Detection of Small Ventricular Septal Defects

Comparison of Selective Left Ventricular Cineangiography with Indicator-Dilution Techniques

By Jo Craenen, M.D., Douglas Moore, M.D., Arno R. Hohn, M.D., and Edward C. Lambert, M.D.

SUMMARY
The value of selective left ventricular cineangiography in the detection of small ventricular septal defects was assessed in 23 patients in whom no shunt was detected by blood oxygen saturation change. A comparison was made with selective indocyanine-green indicator-dilution curves in 10 of these patients. A ventricular septal defect was demonstrated by both methods in 10. However, in one case, the indicator curve showed a left-to-right shunt whereas selective left ventricular cineangiography failed to demonstrate it. Conversely, in two other cases, selective left ventricular cineangiography demonstrated a small ventricular septal defect while a normal curve was obtained by indicator-dilution technique.

Comparing our experience with cineangiography with that of others, using hydrogen ion and indocyanine-green indicator-dilution techniques for the detection of small left-to-right intracardiac shunts, it seems there is little difference in the sensitivity of the three methods. Each is capable of detecting ventricular septal defects which cause left-to-right shunts too small to produce measurable blood oxygen saturation variations.

Additional Indexing Words:
Oxygen saturation of blood Hydrogen-ion indicator Indocyanine indicator

The diagnosis of a ventricular septal defect can be made during cardiac catheterization by consistent increases in blood oxygen saturation in samples obtained distal to the defect compared to those obtained in the right atrium and superior vena cava. Small ventricular septal defects with little or no change in the blood oxygen saturation in the samples obtained from the right heart, however, may not be detected by this approach.

Several methods have been employed in recent years to detect small intracardiac shunts. These include indicator-dilution techniques utilizing either indocyanine green, ascorbic acid, hydrogen ion by inhalation or injection, or a radioactive gas (85krypton) as indicators. Selective cineangiography has also been considered to be a sensitive method. Of these techniques indocyanine green, hydrogen ion, and cineangiography are the most generally used. Comparative studies to determine the relative accuracy of hydrogen ion inhalation and indocyanine green as indicators were performed by Hyman and co-workers and Hugenholtz and associates. We have found no reports comparing the accuracy of selective left ventricular cineangiography with selective injection of indocyanine green into the left ventricle as indicator for the demonstration of small ventricular shunts.
During the past 4 years we have encountered 23 children in whom small ventricular septal defects were not detected by a change in blood oxygen saturation. In 22, the defect was demonstrated by injection of contrast media into the left ventricle. Twelve of these patients had selective indocyanine green-indicator curves, 10 of which revealed a left-to-right shunt. It is our purpose to present the data on these patients to emphasize and compare the value of these approaches.

Methods

Seven hundred seventy-six patients underwent cardiac catheterization and selective cineangiography in the Children's Hospital of Buffalo from 1962 through 1965. As a result of these studies, a diagnosis of isolated ventricular septal defect was made in 132 children over the age of 2 years. In the 23 children who are reported on herein, the increase in blood oxygen saturation between serial samples collected in the right atrium or superior vena cava and the pulmonary artery was less than 3% (table 1). This was, in these children, equivalent to a variation of 0.4 volumes per cent or less. These values are all within the normal range of variation,

\[\text{values within normal range of variation}^{9-11}; \text{hence no definite diagnosis of a left-to-right shunt was possible on the basis of oxygen content variation.}

Other information obtained during catheterization was normal. All were sedated prior to cardiac catheterization with an atracast mixture containing meperidine, promethazine, and chlorpromazine.\[12 Complete right and left heart catheterization was performed by methods previously described.\[13]

Of the 23 patients retained for this study, none had been symptomatic prior to cardiac catheterization. With one exception, no cardiac enlargement was found on chest roentgenograms (table 1), and the electrocardiograms failed to show any evidence of chamber enlargement.

Blood oxygen saturations were determined in all 23 patients by a reflection oximeter.\[ In 12 patients, indicator-dilution curves were obtained after automatic injection of a standard amount of indocyanine green (7.25 mg) into the left ventricle; blood was then withdrawn through a Gilford densitometer (Model IR 108) at a constant rate of 25 ml/min from sampling sites on the right side of the heart with the resulting curves recorded photographically.\[ In all 23 patients, selective cineangiography was performed with the patient in the left lateral position. The contrast material was injected automatically under high pressure into the left ventricle in a dose of 1 ml/kg of body weight to a maximum of 40 ml. The image was recorded at a frame rate of 60 per minute. The resulting cineangiograms were individually reviewed by three observers. Evidence of a left-to-right shunt at the ventricular level by cineangiography was accepted only if each of the three observers agreed that contrast material passed directly from the left to the right ventricle during systole.

Results

In 22 of the 23 children, a diagnosis of ventricular septal defect was made on the basis of selective left ventricular cineangiography (table 1), which demonstrated passage of contrast material from the left to the right ventricle during systole in the region just below the aortic valve. In the other patient, the ventricular septum appeared intact.

In 10 of these children, a left-to-right shunt at the ventricular level was also demonstrated by the early appearance of indocyanine green in curves recorded serially from the pulmonary artery and the right ventricle, but not in those recorded from the right atrium or vena cava. In two patients, normal recirculation curves were recorded throughout the right heart.

In patient 13 (table 1) in whom a shunt at the ventricular level was not visualized by selective left ventricular cineangiography, the early appearance of indocyanine green in indicator curves recorded from the pulmonary artery and the right ventricle, but not in the curves recorded from the right atrium or from the inferior vena cava (fig. 1), demonstrated the existence of a ventricular septal defect. In this patient, neither the clinical features nor the aortogram indicated the presence of a coronary cameral fistula. Similarly, in the two children in whom there was no early appearance of indicator in serial curves recorded from the pulmonary artery, right ventricle, or right atrium, a small left-to-right shunt of contrast medium into the right

---

*American Optical Company, Model 10800, Southbridge, Massachusetts.
‡Electronics for Medicine, Model DR8, White Plains, New York.

Circulation, Volume XXXV, March 1967

‡Hypaque 75% or Renovist 70%.
Table 1

Clinical Features and Cardiac Catheterization Findings

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yr)</th>
<th>Murmur</th>
<th>Thrill</th>
<th>Chest x-ray (% CT ratio)</th>
<th>% Os saturation</th>
<th>Shunt by Dye* Cine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SVC</td>
<td>RA</td>
<td>RV</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>43</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>44</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>43</td>
<td>74</td>
<td>73</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>48</td>
<td>85</td>
<td>82</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>47</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>47</td>
<td>79</td>
<td>77</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>46</td>
<td>76</td>
<td>74</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>49</td>
<td>78</td>
<td>81</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>Mod. loud</td>
<td>Present</td>
<td>45</td>
<td>77</td>
<td>75</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Loud</td>
<td>Present</td>
<td>42</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>45</td>
<td>78</td>
<td>80</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>41</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>45</td>
<td>77</td>
<td>79</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>Mod. loud</td>
<td>Present</td>
<td>51</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>15</td>
<td>13</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>41</td>
<td>81</td>
<td>82</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>Mod. loud</td>
<td>Present</td>
<td>49</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>42</td>
<td>80</td>
<td>74</td>
</tr>
<tr>
<td>18</td>
<td>11</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>41</td>
<td>83</td>
<td>77</td>
</tr>
<tr>
<td>19</td>
<td>14</td>
<td>Mod. loud</td>
<td>Present</td>
<td>38</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>20</td>
<td>18</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>47</td>
<td>75</td>
<td>73</td>
</tr>
<tr>
<td>21</td>
<td>10</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>46</td>
<td>75</td>
<td>73</td>
</tr>
<tr>
<td>22</td>
<td>11</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>45</td>
<td>87</td>
<td>78</td>
</tr>
<tr>
<td>23</td>
<td>6</td>
<td>Mod. loud</td>
<td>Absent</td>
<td>41</td>
<td>84</td>
<td>81</td>
</tr>
</tbody>
</table>

*Series of indocyanine green indicator-dilution curves.
0 = not done; + = shunt detected; − = shunt not detected.
ventricle was visualized following selective left ventricular cineangiography.

Discussion

The diagnostic value of changes in blood oxygen saturation in serial samples taken from different areas in the right heart is well established and has been an integral part of the diagnosis of left-to-right intracardiac shunts since the first report published by Baldwin and associates in 1946. However, this method becomes unreliable when the left-to-right shunt of oxygenated blood is small. In the determination of ventricular septal defects, it has been recommended that at least a 5% difference be present in oxygen saturation between two serial samples obtained from the right atrium and the right ventricle. Grayzel and Jameson developed criteria for the diagnosis of ventricular septal defect from measurements of blood oxygen saturation by spectrophotometric methods. In their discussion, these authors considered the work of Barratt-Boyes and Wood, who had suggested that a difference equivalent to a 3% or greater saturation in paired samples of blood from the right ventricle than from the right atrium could be considered as indicative of a left-to-right shunt. Grayzel and Jameson concluded from an analysis of their own data that the presence of a 3% or greater increment in all pairs of samples was 100% reliable (the probability of correctly excluding a shunt when none exists), but only 70% sensitive (the probability of diagnosing an existing shunt).

In our review of the 132 patients with proven isolated ventricular septal defects, 23 had less than a 3% maximum difference between right atrial or superior vena caval and pulmonary arterial blood oxygen saturations (table 1), indicating a sensitivity by this criterion in our hands of 83%.

Of the various auxiliary methods available which are in general use in diagnostic cardiac laboratories, it would appear that indicator-dilution curves, using hydrogen ion or indocyanine green as indicators, and selective left ventricular cineangiography are the most valuable. Hugenholtz and his associates found 18 patients in whom an early appearance of hydrogen ion in the right heart demonstrated the presence of a left-to-right shunt when the oxygen data had proven inconclusive. In 11 of these 18, the presence of the shunt was confirmed by means of surgery, cineangiography, dye-dilution curves, or intracardiac phonocardiograms. They experienced one instance of a false-positive re-

Figure 1

Serial dye curves obtained in patient 13 (table 1) by rapid injection of 7.25 mg of indocyanine green into the left ventricle (LV) and sampling blood sequentially from the pulmonary artery (PA), right ventricle (RV), right atrium (RA), and inferior vena cava (IVC). The line pointed out by the arrow indicates the time of injection. Paper speed is 5 mm/sec and time lines are at 1 sec intervals. The early appearance of dye in the PA and RV blood, but not in the RA and IVC, indicates a left-to-right shunt at the ventricular level.

Circulation, Volume XXXV, March 1967
cording in a child in whom no shunt existed and encountered two other cases in which the early appearance of hydrogen ion in the right ventricle might have caused confusion in diagnosis if hydrogen curves from the femoral artery had not been subsequently recorded. Likewise, Vogel and associates demonstrated the value of hydrogen ion curves in establishing the presence of a left-to-right shunt in 10 patients in whom serial blood oxygen determinations were equivocal. Hyman and co-workers in comparing the sensitivity of the hydrogen electrode with indocyanine-green indicator-dilution curves and oxygen techniques found four patients in whom both the hydrogen system and the green-dye technique demonstrated the presence of a left-to-right shunt, while the oxygen method gave equivocal or negative results. In none of these three studies was comparison made between the sensitivity of the hydrogen technique or indocyanine green with selective left ventricular cineangiography.

In our study, left ventricular cineangiography failed once in the 23 patients, in whom the presence of a ventricular septal defect had not been demonstrated by blood oxygen determinations. Indocyanine green-indicator curves failed twice in the 12 children in whom they were performed.

Comparing our experience with selective left ventricular cineangiography and indocyanine-green indicator-dilution curves with that of others comparing indocyanine green with hydrogen as indicators, it seems that there is little difference in the overall sensitivity of these three methods in the detection of small ventricular shunts. For the complete exclusion of a ventricular septal defect, more than one technique should be used.

References
SMALL VENTRICULAR SEPTAL DEFECTS


Elusive Causes of Closure of Ductus Arteriosus

From data presently available it appears that, contrary to earlier observations in animals, the ductus arteriosus in man does not close immediately but remains patent for at least several hours after birth. Immediately after birth, a right to left or bidirectional shunt occurs, and this later replaced by a predominantly left to right shunt. Functional closure occurs several hours to several days after birth, depending upon a number if incompletely understood factors. Available evidence suggests that oxygen is probably the important factor causing closure of the ductus arteriosus. Hypoxemia, prematurity, and respiratory distress may be associated with delayed closure, but the basis for persistent patency of the ductus arteriosus has not yet been determined.

Detection of Small Ventricular Septal Defects: Comparison of Selective Left Ventricular Cineangiography with Indicator-Dilution Techniques
JO CRAENEN, DOUGLAS MOORE, ARNO R. HOHN and EDWARD C. LAMBERT

Circulation. 1967;35:442-447
doi: 10.1161/01.CIR.35.3.442

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1967 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/35/3/442

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/