Manufacturer-Provided Effective Orifice Area Index Charts and the Prevention of Prosthesis-Patient Mismatch

Chad M. House1,2, William B. Nelson1,2,3, Timothy J. Kroshus2,4, Ranjan Dahiya1,2, Philippe Pibarat5

1Regions Hospital, Department of Cardiology, St. Paul, MN, 2HealthPartners Medical Group, Bloomington, MN, 3University of Minnesota Medical School, Minneapolis, MN, USA, 4Regions Hospital, Department of Cardiothoracic Surgery, 5Institut Universitaire de Cardiologie et de Pneumologie de Québec/Québec Heart & Lung Institute, Department of Medicine, Laval University, Québec, Canada

Prosthesis-patient mismatch (PPM) occurs when an implanted prosthesis is too small relative to the patient’s body surface area (BSA). However, mismatch can often be prevented by indexing the expected effective orifice area (EOA) of a prosthesis to the patient’s BSA and then selecting the largest implantable prosthesis to avoid mismatch. Previously, prosthesis manufacturers have attempted to simplify this process by providing charts that include the expected EOA for their prosthesis, already indexed into an array of BSA values. One caveat with these charts is that the expected EOA data must truly be reliable, or the charts will misguide the implanting surgeon. Manufacturer-provided charts could be improved by standardizing the EOA data, with one potential source being the hemodynamic data submitted to the United States Food and Drug Administration. This review discusses PPM, manufacturer-provided EOA charts, and the regulation of EOA data.

The Journal of Heart Valve Disease 2012;21:107-111

Prosthesis-patient mismatch (PPM) is predictable at the time of valve implantation and, subsequently, its incidence can be reduced (1,2). The prediction of PPM is achieved by using reliable effective orifice area (EOA) data to forecast the postoperative EOA for an implanted prosthesis. The manufacturers of prosthetic heart valves frequently provide charts for their prostheses, the aim being to help the surgeon select the optimal prosthesis size for implantation (Fig. 1). The present review is focused primarily at the role of these charts.

Background

The concept of valve prosthesis-patient mismatch (PPM) was first introduced by Rahimtoola in 1978 (3). Typically, PPM occurs when the EOA of a normally functioning prosthesis is too small relative to the patient’s body surface area (BSA). The qualification and quantification of PPM is best accomplished by indexing the EOA of the prosthesis, as measured by the continuity equation, into the patient’s BSA (4). No significant PPM is present when the effective orifice area index (EOAi) exceeds 0.85 cm²/m², moderate PPM is present when the EOAi is between 0.65 and 0.85 cm²/m², and severe PPM is present when the EOAi is less than 0.65 cm²/m² (4). These gradations of PPM are based on the exponential curve associated with the mean gradient and EOAi relationship (4,5) (Fig. 2).

Generally, PPM is clearly associated with an increased transprosthetic gradient (4-6), and also appears to be associated with an increased short-term
PPM, although these authors utilized the EOAI (based on reference EOAI data) to define the presence of PPM and identified only those patients with the smallest 10% of EOAI-values as having PPM. This would most likely result in a degree of overlap between the PPM and no-PPM arms of the study, as those patients with severe PPM had been compared to a group in which patients with moderate to severe PPM, mild PPM and no PPM were pooled together. In addition, there appeared to be certain differences between the two groups, with the PPM patients being significantly younger and primarily female, both of which factors affect life expectancy. Significant differences were also noted in terms of early mortality and low-output syndrome, with the PPM group having a higher early mortality rate and an increased prevalence of low-output syndrome.

In several studies, reference EOAs from previous publications have been used instead of the EOAs measured for each individual in the patient cohort. The advantage of this method is that it can be applied in the operating room prior to prosthesis implantation, in order to anticipate the risk of PPM and, eventually, to use an alternative surgical procedure/prosthesis to prevent this problem from occurring. Another advantage of the projected EOAI, as calculated from the normal reference EOAI, is that it is not influenced by: (i) measurement errors; (ii) variations in hemodynamic conditions including transvalvular flow; and (iii) any acquired pathologic process that might occur after implantation (e.g., prosthesis thrombosis, parus, and calcific degeneration). Thus, the projected EOAI might
provide a more accurate index of the intrinsic hemodynamic performance of the normally functioning prosthesis. The main limitation of this index, however, is that it requires a reliable and accurate source of normal reference EOAs for each model and size of prosthesis.

Recently, projected EOAi-values have been shown to incorrectly stratify patients with or without PPM in approximately one-third of all cases, while the degree of misclassification varied extensively depending on the source of the reference EOA used to calculate the projected EOAi (14). Nonetheless, it has been shown in several studies that when the projected EOAi is calculated systematically by using a reliable source or reference EOA-value, then the incidence of PPM can be significantly reduced (1,2).

Effective Orifice Area Index Charts

For this review, Edwards Lifesciences (Irvine, CA, USA), St. Jude Medical (St. Paul, MN, USA), Medtronic (Minneapolis, MN, USA) and Sorin Group (Burnaby, British Columbia, Canada) were each contacted to provide an historical insight into the EO Ai charts. Subsequently, St. Jude Medical, Medtronic and Sorin responded to the inquiries and provided both global perspective as well as company-specific perspectives on the history of EO Ai charts.

The first iterations of EO Ai charts seem quite possibly to be attributable to either St. Jude Medical or Medtronic. Both companies introduced their stentless bioprostheses in 1997, and separately corroborated this timeframe to be associated with their initial EO Ai charts. It might be speculated, however, that these charts were constructed to showcase the hemodynamically advantageous associated with stentless bioprosthetic valves.

Currently, EO Ai charts are ubiquitous in operating rooms, and are provided by essentially every heart valve manufacturer. Whilst it is unclear whether the initial EO Ai charts were intended to be a clinical tool, the contemporary charts are utilized as such, with an apparently patient-centered goal of reducing the incidence of PPM. These charts are hung on the operating room walls and are referenced when determining the size of prosthesis that a patient should receive.

The Problem

Although EO Ai charts are used as a clinical tool, there is very little understanding or documentation of their efficacy at accomplishing their primary goal of reducing the incidence of PPM. Very few of these charts have ever undergone any critical evaluation, and of the few that do exist most have performed poorly at predicting postoperative EOAs and subsequently reducing the incidence of PPM (15,16). Some charts exhibit a good performance to predict the risk of PPM, whereas others are based on less-reliable reference EOA data and have a low sensitivity for predicting PPM. These latter EO Ai charts are not beneficial to patient care, with regards to reducing PPM, and may actually be detrimental by inducing PPM in some patients.

The central component of an EO Ai chart is the reference EOA data, the accuracy of which is critical with regards to the efficacy of a chart to reduce PPM. The importance of knowing the origin of the EOA data being used was stressed by Bleiziffer et al. (2).

The EO Ai data that constitute the EO Ai charts typically originate from one of three sources:

- In vivo data derived from Doppler echocardiography.
- In vitro data derived from a pulse duplicator.
- Geometric area of the prosthesis stent orifice.

From where these data originate requires an evaluation of the references provided on the EO Ai chart. Typically, two types of reference are included on a manufacturer-provided EO Ai chart:

- References to establish the concept of PPM, that it is hemodynamically and clinically deleterious, and that it can be predicted and prevented.
- References which identify the source(s) of the EOA data utilized on the chart.

It is this second type of reference that must be closely scrutinized. Such references may include data obtained from large, peer-reviewed Doppler echocardiography cohorts, from small, single-center Doppler echocardiography cohorts, pulse duplicator data (which may often be listed as 'data on file'), and even simple geometric orifice area (GOA) calculations. The latter usually involves simply the area (mm²) of the stent orifice, with the assumption being made that there are no leaflets or mechanical occluders within the orifice, and that there is no obstruction of flow when it passes though the prosthesis orifice (which is not the case).

Both, the in vitro data and GOA calculations have been shown to be inaccurate for predicting the in vivo EOA, and thus are unreliable sources for creating an EO Ai chart (2,19). Echocardiographically derived EOA data can be used to predict the EOAs and, subsequently, to reduce the incidence of PPM, although the caveat here is that the data must derive from a reliable and reproducible source (1,2). Several of the currently used charts are based on EOA data from small-cohort echocardiography studies, although unfortunately such data may overestimate postoperative EO Ai-values and subsequently result in a higher incidence of PPM than might be expected (20).
Currently, no standards or regulations for EOAi charts are in existence; rather, the source of EOA data is the sole responsibility of the marketing department for each respective heart valve manufacturer. Thus, a conflict of interest would appear inevitable, as companies must decide either to create a clinically relevant chart, based on reproducible EOA data, or to market their product aggressively in an unregulated environment.

Pre-Market Approval Data: Potentially a More Reliable Data Source

All medical devices marketed in the United States undergo review by the United States Food and Drug Administration (FDA), in addition to a specific type of review known as pre-market approval (PMA). Within the PMA submission for heart valve prostheses, the device company must include hemodynamic data for their respective valvular prosthesis. These data provide the FDA with expected in vivo hemodynamic findings for the prosthesis under consideration. The data typically includes mean values (+1 SD) for both mean gradient and EOA. The hemodynamic data from the PMA submission can often be found in the instructions for use (IFU) that are packaged with prosthetic valves. Directly comparing the IFU data to that provided on an EOAi chart often results in incongruent findings, with the chart-based EOA-values often being much larger than those given in the PMA submission or in the IFU. This would appear to be a misrepresentation of the product’s true or expected hemodynamics.

A Realistic Role

The regulation of the EOAi charts, by mandating that manufacturers use their PMA submission data, would likely result in more reliable charts. The PMA data are readily available for prostheses currently marketed in the United States, and have already been reviewed by the FDA. A recent editorial even provided an EOAi chart for four currently used bioprostheses, based on their PMA submission data (21).

An editorial from 2007 opined that “...manufacturers have a clear responsibility in providing and disseminating accurate reference values so that the prediction and prevention of VP-PM can be easily incorporated into the clinical decision-making process. Hence, the charts should be as reliable and user friendly as possible, and should be conceived as a tool to improve patient outcome rather than a sales argument (22). This viewpoint should serve as direction for the task of regulating EOAi charts.

In conclusion, in an era of guidelines and standardization, the regulation of EOAi charts is advocated in order to provide surgeons with more reliable estimates of postoperative EOA. The PMA data submitted to the FDA represent a possible source for standardized EOA data.

Acknowledgements

Dr. Pibarot has received modest research grants from Edwards Lifesciences and Medtronic.

References


