A Nomogram for Estimation of the Cardiac Valve Areas

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SINCE the introduction of the formula by Gorlin and Gorlin in 1951,1 the cardiologist has been able to predict cardiac valve areas with considerable accuracy. Although the formula has distinct limitations, particularly in the presence of valvular regurgitation, its application in determining the severity of valvular and outflow tract stenosis has been widely accepted.

The mathematics of the formula itself involve the derivation of a square root, two steps in division, and one step in multiplication. Final solution of the equation requires a moderate expenditure of time and invites four opportunities for mathematical error. In order to circumvent these disadvantages and at the same time to enhance the understanding of the relationships between the various factors employed in the formula, a nomogram has been devised.2

**Principle**

The principle of the nomogram is based on the formula developed by Gorlin and Gorlin:1

\[
VA = \frac{F}{CV \times 2g \times (P_1 - P_2)} \quad \text{or} \quad \frac{CO}{(DFP \text{ or } SEP)}
\]

where:

- \(VA\) = cardiac valve area in cm.²
- \(F\) = blood flow across the valve in ml. per unit time
- \(g\) = gravity acceleration in cm. per sec. per sec. (= 980) \(\sqrt{2g} = \sqrt{2 \times 980} = 44.5\)
- \(C\) = empirical constant (0.7 for the atrioventricular and 1.0 for the semilunar valves)
- \(P_1\) = mean pressure in mm. Hg in the cardiac chamber proximal to the valve when the valve is open
- \(P_2\) = mean pressure in mm. Hg in the cardiac chamber distal to the valve when the valve is open
- mean gradient = \(P_1 - P_2\) in mm. Hg
- \(CO\) = cardiac output in ml. per minute
- \(DFP\) = diastolic filling period in seconds per minute
- \(SEP\) = systolic ejection period in seconds per minute.

By reduction,

- atrioventricular area = \(\frac{CO}{DFP}\)
- 31\(\sqrt{\text{diastolic mean gradient}}\) (or \(DG\))
- and semilunar valve area = \(\frac{CO}{SEP}\)
- 44.5\(\sqrt{\text{systolic mean gradient}}\) (or \(SG\))

To satisfy these equations, a composite nomogram consisting of two superimposed nomograms may be derived to estimate valve area (fig. 1). The first nomogram deals with the numerator. CO divided by DFP or SEP yields a quotient, "F," which represents the flow across the valve in ml. per second. Interchanging, \(CO = "F" \times \text{DFP (or SEP)}\). Stated logarithmically, log \(CO = \text{log "F" + log DFP (or log SEP).} A nomogram may be constructed consisting of three vertical equidistant lines with logarithmic graduations so that two log cycles in the middle line \(CO\) will equal one log cycle on each of the other two lines (DFP or SEP on the left, "F" on the right). Therefore, for any straight line transecting these three lines, the log value of \(CO\) will equal the log sum of \(DFP\) or \(SEP\) and "F." Seconds per minute are substituted directly into the left-hand line at the appropriate graduations and liters per minute into the middle line. The flow across the valve per second may be immediately determined for any combination of diastolic filling or systolic ejection periods and cardiac outputs by drawing a straight line through the points in question to transect line "F." The formula is now reduced to

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atrioventricular valve area (VA) = \frac{\text{Quotient } "F"}{31 \sqrt{DG}}

semilunar valve area (VA) = \frac{\text{Quotient } "F"}{44.5 \sqrt{SG}}

Similarly, log "F" = log VA + log 31 \sqrt{DG} or log 44.5 \sqrt{SG}. With the same principle employed in the first nomogram, a second nomogram may be constructed with line "F" serving as the middle line. Lines representing the gradient "G" (in mm. Hg) and valve area "VA" (in cm²) are placed equidistant from "F" on the left and right, respectively. As previously, two log cycles of the middle line "F" will equal one log cycle on the outer lines "G" and "VA." To accommodate the difference in empirical constants between the atrioventricular and semilunar valves, line "G" is divided into two components: diastolic gradients on the left and systolic gradients on the right. The line is graduated in the following manner; a series of gradients is introduced into the formulas 31 \sqrt{DG} and 44.5 \sqrt{SG}. The answers obtained are plotted on the scale of line "G," and the gradient used is entered on the appropriate side of the line at that point. For example, 31 \sqrt{10} = 98.0; 10 is entered on the left side of line "G" at 98.0. In contrast, 44.5 \sqrt{10} = 140.6; 10 is entered on the right side of line "G" at 140.6. The valve area may now be obtained by extending a straight line between the previously obtained point on line "F" and the gradient to transect line "VA," which has been graduated directly in cm².

Construction of the Nomogram

The nomogram may be constructed as shown in figure 2:

1. On a piece of semilogarithmic paper, draw a vertical line in the first log cycle for DFP or SEP and mark it from 10 to 100.
2. At an arbitrary distance, draw a second vertical line for "F" and mark the first cycle from 10 to 100 (at the same level as the markings on the first line) and the second cycle from 100 to 1,000.
3. Midway between these two lines, draw a third vertical line for the CO. Mark the first cycle from 100 to 10,000; 10,000 on CO will be at the same level as 100 on the other two lines.
4. At an arbitrary distance on the left side of line "F" draw a vertical line "G" and mark it from 100 to 1,000 over the length of two cycles.
5. At the same distance to the right side of "F" draw another line "VA" and mark it from 0.1 to 1.0 over two cycles.
6. 100 in "G" should be at the same level as 10 in "F" and 0.1 in "VA." 1,000 in "G" should be in line with 1,000 in "F" and 1.0 in "VA."
7. Pick a series of mean gradients in mm. Hg from 5 to 200 and calculate the results of 31 \sqrt{DG} for diastolic gradients and 44.5 \sqrt{SG} for the systolic gradients. Substitute the markings in line "G" by the results of the calculation with reference to different gradients. Put the diastolic gradients on the left side of line "G" and the systolic gradients on the right side of line "G," e.g., for a diastolic gradient of 10, 31 \sqrt{DG} equals 98.0. Put 10 on the left side along line "G" where it reads 98.0. For a systolic gradient of 10, 44.5 \sqrt{SG} equals 140.6; write 10 on the right side of line "G" where it reads 140.6.
8. The nomogram is now completed. Since DFP or SEP is applicable only to 60, that portion above 60 may be omitted.

Application

Use of the nomogram may be illustrated by the following examples:

Example I. Determination of Mitral Valve Area

Diastolic filling period of 30 seconds per minute, cardiac output of 4,000 ml. per minute, and diastolic mean gradient of 20 mm. Hg across the mitral valve.

With the point of a sharp pencil, mark 30 on
line "DFP" and mark 4 on line "CO." Join these two points and extend the line to meet line "F." By joining the point obtained on line "F" and the diastolic gradient 20 on line "DG," a straight line may be drawn to meet line "VA," yielding an answer of 0.96 cm.².

Example II. Determination of Aortic Valve Area

Systolic ejection period of 28 seconds per minute, cardiac output of 5,000 ml. per minute, and systolic mean gradient of 50 mm. Hg across the aortic valve.

As described above, join 28 on line "SEP" to 5 on line "CO" and extend the line to meet line "F." Join the point on line "F" and 50 on line "SG" and extend the line to "VA." The aortic valve area is 0.57 cm.².

The area of stenotic pulmonary or tricuspid valves can be calculated in a similar manner. If done carefully, the answer should be as accurate as calculation done with a standard slide rule or with a calculator.

Summary

A nomogram for the estimation of cardiac valve areas by the Gorlin formula has been described. The advantages of the nomographic approach are four-fold: (1) it results in considerable time saving in doing mathematical calculations; (2) it lessens the chance of mathematical error; (3) it provides a rapid means of checking the accuracy of a valve area calculated in the conventional manner; (4) it facilitates the understanding of the relationships between the various factors employed in the valve area formula.

As a result, the nomogram will be a useful adjunct in the operation of the cardiac catheterization laboratory and in the education of its physician personnel.

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References


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