The normal ranges of cardiovascular parameters in children measured using the Ultrasonic Cardiac Output Monitor

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Objective: **The Ultrasonic Cardiac Output Monitor is a noninvasive method of hemodynamic assessment and monitoring in critically ill patients. There are no published reference ranges for normal values in children for this device. This study aimed to establish normal ranges for cardiovascular indices measured using Ultrasonic Cardiac Output Monitor in children aged 0–12 yrs old and to assess interobserver reliability.**

Design: **This was a population-based cross-sectional observational study.**

Setting: **Schools and kindergartens in Hong Kong.**

Subjects: **Chinese children aged up to 12 yrs old.**

Interventions: **Two operators performed Ultrasonic Cardiac Output Monitor scans on each child together with standard oscillometric measurement of blood pressure and heart rate. Software intrinsic to the Ultrasonic Cardiac Output Monitor device produces values for stroke volume, cardiac output, and systemic vascular resistance. For each parameter, normal ranges were defined as lying between the 2.5th and 97.5th percentiles. Interobserver reliability was assessed with Bland-Altman plots, coefficients of variation, and intraclass correlation.**

Measurements and Main Results: **A total of 1,197 Chinese children (55% boys) were scanned. Normal ranges of values for cardiac output, stroke volume, and systemic vascular resistance indices are presented. Interobserver reliability for Ultrasonic Cardiac Output Monitor was superior to that for standard blood pressure and heart rate measurement.**

Conclusions: **This large study presents normal values for cardiovascular indices in children using the Ultrasonic Cardiac Output Monitor with good interobserver reliability. (Crit Care Med 2010; 38:1875–1881)**

KEY WORDS: pediatrics; resuscitation; ultrasonography; Doppler; hemodynamics; diagnostic techniques and procedures

The measurement of cardiovascular parameters is important in the management of critically ill patients. Assessment of cardiac output (CO), stroke volume (SV), systemic vascular resistance, and their indices enables the differentiation between shock states and helps monitor the progression of illness and the response to therapy.

The Ultrasonic Cardiac Output Monitor (USCOM1A; USCOM Pty Ltd, Coffs Harbor, NSW, Australia) was introduced for clinical use in 2001, providing a rapid and noninvasive measure of cardiac function. USCOM uses Doppler ultrasound to measure the velocity of blood flow through the aortic or pulmonary valve. The software calculates the SV using algorithms based on the patient's weight and height to determine the area of the valve. USCOM also measures the heart rate (HR) and therefore gives a calculated CO (CO = SV × HR). Blood pressure (BP) is entered manually, from which USCOM calculates the mean arterial pressure (MAP) and systemic vascular resistance (SVR = MAP/CO) (1, 2).

The machine is portable, consisting of a screen and probe. The probe is about the size of a pen and is placed in the suprasternal notch to obtain a Doppler measurement of flow through the aortic valve or in the third to fourth left intercostal space parasternally for the pulmonary valve. An optimal signal is obtained when the probe is directly parallel to flow through the valve. The screen displays a two-dimensional image of the flow detected with each ejection (Fig. 1). The onset of systole is marked by a vertical "click" as the valve opens; blood flow in systole is characteristically seen as a triangle. A good-quality trace should have a clear, straight upstroke (as flow accelerates) to a sharp peak (at peak velocity) and a clear, straight downstroke before valve closure, which is also marked by a vertical "click." The trace should return to the baseline in diastole with a typical "M" shape reflecting early ventricular filling and atrial contraction. A typical screen shot includes several ventricular cycles, and it is recommended to select the best three consecutive cycles for analysis (1, 2).

Historically, the standard method for CO measurement in intensive care settings has been pulmonary artery thermodilution (PATD), which is time-consuming, requires a high degree of expertise, and is very invasive. Other techniques include echocardiography, transesophageal Doppler, lithium dilution, pulse contour, and central venous fiberoptic oximetry methods (3). USCOM

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Supported by an internal grant of HK $72,000 (approximately US $9,000) from the Chinese University of Hong Kong to conduct the "Healthy Children's Vital Signs and USCOM Study." Also supported by a grant of HK $100,000 (approximately US $13,000) from the Hong Kong College of Emergency Medicine, and by a grant from Hong Kong's Health and Health Services Research Fund.

The distributors of USCOM in Hong Kong (Pacific Medical Systems) loaned us an USCOM machine for the duration of the project.

A preliminary report related to this study has been published in abstract form: Leung PYM, Cattermole GN, Mak SKP, et al: Comparison of normal ranges of cardiovascular indices for Chinese and Australian children derived using the Ultrasound Cardiac Output Monitor (USCOM). *HK J Emerg Med* 2009; 16:289.

The authors have not disclosed any potential conflicts of interest.

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DOI: 10.1097/CCM.0b013e3181e8adee

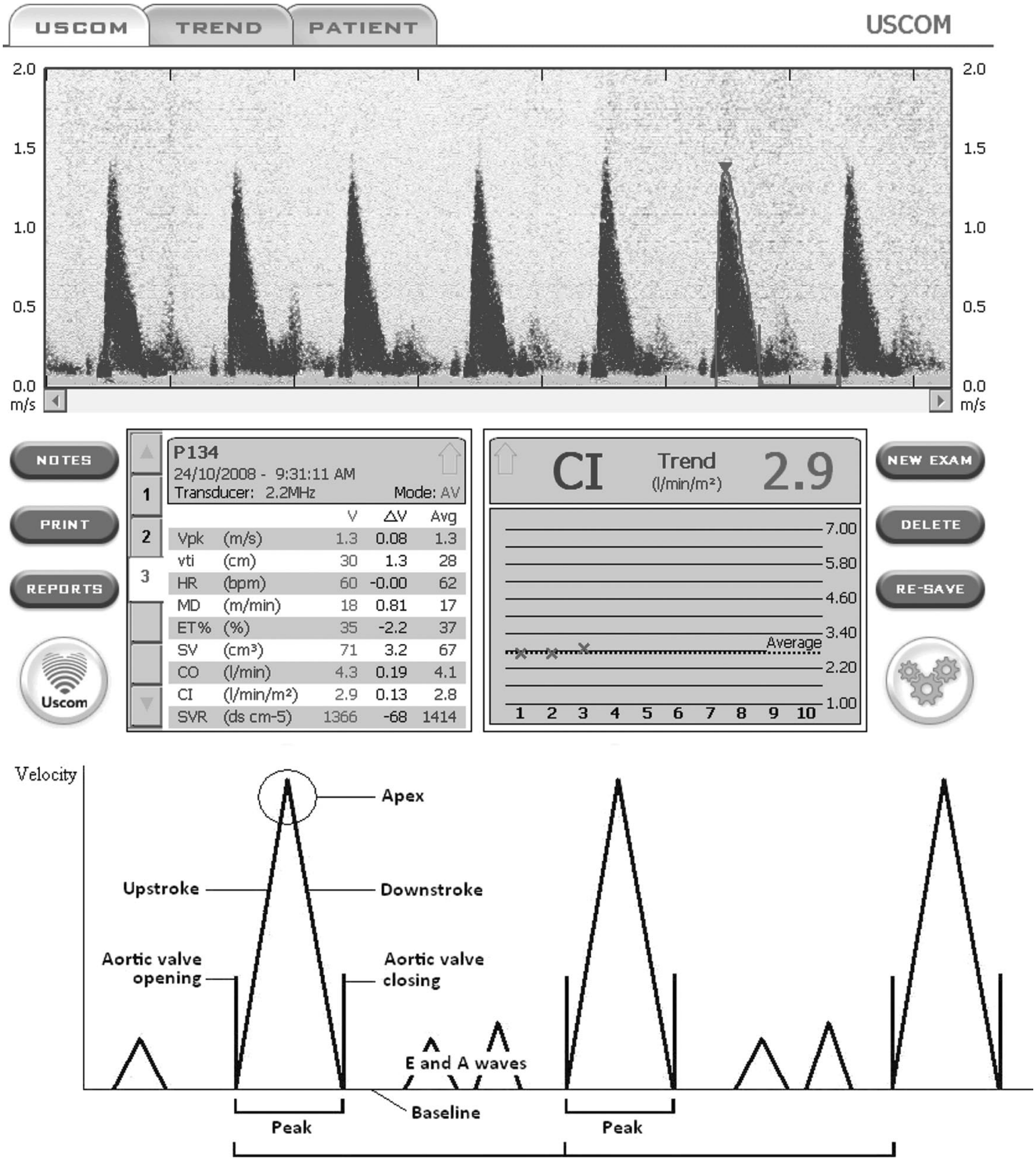

Figure 1. Ultrasonic Cardiac Output Monitor (*USCOM*) traces: screen capture (*above*); description of waveform (*below*).

has been compared favorably with a wide range of CO measurement techniques, including PATD, with good interobserver reliability (4, 5). The recent guidelines from the American College of Critical Care Medicine recommend the use of pulmonary or femoral artery thermodilution, pulse contour, or Doppler ultrasound (6). USCOM is the least invasive of these recommended techniques and is likely to become more widely used in critical care settings. This is especially true for children (in whom the issue of invasiveness is more important) and in emergency departments (where the equipment and expertise to perform PATD or pulse contour are often absent).

For USCOM to be useful clinically, it is important to know the range of normality. Normal pediatric values according to age of peak aortic flow measured with a suprasternal ultrasonic device have previously been published, but the device used did not produce values for SV, CO, or SVR (7). A reference range for these indices measured with USCOM has been produced based on unpublished data from 500 healthy subjects in a rural Australian community, of whom <100 were children and none were <2 yrs old (BE Smith, personal communication). There are no other published normal ranges for USCOM in children nor in a Chinese population.

This study aimed to establish normal ranges for USCOM-derived cardiovascular indices in Hong Kong Chinese children aged 0–12 yrs old.

MATERIALS AND METHODS

This pragmatic observational study was part of the prospective "Healthy Children's Vital Signs and USCOM Values" cross-sectional study conducted between October 2008 and January 2009.

Table 1. Age and sex distribution

Age at Last Birthday, yrs	Boys		Girls		Total
0	1	14%	6	86%	7
1	10	50%	10	50%	20
2	14	37%	24	63%	38
3	55	59%	39	41%	94
4	74	54%	62	46%	136
5	80	65%	43	35%	123
6	78	60%	52	40%	130
7	78	56%	62	44%	140
8	73	51%	70	49%	143
9	66	55%	54	45%	120
10	51	54%	43	46%	94
11	71	52%	66	48%	137
12	6	40%	9	60%	15
Total	657	55%	540	45%	1197

Participants and Setting. Healthy Chinese children aged 0–12 yrs were recruited through kindergartens and schools in the Shatin district of Hong Kong. A list of all schools and kindergartens was obtained from the Education Bureau. All 48 schools on the list were invited, and 46 kindergartens were selected using a random-order generator. Invitation letters were sent to the principals of each institution. Eight kindergartens and six primary schools agreed to participate. Participating institutions selected classes to provide a representative distribution of age and distributed fact sheets and consent forms in Chinese to parents of children in those classes. Exclusion criteria included lack of consent; non-Chinese children; current symptoms of illness (e.g., respiratory tract infection, gastroenteritis); congenital or long-term conditions (e.g., diabetes, asthma, congenital heart disease); and current use of medication (whether over-the-counter or prescribed by a physician or Chinese medical practitioner). Children with parental consent but who themselves declined to participate were also excluded.

The study took place in school classrooms or assembly halls as was practical for that institution. Children were brought to the researchers by staff members in groups as they were released from their classes, and measurements had to be completed within the time limit prescribed by the school. Children were expected to wait their turn seated at rest. In each situation, we used tables or mattresses for supine examination.

Measurements. A team of three operators was trained to perform USCOM by a local expert physician and a company representative. Ten adult scans were performed in training and a further 40 pediatric scans each in a pilot study before the operators were considered competent to perform scans independently. Other members of the team were trained to measure children's height, weight, and BP.

Standing height was measured to the nearest 0.1 cm using a stadiometer (Harpenden Portable Stadiometer, Holtain, UK). Children too young to stand were measured supine on a flat surface with a tape measure. Body weight was measured to the nearest 0.2 kg in school uniform (shorts and T-shirt) using electronic scales (Compact Precision Scale C200H; Conair Far East Ltd, Hong Kong, China). School uniforms were weighed separately and subsequent adjustment made to the measured weight of each child. BP and pulse rate were measured in the right arm with an appropriately sized cuff using a standard emergency department oscillometric device (Patient Monitor BX-10ne; Omron Healthcare Co Ltd, Kyoto, Japan). BP, HR, and USCOM were performed supine at rest. Height and weight were measured first; BP was measured immediately before USCOM. To assess variation, a convenience sample of at least 10% of subjects had repeat measurements of BP and HR within 5 mins of the first measurement.

The first USCOM operator entered the subject's weight, height, and BP using a new account for each child. Scans were obtained using the aortic access area (suprasternal notch), because it was not felt appropriate to require children to remove their clothing to obtain the pulmonary view. Each scan attempted to obtain at least three good-quality consecutive cycles as described. On achieving an optimal view, the scan was saved. This procedure was performed three times for each operator with three scans saved in the child's file. The file was then closed, and a second operator blind to the results of the first operator opened a new file for the same child and obtained a further three scans in the same way. The second set of scans was performed immediately after the first using the same measurements for height, weight, and BP.

Statistical Analysis. StatView version 5.0 (SAS Institute Inc, Cary, NC) was used to calculate means and SDs for cardiovascular indices according to age groups. Age groups are as defined in the Advanced Trauma Life Support course manual (8): infants (0–12 months), toddlers (1–2 yrs), preschool (3–5 yrs), and school age (6–12 yrs). Unpaired Student's t tests were used to compare sexes. Statistical significance was set at $p < .05$.

LMS Chartmaker Pro version 2.3 software (T. Cole and H. Pan, Medical Research Council, London, UK) was used to describe the data in percentile curves (2.5th, 10th, 50th, 90th, 97.5th). The relationship between age and USCOM-derived cardiovascular indices was modeled by the LMS method of Cole and Green (9). Briefly, the relationship is described by three age-specific cubic spline curves known as L, M, and S. M represents the median, S is the coefficient of variation, and L is the Box-Cox transformation that renders the data to follow a normal distribution conditional on age. A combination of these three functions generates percentile values for each parameter. Analysis was weighted according to the size of sex groups.

MedCalc version 10.4 (F. Schoonjans, 2009) was used to determine interobserver reliability for measurement of SV, BP, and HR. Intraclass correlation used the one-way random effects model for absolute agreement of single paired observations with raters selected at random. Bland-Altman limits of agreement were calculated for the percentage difference between observations (10). Coefficient of variation was calculated as the percentage ratio of the SD of the differences between the two measurements and the overall mean (11).

Sample Size. From the results of our pilot study, the mean and SD for SV were used to calculate a sample size of 105 subjects in each year group to achieve 95% confidence that the true mean lies within 5% of that observed.

Ethical Approval. The study was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong (reference number CRE-2008.290).

RESULTS

In the six schools that recorded how many invitation letters they sent, 48% consented to participate. In total, 1,456 consent forms were signed. Thirty-eight children were absent on the day of study or refused to participate on arrival. In one school (115 children), we were unable to perform USCOM at all owing to the time given us with each class. Similar time limitations prevented us from performing USCOM in a further 101 children in the other 13 schools and kindergartens. These children were those from each class brought by staff to us last; selection was not made by the researchers.

A total of 1,197 children (657 boys [55%]) were scanned with USCOM. The age and sex distribution are shown in Table 1.

Cardiovascular Indices. Percentile curves (2.5th, 10th, 50th, 90th, 97.5th) for SV, SV index, CO, cardiac index, SVR, and systemic vascular resistance index are presented in Figure 2. Medians and ranges (defined as lying between the 2.5th and 97.5th percentiles) for SV, SV index, CO, cardiac index, SVR, systemic vascular resistance index, MAP, HR, weight, and height are presented in Table 2.

Sex Differences. Means and SDs are presented in Table 3 according to sex and age group for the four independent variables used by USCOM: SV, MAP, HR, and body surface area. p values are calculated using unpaired Student's t tests. Several small differences are noted between

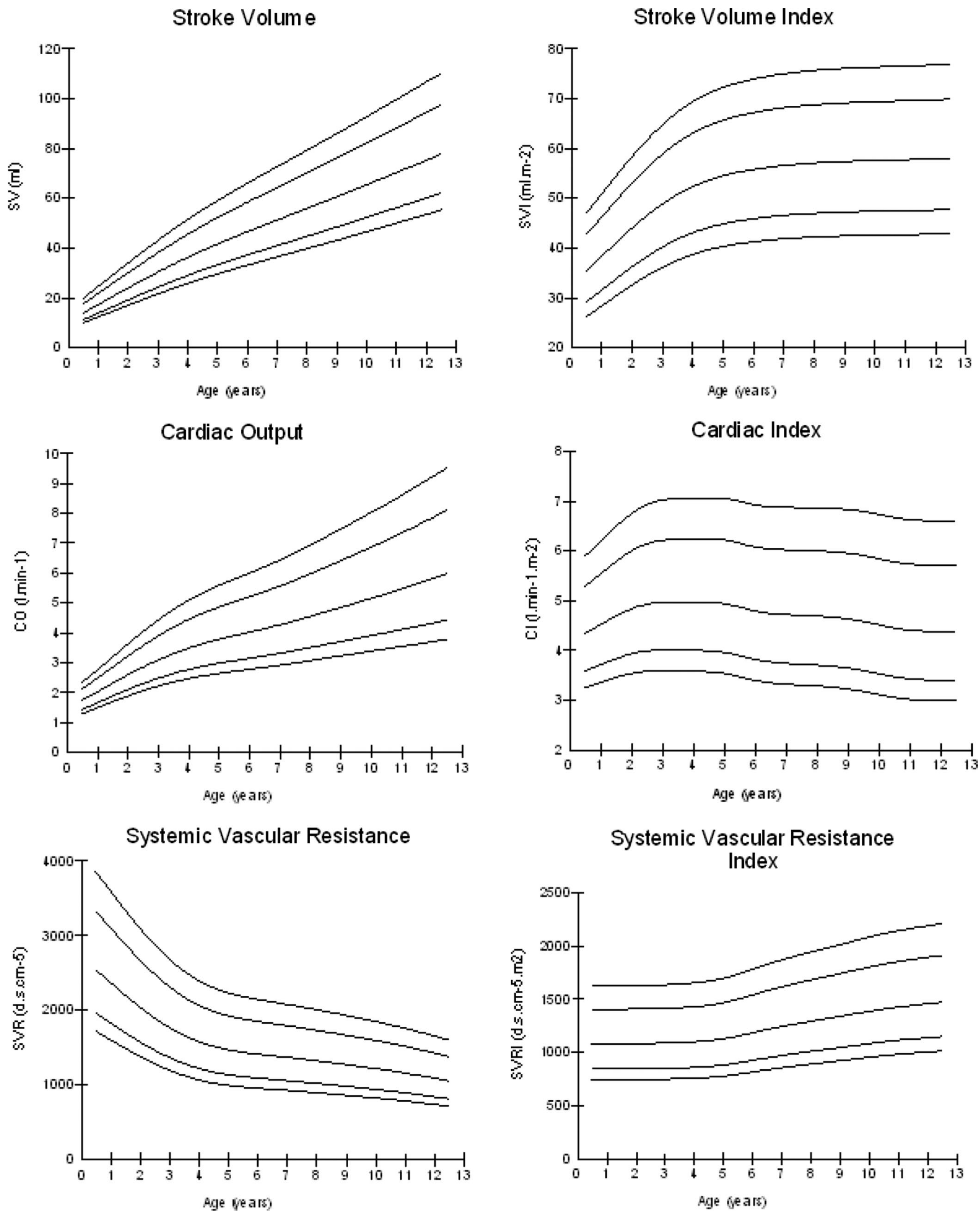

Figure 2. Cardiovascular indices: percentile curves (2.5th, 10th, 50th, 90th, 97.5th). *SV*, stroke volume; *CO*, cardiac output; *SVR*, systemic vascular resistance.

sexes, which reach statistical significance, but none is clinically relevant.

Interobserver Variation. A total of 1,059 (88%) children were scanned independently by a second operator. Time constraints imposed by the school timetable prevented us from performing a second set of scans on all children. One hundred eighty-three children (15%) had a second BP and HR measurement.

Coefficient of variation, intraclass correlation, and Bland-Altman limits of agreement for SV, BP, and HR are presented in Table 4. By any measure, USCOM has better interobserver variation than the standard automated oscillometric device does for BP or HR.

Normal Ranges for Clinical Use in Resuscitation. It is clear from the graphs (Fig. 2) that SV index, and to a lesser extent cardiac index and systemic vascular resistance index, plateau after the age of 5 yrs. For convenient use in a resuscitation room, we have therefore summarized approximated normal ranges according to the following age groups: 1–2 yrs, 3–4 yrs, and 5–12 yrs (Table 5).

DISCUSSION

This is the largest study to formally present normal ranges for cardiovascular indices measured using USCOM. It is several times larger than the rural Australian study from which USCOM Ltd obtained its data for children. It is the first study to present USCOM data for a Chinese population. Until similar studies are repeated in other populations, these ranges will be useful for anyone using USCOM in children (Table 5).

We used 2.5th and 97.5th percentiles to define the expected range of 95% of the population. There is a probability of .05 that a healthy child will be found to have USCOM measurements outside this range, which is the customary level to take statistical significance.

Our results were consistent with those of Smith and Madigan using USCOM in 100 children aged 1–16 yrs (12) and with those using the earlier suprasternal ultrasonic device (7). Normal pediatric ranges for SV measured using echocardiography have been published according to weight and height, but not according to age, preventing direct comparison with our results (13). Our ranges for cardiac index are slightly higher than those published in pediatric textbooks (14–16). Textbook figures relate to more invasive methods, but data that underpin these normal reference ranges in children are extremely limited (17). PATD and other invasive methods of measurement have been studied only in critical care settings, and it would be unethical to perform such procedures in healthy normal children. It is likely that published normal values for children depend to some extent on extrapolation from adult values and from values in critically ill children. Because USCOM is noninvasive, we have been able to obtain estimates of true normal cardiovascular indices in children.

Alternatively, it is possible that USCOM systematically overestimates its measure of SV (from which the software derives the other indices) compared with the gold standard. Knirsch et al (18) found a CO measurement bias of 0.13 $L \cdot min^{-1}$ with USCOM compared with PATD. However, that was a small study of 24 children with congenital heart disease undergoing cardiac catheterization under general anesthesia. Other studies have found good correlation between USCOM and PATD. In a recent review of five comparison studies (USCOM vs. thermodilution methods), there was no systematic bias and reasonable precision (19). Jain (20) found the two techniques to be closely comparable and recommended USCOM as a safe and accurate alternative to pulmonary artery catheterization. Pediatric USCOM has also been shown to compare well with other accepted noninvasive methods of assessment, including magnetic resonance imaging (21) and echocardiography (22, 23).

For any method of clinical measurement, it is essential to know the reference ranges obtained with that method, even if they systematically differ from a gold standard, because one needs to know whether a measurement in practice reflects a departure from normal for that method of measurement. However, it would appear that USCOM is as accurate as other methods of CO measurement. Even if it were not, Knirsch (18) has emphasized the importance of USCOM as a monitor of trends; if an individual measurement were not a reliable indicator of what is "actually" the CO, repeated measurements demonstrating change would remain important clinically.

Our interrater reliability was good. We used three measures: coefficient of variation, Bland-Altman limits of agreement, and intraclass correlation (11). On all measures, there was less variability with USCOM than with noninvasive BP and HR measurement using our standard emergency department oscillometric device. In all cases, the second measurement was performed by an independent second observer, using the same machine, approximately 5–10 mins apart. Our interobserver agreement was superior to that demonstrated by Stewart et al (24), which was considered acceptable. Our results might reflect improvement in the USCOM software trace analysis, our longer training period, or the fact that our subjects were healthy volunteers rather than patients who might have been less cooperative. Other studies have found good interrater reliability in children (4, 5).

Although there were some statistical differences between values for boys and girls, these did not reflect differences of clinical relevance; all the differences were <5%. Differences were analyzed in age groups (the Advanced Trauma Life Support age groups were used as a convenient and accepted definition) to avoid a type 1 error from comparing a large number of smaller samples. The preschool and school-aged groups were both large enough to detect a 10% difference in means with an α of 0.05 and power of 80%. Furthermore, for rapid and easy use in a resuscitation room, it is less convenient to refer to separate tables for male and female. In keeping with other published cardiovascular indices (8, 14–16), we have therefore not presented percentile curves or normal ranges for each sex separately.

We chose to include all scans regardless of quality, and for this study, we analyzed only traces obtained by the first operator. We have developed a scoring system to assess the quality of each trace, and after approximately 30 scans, each operator reached a "steady state" in their cumulative average scan quality (25). All the scans in this study were conducted after the end of this learning curve, but highly experienced operators will still sometimes fail to obtain a good-quality trace; sometimes this is the result of the compliance or morphology of the subject. The inclusion of scans of any quality was considered better to reflect the real-life situation. Similarly, for pragmatism, we did not use the second scan performed in each subject to derive the normal values presented. In the resuscitation room, there is likely to be just one operator using USCOM, although it is reasonable to assume that operator will obtain several views. In our study, each operator

Table 2. Cardiovascular indices: median and range according to nearest age

Parameter	Median (Range) for Indicated Age, yrs 1	2	3	4	5
SV, mL	17.5 (12.4–19.8)	24.1 (17.1–34.1)	30.4 (21.6–43.1)	36.3 (25.8–51.5)	41.7 (29.7–59.1)
SVI, mL·m^{-2}	38.4 (28.4–50.9)	44.1 (32.6–58.4)	48.9 (36.2–64.8)	52.4 (38.7–69.4)	54.5 (40.3–72.3)
CO, L·min^{-1}	2.0 (1.5–2.8)	2.6 (1.9–3.6)	3.1 (2.2–4.4)	3.5 (2.5–5.1)	3.8 (2.6–5.6)
CI, L·min^{-1}·m^{-2}	4.5 (3.4–6.2)	4.8 (3.5–6.8)	5.0 (3.6–7.0)	5.0 (3.6–7.1)	4.9 (3.5–7.1)
SVR, d.s.cm^{-5}	2362 (1600–3582)	2036 (1379–3087)	1766 (1196–2677)	1577 (1069–2392)	1472 (997–2231)
SVRI, d.s.cm^{-5}·m^2	1082 (746–1626)	1084 (747–1629)	1089 (751–1636)	1101 (759–1654)	1130 (779–1698)
MAP, mm Hg	64.2 (47.7–82.0)	65.8 (49.3–83.6)	67.4 (50.9–85.2)	68.9 (52.4–86.6)	70.5 (54.0–88.1)
HR, min^{-1}	120.1 (97.6–149.9)	110.3 (88.3–140.0)	101.8 (80.3–131.3)	95.4 (74.3–124.9)	90.3 (69.6–119.8)
Weight, kg	8.9 (7.4–11.3)	11.4 (9.3–15.0)	13.9 (11.2–18.8)	16.2 (12.8–22.7)	18.4 (14.4–26.5)
Height, cm	76.4 (70.7–82.2)	86.0 (79.4–92.8)	94.8 (87.3–102.5)	102.5 (94.1–111.1)	109.3 (100.1–118.6)

SV, stroke volume; SVI, stroke volume index; CO, cardiac output; CI, cardiac index; SVR, systemic vascular resistance; SVRI, systemic vascular resistance index; MAP, mean arterial pressure; HR, heart rate.

Table 3. Cardiovascular indices: mean and SD according to age groups for boys and girls

	No.		SV, mL			MAP, mm Hg			HR, min^{-1}			BSA, m^2		
Age Group	Boys	Girls	Boys	Girls	*p*	Boys	Girls	*p*	Boys	Girls	*p*	Boys	Girls	*p*
Infant	1	6	11.8	15.3 ± 1.4	—	64	63.1 ± 7.0	—	147.7	120.4 ± 19.9	—	0.41	0.42 ± 0.03	—
Toddler	24	34	25.2 ± 7.4	26.4 ± 6.6	.54	67.0 ± 9.6	65.4 ± 7.7	.48	108.0 ± 16.1	109.4 ± 13.3	.73	0.58 ± 0.08	0.56 ± 0.06	.36
Preschool	209	144	41.2 ± 7.9	39.5 ± 7.9	.04	70.0 ± 8.4	69.4 ± 8.7	.53	93.6 ± 13.1	94.2 ± 13.9	.7	0.76 ± 0.1	0.73 ± 0.08	.01
School age	417	347	61.1 ± 13.5	60.8 ± 15.0	.79	76.9 ± 8.6	77.9 ± 9.1	.11	80.9 ± 13.0	83.3 ± 12.7	.01	1.07 ± 0.21	1.06 ± 0.2	.39
Total	657	540	53.7 ± 16.4	52.8 ± 18.2	.4	74.4 ± 9.3	74.8 ± 10.1	.47	86.0 ± 15.2	88.3 ± 15.4	.01	0.96 ± 0.24	0.94 ± 0.26	.19

SV, stroke volume; MAP, mean arterial pressure; HR, heart rate; BSA, body surface area.

Table 4. Interobserver variation

Parameter	Stroke Volume	Systolic BP	Heart Rate
Method of measurement	USCOM	Oscillometric monitor device	
Number of subjects	1059	183	
Coefficient of variation	11.3%	13.0%	11.5%
Intraclass correlation (95% CI)	0.94 (0.93 to 0.94)	0.50 (0.38 to 0.60)	0.76 (0.69 to 0.82)
Bland-Altman limits of agreement			
Upper limit (95% CI)	22.3% (21.2% to 23.4%)	26.1% (22.8% to 29.3%)	22.3% (19.5% to 25.1%)
Lower limit (95% CI)	−20.5% (−19.3% to − 21.6%)	−24.5% (−21.3% to − 27.8%)	−21.9% (−19.1% to − 24.7%)

BP, blood pressure; CI, confidence interval; USCOM, Ultrasonic Cardiac Output Monitor.

Table 5. Summary chart of normal ranges for cardiovascular indices (approximated to 2 significant figures)

Age, yrs	SVI, mL·m^{-2}	CI, L.min^{-1}·m^{-2}	SVRI, d.s.cm^{-5}·m^2	MAP, mm Hg	HR, min^{-1}
1–2	31–55	3.5–6.5	750–1600	48–83	93–140
3–4	37–67	3.6–7.1	750–1700	52–86	78–130
5–12	42–76	3.3–6.9	910–2000	61–94	62–110

SVI, stroke volume index; CI, cardiac index, SVRI, systemic vascular resistance index; MAP, mean arterial pressure; HR, heart rate.

obtained three separate screenshots, which we think represents realistic practice. Sensitivity analysis was performed, however; by analyzing only those subjects for whom two very good-quality scans were obtained, and taking the average values for those scans, we found little difference. Median SVs obtained with better quality, averaged scans were approximately 4% greater than presented. In view of the wide range of normality, we do not consider this difference clinically relevant.

Our study was limited by the time allocated us in the schools and kindergartens, and we were unable to obtain two USCOM scans in all children. However, those children not scanned were unlikely to be systematically different from those who were, and we do not consider this a source of bias. Similarly, just under 50% of parents consented. Some of these children may have been unwell and would not be eligible for the study. It is unlikely that healthy children without consent were systematically different from those with consent. We also recruited from only one area of Hong Kong (the Shatin district), and only 15% of the institutions invited agreed to participate. This figure is similar to previous anthropometric studies in Hong Kong (26), and again we think a systematic difference is unlikely between Chinese children in participat-

Table 2. —*Continued*

Median (Range) for Indicated Age, yrs						
6	7	8	9	10	11	12
46.6 (33.2–66.1)	51.3 (36.5–72.7)	56.0 (39.8–79.3)	60.7 (43.2–86.0)	65.5 (46.6–92.8)	70.3 (50.0–99.7)	75.3 (53.5–106.7)
55.8 (41.3–73.9)	56.6 (41.9–75.0)	57.1 (42.2–75.6)	57.4 (42.4–76.0)	57.6 (42.6–76.3)	57.7 (42.7–76.5)	57.9 (42.8–76.7)
4.0 (2.8–6.0)	4.3 (2.9–6.4)	4.6 (3.1–6.9)	4.9 (3.2–7.5)	5.2 (3.4–8.0)	5.5 (3.6–8.6)	5.8 (3.7–9.2)
4.8 (3.4–6.9)	4.7 (3.3–6.9)	4.7 (3.3–6.9)	4.6 (3.2–6.8)	4.5 (3.1–6.7)	4.4 (3.0–6.6)	4.4 (3.0–6.6)
1414 (958–2145)	1370 (928–2078)	1324 (897–2008)	1274 (863–1931)	1221 (827–1851)	1161 (787–1761)	1092 (740–1656)
1187 (818–1783)	1245 (858–1870)	1294 (892–1944)	1341 (924–2014)	1387 (956–2084)	1427 (984–2144)	1458 (1004–2190)
72.3 (55.8–89.8)	74.2 (57.8–91.5)	76.0 (59.7–93.2)	77.5 (61.4–94.6)	78.9 (62.9–95.8)	80.1 (64.3–96.8)	81.4 (65.7–97.9)
86.4 (66.0–115.8)	83.9 (63.7–113.1)	82.3 (62.2–111.4)	80.8 (61.0–109.9)	79.2 (59.5–108.1)	77.6 (58.1–106.4)	76.2 (56.9–104.9)
20.7 (15.8–30.6)	23.1 (17.1–35.1)	26.0 (18.4–40.3)	29.2 (20.1–46.6)	32.8 (22.3–53.7)	36.6 (24.9–60.1)	40.6 (27.8–65.9)
115.4 (105.5–125.5)	121.2 (110.5–132.0)	126.8 (115.5–138.4)	132.6 (120.5–144.9)	138.5 (125.6–151.6)	144.5 (130.9–158.4)	150.6 (136.1–165.3)

ing schools and those in nonparticipating Shatin schools or schools in other districts in Hong Kong.

Another limitation was the numbers of children recruited who were aged 0–2 and 12 yrs old, which failed to reach the required sample size. However, we still recruited more children of these ages than have been studied previously, and the observed ranges for BP, HR, weight, and height are as expected, which suggests that our sample is representative. We hope to repeat the study in 0–2 yr olds and adolescents.

CONCLUSION

This large Hong Kong study presents normal values for cardiovascular indices in children using an ultrasonic CO monitor with good interobserver reliability.

ACKNOWLEDGMENTS

We thank the Chinese University of Hong Kong and the Hong Kong College of Emergency Medicine, for their generous support of this study. We also thank the children, parents, and school staff, without whom this study could not have been carried out.

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