Non-invasive cardiac output assessment in children

EDITOR,—We agree with Richardson and colleagues that it is important to be able to estimate changes in circulating blood volume in children. 1 When invasive methods for assessment of cardiac output (blood flow) are contraindicated, a non-invasive technique could be of great clinical benefit. Suprasternal aortovelography is a relatively simple non-invasive technique for assessing the velocity profile of blood flowing in the aortic arch using, in this case, Doppler ultrasound. Stroke distance is a proxy for left ventricular stroke volume and can be derived mathematically from the measured systolic velocity-time curve. Our group has shown that this technique can produce reliable and reproducible results such as fractions of stroke distance in normal, resting children if the limitations to its use are appreciated. 2

Richardson and colleagues hypothesised that a single measurement of stroke distance in an ill child could provide an objective, absolute value of cardiac output for comparison with an established normal range of values. 1 We do not believe that this is the best use of this technique for children when one reviews the available evidence. Furthermore, we are concerned about Richardson's meaning of a "normal range" of values for stroke distance. 2

Richardson and colleagues report a "normal range of values" for stroke distance at different ages. The authors imply that this "normal" range could be used to understand measurements made during future clinical studies. We understand that these children were being discharged from an accident and emergency (A& E) review clinic. However, we are not informed of the reasons for attendance or the length of time since the onset of their pathology. We can only assume that the majority of these children were being reviewed after minor or moderate illnesses, perhaps after blunt injury? Reporting these fundamental details is important if one wishes to accept Richardson's hypothesis, mentioned above, or if one wishes to compare the results of Richardson et al with any other group (for example our own). With few exceptions, stroke distance in our study ranges from 20-30 cm (mean (SD) 24.4 (4.0) cm) whereas those of Richardson et al were somewhat higher (mean (SD) 31.8 (5.1) cm). This difference between these two studies is apparent at any given age. Confounding factors such as different observers, measuring techniques, and subjects can be important when attempting to establish norms for any physiological parameter. These two independent groups appear to have a similar age distribution, the same technique was adopted in the two centres and the same measuring instrument was used. However, other fundamental differences and between the two groups of children could be important. This is particularly true if blunt injury was the cause for inclusion in Richardson's study. Cardiovascular control mechanisms in adult patients are significantly affected by the presence of moderate blunt injury. 1 These effects occur within three hours of injury and have not fully recovered by two weeks. In adults this results in a higher than expected blood pressure and a relative tachycardia. We are currently investigating this relationship in injured children arriving in A& E departments throughout the UK. Early results suggest that cardiovascular control mechanisms in all injured children, regardless of injury severity and age, are also significantly affected by the presence of blunt injury. 1 Therefore, it would be helpful if Richardson and colleagues could define more clearly what they mean as "normal" children.

Our own recently reported stroke distance measurements ranged from 143 normal, resting children in a nursery and a school. 1 These children were similar in ages (2.4-11.5 years, median 6.6 years) to those reported by Richardson et al (2-14 years, mean 9.6 years). A positive and significant correlation between stroke distance and age was recorded in both studies (r=0.339, p<0.0001 in our group compared with r=0.26, p<0.01 in Richardson's group). However, from these two studies it appears that at any given age the range of stroke distance is rather wide. This accounts for the very weak relationship between distance and age in both studies. Furthermore, we investigated the within-observer and between-observer variability for the measurement of stroke distance in our normal, resting children. 1 Our results suggest that the most useful of this technique, in its current form, is to monitor trend changes in blood flow for an individual patient over time. This is best achieved by making serial measurements of stroke distance for an individual patient using the same operator without reference to a "normal range" (for example as used clinically in the emergency department by Dark et al). Therefore, we do not endorse the concept of Richardson and colleagues regarding the usefulness of a single stroke distance measurement and its comparison with established "normal ranges". Furthermore, we would suggest that serial measurements provide far more than just "additional information".

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The authors reply

We agree with Childs and Dark that serial measurement of stroke distance has great potential for the evaluation of hypovolaemia 1 and monitoring the response of the sick or injured child to fluid resuscitation. 2 Before any technique can be useful for monitoring children it is important to have a reference range for any meaningful interpretation of the results. The aim of our study was to establish a normal range for children "as a prelude to evaluating this technique in the assessment and management of hypovolaemia" 1.

We are concerned about the differences in the measurements of stroke distance between Childs and our results (mean (SD) 31.8 (5.1) cm). Suprasternal aortovelography utilises Doppler ultrasound to assess the velocity of blood flowing in the aortic arch. It therefore provides a velocity-time curve for which the stroke distance is calculated. Mean peak aortic blood velocity in our study was identical to that measured by Light et al in 1978. 3 Unfortunately, the peak aortic velocity and stroke distance are slightly higher in children than in the youngest group of adults, as would be expected.

The suggestion that a history of moderate trauma could have been responsible for the haemodynamic changes resulting in our higher values for stroke distance is extremely unlikely. It is recognised that moderate trauma (such as fractures) may result in changes to baroreceptor reflex sensitivity which gives a persistent tachycardia not related to hypovolaemia. 4 Children attending the A&E review clinic do not fall within this group of significantly low values that we have reviewed in other clinics. Those participating in our study had generally suffered minor sprains or skin wounds, and at the time of their involvement in this study their symptoms had resolved. Many "normal" children in school are likely to have suffered similar minor injuries within the preceding few weeks.

Other potential reasons for the differences in the results must also be considered. Childs' study involved two operators who had three weeks' experience of using the technique. It was reported that both operators "felt more at ease with the technique after a few days of intensive measurements during the first week of the study" 2. This may have added to measurement error in the earlier part of their study. It was noted that differences between the operators for any measurement was up to 5 cm.

In our study all the measurements were made by a single operator with several months' experience of using the technique on both children and adults.

There is no stimulus that potentially distress the child could result in an increase in heart rate and therefore, unless there is a significant increase in peak velocity of aortic blood flow, the stroke distance would be decreased. Our study ensured that the subjects were resting and not distressed. The measurement of blood pressure is uncomfortable and this was performed after stroke distance in all cases. We believe that Childs' results were from a single operator with several months' experience of using the technique on both children and adults.

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