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Introduction:

Longitudinal LV systolic function, as determined by mitral annular peak systolic velocity (Sm), may add significant information to conventional parameters, such as ejection fraction (EF), and has been shown to be as sensitive in detecting LV impairment compared to conventionally used methods such as the M-Mode in adults with various heart conditions. The Sm has been described to correlate well with LVEF in adults. The Sm is not a measure of the percentage shortening of the LV long axis, and therefore smaller persons with a smaller LV may have a smaller Sm. It is therefore crucial to have normal values for the pediatric age group, as normal adult values may not apply for children. We conducted a prospective study in a large cohort of children to determine normal values for the Sm from infancy to adolescence and to correlate them to age, sex, and body surface area (BSA). Furthermore a possible correlation between tissue Doppler imaging (TDI) measurements of Sm and M-Mode measured tricuspid annular excursion (MAPSE) in healthy children and adolescents was investigated.

Methods:

The study group consisted of 690 pediatric patients (345 male; 345 female) with a normal echocardiogram. The study group encompassed neonates to adolescents, including 40 newborns and 103 infants. Pulsed-wave (PW)-TDI of the lateral mitral annulus was performed using transducer frequencies of 3 – 8 MHz with spectral Doppler filters adjusted until a Nyquist limit of 5-20 cm/s. Guided by the 4-chamber view, a 2 - 5 mm sample volume was placed at the lateral corner of the mitral annulus at the attachment of the anterior leaflet of the mitral valve. Peak annular velocities during systole were recorded for three to five cardiac cycles, averaged, and analyzed off-line.

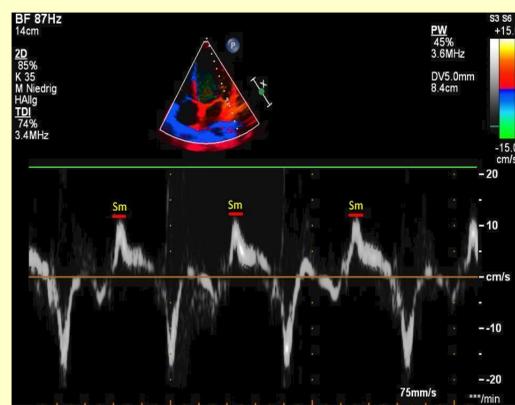


Figure 1: Apical 4-chamber view. The white broken line indicates M-Mode cursor placement at the mitral lateral annulus. Representative image of the mitral annular peak systolic velocity (Sm) measured in a 4 year old child with normal right and left ventricular function is depicted.

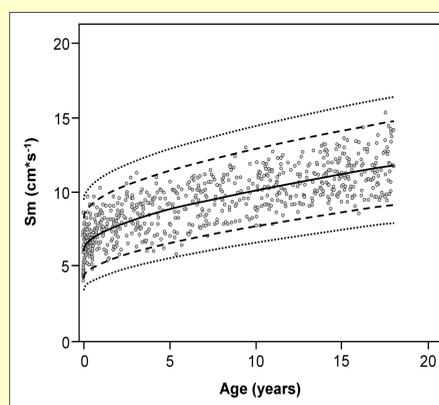


Figure 2: Age versus mean value of mitral annular peak systolic velocity (Sm) plus or minus 2 and 3 z-scores for age versus Sm. The mean is given as the black solid line. The z-score ± 2 and z-score ± 3 lines are given as the black broken line, and black dotted line, respectively.

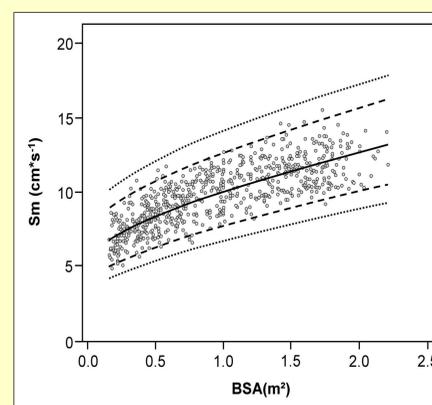


Figure 3: Body surface area (BSA) versus mean value of mitral annular peak systolic velocity (Sm) plus or minus 2 and 3 z-scores for BSA versus Sm. The mean is given as the black solid line. The z-score ± 2 and z-score ± 3 lines are given as the black broken line with circles, and black dotted line, respectively.

Month	n	MAPSV					BSA									
		Observed	Mean	-2SD	-3SD	+3SD	Predicted	Mean	-2SD	-3SD	+3SD	Mean	Min	Max		
1	40	5.8	5.8	3.6	8.0	2.5	9.1	6.3	4.3	8.6	3.7	9.8	0.22	0.16	0.52	
2	17	6.6	6.6	5.1	8.0	4.4	8.7	6.5	4.6	8.6	3.8	10.0	0.25	0.18	0.39	
3	14	7.1	7.1	4.7	9.5	3.5	10.7	6.6	4.7	8.9	3.9	10.1	0.27	0.16	0.39	
4-6	39	6.9	6.9	4.0	8.9	3.8	9.9	6.8	4.9	9.1	4.0	10.4	0.32	0.22	0.45	
7-12	42	7.4	7.4	5.2	9.7	4.1	10.6	7.2	5.1	9.5	4.3	10.6	0.41	0.32	0.47	
Year	2	63	7.6	7.6	5.6	9.6	4.7	10.6	7.6	5.5	10.0	4.6	11.3	0.50	0.40	0.67
3	37	8.6	8.6	6.3	10.9	5.1	12.1	8.0	5.9	10.5	4.9	11.8	0.56	0.43	0.70	
4	37	8.3	8.3	5.9	10.7	4.7	12.0	8.4	6.3	10.9	5.2	12.3	0.65	0.52	1.22	
5	26	8.7	8.7	6.0	11.4	4.7	12.7	8.7	6.5	11.3	5.5	12.7	0.74	0.66	0.99	
6	24	9.8	9.8	6.0	11.5	4.7	12.9	9.0	6.8	11.6	5.7	13.1	0.74	0.51	1.01	
7	30	9.6	9.6	7.1	12.0	5.6	13.2	9.3	7.0	11.9	6.0	13.4	0.87	0.57	1.12	
8	28	9.6	9.6	7.0	12.1	5.7	13.4	9.6	7.2	12.2	6.2	13.7	0.93	0.49	1.17	
9	30	9.9	9.9	7.3	12.6	5.8	14.0	9.8	7.4	12.5	6.4	14.0	1.04	0.67	1.33	
10	17	9.9	9.9	7.3	12.6	5.8	13.9	10.1	7.7	12.8	6.6	14.3	1.07	0.90	1.40	
11	42	10.3	10.3	7.7	12.8	6.4	14.2	10.3	7.8	13.1	6.8	14.6	1.20	0.90	1.48	
12	27	10.5	10.5	8.0	13.0	6.7	14.3	10.5	8.0	13.3	6.9	14.8	1.28	1.00	2.00	
13	25	10.5	10.5	8.3	13.2	7.2	13.9	10.7	8.2	13.5	7.1	15.1	1.42	0.97	1.77	
14	27	11.0	11.0	8.6	13.5	7.3	14.7	10.9	8.4	13.8	7.3	15.3	1.54	1.02	2.01	
15	38	11.3	11.3	8.8	13.7	7.6	14.9	11.1	8.6	14.0	7.4	15.6	1.64	1.31	2.00	
16	38	11.2	11.2	8.6	13.9	7.2	15.3	11.3	8.8	14.2	7.6	15.8	1.70	1.32	2.03	
17	29	11.4	11.4	9.0	13.8	7.8	15.0	11.5	8.9	14.4	7.8	16.0	1.70	1.27	2.21	
18	39	11.8	11.8	8.5	15.1	6.9	16.7	11.7	9.1	14.6	7.9	16.2	1.73	1.32	2.20	

Table 1: Classification table for the mitral annular peak systolic velocity (MAPSV or Sm) values of our healthy individuals. For each age group the observed and predicted mean, mean ± 2 standard deviation (SD) and mean ± 3 SD is shown. The corresponding BSA values are also given.

Results:

A representative image of the Sm in an four year old patient with normal RV and LV function is shown in Figure 1. The Sm ranged from a mean of 5.8 cm/s (Z-score ± 2 : 3.6 – 8.0 cm/s) in the newborn to 11.8 cm/s (Z-score ± 2 : 8.5 – 15.1 cm/s) in the 18 year old adolescent (Table 1). There were significant correlations between Sm and age ($r = 0.80$, $p < 0.001$) (Figure 2) and between Sm and BSA ($r = 0.79$, $p < 0.001$) (Figure 3). The Sm values increased from neonates to adolescents in a nonlinear way, as is expected because of the larger cardiac and thoracic size. BSA related z-scores ± 2 for Sm are shown in Table 1. A significant correlation was seen between Sm z-scores and MAPSE z-score ($r = 0.505$; $p < 0.001$).

Discussion:

MAPSE values increase with GA and BW. Due to developmental changes it is accurate not to use a single value throughout the population but rather reference the MAPSE to both GA and to BW to best interpret the results. MAPSE values were lower in preterm neonates compared to term neonates in this study. If the markedly lower MAPSE in lower weeks of gestation is solely a marker of growth-related changes within the study population or if it is a sign of altered systolic function in lower GA neonates due to the immaturity of the LV musculature remains unclear. As expected our normal values for MAPSE in the 40/0-6 term neonates are similar to MAPSE normal reference values of infants available in the literature. In our current study no significant differences of MAPSE values were found between male and female neonates. We did not find significant differences in the MAPSE values between 10 preterm neonates (GA: 26/0-6 – 28/0-6) without the need for nasal CPAP support and in 12 GA-matched preterm neonates with CPAP therapy.

Conclusion:

This report summarizes our experience with the use of Sm and MAPSE in assessing longitudinal systolic LV function in a large cohort of healthy children and adolescents. Sm in our opinion is an attractive technique because of its simplicity and ease of application. The positive but rather weak correlation between Sm and MAPSE measurements support our notion that in the future both measurements should be included in the battery of echocardiographic markers in pediatric patients with CHDs as in our opinion the measurements techniques and their results are not interchangeable.