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Review Article

Intraoperative Echocardiographic Assessment of Prosthetic Valves: A Practical Approach

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INTRAOPERATIVE ASSESSMENT of prosthetic valves is performed either immediately after replacement of a native valve as part of a redo valve surgery or after an incidental discovery of a diseased valve during unrelated cardiac surgery.[1] It is a challenging undertaking that requires the highest levels of clinical multitasking under very labile hemodynamic circumstances. Echocardiographers involved in this decision-making should possess advanced training in perioperative transesophageal echocardiography (TEE) and significant clinical experience. There are multiple types of bioprosthetic and mechanical valves (Figs 1 and 2), and they vary in their structure, function, and echocardiographic appearance. Most are interchangeable in position, and their intracardiac location can affect (structurally and functionally) the surrounding structures. Most commonly in the perioperative arena, echocardiographic assessment of prosthetic valves is performed after immediate separation from cardiopulmonary bypass (CPB).[2] The context and the time constraint mandate that every echocardiographer develop a patient-specific contextual, methodic, and objective decision-oriented echocardiographic evaluation plan. Whereas the details of the specific characteristics of each prosthetic valve are beyond the scope of this article, the authors present a general qualitative and quantitative approach toward immediate post-CPB evaluation of prosthetic valves.[3]

More than one quarter million prosthetic valves are implanted each year worldwide, with a 50% distribution between bioprosthetic and mechanical valves.[3] Due to ongoing technologic and design improvements, new and improved prosthetic valves continuously are introduced into clinical practice. The requirements of an ideal prosthetic valve include, but are not limited to, absence of stenosis or regurgitation, nonthrombogenic and noninfectious, and possibly possess self-repairing capability (Fig 3). In reality, these valves do not possess any of the aforementioned characteristics. They are an imperfect solution with their own associated problems (eg, infection, thromboembolism, degeneration), referred to as "prosthetic valve disease."[4–6] Decision to implant a specific prosthetic valve in a patient is contextual and varies with circumstances (Fig 4).

American Society of Echocardiography guidelines for the assessment of prosthetic valves outline a detailed description of echocardiographic evaluation of prosthetic valves. However, most recommendations are based on transthoracic echocardiography imaging in the outpatient setting.[1] Whereas TEE evaluation has been mentioned in the guidelines, there is no specific focus on an intraoperative evaluation of prosthetic valves. In this review article, the authors present a brief historic perspective of prosthetic valve development followed by a broad introduction to the types of prosthetic valves, their

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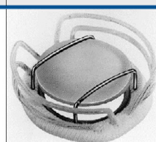
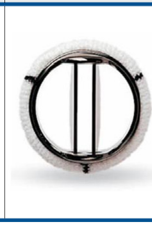
	Valve Type	Timeline	Diagram	Description	Pros	Cons	Current Status
MECHANICAL VALVES	Ball and Cage Valves	Hufnagel Caged Ball Valve (1952)		Consists of a hollow nylon ball coated in silicone rubber The valvular ring is a methacrylate structure Valve is surgically placed in the descending aorta	Partial relief of aortic regurgitation First prosthetic valve ever used	Partial relief High thrombogenic risk Audible "clicking" No improvement in coronary flow	Discontinued
		Starr Edwards Silastic Ball Valve (1960)		Heat-treated Silastic ball in a stainless steel cage	Durable Mitral and aortic position Low risk of mechanical failure	Poor EOA Thrombogenicity Turbulent flow Hemolysis Noise	Discontinued
	Nontilting Disc	Kay-Shiley (1965) Beall Prostheses (1967)		Similar design to ball-cage Ball is replaced by a disc mechanism ("poppet")	Low risk of failure Lower profile Easier implantation Decreased regurgitation	No central blood flow (decreased EOA) Turbulent blood flow Thrombogenicity	Discontinued
	Tilting Disc	Bjork-Shiley (1969) Lillehei-Kaster (1970) Medtronic Hall (1977)		Single polymer disc secured by lateral or central metal struts Opening angle of leaflet relative to valve ranges from 60°-80°	Larger EOA Less thrombogenic Less turbulence Durable	Mild regurgitant volume Tendency toward total mechanical failure Thrombogenicity	Discontinued
	Bileaflet Valves	St Jude Medical (1978) Bileaflet Bicarbon-Sorin (1990) CarboMedics Valves (1986) Medtronic Advantage (2003)		Two semilunar discs attached to a rigid valvular ring Opening angle from 75°-90° One central and 2 lateral orifices	Large EOA which helped avoid patient-prosthesis mismatch Durable	Significant regurgitant volume Turbulence with stress-associated platelet activation and hemolysis Thrombogenicity	Most popular mechanical design accounts for ~80% of implanted valves

Fig 1. Mechanical valves. EOA, effective orifice area.

selection criteria, and practical intraoperative assessment (qualitative and quantitative) with clinical examples.

There also are a number of percutaneously implanted prosthetic valves in clinical use, and the intraoperative assessment of these valves is performed on the same principles as for conventional prosthetic valves. Prosthetic valve assessment, as described in this review, involves echocardiographic confirmation of suitability for implantation, procedural guidance, confirmation of success, and exclusion of complications. In addition, a section of this article is dedicated to the post-deployment assessment of transcatheter heart valves.

Historic Perspective

An epidemic of rheumatic heart disease in the early 20th century highlighted the lack of therapeutic options for diseased heart valves. Initial attempts at finger fracture of leaflets, manual reconstruction with polymeric materials, and decalcification of native leaflets had disappointing results. Frequently these procedures resulted in both stenosis and regurgitation with significant leaflet degeneration and subsequent accelerated valvular calcification.[7] Multiple animal implants were attempted before 1954, when Charles Hufnagel et al[5]

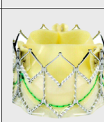
Valve	Valve Type	Timeline	Diagram	Description	Pros	Cons	Current Status
Bioprosthetic Valves	Stented	Hancock porcine xenograft (1970) Carpentier-Edwards Pericardial valve 1980		Porcine valves are tricuspid valves implanted with in an assembly Pericardial valves are fabricated from bovine pericardium	Central orificial flow No requirement for anti coagulation	Durability (8-10 years) Glutaraldehyde fixation - cell death & degeneration Smaller EOA	Resurgence in its use due to the possibility of valve-in-valve therapy
	Stentless	Toronto SPV Valve (1997) Medtronic Freestyle Valve Edwards Prima Valve		Porcine or bovine xenograft Neither stent nor sewing cuff	Larger EOA due to no surrounding assembly	Complex surgery Longer CPB time Degeneration and calcification	Used initially as pulmonary autograft for aortic valve replacement (Ross Procedure-1972)
	Percutaneous Bioprosthesis	(2002) Medtronic CoreValve Edwards Sapien Valve		Self-anchoring and self-expanding bovine pericardium mounted on an elastic alloy frame	Percutaneous placement Deployment as valve-in-valve prosthesis at other locations	Inconclusive data on benefits over other bioprosthetic valves	Long-term data lacking

Fig 2. Bioprosthetic valves. CPB, cardiopulmonary bypass; EOA, effective regurgitant orifice area.

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