Coronary Artery Caliber in Normal Children and Patients With Kawasaki Disease but Without Aneurysms: An Echocardiographic and Angiographic Study

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A total of 110 children aged 3 months to 16 years underwent two-dimensional echocardiography of the coronary arteries. Forty-two normal subjects and 68 patients with Kawasaki disease were evaluated. All 68 patients with Kawasaki disease underwent selective coronary arteriography. The objectives of this study were to 1) develop a normal profile of the proximal left and right coronary arteries as to caliber and shape in infants, toddlers and children using echocardiography; 2) compare the dimensions and shape of the coronary arteries of patients with Kawasaki disease but no obvious aneurysms with those of the coronary arteries of normal children; and 3) develop criteria that would permit distinguishing a large but normal coronary artery from a true aneurysm in patients with Kawasaki disease.

In the normal subjects and patients with Kawasaki disease, the caliber of the coronary arteries showed little variability from the ostium to 10 mm distally, and ranged in size from 2 mm in infants to 5 mm in teenagers. There was no significant difference between male and female subjects. The feature that distinguished the large but normal coronary artery without aneurysm from that with an aneurysm was its uniformity of caliber. Also, the caliber of the opposite coronary artery was generally at the lower limits of normal. It appears that the proximal coronary arteries of infants and children can be accurately assessed using high resolution two-dimensional echocardiography, and that sequential evaluation of subtle changes over time may be performed.

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Since 1974, when Kawasaki et al. (1) provided the first published description in the United States of mucocutaneous lymph node syndrome, the incidence of the disease in this country has steadily increased (2–5). The development of coronary artery aneurysms with thrombosis constitutes a major complication of the disease. Numerous publications (6–12) have demonstrated the efficacy and accuracy of two-dimensional echocardiography in detecting and characterizing the aneurysms. However, only preliminary echocardiographic data characterizing the normal coronary arteries in infants, toddlers and children are available (13). In addition, the problem of recognizing and distinguishing large but normal coronary arteries from those with an aneurysm in a patient with Kawasaki disease has not been addressed. This problem may lead to a false positive diagnosis of aneurysm by two-dimensional echocardiography (12).

Therefore, the objectives of this study were to 1) develop reliable standards for caliber and shape of the normal proximal left and right coronary arteries in infants, toddlers and children using echocardiography; 2) compare the coronary artery dimensions and shape in patients with Kawasaki disease who have no obvious aneurysms with those in normal children; and 3) analyze the features of the large but normal coronary artery that would allow us to distinguish it from one with a true aneurysm in patients with Kawasaki disease.

Methods

Study patients. A total of 110 children underwent two-dimensional echocardiography with special attention to the coronary arteries. Forty-two normal subjects ranged in age

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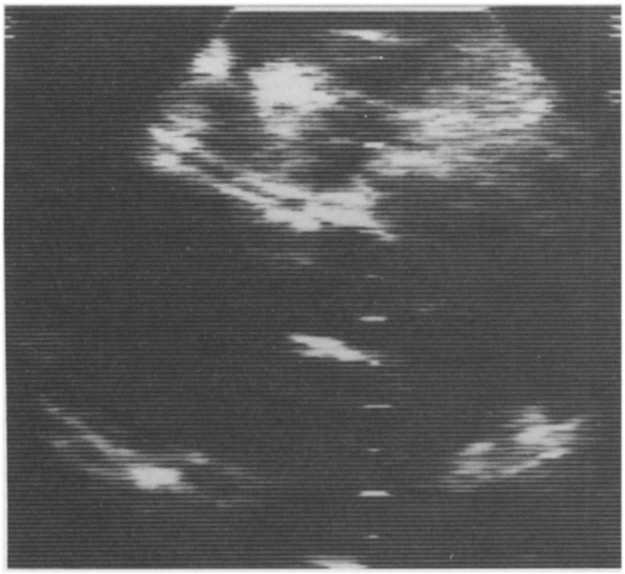


Figure 1. Two-dimensional echocardiogram of a normal proximal right coronary artery.

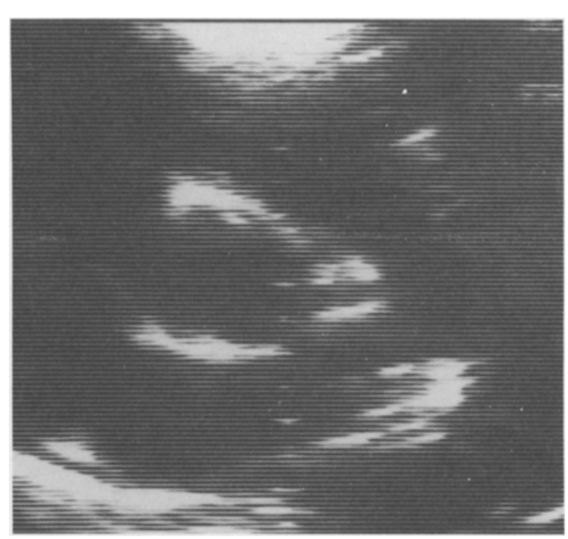
from 3 months to 16 years. These children had either a normal heart or insignificant asymptomatic arrhythmia, and all of them had normal echocardiograms (14). A second group of 68 patients ranged in age from 3 months to 15 years and had Kawasaki disease but no evidence of coronary artery aneurysm by two-dimensional echocardiography and selective coronary angiography. All 68 patients in this group underwent selective coronary arteriography within 6 to 8 weeks after the onset of the disease according to the following protocol. Each patient had a two-dimensional echocardiogram at the time of diagnosis and 4 weeks later. If an aneurysm was demonstrated by echocardiography in either study (12), cardiac catheterization, left ventriculography and selective coronary anteriography were performed within 2 to 4 weeks. If no aneurysm was detected, then cardiac catheterization and angiography were performed at 6 to 8 weeks after diagnosis. A repeat echocardiographic study was performed at the time of catheterization for comparison with the angiograms. Subsequent serial echograms were obtained at 12 to 14 weeks, 6 months and then yearly. Coronary aneurysm was never documented in the patients in this study.

Echocardiographic recording technique. Two-dimensional echocardiograms of the coronary arteries were obtained using our previously published method (13) and were recorded at the maximal expandable depth to minimize errors in measurements. Most coronary arteries were recorded within 3 to 4 cm of the transducer face. Whenever possible, a 7.5 MHz transducer with an axial resolution of 0.2 mm, focal zone of 1 to 4 cm and focal point of 2 cm was used unless adequate images of the coronary arteries were not obtained. In such cases, a 5 MHz transducer with an axial resolution of 0.3 mm, focal zone of 2 to 6 cm and focal point of 3 cm was used.

To image the proximal third of the right coronary artery, a standard precordial short-axis view of the great vessels was first obtained. Then, after the aortic and tricuspid valve leaflets were identified, the transducer was angled superiorly until the tricuspid leaflets were lost and the characteristic tricuspid ring echo and linear echoes of the proximal third of the right coronary artery were visualized (Fig. 1). Usually, slight rotation of the transducer (clockwise or counterclockwise) was necessary to record the origin of the right coronary artery, which varied in location from 11 o'clock (most common) to 2 o'clock (rare), within the sinus of the right coronary cusp. In some instances, placing the patient in a left lateral decubitus position helped to visualize the margins of the right coronary artery and record a longer segment of the right coronary artery. These maneuvers resulted in imaging the coronary artery in all these patients.

The left main coronary artery was recorded most successfully from the standard short-axis view of the aorta (Fig. 2). The bifurcation of the left main coronary artery into the left anterior descending and circumflex branches was best seen by moving the transducer superiorly one or two interspaces and toward the left shoulder while angling it inferiorly. From this position, a clockwise rotation of the transducer enhanced the imaging of the left main coronary artery and the continuation of a longer segment of the left anterior descending coronary artery. Usually, the lumen of the pulmonary artery was completely lost and a dense wedge-shaped echo containing these branches was seen. Often, moving the transducer closer to the sternum helped. In 99% of patients, these approaches permitted visualization of the left coronary artery. The circumflex branch usually was

Figure 2. Two-dimensional echocardiogram of a normal left main coronary artery.



visualized only a short distance beyond the bifurcation and was not included in the analysis.

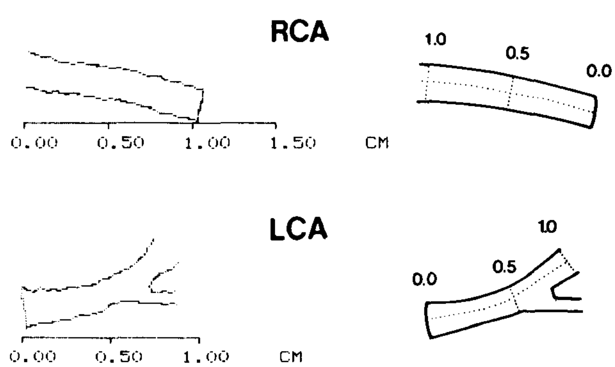
In every patient, the gain and preprocessing and post-processing of signals were adjusted to enhance the coronary artery wall and permit more discrete luminal boundaries for measurement. To avoid foreshortening of the artery, alignment of the image plane parallel to the long axis of the coronary vessel was maintained, even though the wall of the aorta may have been lost (Fig. 1 and 2). This also permitted better tracking of the artery.

The right and left coronary arteries could also be visualized from the apical and subcostal angles; however, the coronary arteries were measured only from the short-axis views because maximal depth expansion was possible only in this view.

Measurements. The coronary arteries were measured in the following manner. To standardize the method, the luminal boundaries of the artery were traced from selected videotape still frames with a sonic pen using a Digisonics EchoComp Image Analyzer and plotted on paper (Fig. 3). A straight line was drawn through the center of the lumen, parallel to the linear boundaries of the artery. Then a perpendicular distance between the two luminal boundaries was measured to determine the caliber of the artery. Because the absolute theoretic axial resolution of the 7.5 MHz and 5 MHz transducers is 0.2 mm and 0.3 mm, respectively, the computer rounded the measurements to the nearest millimeter. We believed that anything less would correctly be suspect because of coronary artery motion and hand measurement artifacts. Aneurysms occur in the most proximal portion of coronary arteries; thus, we chose to make luminal measurements at the ostium and at 0.5 and 1 cm from the ostium. In addition, we chose absolute distance rather than anatomic landmarks to more accurately assess variations in the caliber of the proximal coronary artery.

Interobserver error. Interobserver variability for measuring the coronary artery dimension by two-dimensional echocardiography was tested in 19 patients. Two experienced observers independently selected frames and measured the left and right coronary arteries at their origin from the aorta and at 0.5 and 1 cm from the origin. Least-squares regression analysis was used, and the corresponding correlation coefficient was calculated.

Figure 3. Digitized plots of the left (LCA) and right (RCA) coronary arteries, showing method of measuring the internal caliber.



Arteriography. Selective coronary arteriograms of the right and left coronary arteries were performed utilizing the Judkins technique (15), with hand injections in the following projections: anteroposterior, lateral, 30° right anterior oblique and 60° left anterior oblique. In some instances, the left coronary artery was recorded in a 60° left anterior oblique projection with 30° cranial angulation.

The coronary arteries were traced from a Vanguard XR 35 projector with the sonic pen. These were plotted and measured in the same manner as the echocardiograms. To avoid foreshortening of the left main coronary artery, the right anterior oblique projection was used to trace the left main coronary artery and its anterior descending and circumflex branches. The left anterior oblique projection was the most suitable projection for visualizing the right coronary artery in its entirety.

In addition, a separate hand measurement of the coronary arteries was performed by a second independent observer. The caliber of each coronary artery was determined by comparing its luminal boundary dimension with that of the catheter used according to the method of Vieweg et al. (16). The arteriograms were expanded by projecting images onto a screen 1.2 to 1.8 m away and tracing several frames of the catheter and coronary arteries. Comparison of the coronary arteries with the scale of the catheter was done and approximated to 0.1 mm.

Calibration for the measurements was accomplished with a predetermined catheter size and confirmed with a grid calibrated to 1 cm. At the end of each angiographic procedure, the right and left coronary catheters were taped to the grid, which was then placed at midthoracic level, and a brief cine exposure performed (16).

Results

Echocardiography. The caliber of the coronary arteries determined by echocardiography in the normal subjects showed little variability from the ostium to 1 cm, and ranged in size from 2 mm in infants and children to 5 mm in the older child and young adult (Fig. 4). There was a small but progressive increase in size with increasing age, and no significant difference between male and female subjects. In the patients with Kawasaki disease, coronary artery size did not differ statistically from normal (Fig. 4), ranging from 2 mm in infants to 5 mm in teenagers. The caliber of the arteries in patients without aneurysm remained constant from the ostium to 10 mm distally by both techniques. Three patients with Kawasaki disease had a left coronary artery dimension at the upper limits of normal (Fig. 5A), but the coronary artery caliber remained uniform. This is in contrast

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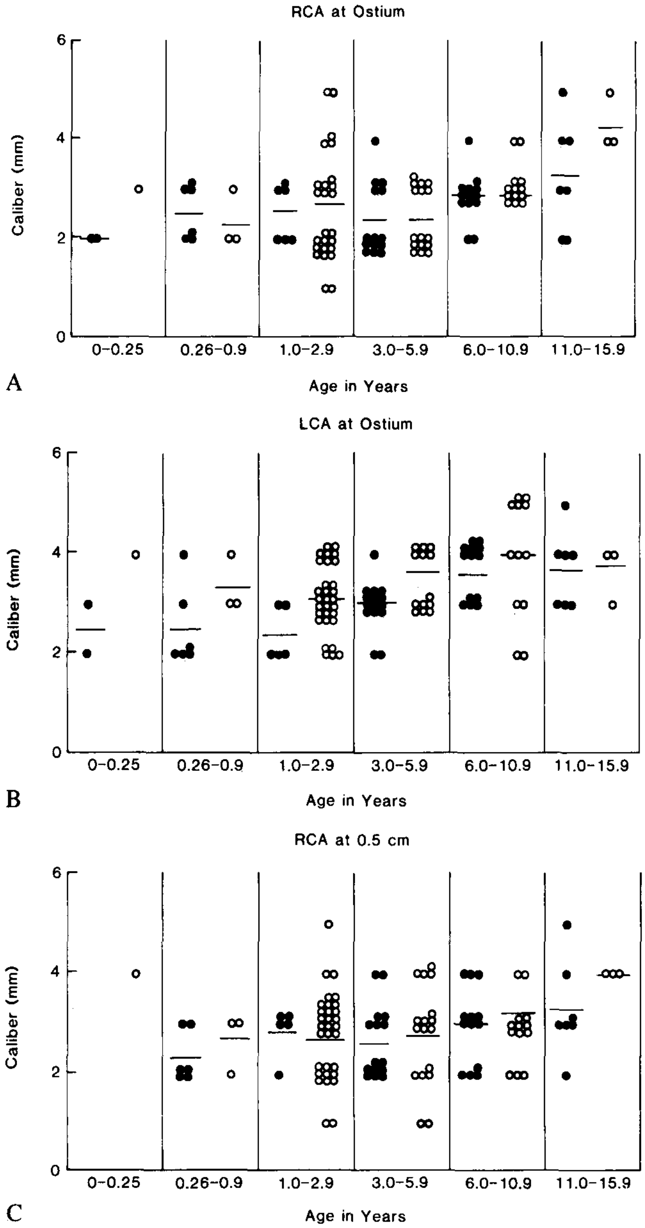

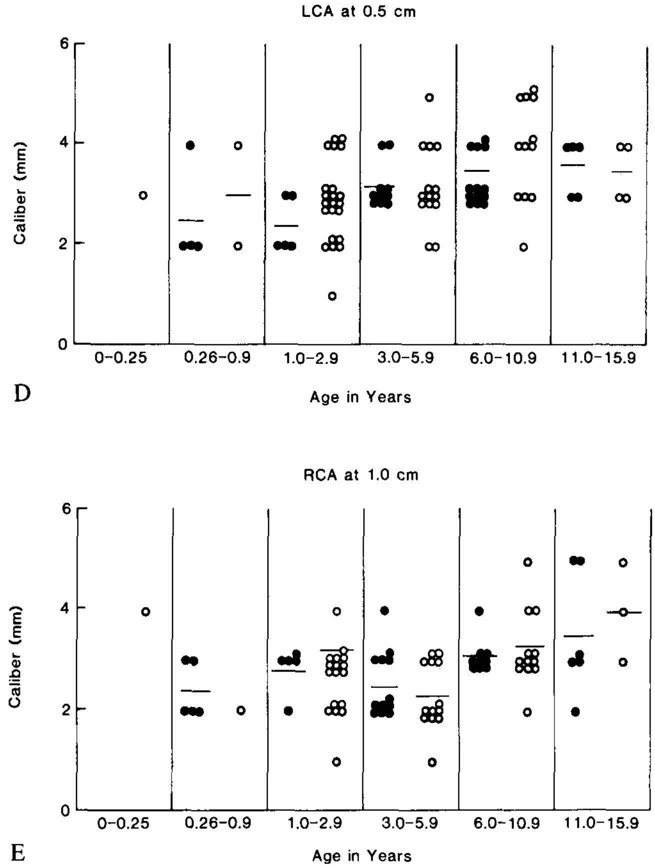

Figure 4. The caliber of the right (RCA) and left (LCA) coronary arteries for the different age groups at the ostium (**A** and **B**) and at 0.5 (**C** and **D**) and 1 cm (**E**) from the ostium in normal patients and patients with Kawasaki disease. — = mean value; ● = normal; ○ = patients with Kawasaki disease.

to the saccular aneurysms of similar size found in patients with Kawasaki disease (Fig. 6). In the four normal control (non-Kawasaki disease) patients who had coronary arteries at the upper limits of normal caliber, the opposite coronary artery generally was at the lower limits of normal caliber.

Interobserver error. The regression analysis of coronary dimensions measured on two-dimensional echocardiography independently by two observers demonstrated correlation coefficients of r = 0.81 at the origin of the right coronary artery, r = 0.78 at 0.5 cm from its origin and 0.91 at 1 cm from its origin. For the left coronary artery, the correlation coefficients for interobserver variability were r = 0.82 at the origin, r = 0.83 at 0.5 cm from its origin and r = 0.97 at 1 cm from its origin.

Coronary angiography. The caliber of the coronary arteries determined by angiography in patients with Kawasaki disease was comparable with but consistently smaller than the values obtained by echocardiography (Fig. 7). The mean dimension of the right coronary artery was 2.7 mm on echocardiography compared with 2 mm on angiography. For the left coronary artery, the same held true. On echocardiography, the mean diameter was 3.2 mm, and on angiography it was 2.8 mm.

Discussion

Echocardiography. Imaging the coronary arteries using two-dimensional echocardiography in infants and children with Kawasaki disease has been shown to be accurate and reliable (4–9,11). Increased experience and attention to details of the technique have resulted in improved sensitivity and accuracy in detecting coronary aneurysm in our patients with Kawasaki disease (12). We found that adequate time must be devoted to imaging the coronary arteries, which may add 20 to 30 minutes to each study. The vessels are not only small, but move constantly through the imaging plane. In addition, maintaining a plane parallel to the long axis of the artery minimized foreshortening, improved accuracy and allowed longer segments of the vessels to be

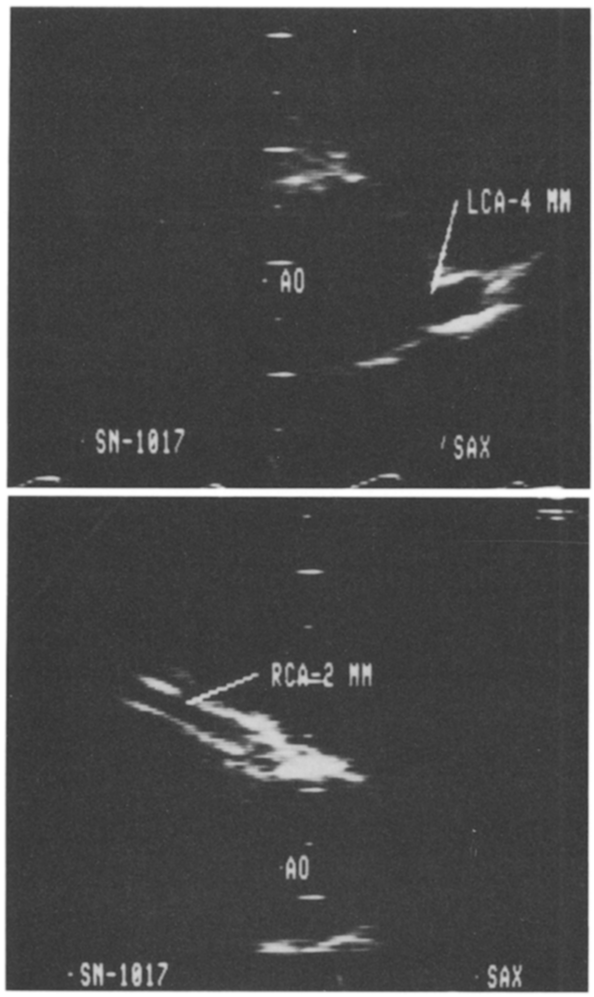

Figure 5. Two-dimensional echocardiogram of the coronary arteries of a 3 year old patient with Kawasaki disease but no aneurysms showing (**A**) a left coronary artery (LCA) dimension at the upper limit of normal (4 mm) and (**B**) a right coronary artery (RCA) dimension at the lower limit of normal (2 mm). AO = aorta.

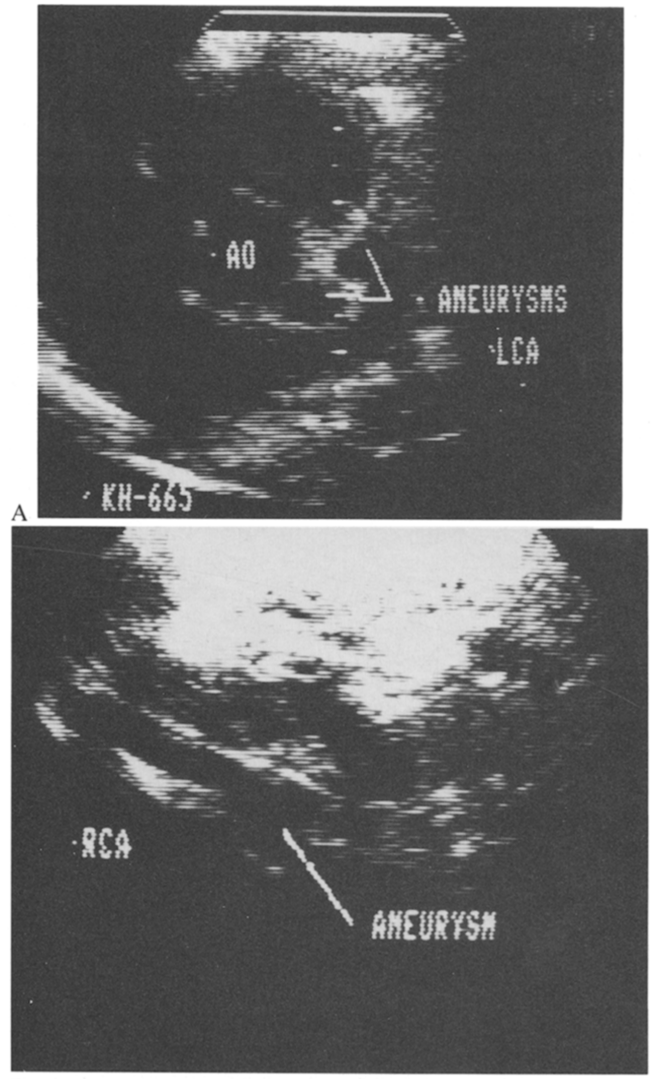

Figure 6. Patient with saccular aneurysms of the proximal left coronary artery (LCA) (**A**) and of the right coronary artery (RCA)(**B**). There is tapering of the right coronary artery beyond the aneurysm.

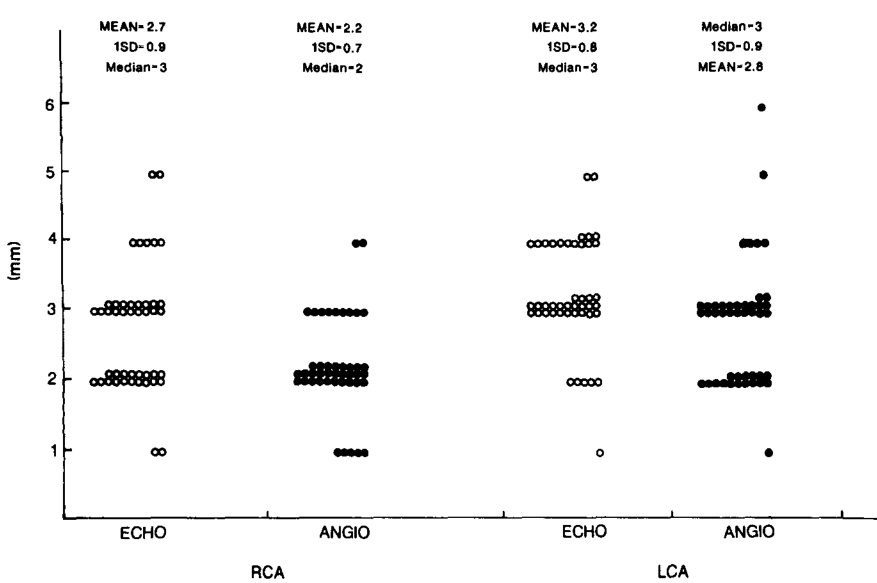

Figure 7. Comparison of echocardiographic (echo) and angiographic (angio) measurements of the right (RCA) and left (LCA) coronary arteries in patients with Kawasaki disease. 1SD = 1 standard deviation.

recorded. Finally, careful frame by frame review of the videotape was necessary for analysis.

The establishment of normal values of proximal coronary artery dimensions measured by echocardiography should prove useful for a variety of clinical conditions, especially for the evaluation of patients with Kawasaki disease. Once the reliability of the echographic technique was confirmed, it was possible to measure the coronary arteries of normal subjects and patients with hemodynamically insignificant cardiac findings, thus developing standards for the normal proximal normal coronary artery dimensions from infancy to adolescence. Although the growth in caliber of the arteries was small, it was definite and progressive.

We found it of great interest that the dimensions of the proximal coronary arteries of patients with Kawasaki disease (in whom aneurysms were not present) were nearly identical to those of the normal subjects (Fig. 4). Because there was no significant difference between these groups, we felt justified in considering these patients to be normal, and thereby effectively enlarged the normal population group.

Coronary angiography. The angiographic measurements were consistently smaller than the echographic values, although the differences were less than 1 mm. The reasons for the discrepancy are not entirely clear. The most likely explanation is that the angiographic measurement of the coronary lumen excludes any portion of the arterial wall, whereas the echographic measurements may include portions of the arterial wall. Another possibility is that coronary artery spasm may be induced by catheter manipulation during coronary angiography (17). Although this is generally a localized phenomenon, the subtle diffuse effects on the arterial wall may not be fully appreciated and could reduce lumen size. Likewise, a direct contrast effect, though negligible, may cause a slight reduction in lumen size (17). Although there is this difference in measurements between echocardiography and angiography when comparing one technique with another, the value of comparing serial measurements by a single technique should be recognized. Further selective coronary angiography will still be necessary in evaluating the more distal coronary arterial tree.

Conclusions. The feature that distinguished the large coronary artery without an aneurysm from that with an aneurysm was the uniformity of the caliber of the arteries from the ostium to its distal extent. Aneurysms narrow suddenly or taper gradually from a much larger than normal size to a normal caliber. Failure to recognize this feature may have accounted for the previously reported false positive two-dimensional studies (12), as compared with angiographic findings, in patients with Kawasaki disease. Transient dilation was not evident in the patients with Kawasaki disease in this study, as judged by sequential echographic evaluation. Among patients with an apparently enlarged coronary artery, the opposite coronary artery was generally smaller, with its caliber at the lower end of the normal range. Finally, the issue of dominance versus large is not germane to our study because dominance involves distribution of the coronary artery and cannot be established by echocardiography.

Our data indicate that the proximal coronary arteries of infants and children can be accurately assessed using high resolution echocardiography. This should permit sequential evaluation and detection of subtle changes that may take place over time in patients with diseases that may affect the coronary arteries. In addition, the echographic characterization and measurement of a much greater extent of the course of normal coronary arteries in infants, children and adults should be forthcoming as our experience broadens.

References

1. Kawasaki T, Kosaki F, Okawa S, et al. A new infantile acute febrile mucocutaneous lymph node syndrome (MLNS) prevailing in Japan. Pediatrics 1974;54:271.
2. Bell DM, Morens DM, Holman RC, Hurwitz MD, Hunter MK. Kawasaki syndrome in the United States. Am J Dis Child 1983;137:211–4.
3. Dean AG, Melish ME, Hicks R, Palumbo NE. An epidemic of Kawasaki syndrome in Hawaii. J Pediatr 1982;100:552–7.
4. Hiraishi S, Yashiro K, Kusano S. Noninvasive visualization of coronary arterial aneurysm in infants and young children with mucocutaneous lymph node syndrome with two dimensional echocardiography. Am J Cardiol 1979;43:1225–33.
5. Yoshida H, Funabishi T, Nakaya S, et al. Mucocutaneous lymph node syndrome: a cross-sectional echocardiographic diagnosis of coronary aneurysms. Am J Dis Child 1979;133:1244–7.
6. Yoshida H, Maeda T, Funabashi T, et al. Subcostal two dimensional echocardiographic imaging of peripheral right coronary artery in Kawasaki disease. Circulation 1982;65:956–61.
7. Chung KJ, Brandt L, Fulton DR, et al. Cardiac and coronary arterial involvement in infants and children from New England with mucocutaneous lymph node syndrome (Kawasaki disease). Angio cardiographic-echocardiographic correlations. Am J Cardiol 1982;50:136–42.
8. Hirose O, Misawa H, Kijima Y, et al. Two-dimensional echocardiography of coronary artery in Kawasaki disease (MCLS): detection, changes in acute phase, and follow-up observation of the aneurysm. J Cardiogr 1981;11:89–104.
9. Kalavathy A, Meyer RA. The differentiation of dominant left coronary arteries from aneurysms in Kawasaki disease using two dimensional echocardiography (abstr). J Ultrasound Med 1982;1:122.
10. Anderson T, Meyer RA, Kaplan S. Long-term evaluation of cardiac size and function in patients with Kawasaki disease. Am Heart J 1985;110:107–15.
11. Reller M, DeCristafaro J, Schwartz DC. Coronary aneurysms in a patient with atypical Kawasaki syndrome and a streptococcal infection. Pediatr Cardiol 1984;5:205–8.
12. Capannari TE, Daniels SR, Meyer RA, Schwartz DC, Kaplan S. The sensitivity, specificity and predictive value of two-dimensional echocardiography in detecting coronary artery aneurysms in patients with Kawasaki disease. J Am Coll Cardiol 1986;7:355–60.
13. Meyer RA. Kawasaki syndrome: coronary artery disease in the young. Echocardiography 1984;1:75–86.
14. Meyer RA. Pediatric Echocardiography. Philadelphia; Lea and Febiger, 1977:295.
15. Judkins MP. Selective coronary anteriography, part 1: a percutaneous transfemoral technic. Radiology 1967;89:815–24.
16. Vieweg WVR, Alpert JS, Hagan AD. Caliber and distribution of normal coronary arterial anatomy. Cathet Cardiovasc Diagn 1976;2:269–80.
17. Gensini GG. Coronary arteriography. In: Braunwald E, ed. Heart Disease. A Textbook of Cardiovascular Medicine. Philadelphia: WB Saunders, 1980:314.