Echocardiographic Evaluation of the Bjork-Shiley Prosthetic Valve

By JOHN E. DOUGLAS, M.D. AND G. DOYNE WILLIAMS, M.D.

SUMMARY

The in vitro and in vivo echocardiographic characteristics of the Bjork-Shiley tilting disc prosthetic valve are described. Optimal position of transducer and valve for detecting maximal disc excursion occurs when the ultrasound beam is perpendicular to the maximally opened disc. This alignment may vary from patient to patient requiring individualization by the echocardiographer. Rotation of the inner valve annulus at the time of surgery, when physiologically feasible, can facilitate optimal valve and ultrasound transducer alignment for serial postoperative evaluations of valve function.

Additional Indexing Words:
Ultrasound  Tilting disc prosthetic valves

THE POTENTIAL OF ULTRASOUND is just beginning to be explored in assessing prosthetic valve function. Several reports have reviewed the echocardiographic characteristics of the ball valve prostheses.\textsuperscript{1, 2, 3} Two recent articles have also examined the echocardiographic properties of the floating disc Beall mitral valve and Kay-Shiley tilting valve.\textsuperscript{4, 5} The echo characteristics of the Bjork-Shiley tilting disc valve,\textsuperscript{6} however, have not been reported. Because this valve, unlike the ball or floating disc, is asymmetric around its X, Y, and Z axes (fig. 1), the patterns of echoes reflected from its blood-disc interface are not as predictable. The disc is tethered off center in a stellite cage and pivots to 60° during ejection. The maximal disc excursions of the greater curvature are provided for the various sized prostheses in table 1. It is the purpose of this report to describe the echo properties of the in vitro and in vivo Bjork-Shiley prosthetic valve, and to suggest means of attaining optimal alignment of the ultrasound transducer and the disc valve.

Methods

For the in vitro studies a number 23 Bjork-Shiley aortic prosthetic valve was mounted in line with a pulse duplicator having a stroke volume varying between 20 and 100 cc and a stroke frequency of 30 to 150/min. To aid graphic discrimination of the opened from the closed position, the ejection period was adjusted to one-quarter to one-third the total cycle length. Polaroid and continuous strip chart recordings of M mode echocardiograms were obtained with a one centimeter, 2.25 MHz transducer focused at 7.5 cm and a series 100 Unirad Echo System and Textronic recorder. The transducer, at 2-4 cm from the valve, was rotated around the valve's Z and X axes of rotation, and the resulting echograms recorded. The closer position facilitated separating the annulus echoes from the disc echoes.

Twelve patients with Bjork-Shiley prosthetic valves in either the aortic or the mitral position were studied one week to six months postoperatively. The pattern of disc motion inscribed by the echogram was correlated with the plane of tilt of the disc as determined by PA and lateral chest X-rays.

Results

Disc motion of the tilting Bjork-Shiley prosthetic valve can be observed readily by ultrasound. The direction of tilt of the disc in relation to the transducer position, however, is important in determining the configuration and amplitude of the recorded excursion of the disc. Figure 1 illustrates eleven different patterns. Each echogram is placed at the approximate position of the transducer in relation to the valve which produced the echo. In I A the transducer is approximately 45° above the plane of the annulus and the dense echoes are arising from the disc in the closed position. During ejection the disc moves out of the plane of the echo sound beam which now passes through the valve orifice catching a few echoes from the disc's lesser segment. In IB a similar set of echoes is obtained while the valve is closed. However, the opened disc does obliquely intersect the echo beam during ejection. When the valve is sounded from directly above, as in 1C, echoes arising from the disc are readily observed in both the closed and opened position. When the transducer is placed above but behind the valve as pictured in figure 1, a dampened version of 1C as shown in 1D is obtained. With the

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transducer at a 2 o’clock position as in figure 1E the disc’s larger segment moves during ejection towards the transducer into a plane nearly perpendicular to it. This presents maximum disc surface area to the transducer, increasing the chance of obtaining a strong echo at maximum disc excursion. The dense distal echoes seen during valve closure (black on white arrow) represent the distal position of the annulus approximately 1½ cm behind the dense echoes arising from the fulcrum portion of the disc and its metallic strut-hinges (double white arrow). During ejection the echoes arising from the distal annulus are obliterated by the opened disc. In the last cycle in figure 1E and the first in figure 1F, echoes arising from the lesser segment of the disc (black arrow) can be seen receding from the transducer below the echoes arising from the hinge. From this view it is possible to move the transducer to aim closer to the free edge of the disc, as in the last two cycles of figure 1F. This eliminates the echoes returning from the disc’s smaller segment and reduces the number produced by the hinge.

In 1G the transducer beam catches the edge of the

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**Table 1**

**Dimensions and Maximal Excursion of the Bjork-Shiley Valves**

<table>
<thead>
<tr>
<th>Size (mm) (tissue annulus)</th>
<th>17</th>
<th>19</th>
<th>21</th>
<th>23</th>
<th>25</th>
<th>27</th>
<th>29</th>
<th>31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice diameter (mm)</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Excursion (to nearest mm)</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>17</td>
</tr>
</tbody>
</table>

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**Figure 1**

*Bjork-Shiley aortic prosthesis with the echograms placed around it in the relative position of the transducer at the time each tracing was obtained. In the X-Z plane, echoes returning from the annulus mask most of the echoes from the disc and cage as in H and J. In the Y-Z plane, except at the 12 o’clock and 6 o’clock positions, the amplitude of the disc excursion is damped as in D. The clearest identification of structures and maximal disc excursion is best observed from the 2 o’clock and 8 o’clock positions in the X-Y plane. Echograms E and F illustrate echoes obtained in the X-Y plane from the 2 o’clock position. During ejection, the major disc segment can be seen to move 13 mm proximal to the cage (double white arrow), while the lesser segment of the disc (black arrow) moves 4 to 5 mm away from the cage. Echoes returning from the distal annulus (black on white arrow) are lost as the transducer beam is tilted upward, during the last two cycles in F.*

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valve annulus and the more central portion of the disc. The observed disc excursion, therefore, is less and at no time does the disc appear closer than the annulus to the transducer. Minimal change in beam tilt from this point makes identification of structures more difficult by aggravating problems of beam width. In 1H the beam lies right along the X axis. The cascading echoes returning from the annulus camouflage disc motion. Figure 11 is actually a 7 o’clock to 8 o’clock view and demonstrates the disc moving away from the annulus during ejection and lying just behind the annulus when the valve is closed. In 1J the transducer is directed along the X axis from the 9 o’clock position, and as in 1H it is not possible to identify accurately the sources for the tangle of echoes.

Echocardiographic localization of the prosthetic valve in patients who have had either their mitral or aortic valve replaced is a relatively quick and simple procedure. As might be anticipated from the in vitro results, however, the relative alignment of the transducer is important to demonstrate maximum disc excursion. Figure 2A provides the chest X-ray illustrating the position of a patient’s number 23 Bjork-Shiley aortic valve (disc diameter equals 18 mm). Figure 2B is her accompanying echogram. In this patient, directing the transducer towards her aortic valve from her second intercostal space at the left sternal border demonstrated a maximal disc excursion of 16 mm. Since the smaller segment for this patient’s disc is directed anterior-superior and to the left, di-
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recting the transducer in this plane was comparable to the \textit{in vitro} alignment shown in figure 1E or 1F.

Figure 3A provides the chest X-rays and figure 3B the echogram of a patient in atrial fibrillation with a number 25 Bjork-Shiley mitral prosthesis (disc diameter equals 20 mm). In this patient it was possible to orient the disc at the time of surgery so that the smaller disc segment was placed inferiorly. The disc thus swings down towards the anterior papillary muscle. Optimal transducer alignment in this patient would occur when sounding from the area of the apex. Overlying lung, however, precluded this and the technically most satisfactory records were obtained from the fourth intercostal space 4 cm to the left of the left sternal border. This alignment is equivalent to that in figure 1B. From this perspective this patient’s maximal disc excursion equaled 12 mm.

Figure 4A is the PA and lateral chest X-ray of a 19-year-old male one week after closure of an infracristal ventricular septal defect (VSD) and replacement of his prolapsing aortic valve with a number 27 Bjork-Shiley prosthesis. In this patient the aortic prosthesis was inserted so the lesser segment of the disc is located to the right and posteriorly. This was done to minimize the possibility of interference with disc function by the patch graft. During ventricular systole, therefore,

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Posterior-anterior and lateral chest X-rays (A) and echogram (B) from a patient in atrial fibrillation with a Bjork-Shiley prosthetic mitral valve. The echogram was obtained from the fourth intercostal space, 4 cm to the left of the left sternal border. Transducer and prosthetic alignment can be deduced from the X-rays. With systole, total disc excursion equaled approximately 12 mm. Disc excursion was measured between the tips of the two black arrows. R.V. = right ventricle; IVS = interventricular septum.}
\end{figure}
the disc opens so its underside faces to the left and anteriorly. Placing the transducer in this patient's fifth intercostal space 3 cm to the left of the left sternal border provided the most satisfactory assessment of disc excursion as seen in figure 4B. With minimal changes in transducer angle it was possible to locate both receding (thick black arrow) and approaching (thin black arrow) portions of the disc around its hinge. Alignment in this instance is similar to that in figure 11. Maximum disc excursion equalled 15 mm.

Discussion

Since the ball and floating disc valves are symmetric around their Y axes, with maximal ball or disc motion occurring along this axis, directing the echo transducer along the Y axis and tilting it in either an X

Figure 4

Posterior-anterior and lateral chest X-rays (A) and echogram (B) one week after surgical correction of an infracristal ventricular septal defect with aortic prolapse and severe aortic insufficiency. A number 27 Bjork-Shiley aortic prosthesis was implanted and produced clear echoes demonstrating a maximal 15 mm excursion distal to the disc cage when viewed from the patient's fifth intercostal space 3 cm to the left of his left sternal border.
or Z plane provides satisfactory images of ball or disc motion. However, the asymmetry of the tilting disc valve allows an infinite potential for different views by rotating the disc on any one or combination of its three axes. The results of our study indicate that optimal alignment of the transducer with the Bjork-Shiley valve is of great importance. Ideal alignment occurs when the plane of the opened disc is perpendicular to the echo beam. Disc excursion can be most accurately determined when echoes from both segments of the disc in the open position can be seen with the echoes arising from the metallic struts located one-third to one-half way between them as in the first cycle of figure 1F and in figures 3B and 4B.

It behooves the technician or physician obtaining and/or interpreting the echograms to ascertain if a decreased disc excursion is a result of varying alignment of the tilting valve or valve malfunction. As shown in figure 1D and 1C, minimal changes in transducer-disc alignment may reduce apparent maximal disc excursion. Therefore, once the disc has been located it is mandatory that the transducer be tilted through multiple arcs while recording the echogram. Since the rotation of the valve on its Y axis may vary considerably from patient to patient, each patient optimally should serve as his own control and have an initial valve echogram as soon as possible after surgery, correlating this with the position established at surgery and by chest X-ray.

To date, we have been most fortunate in having a zero incidence of clinically apparent Bjork-Shiley prosthetic valve dysfunction. Therefore, we cannot attest to the value of echocardiography in detecting or confirming the presence of this complication. If a patient has demonstrated the predicted maximal excursion on a previous echogram, and a repeat echogram is unchanged, we would feel reasonably assured that the prosthetic valve itself was not malfunctioning. If, however, a patient previously demonstrated a pattern and excursion as shown in figure 1C or 1E, and subsequently, using the same technique and alignment, showed pattern 1D, we would suspect intrinsic prosthetic valve dysfunction.

Inasmuch as the inner anular ring of the Bjork-Shiley valve can be rotated on its Y axis within the sutured annulus, it is feasible to position the valve at the time of surgery so as to facilitate optimal echocardiographic recordings postoperatively. For the aortic valve this would usually mean directing the smaller disc segment towards the commissure between the left and right coronary cusps. Similar rotation of the mitral annulus is technically possible. However, because of the limitations of the anatomic relations within the left ventricular cavity, orientation of the disc must be predicated on optimal mobility of the disc. As a result of small left ventricles in patients with mitral stenosis, it may be necessary to settle for less than optimal positioning of the prosthesis for serial echograms in order to achieve optimal valve function.

Conclusions

Disc motion of the Bjork-Shiley prosthetic valve can be readily assessed by echocardiography. Because of the asymmetry of the valve, proper disc and echo transducer alignment is necessary for optimal detection of disc excursion. This occurs when the ultrasound beam is perpendicular to the maximally opened disc. Such alignment is usually most readily achieved with the aortic valve when the smaller disc segment is directed towards the commissure of the left and right coronary cusps, the transducer is placed in the second or third left intercostal space at the left sternal border and directed medially and slightly inferiorly. Comparable alignment for the mitral prosthesis can be achieved where surgically feasible, by rotating the smaller disc segment towards the anterior left ventricular free wall and by placing the transducer in the conventional position for obtaining an echogram of the normal mitral valve. Patients who are to be followed with serial echocardiograms to assess the function of their prosthetic valves should have an initial prosthetic echogram accomplished postoperatively as soon as is technically feasible. The topographical location on their chest where transducer placement elicits maximal disc excursion should be noted at that time and used as reference for future echograms.

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References

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