*</td>
<td>Y = 423 - 1.60 HR (0.13)</td>
<td>19.6</td>
</tr>
</tbody>
</table>

*Group 2 comprises the subjects with definite and probable ischemic heart disease.

HR, the mean LVET of the subjects with definite IHD was probably significantly \( P = 0.05 \) shorter than in subjects without IHD.

Although the slopes of the lines in cases with IHD were steeper, no statistical difference could be demonstrated between the regression coefficients of the linear equations relating HR to LVET in these subgroups (table 4).

Relationship Between HR and LVET in So-called Normal Old Subjects

The so-called normal old subjects were selected according to the following criteria: systolic blood pressure below 160 mm Hg and diastolic pressure below 90 mm Hg; no evidence or suspicion of IHD; normal ECG; arm-to-tongue circulation time below 20 sec for men and below 16 sec for women; maximal transverse diameter of the heart below 160 mm for men and below 150 mm for women; no intake of drugs, particularly no intake of digitalis, diuretics, or antihypertensive drugs. Only 72 subjects, 39 (18.8%) of the men studied and 33 (10.7%) of the women, met all these criteria of "normality." No statistically significant difference could be demonstrated between the regression lines relating HR to LVET in the group of the so-called normal old subjects compared to the total group (table 5).

Discussion

The data obtained in this study show that in elderly subjects, as well as in young and middle-aged,2, 6–11 heart rate is the most important determinant of LVET.

At all heart rates, mean LVET values 10 to 20 msec greater than the normal values, calculated according to the commonly used regression equations of Weissler and associates2, 15, 16 were observed. The finding of a slightly prolonged LVET in elderly as compared to young subjects is in agreement with the results of Michel4 Strandell,5 and Jung and associates17 and also with a recent study of Slodki and co-workers,18 who reported on the prolongation of the Q-II interval (Q to second heart sound), as a result of aging. However in these studies a separate influence
of blood pressure on LVET was not entirely excluded.

To rule out the effect of blood pressure differences between young and old subjects, multiple regression analysis was performed, using our previously published data on younger subjects, which were nearly identical to those published by others. In the combined group of young and elderly subjects, a small but statistically significant influence of age on LVET, independent of changes in heart rate and blood pressure, could still be demonstrated. LVET increased by 2 msec/decade in the total population, independently of changes in heart rate and blood pressure.

A decline in sympathetic nervous tonus and in myocardial contractility and an increase in aortic impedance are probably the main determining factors in the prolongation of LVET with rising age. A decrease of the aortic compliance, as occurs with aging, has been demonstrated to increase the impedance to ejection and to increase the tension load on the myocardium, independent of changes in aortic pressure.

The failure of previous studies, including our own, to detect a significant effect of age on LVET can probably be ascribed to the fact that in those studies mainly subjects below age 60 were investigated and also by the fact that the influence of aging is indeed rather slight and occurs mainly at old age. Also the large population, used in the present study, facilitates the statistical demonstration of weak correlations. It is indeed remarkable that the duration of left ventricular ejection varies so little relative to heart rate over the range of ages studied.

Besides the effect of aging the influence of some other parameters on LVET was studied. At all heart rates LVET in aged women was statistically longer than in aged men. This is in accordance with the results obtained by others in young subjects.

In the total group of elderly people a small but statistically significant positive correlation was found between systolic blood pressure and LVET, independent of all other parameters studied. The partial regression coefficient was +0.134 (sn, 0.030), which means that for each increment of systolic blood pressure by 10 mm Hg the average increment of LVET was 1.34 msec. In this connection, it should be mentioned that Shaver and associates observed prolongation of LVET during acute elevation of blood pressure by methoxamine in man, at fixed heart rate and stroke volume. Varying effects of systolic aortic pressure on LVET have been found in other studies.

A significant negative correlation was found between heart size, as judged from the transverse diameter of the heart and the cardiothoracic ratio, and LVET corrected for changes in heart rate. Also a negative correlation was calculated between the arm-to-tongue circulation time and LVET. These findings are in agreement with the well-known shortening of LVET with decreasing stroke volume, as occurs in heart failure.

The relationship between LVET and HR was studied in the subjects with definite and probable ischemic heart disease as compared to normal old subjects. Probably due to an insufficient number of subjects no statistically significant difference could be demonstrated in the male or female group taken separately. When taken together, it was found that LVET, corrected for changes in heart rate, was probably significantly (P = 0.05) lower in patients with definite ischemic heart disease than in normal old subjects. All the subjects we studied were not hospitalized and most of them were physically active. Only six men and three women presented clinical signs of heart
failure. Our data indicate that LVET, recorded at rest and in the supine position, remains within normal range even in elderly subjects with ischemic heart disease, as long as they are not hemodynamically disabled.

Acknowledgment
We are indebted to Misses J. Henskens, Y. De Man, J. Rongy, R. VanRoy and to Mrs. Weytjens-Cops for technical assistance and to D.Sc.H. Van de Vel of the computing center for programming. We appreciated very much the cooperation of the Geriatrisch Instituut van de Middenstand.

References
1. Lombard WP, Cope OM: The duration of the systole of the left ventricle of man. Amer J Physiol 77: 263, 1926
20. Lombard WP, Cope OM: Sex difference in heart action, duration of systole. Amer J Physiol 83: 37, 1927
The Left Ventricular Ejection Time in Elderly Subjects
JOS L. WILLEMS, JOS ROELANDT, HILAIRE DE GEEST, HUGO KESTELOOT
and JOZEF V. JOOSSENS

doi: 10.1161/01.CIR.42.1.37
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1970 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/42/1/37

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/