Influence of transcutaneous aortic valve implantation on aortic stiffness: Correlation with improvement in left ventricular function indices

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By

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Abstract

Background: Transcatheter aortic valve implantation (TAVI) is a treatment option for elderly with severe aortic stenosis (AS). Severe AS in elderly is associated with increased aortic stiffness. Carotid femoral pulse wave velocity (CF-PWV) is robust surrogate of aortic stiffness. The effects of TAVI on aortic stiffness as measured by CF-PWV in elderly with severe AS are not known. **Objective:** Study the effect of TAVI in patients with severe AS on aortic stiffness and left ventricular (LV) function and the correlation between aortic stiffness and LV function indices before and after TAVI. **Patients and Methods:** We measured CF-PWV in 36 consecutive patients before and 4-months after TAVI. **Results:** Aortic valve area increased (1.71 ± 0.34 cm^2 vs. 0.74 ± 0.20 cm^2, $p < 0.001$) and mean blood pressure gradient across the aortic valve (10 ± 4 torr vs. 48 ± 19 torr, $p < 0.001$) decreased after TAVI. CF-PWV (11.3 (9.5, 14.6) m/s) did not significantly change after TAVI compared to baseline (10.5 (9.6, 14.5) m/s, p = 0.17. CF-PWV at baseline correlated with heart rate (r= 0.56, p< 0.001), Aortic regurgitation grade (r= -0.38, p= 0.022), stroke volume index (r= -0.40, p= 0.031) and grade of LV diastolic dysfunction (r= 0.49, p= 0.008). **Conclusion:** Aortic stiffness did not change significantly in elderly with severe AS after TAVI, possibly the damage is too advanced and irreversible in this patient group. Nevertheless, aortic stiffness adds to the hemodynamic load in these patients and is associated with both worsened systolic and diastolic performance.

Keywords: TAVI, aortic stenosis, arterial stiffness, pulsed wave velocity, left ventricular function

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List of abbreviations

AASI : Ambulatory arterial stiffness index

AIx: Augmentation index

ASEM: Aortic systolic ejection murmur

AR: Aortic regurgitation

AS: Aortic stenosis

AVA: Aortic valve area

AVR: Aortic valve replacement

BNP: B-type natriuretic peptide

BP: Blood pressure

BSA: Body surface area

CAD: Coronary artery disease

CHF: Congestive heart failure

CO: Cardiac output

CI: Cardiac index

CF-PWV: Carotid femoral pulse wave velocity

CW: Continuous wave

DBP: Diastolic blood pressure

DT: Deceleration time

LA: Left atrium

LV: Left ventricle

LVEDP: Left ventricular end diastolic pressure

LVEF: Left ventricular ejection fraction

LVH: Left ventricular hypertrophy

LVOT: Left ventricular outflow tract

MRI: Magnetic resonance imaging

NYHA: New York Heart Association

PWV: Pulse wave velocity

RV: Right ventricle

SAC: Systemic arterial compliance

SV: Stroke volume

SVI: Stroke volume index

TAVI: Transcatheter aortic valve implantation

(Transcutaneous aortic valve implantation)

VTI: Time velocity integral

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Hypothesis

Severe aortic stenosis (AS) is associated with increased stiffness of the ascending aorta that that is improved after aortic valve replacement surgery[1]. Transcatheter aortic valve implantation (TAVI) is a contemporary alternative treatment modality for elderly patients with severe AS and high or unacceptable surgical risk[2]. TAVI is associated with improved survival[3] and improved left ventricular (LV) function[4] in these patients. Age is a predominant predictor for increased aortic stiffness[5]. Effect of TAVI on aortic stiffness in the elderly is not investigated. Yet, intervention studies in elderly hypertensives showed possibility of improvement of aortic stiffness with medications[6]. We hypothesised that aortic stiffness may improve after TAVI in the elderly with severe AS and aimed at studying the correlation between Aortic stiffness and LV function before and after TAVI.

Aim of Work

1. Study the effect of TAVI in patients with severe AS on aortic stiffness and LV function.

2. Correlation between aortic stiffness and LV function indices before and after TAVI.

Review of Literature

Chapter 1

Valvular aortic stenosis in the elderly

Calcified degenerative aortic valve stenosis is currently the most frequent native valve disease in Europe. Furthermore, it is most often seen in elderly patients with comorbidities[7]. Once symptoms develop, in the form of angina, syncope or congestive heart failure, the prognosis in these patients deteriorates rapidly, with an estimated life expectancy of two to five years[2].

Anatomical background:

Aortic root and annulus: The aortic root is the direct continuation of the left ventricular outflow tract. It is located to the right and posterior, relative to the sub-pulmonary infundibulum. It extends from the basal attachment of the aortic valvular leaflets within the left ventricle to their peripheral attachment at the level of the sino-tubular junction. The aortic annulus described by surgeons is usually the semilunar crown-like structure demarcated by the hinges of the leaflets. Thus, the aortic root contains at least 3 circular rings and 1 crown-like ring[8]. The base of the crown is a virtual ring, formed by joining the basal attachment points of the leaflets within the left ventricle. This plane represents the inlet from the left ventricular outflow tract into the aortic root. The top of the crown is a true ring, the sinutubular junction that forms the outlet of the aortic root into the ascending aorta. The diameters of inlet and outlet, when expressed as a percentage of the largest diameter at the level of the expanded aortic sinuses, have been calculated as 97% and 81%, respectively. It is for these reasons that the aortic root is sometimes described as a truncated cone[9]. For purposes of design of aortic valvular prostheses, geometric principles based on ratios of "normal" aortic root dimensions need to be respected for their normal function and durability[10]. These design principles may be compromised during the selection (ie, patient-prosthetic mismatch) or implantation process and lead to nonstructural dysfunction of the prosthetic valve[11]. For instance, an oversized prosthetic valve relative to the dimensions of the patient's aortic root can result in redundancy of leaflet tissue, thus creating folds. These folds will generate regions of compressive and tensile stresses and may alter the function or reduce the durability of the valve[10]. On the contrary, if the valvular prosthesis is too small for the patient, the inserted prosthesis will prove to be stenotic. Accurate measurement of the components of the aortic root and selection of the appropriate sized prosthesis may circumvent these potential issues (**Figure 1**).

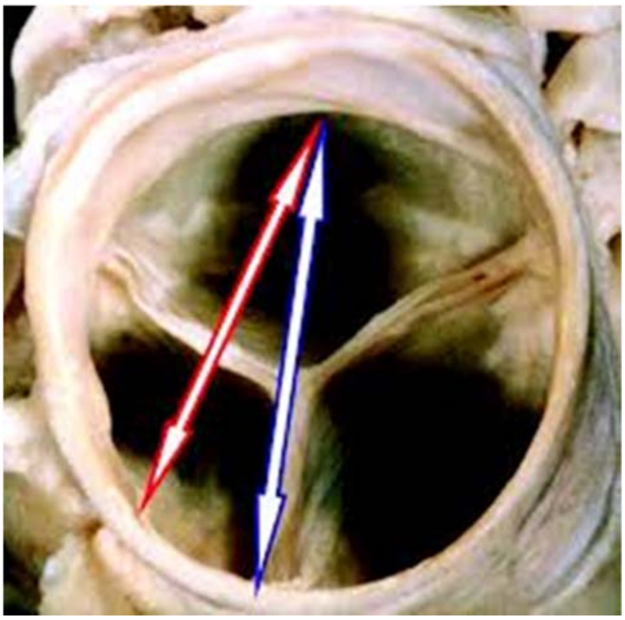

Figure 1: *Basal short-axis view shows the closed aortic valve: The arrows demonstrate the potential hazard of 2-dimensional imaging techniques (echocardiography, contrast aortography) for measuring the "aortic valve annulus." Measurements made using the basal attachment of the leaflets do not transect the full diameter of the outflow tract but instead a tangent cut across the root.*[12]

Aortic valve leaflets: The normal aortic valve is trifoliate. Proper functioning of the valve depends on the proper relationship between the leaflets within the aortic root. Not only do variations exist among individuals in the dimensions of the root, but in the same individual, marked variations can exist in all aspects of the dimensions of the individual leaflets, including the height, width, surface area, and volume of each of the supporting sinuses of Valsalva. Such individual variations in geometry need to be taken into account during measurement of the aortic root aimed at sizing the prosthesis.

The coronary arteries: In the majority of cases, the orifices of the coronary arteries arise within the 2 anterior sinuses of Valsalva, usually positioned just below the sinutubular junction[9,13]. It is not unusual, however, for the arteries to be positioned superior relative to the sinutubular junction. Knowledge of the location of the coronary arteries, of course, is essential for appropriate percutaneous replacement of the aortic valve. The valvular prostheses are designed such that a skirt of fabric or tissue is sewn within the stent or frame to help to create a seal and prevent paravalvular leakage. In situations in which the coronary arteries take their origin low within the sinus of Valsalva and/or the prosthesis is placed too high, the skirt may obstruct their orifices and thus impede coronary arterial flow.

Relationship between the Left Ventricular Outflow Tract and the Aortic Root: The left ventricular outflow tract is composed of a muscular component (ie, the muscular ventricular septum) and fibrous component (ie, the area of fibrous continuity between the leaflets of the aortic and mitral valves), with the former being more extensive. The orientation of the outflow tract to the aortic root is known to change with aging. In hearts from individuals aged >60 years, the angle varied between 90 and 120 degrees. In those from individuals aged <20 years, the angle varied between 135 and 180 degrees. In these younger patients, the left ventricular outflow tract represented a more direct and straight extension into the aortic root[14]. This would also seem to explain the additional observation that in all of the elderly hearts, the majority of the circumference of the aortic inlet projected to the right of a line drawn through the outlet part of the muscular ventricular septum. In contrast, in the younger individuals, the majority of the circumference of the inlet projected either to the right or to the left. The presence of a sub-aortic septal bulge and an extension of this producing asymmetrical septal hypertrophy may create an obstacle to proper seating of the aortic prosthesis within the left ventricular outflow tract. The presence of a significant sub-aortic bulge or a hypertrophied septum has been considered by some to be a relative contraindication to the implantation of a certain type of aortic prostheses.

Relationship between the Aortic Valve and the Conduction System: Within the right atrium, the atrioventricular node is located within the triangle of Koch. This important triangle is demarcated by the tendon of Todaro, the attachment of the septal leaflet of the tricuspid valve, and the orifice of the coronary sinus. The apex of this triangle is occupied by the atrioventricular component of the membranous septum. The atrioventricular node is located just inferior to the apex of the triangle adjacent to the membranous septum, and therefore the atrioventricular node is in fact in close proximity to the sub-aortic region and membranous septum of the left ventricular outflow tract. This relationship allowed understanding why pathologies involving the aortic valve can lead to complete heart block or intraventricular conduction abnormalities. The atrioventricular node continues as the bundle of His, piercing the membranous septum and penetrating to the left through the central fibrous body. On the left side, the conduction axis exits immediately beneath the membranous septum and runs superficially along the crest of the ventricular septum, giving rise to the fascicles of the left bundle branch. This has important implications with the potential to induce abnormalities of conduction after percutaneous insertion of a new aortic valve.

Location of Percutaneously Inserted Valvular Prostheses: Recommendations on the optimal positioning of the prostheses within the aortic root vary according to the design of the