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Editorial

Stroke distance—an improved measure of cardiovascular function?

D G GIBSON

From the Cardiac Department, Brompton Hospital, London

Over the past few years, methods of measuring cardiac output based on ultrasound techniques have shown considerable promise. These estimates combine the time integral of blood flow velocity, determined by Doppler, with the cross sectional area at the point of measurement.[1-3] The method has been shown to be applicable at several points within the circulation including the atrioventricular valves, the pulmonary valve, and the aortic root or ascending aorta. A number of practical problems remain. It must be assumed that blood flow is laminar. Cross sectional areas estimated by M mode or cross sectional echocardiography are dependent on the resolution of these techniques. The orifice must be assumed to be circular and not to vary during the cardiac cycle, or its geometry must be measured throughout. Despite these limitations, published results indicate that values can be obtained over a wide range from individual patients which agree closely with those derived from established invasive methods.

A new approach to these measurements is put forward in the paper by Haites *et al* in the present issue of this journal (p 123). They have used transaortic velography to determine blood flow velocity and its time integral over systole, which they refer to as stroke distance. They suggest that such measurements may be used to assess cardiac output without conversion to a volumetric measurement or correction for body size. Both stroke distance and minute distance decline during adult life at a rate of approximately 1% a year. Values of both are higher than normal in pregnant women, decreased in patients with hypertension, atrial fibrillation, or cardiac failure, and normal in those convalescing after myocardial infarction. The authors conclude that such measurements constitute a "safe, simple, and physiologically valid way of assessing cardiac output." They also suggest that they may approximate even more closely to stroke index, since the Doppler time integral is multiplied by one quantity with the dimensions of cm^2, aortic cross sectional area, and divided by another, body surface area.

Requests for reprints to Dr D Gibson, Cardiac Department, Brompton Hospital, London SW3 6HP.

There are several ways in which the suggestions put forward here might have been substantiated. A close correlation between stroke index and stroke distance might have been demonstrated in individual patients; however, no independent measurements of cardiac output were made, although this might have been expected in such a study. It might have been possible to show that the extent of natural variation in a normal population was lower for stroke distance than for other more commonly used measures of flow. This problem has not been specifically addressed, and the use of standard errors rather than standard deviations does not highlight the information. Nevertheless, the 95% confidence limits around the normal populations in Fig. 3 and 4 (p 126) are substantial, and at first sight do not seem to be significantly less than those around cardiac or stroke index. The suggestion is also made that aortic cross sectional area reflects body size and metabolic requirements better than surface area. Again, no data are presented to support this hypothesis, and measurements in published reports lend no support to it. Even during the period of growth when correlation between aortic size and body surface area would be expected, directly measured confidence limits are wide, the 95% limits for aortic dimension being 16% in the study of Henry *et al*,[4] corresponding to a 30% variation in area. That demonstrated by Rogé *et al* is even larger,[5] the 90% limits being approximately 30% in dimension at a body surface area of $1{\cdot}5\ m^2$, corresponding to a range of area of more than 50%. There seems to be no reason to suppose that these limits would be any narrower in disease or that they would be reduced if "metabolic requirements" were taken into account. Thus, although the authors' thesis that stroke index and stroke distance both have the same units—length—is correct, this dimensional equivalence is not accompanied by corresponding biological significance.

While the positive findings in the different patient groups in this study are of interest, they are not specific. In the present series, stroke distance fell with age; this might have been due to a reduction in stroke index or to an increase in aortic cross sectional area. In hypertensive patients, particularly when some are receiving treatment with beta blocking drugs, a variety of mechanisms can be invoked, including depression of ventricular function, increased afterload, sympathetic inhibition, and increase in cardiac output in the early stages of the disease, so that any value of stroke distance can be explained, whether high, normal, or low. Similar considerations apply for patients with atrial fibrillation of differing aetiology or for an unselected group after myocardial infarction, where low as well as normal values could be accounted for with equal facility. Stroke distance seems to have much in common with other measurements such as arteriovenous oxygen difference or even circulation time, which are likely to have varied in a similar manner as stroke index in the patients studied. These all share the disadvantage that when values occur outside the expected range the underlying mechanism is never clear.

In summary, I consider that measurements of cross sectional area should continue to be made in association with estimates of blood flow velocity. In this way stroke volume and cardiac output can be obtained, which are recognised variables describing circulatory function and which can be estimated and correlated with more direct measurements. Failure to determine aortic root area will introduce a major additional source of variance in the relation between stroke distance and stroke volume index, which could readily be avoided by simple echocardiographic measurements. The case for considering stroke or minute distance as equal or even superior to current measurements of blood flow remains unproved.

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