

Aortic Valve Leaflet Sizer: A New Device for Aortic Valve Sparing

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In aortic valve-sparing surgery, the native valve of the patient is left in place but may need correction of its dimensions in order to regain full competence. A sizer was designed that can simultaneously measure the leaflet height and free edge length. A prototype was built and successfully used in porcine hearts of various sizes. The sizer is easy to use and provides

dependable measurement of the aortic leaflet dimensions. Moreover, it represents a new resource on which surgeons may draw on to perform aortic valve-sparing surgery, with a better outcome for the patients.

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Recent research into aortic valve sparing has emphasized the need for considering the dimensions of all the valve components and not only the valve's gross appearance (1). Pathological changes may affect not only the aortic root but also the leaflets, and any severe geometric mismatch may induce regurgitation (2,3). Although some dimensional information is available from a preoperative examination, it is ultimately in the operating room that the surgeon is able to measure all valve components with best accuracy. Measuring the leaflets represents a major challenge, however, given their ability to deform and stretch easily. In the absence of a better technique, surgeons may on occasion use a flexible ruler or a silk thread. The study aim was to propose a solution to aortic leaflet measurement in the operating room, which would enhance the chances for a perfect restoration of valve competence.

Materials and methods

Necessary background information to design a leaflet sizer was accumulated while measuring leaflets using different techniques, both in normal subjects and patients (1). The useful dimensions of an aortic leaflet are its height, measured from the lowest point of the line of attachment to the middle of the free edge (dis-

regarding the Arantius nodule), and the free edge length. The measurement of leaflet dimensions in 20 silicone rubber molds of normal human aortic valves pressurized at 80 mmHg yielded a range of 12.2 to 18.7 mm for leaflet height, and a range of 26.2 to 35.4 mm for leaflet free edge length. By contrast, the measurement of leaflet dimensions in 14 patients with aortic root dilatation and aortic regurgitation using transesophageal echocardiography yielded a range of 13.2 to 24.9 mm for leaflet height, and a range of 25.1 to 39.3 mm for leaflet free edge length. The range of measurable dimensions was therefore specified as 11 to 25 mm for leaflet height, and 24 to 38 mm for leaflet free edge length.

Although, in theory, all combinations of leaflet height and free edge sizes could exist (especially in diseased valves), close examination of the measurements reported previously (1) suggests that relatively few do. This led the present authors to devise a 'shoe-tree' tool which was designed simultaneously to measure leaflet height and free edge length. Modeling software (Rhinoceros 3D; RSI, Germany) was used to create a three-dimensional representation of the tool, and a stereolithographic prototype was ordered from a rapid-prototyping subcontractor. The hearts of six pigs (bodyweight 50-120 kg) were obtained from a local abattoir, and the aortic roots scalloped. This allowed direct insertion of the sizer between the leaflet and the remaining rim of the aortic wall (sinus), with the belly side of the sizer pointing towards the center of the valve.

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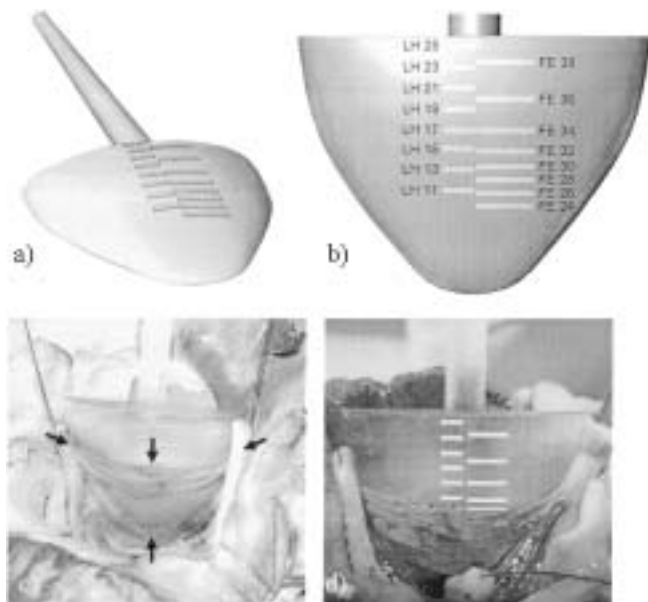


Figure 1: a) Perspective view of the leaflet sizer with handle. b) Front view of the sizer's two sets of scales - leaflet height (LH) on the left, short scales, odd numbers; leaflet free edge length (FE) on the right, long scales, even numbers. c) The sizer is in position for measurement of a leaflet in a scalloped porcine aortic root. The vertical arrows describe the leaflet height; the oblique arrows delimit the leaflet free edge length. d) Close-up view of another porcine aortic valve showing how the measurements for leaflet height and leaflet free edge length are obtained simultaneously. The photograph has been enhanced to show the scales even in low-contrast black and white.

Results

The sizer and its handle is illustrated in Figure 1(a). The sizer has a flat back, and the edges are rounded so that they do not cut through the valve tissue. The rounded tip allows for easy insertion of the sizer, while two sets of scales on the belly correspond to dimensions of the leaflet height and free edge length (Fig. 1(b)). In order to minimize risks of confusion during the measurement, the scales for the leaflet height are short and marked with odd numbers, while those for the free edge length are long and marked with even numbers. Because actual dimensions were not written on the sizer (due to a lack of space), a reading technique from the top down was adopted, starting from 25 mm for leaflet height, and from 38 mm for leaflet free edge length, in 2-mm decrements, until the leaflet masked the lower scales. The sizer, ready for measurement of a leaflet, is shown in Figure 1(c). The commissures of the leaflets being measured were gently pulled straight up so as not to overstretch the leaflet dimensions, while allowing the sizer to reach the leaflet attachment line at the bottom. Unwanted gaps

between the leaflet and sizer were avoided by orienting the sizer correctly, using its handle. It can be seen that the leaflet (Fig. 1(d)) has a height of 13 mm, and a free edge length of 30 mm. In all of the hearts tested, repeated measurements on the same leaflets by two independent observers yielded similar results. Any uncertainty on these measurements was systematically less than the 2-mm interval between the scales.

Discussion

Only three to four trial measurements were required until two observers achieved repeatable and similar results within seconds. The measured dimensions were also in excellent agreement with those determined by using two forceps to overlay a silk thread either on the leaflet free edge or the leaflet height, and by measuring the distance between the tips of the forceps clamped on the thread, once outside the valve. By pulling vertically on the commissural pillars, it was possible to make the sizer consistently fit the leaflets; the unfolding or limited extension of the leaflet free edge made the central prominence of the Arantius nodule almost disappear, providing for an easy reading from the sizer. In Figures 1(c) and (d), the natural rise of the commissures at both extremities of the free edge is accentuated by the perspective of the photograph and the curved belly of the sizer. The resulting uncertainty in the measurement of the leaflet dimensions is on the order of ± 1 mm, which is acceptable for the intended use of the dimensions, as explained below.

The measured dimensions of the three aortic valve leaflets are intended to be used to help surgeons establish which parameters require fixing during aortic valve-sparing surgery, in order for the patient's valve to regain competence. With the sizer, it is possible for surgeons not only to establish the extent of tailoring of the leaflets required, but also to check the leaflet dimensions after correction. Surgeons may elect to follow their own technique for dimensioning the valve components, or to exploit the tables established previously (2,3). As few aortic valves have leaflets of equal size, it may be necessary to average the dimensions measured from the three leaflets in order to use these tables, which consider identical sizes for all three leaflets. This approach is considered to be safe, as the tabulated values demonstrate how the valve components can vary in size by several millimeters before the valve becomes non-functional (2).

Overall, the sizer represents a 'missing link' in current efforts to rationalize the planning and execution of aortic valve-sparing surgery. Based on the prototype described herein, sterile autoclavable, or disposable sizers with high-contrast scales can easily be manufac-

tured. For more oddly shaped leaflets, additional sizers can also be produced by increasing or decreasing the protrusion of the sizer belly.

References

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