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SPECIAL SECTION ON CORONARY ANOMALIES

WILEY Congenital Heart Disease

Clinical assessment of coronary arteries in Kawasaki disease: Focus on echocardiographic assessment

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Abstract

Echocardiography is an excellent noninvasive imaging modality for evaluation and follow-up of cardiac lesions, especially coronary artery changes occurring as a result of Kawasaki disease. The information obtained has prognostic implications and can be complemented with other modes of imaging for risk stratification and optimization of both medical and interventional therapy. The aim of this article is to describe the time line of echocardiographic follow-up of patients affected with Kawasaki disease. The classification of coronary artery changes and transthoracic echocardiographic views recommended for detailed evaluation of the coronary arteries are delineated in detail in this report.

KEYWORDS
coronary artery aneurysm, echocardiography, Kawasaki disease, sudden cardiac death

1 | INTRODUCTION

Echocardiography is an essential imaging tool for evaluating the patient with Kawasaki disease (KD). The recommended timing of routine echocardiograms in patients diagnosed with or suspected to have Kawasaki disease takes into account the timing of evolution of cardiac involvement and particularly coronary changes.[1] The baseline echo is ordered at diagnosis or in some cases to help make the diagnosis. Those circumstances where echo can assist with the diagnosis of KD include:

- Patients with fever >5 days, 2–3 clinical criteria, elevated CRP/ESR, and positive supplemental lab data
- Infants ≤6 months with fever ≥7 days and elevated CRP/ESR

It is important to bear in mind, however, that a negative echo does not rule out KD.

On the baseline echo, there may be features of pancarditis with myocarditis, valvulitis, and/or pericardial effusion. Left ventricular (LV) dysfunction has been reported in 20% and has been associated with greater odds of coronary dilation.[2] Coronary changes may be seen on the baseline echo. Even though the proximal coronaries may measure within normal limits for body surface, they may still decrease in size after the patient has recovered from Kawasaki Disease.[3] These larger coronary dimensions seem to be more than attributable to fever alone, and thus reflect a relative coronary dilation.[4] Coronary ectasia (≥ 2.5 Z-scores) has been reported in 26%–77% by day 10 of illness.[5] Echocardiography is considered positive in cases of suspected incomplete Kawasaki disease if any of 3 conditions are met: Z-score of left anterior descending coronary artery or right coronary artery ≥2.5; coronary artery aneurysm is observed; or ≥3 other suggestive features exist, including decreased left ventricular function, mitral regurgitation, pericardial effusion, or Z-scores in left anterior descending coronary artery or right coronary artery of 2 to 2.5.[1] Importantly, of those who later are found to have significant dilation or aneurysms, up to 80% have some abnormality noted on this baseline echo.[5]

If the baseline echo is unremarkable, then the next recommended time for echo is at 1–2 weeks of illness, as aneurysms typically begin to manifest by 10–14 days of illness and can progress during the first 4–6 weeks.[1] The third echo is obtained at 6–8 weeks (4–6 weeks posttreatment), generally past the time when further coronary changes would be expected to occur in routine, intravenous immunoglobulin responsive patients. As well, those patients with demonstrated only coronary dilation (+Z-scores >2 and <2.5) will typically have resolution by 8 weeks of illness.[1]

In evaluating the coronaries by echo, it is important to keep in mind that while the most common sites of aneurysm development are the proximal left anterior descending (LAD) and proximal right coronary artery (RCA) and at branch points, aneurysms can occur anywhere within the coronary circulation. Therefore, it is important to assess all coronary segments. How well pediatric echocardiography labs have

done in visualizing coronaries was assessed in a Pediatric Heart Network study in 2011.[6] The left main, proximal LAD, and proximal RCA were demonstrated >91% of the time. However, the distal right was demonstrated only in 65%, the circumflex in 86%, and posterior descending 54%. Importantly, the distal RCA and circumflex visualization rates improved with practice.

2 | ECHO TIPS

Sedation is a key tip for obtaining excellent coronary images in crabby, irritable infants, and toddlers. If an initial study is unsedated and, therefore, of poor quality, a sedated study should be obtained within 48 hours after diagnosis and initial treatment to provide the essential baseline for longitudinal follow up over time.[1] Other tips include using the highest frequency transducer possible, reducing 2D gain and adjusting the compression to improve visualization of the endovascular lumens. It is crucial to assess for coronary flow with color Doppler. One should avoid too much gain and thus creating false perivascular brightness. Coronary diameters should be measured from inner edge to inner edge of the vessel lumens. Finally, coronary assessment should not be limited to the parasternal views, with apical and subcostal imaging providing valuable information, particularly if the coronaries are dilated or if there is perivascular brightness highlighting the coronary course.

3 | VISUALIZING THE LEFT CORONARY SYSTEM

Parasternal short-axis view (PSSA): The left coronary can be visualized at the level of aortic root with a slight clockwise rotation (Figure 1). The distal LAD is generally considered that segment past the pulmonary valve annulus. Measure the left main coronary artery (LMCA) at its midpoint, past the normal flaring at aortic orifice, keeping in mind that left main involvement does not involve the orifice. Avoid routinely measuring at the branch point with LAD and circumflex as this is naturally is a bit larger. However, inspect this area carefully, as aneurysms not uncommonly occur at this point. Also, watch for dilation of the more distal vessels when sweeping inferiorly in the short axis view.

Parasternal long axis view (PSLA): A dilated circumflex may be seen in the left atrioventricular (AV) groove. Sweeping right to left between the aorta and pulmonary artery will demonstrate the LMCA, proximal LAD and circumflex.

Apical view: The origin of the left main and the bifurcation may be visualized sweeping anteriorly from the four-chamber view. The LAD may be visualized coursing down the septum, particularly if there is prominent perivascular brightness or dilation. Angling toward the left AV groove may demonstrate the circumflex.

Subcostal long axis imaging can demonstrate the circumflex, while the coronal views can demonstrate the LAD.

4 | VISUALIZING THE RIGHT CORONARY SYSTEM AND POSTERIOR DESCENDING

PSSA: The RCA origin and proximal course can usually be assessed at the level of the aortic root with slight clockwise turn. Measure the RCA just after initial rightward turn.

Follow the RCA laterally as far as possible, moving to the right parasternal if necessary.[7]

PSLA: The RCA origin and proximal course may be visualized arising anteriorly from the right aortic sinus in the long PSLA view. By

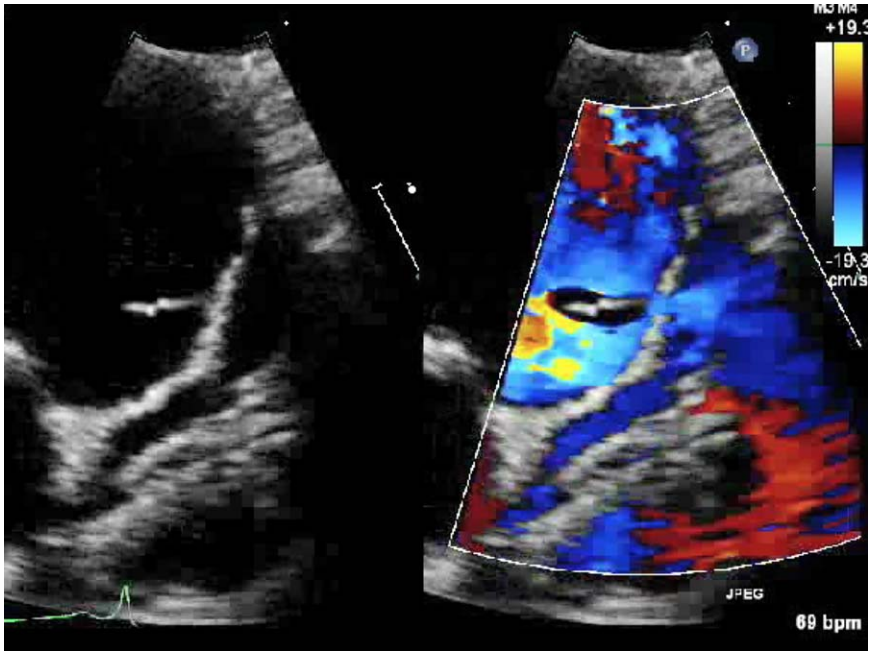

FIGURE 1 Color compare in the parasternal short-axis view showing diffuse dilation of the left main and left anterior descending coronary artery

angling toward the TV and lateral AV groove, the RCA in cross section may be demonstrated. By angling posteriorly, the RCA in the right AV groove can be in seen.

Apical views: scan the right AV groove anteriorly for the proximal and mid RCA, and rightward and posteriorly to assess the distal RCA and posterior descending artery (PDA) junction with the PDA.

Subcostal images: on subcostal coronal view of the right ventricular outflow tract the RCA can be seen. Subcostal short axis allows imaging of the RCA in the right AV groove. Subcostal LV long axis views will allow visualization of the mid RCA. The RCA/PDA junction and proximal PDA course may be able to be visualized with scanning from the right AV groove and then posteriorly along the diaphragmatic surface.

5 | ANEURYSM CLASSIFICATION

When assessing coronary aneurysms, determine and describe the shape of the aneurysm. Saccular aneurysms have equal axial and lateral dimensions. Fusiform aneurysms exhibit symmetric dilation with gradual distal and proximal tapering. Fusiform aneurysms may be more likely to resolve, but also more likely to develop thrombosis.[8]

Accurately measuring the diameters of the involved coronaries is very important as the severity of dilation has a huge impact on short-term and long-term management and prognosis in KD. Accurate measurement of height and weight is essential to determine accurate Z-scores. The 2017 American Heart Association guidelines outline a classification of coronary involvement based on raw dimensions and Z score (1).

Z-Score Classification

1. No involvement: Always <2
2. Dilation only: 2 to <2.5; or if initially <2, a decrease in Z-score during follow-up ≥ 1
3. Small aneurysm: ≥ 2.5 to <5
4. Medium aneurysm: ≥ 5 to <10, and absolute dimension <8 mm
5. Large or giant aneurysm: ≥ 10, or absolute dimension ≥ 8 mm[1]

Aneurysms may occur in series with narrowing of the affected vessel between the aneurysms. Ectasia refers to coronary dilation without a segmental aneurysm.[1]

If coronaries are noted to be abnormal on any of the standard echocardiograms, frequent echoes are crucial in helping to determine management as aneurysms can expand rapidly. Risk for thrombosis can be particularly high for those with rapidly expanding aneurysms. Echocardiograms should be done at least twice weekly while aneurysms are rapidly expanding until stable in size. Thereafter, for those with large or giant aneurysms, scans should be performed at least once weekly for the first 45 days and monthly for the first 3 months. Those with moderate or larger aneurysms should have scan thereafter at least once every 3 months for the first year.[9] Color Doppler interrogation is important to assess for flow within the dilated coronaries as well. The dilated coronaries should be images from multiple views at each study to assess for change in size, intraluminal echodensity suggestive of thrombus, and flow.

The 2017 American Heart Association (AHA) updated guidelines outline a classification of severity of vessel involvement based on raw dimensions and Z-scores.

6 | IMAGING BEYOND ECHO

Additional imaging modalities in KD become necessary in those with suspected distal disease by echo, including those with multiple or proximal large aneurysms. During the acute illness, the best choices are magnetic resonance imaging (MRI) and computed tomography angiography (CTA). These noninvasive modalities both demonstrate distal

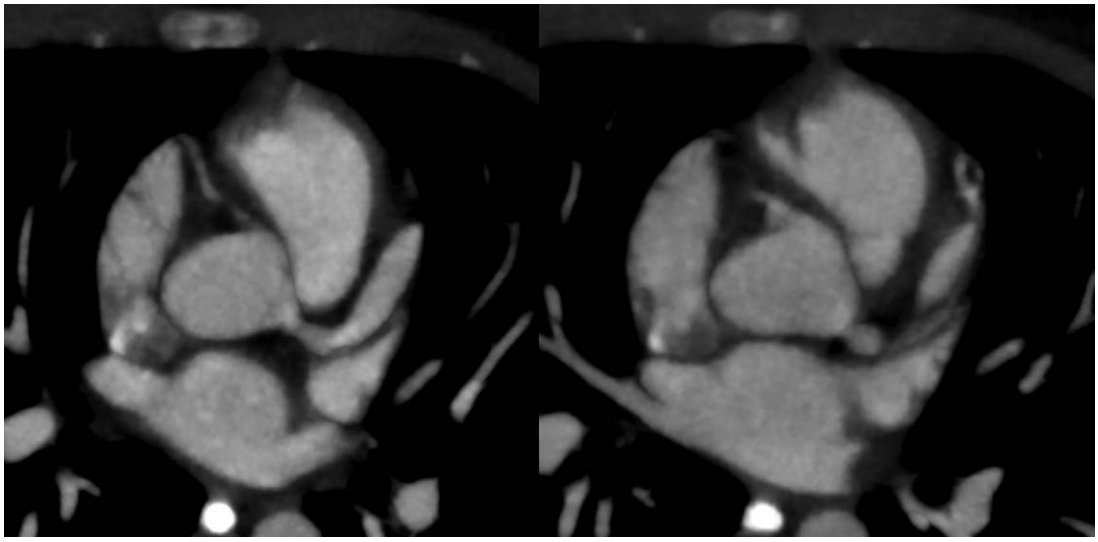

FIGURE 2 Computed tomography angiographic images showing a saccular aneurysm in the proximal left main and the right coronary artery. A fusiform aneurysm is present in the left anterior descending coronary artery

vessel dilation extremely well. Magnetic resonance imaging avoids radiation and can assess for biventricular perfusion or scarring, but requires anesthesia. Computed tomography angiography (volumetric scanner) can achieve an entire scan in less than 0.5 seconds and thus avoids need for anesthesia. Computed tomography angiography visualizes thrombus better than MRI (Figure 2), and, with resolution to 0.25 mm, CTA can better assess for stenosis than MRI.

Of aneurysms ≥6 mm, ~50% are reported develop stenosis by 15 years of follow-up which in turn predisposes to thrombosis.[10] Therefore, imaging modalities in addition to echo are necessary to assess for stenosis, thrombus formation, spontaneous revascularization of stenosed or thrombosed vessels by collaterals, or need for and efficacy of intervention. Catheterization remains the gold standard in assessing coronaries and can demonstrate stenosis and small collaterals better than any other modality. Determination of the need and timing for invasive angiography depends on the clinical situation and complexity and severity of the coronary disease. Concern for stenoses with symptoms of ischemia, changes in function by echo, onset of ventricular arrhythmias, or abnormal functional perfusion assessment by stress testing (stress MRI, stress echo, or stress nuclear imaging) often guide the need for invasive angiography.[1] For patients with current or persistent large to giant aneurysms, the AHA 2017 guidelines note that surveillance by angiography (CT, MRI or invasive) should be considered for diagnostic and prognostic purposes within the first year, and then every 1–5 years.

Functional assessments of coronary perfusion are crucial and go hand in hand with the anatomic assessment. In those with large or giant aneurysms, functional assessment should take place every 6–12 months or if the patient exhibits symptoms of ischemia or ventricular dysfunction by echo.[1] Those with some regression of large or giant aneurysms are still considered to be at risk for the development of stenoses, and assessment for inducible myocardial ischemia is recommended every 2–5 years.[1] Patients with persistent medium size aneurysms (Z-score ≥5 and <10 Z-scores with absolute dimension <8mm) also merit functional assessment every 1–3 years or if the patient has signs or symptoms of ischemia. Patients with persistent or current small (Z-scores ≥2 and <5) aneurysms are recommended for such assessment every 2–3 years in the absence of symptoms or signs of ischemia.[1] Functional assessment can include modalities such as nuclear medicine perfusion imaging exercise tests, stress MRI, PET scans, and stress echo. Nuclear stress tests are readily available, but are limited to an assessment of LV function. As well, balanced right and left coronary stenoses can generate falsely reassuring normal perfusion pattern. Routine dobutamine stress echo (DSE) in Japan has been reported to provide important prognostic information. In a 15-year follow-up of 58 patients, patients with a positive DSE had a cumulative event free survival of only 25.3% compared to 87.5% for those with negative DSE.[11] As well, increased severity/extent of wall motion abnormality at peak stress at initial test was an independent predictor of future adverse cardiac events. Interesting, positive stress tests could be seen in absence of angiographically demonstrated obstruction. This was likely reflective of limited coronary flow reserve and abnormal microvasculature.[11]

7 | CONCLUSIONS

Echo is excellent tool for baseline and ongoing assessment of coronaries in KD. Mandatory reassessment past the first year is needed for any patient with coronary changes beyond mild dilation: combination of echo, and functional myocardial perfusion imaging are essential elements in the evaluation of Kawasaki patients over time for patients with current or persistent aneurysms. Further imaging with angiography (via CTA, MRI, or invasive) is considered in the surveillance and assessment for those with medium or larger size current or persistent aneurysms.[1] CTA, MRI, cath, and functional perfusion stress tests are necessary to monitor and guide management.

CONFLICT OF INTEREST

None.

DISCLOSURES

None.

AUTHOR CONTRIBUTIONS

The author contributed in the concept/design, drafting, critical revision and approval of the article.

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