A Guide to the Radiographic Identification of Prosthetic Heart Valves

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SUMMARY To facilitate the radiographic identification of prosthetic heart valves, radiographic silhouettes of various aortic, mitral and tricuspid valve prostheses were analyzed and schematized. Forty different prosthetic valve models (heterograft and mechanical) were obtained from seven domestic manufacturers. Each prosthesis was positioned to approximate the aortic, mitral or tricuspid valve anulus plane. The valves were then radiographed and photographed as they would appear in posteroanterior and left lateral chest radiographs. The radiographic silhouettes were examined and a scheme was designed to enable easy, yet accurate, differentiation of the many heart valve prostheses. Illustrations of the various valve types are presented as they would appear in routine chest radiographs.

WITH THE CONTINUING INTRODUCTION of new prosthetic heart valves and the increasing awareness of differing prosthesis-related complications, it is important to be able to identify specific types of prosthetic heart valves. This gains particular importance when operation notes may not be available immediately. Both the gross appearances and radiographic silhouettes of many prosthetic heart valves have already been described. Since chest radiographs are easily obtainable and radiographic silhouettes of most prosthetic heart valves are quite distinctive, we have attempted to characterize, compare and classify the radiographic silhouettes of as many as possible of the prosthetic heart valves in use at present, as guidance to their clinical identification.

Methods

Forty different aortic, mitral and tricuspid valve prostheses were obtained from United States manufacturers or designers (table 1). Valves manufactured for only short periods of time or in small numbers were not included. Each prosthesis was mounted in a position simulating its appropriate surgical placement and photographed. It was then radiographed at 65 kV to demonstrate how it would appear in the posteroanterior (PA) and left lateral (LL) chest radiograph views. Several of the Starr-Edwards valve models could not be obtained and in those instances we have used previously published and unpublished illustrations, by courtesy of Dr. Albert Starr.

Although a particular prosthesis is shown in a specific valve site, it should be realized that it may be inserted in other positions. The basic characteristics of the radiographic silhouette of any particular prosthesis, however, will not differ if it is placed in a different valve anulus.

Definition of Terms

The base ring (figs. 2, 4) is the circular structure in the plane of the valve anulus which in the case of mechanical prosthesis supports the cage and which supports the stent of heterograft prostheses. The stent (fig. 2), arising at a right angle to the base ring of a heterograft prosthesis, supports the valve leaflets.

The cage is that portion of a mechanical prosthesis which, in conjunction with the base ring, limits the excursion of the ball or disc. The cage is composed of struts (fig. 4), which join the cage to the base ring. If all of the struts emerge on one side of the base ring plane, the cage is single (fig. 5). If struts emerge on both sides of the base ring plane, the cage is double (fig. 4). If converging struts are not connected, the cage is open (fig. 15); otherwise the cage is considered closed (fig. 16).

Prosthetic Valve Identification from Chest Radiographs

The radiographic identification of prosthetic heart valves is made from the recognition of the following components of the valve defined above: base ring, stent, ball or disc, cage and struts. The initial evaluation will indicate whether it is a mechanical or heterograft prosthesis; more detailed examination of the radiographic appearance is then necessary to identify the actual type and model in both instances.

1. Mechanical or Heterograft Prosthesis

To differentiate a mechanical from a heterograft prosthesis, the base ring (figs. 2, 4) should first be identified. The base rings of heterograft valves (figs. 1–3) are quite distinctive and easy to identify. In heterograft prostheses the only other structure which might be radiopaque and visible is the stent (fig. 2).

2. High or Low-Profile Mechanical Prosthesis

A number of additional observations are necessary to identify a mechanical prosthesis. First, high-profile prostheses (figs. 4–20) should be differentiated from low-profile valves (figs. 21–36). If the mobile portion of the valve is radiopaque, the decision is easy. In high-profile mechanical prostheses, the mobile portion is a ball; low-profile prostheses have a disc. If, however, the ball or disc is radiolucent, examining the cage will give the desired information. In order to accommodate the movements of the ball, the cage of a high-profile prosthesis is considerably taller than the cage of a low-profile prosthesis. Furthermore,
the distal portion of the high-profile cage is somewhat hemispherical in shape. The above notwithstanding, the differentiation between high and low-profile prostheses may be difficult radiographically.

Next, the struts (fig. 4) should be examined. The number of struts is determined by the number of junctions between the base ring and cage. With low-profile valves, one should note whether the struts arise at acute angles to the base ring plane (fig. 21), emerge into the valve orifice (figs. 22–24), or arise at right angles to the base ring plane (figs. 25–36).

After the struts have been identified, it is often important to determine the type of cage present. When evaluating a valve, the struts of which arise at right angles to the base ring, one should note whether the cage is single (fig. 5), or double (fig. 4), and whether the cage is open (fig. 15), or closed (fig. 16).

3. Identification of Prosthetic Valve Model

Tables 2a, 2b, 2c should be used to make further observations as indicated to determine the actual model of prosthetic valve. At the end of each series of observations is the name of the prosthetic model identified, along with the number of the figure where representative radiographs of that valve can be found.

In the legend of each illustration the differentiating characteristics of the radiographic silhouette are noted. In some cases, the subtlety and complexity of the differentiating features may require the observer to study some of the illustrations before decisions can be made. In most instances a photograph of the valve is juxtaposed with the corresponding radiograph, to make the radiographic silhouette more easily understood.

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*Information obtained from manufacturer or designer. In general, the number implanted figures are estimates, lying between total valve sales and number of implant cards returned to manufacturers as of July 1977. If data are not available, na is noted.

†A = aortic; M = mitral; T = tricuspid; P = pulmonary valve.

‡In 1969-70, the Hancock Xenograft had additional radiopaque stent supports not present in valves manufactured since 1971.
FIGURE 1. Edwards Xenograft (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring is radiolucent. Only the serpentine-like wire stent is radiopaque.

FIGURE 2. Hancock Xenograft (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). Only the narrow wire-like base ring can be seen, since the stent is radiolucent.

FIGURE 3. Ionescu-Shiley Xenograft (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). Base ring and stent appear flattened with many perforations in both.

FIGURE 4. Smeloff-Cutter Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). The wide base ring is encircled by two grooves. A double cage is present with large openings at the apex of each cage. Each cage consists of three struts, though the struts of one cage are much longer than the struts of the other cage. The struts of the two cages are not continuous through the base ring. The ball is radiolucent.

FIGURE 5. Starr-Edwards Model 1000 (aortic position: A, photograph; B and C, line drawing and radiograph). The base is heavy with three small feet projecting into the valve orifice. The closed cage, made up of three struts, encloses a radiolucent or, occasionally, radiopaque ball. (Reprinted by permission of the American Heart Association, Inc.)
Table 2. Scheme for Radiographic Identification of Heart Valve Prostheses

A. Heterograft Valves

- Absent
  - No radiopaque parts
  - Radiopaque stent
  - Only ring radiopaque
  - Flattened perforated base ring and stent
- Present
  - Radiopaque parts in addition to ring; no holes in struts
    - High profile cage—table 2B
    - Low profile cage—table 2C

B. High-Profile (Ball) Mechanical Valves

- Double cage
  - Projections into orifice
  - Tapering strut-ring junction
  - Ring edge concave
  - Toroidal prominence on ring edge
  - Serrated ring edge
  - Free ring edge margin serrated—DeBakey-Surgitool
  - Both ring edge margins serrated—Harken Ball
  - Double groove encircles base ring
  - Ring notched at strut junction—Starr-Edwards 2400
  - Single groove encircles base
  - Ring not notched—Starr-Edwards 2310, 2320 (fig. 12)
- Single cage
  - Cage open
    - Small opening
    - Poppet sits near equator
    - Poppet sits far from equator; base ring perforated
    - Hooks emerge from base ring
    - Large opening
    - Smooth base ring
    - Smooth base ring
    - Fluted base ring
    - Cage closed
      - Ring notched at strut junction—Starr-Edwards 6120, 6320 (fig. 17)
      - Ring not notched
      - Asymmetric, conical base ring edge; usually radiolucent ball—Starr-Edwards 6000 (fig. 18)
      - Symmetrically curved base ring edge; radiopaque ball—Starr-Edwards 6400 (fig. 19)
      - Four struts
      - Cage open
        - Poppet sits near equator
        - Poppet sits far from equator
C. Low-Profile (Disc) Mechanical Valves

Wide tapering struts emerge from base ring at acute angles — Lillehei-Kaster
Two short notched projections — Wada-Cutter
Two "U" shaped projections — Björk-Shiley
Two open cages — Cooley-Cutter

"Struts" project horizontally into base ring orifice only

Double cage
One closed, one open cage — Kay-Suzuki

Single cage
Struts Intersecting
Radiopaque disc — Heavy, perforated base ring — Starr-Edwards 6500
Narrow wire ring — Harken Disc

Struts non-intersecting
Radiolucent disc; radiopaque disc marker — Starr-Edwards 6520
3 struts — Cross-Jones

Serrated base ring
4 struts forming 2 bars — Incurved distal strut enclosures — Beall 103, 104

Parallel distal strut enclosures — Beall-Surgitool 105, 106

No muscle guard — Double concentric base rings — Kay-Shiley T
Single base ring — Kay-Shiley K

Smooth base ring — Single muscle guard — Kay-Shiley MGCD
Double muscle guard — Kay-Shiley TGCD
FIGURE 6. Starr-Edwards Model 1200 (aortic position: A, PA radiograph; B and C, LL radiograph and photograph.) The strut-ring junction is tapered. Three struts form a closed cage around a radiolucent or, occasionally, radiopaque ball. The edge of the base ring appears concave.

FIGURE 7. Starr-Edwards Model 1260 (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). The device is similar to Model 1200 (fig. 6), except that there is a toroidal prominence on the outer surface of the base ring. The ball may be radiopaque or radiolucent.

FIGURE 8. DeBakey-Surgitool Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring has numerous serrations along its free margin only. The closed cage is formed by three struts which bend at the strut-base ring junction and follow the base ring for a short distance. Only the irregular central portion of the ball is radiopaque.

FIGURE 9. Harken Ball Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). There are numerous serrations on both margins of the base ring. The closed cage, formed by three struts, encloses a radiopaque ball. The struts, on meeting the base ring, bend to follow the base ring for a short distance.

FIGURE 10. Surgitool 200 Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). Two prominent grooves encircle the base ring. The closed cage is formed by three struts. The ball is radiopaque. Where the struts join the base ring, they bend to follow the ring for a short distance.
FIGURE 11. Starr-Edwards Model 2400 Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). A single groove encircles the base ring, on which small studs are noted. The closed cage, made up of three struts, encloses a radiopaque ball which seats near its equator. The base ring is notched at the strut junctions.

FIGURE 12. Starr-Edwards Model 2310 Prosthesis (aortic position: A, PA radiograph with ball seated; B, PA radiograph with ball in mid-position; C, LL radiograph). The silhouette is similar to that described in figure 11, except that the base ring is not notched at the strut-base ring junction. Like Model 2400, the ball seats close to its equator (compare with fig. 13). Model 2310 was manufactured with a closed cage (as illustrated in this figure) or with an open cage (fig. 13). Model 2320 is radiographically indistinguishable from the closed-cage Model 2310.


FIGURE 14. Magovern-Cromie Prosthesis (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). Numerous hooks emerge from the massive base ring. Three struts form the cage, which has a large apical opening. The ball is radiopaque.

FIGURE 15. Braunwald-Cutter Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The smooth base ring is encircled by a single groove. Three struts form the cage, which has a large apical opening. The ball is radiolucent.

FIGURE 17. Starr-Edwards Model 6310 Prosthesis (mitral position: A, PA radiograph with ball seated; B and C, LL radiograph and photograph with ball at apex). The base ring, encircled by a single groove, has tiny studs in its orifice as seen in the left lateral radiograph. At the strut-base ring junction, the base ring is notched. The cage encloses a radiopaque ball. Model 6310 was manufactured with a closed cage (pictured here) or with an open cage, in which the apical opening appears as that illustrated in figure 20. Model 6320 is radiographically indistinguishable from the closed-cage Model 6310.

FIGURE 18. Starr-Edwards Model 6000 (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). A single groove encircles the base ring, which is smooth and somewhat conical. Four struts form the closed cage around a radiolucent or radiopaque ball. At the strut-base ring junction there is no notch.

FIGURE 19. Starr-Edwards Model 6400 (mitral position: A, PA radiograph; B, right lateral radiograph). A single groove encircles the base ring, whose edge margins are symmetric. Four struts enclose the radiopaque ball in a closed cage. No notch is present at the strut-ring junction. (Radiographs courtesy of Dr. Albert Starr.)

FIGURE 20. Starr-Edwards Model 6300 (mitral position: A, photograph; B and C, line drawing and radiograph). A single groove encircles the perforated base ring, which has no studs in its orifice. Four struts form the cage, which has a small opening at its apex. The ball is radiopaque and sits far from its equator (compare with fig. 17). (Reprinted by permission of the American Heart Association, Inc.)
Figure 21. Lillehei-Kaster Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). Two wide tapering struts emerge from the base ring at acute angles. The disc is radiolucent.

Figure 22. Wada-Cutter Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). Emerging from the base ring orifice are two eccentrically placed, notched projections of equal size. The disc is radiolucent.

Figure 23. Björk-Shiley Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring is encircled by a groove. Emerging from the base ring are two eccentrically placed "U" shaped structures which are of unequal size. The disc is radiolucent.

Figure 24. Björk-Shiley Prosthesis with disc marker (aortic position: A, PA radiograph; B and C, LL radiograph and photograph). The appearance is the same as that in figure 23, except that the radiolucent disc contains a narrow circular radiopaque disc marker.

Figure 25. Cooley-Cutter Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring is encircled by a single groove. Enclosing the radiolucent disc are double open cages, each composed of four struts. The four struts of one cage are continuous through the base ring with the four struts of the other cage.
FIGURE 26. Kay-Suzuki Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). Two cages, each composed of four struts, join the narrow base ring. One of the cages, lying near the plane of the base ring, is open. The other cage, relatively high, has intersecting struts. The disc is radiolucent.

FIGURE 27. Starr-Edwards Model 6500 Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The perforated base ring is encircled by a groove. Four struts intersect to enclose a radiopaque disc.

FIGURE 28. Harken Disc Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The very narrow wire-like base ring joins with four struts which intersect to enclose a radiopaque disc.

FIGURE 29. Starr-Edwards Model 6520 Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring is smooth. Four struts intersect to enclose a radiolucent disc which contains a circular marker.

FIGURE 30. Cross-Jones Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The edge of the base ring is tapered. An open cage composed of three struts encloses a radiolucent disc which contains a circular radiopaque marker.

FIGURE 31. Beall Model 103 Prosthesis (mitral position: A, PA radiograph; B and C, LL radiograph and photograph). The base ring is serrated. Four struts are joined by two incurring bars, which connect pairs of struts. The disc is radiolucent. Model 104 prosthesis has a similar radiographic appearance.
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