Transcatheter Aortic Valve Implantation and Cardiac Conduction Abnormalities

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Transcatheter aortic valve implantation (TAVI) or replacement (TAVR) has become a potential, widely accepted, and effective method of treating aortic stenosis in patients at moderate and high surgical risk and those disqualified from surgery. The method evolved what translates into a noticeable decrease in the incidence of complications and more beneficial clinical outcomes.

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1. Introduction

The incidence of aortic stenosis (AS) increases with age, affecting up to 10% of the population by the eighth decade [1]. It is the most common primary valve lesion requiring surgery or transcatheter intervention in Europe and North America, and its prevalence is rising rapidly as a consequence of the ageing population. Symptomatic severe AS has a dismal prognosis and early intervention is generally recommended. A broad spectrum of patients requires different approaches to treatment. Transcatheter aortic valve implantation (TAVI) or replacement (TAVR) was performed for the first time in 2002 [1][2]. Initially, it was considered as an alternative to surgical aortic valve replacement (SAVR) for severe, symptomatic AS in patients who had a high cardiothoracic surgery risk at clinical evaluation, while more recently published data have shown the feasibility of TAVI in intermediate and low-surgical risk patients as well. According to the 2021 European Society of Cardiology (ESC) guidelines, TAVI is recommended in patients who are at least 75 years of age or in those with high surgical risk evaluated by the Society of Thoracic Surgeons (STS) predicted risk of mortality (PROM) or a EuroSCORE II > 8%, as well as in those who are unsuitable for surgery [1]. These patients should generally be referred to TAVI (class I recommendation, level of evidence A) [1]. Patients who do not fall into the above-mentioned categories should be extensively and individually evaluated, considering not only clinical, anatomical, and procedural factors but also the individual risk-benefit ratio of both SAVR and TAVI procedures [1]. The vascular access evaluation is also very important, and, in most cases, femoral access is preferred. However, among others, trans-axillary, trans-carotid, or trans-apical routes could also be used, depending on anatomical features and risk factors [3]. Transthoracic echocardiography (TTE) is principal in the diagnosis of AS. By definition, severe AS is considered a state in which the aortic valve area (AVA) is less than 1.0 cm^2 (0.6 cm^2/m^2 of body surface area [BSA]). Not only this parameter but also aortic valve pressure gradient, left ventricle ejection fraction (LVEF), and cardiac output determine the severity of stenosis and the type of AS. All the above-mentioned parameters help to determine the appropriate

treatment algorithm [1][4]. Computed tomography (CT) is a preferred method to assess aortic valve, aorta, and iliac arteries anatomy and the level of their calcification. The TAVI procedure lasts a shorter time than the surgical method and is associated with a shorter length of hospitalization [5]. Additionally, TAVI, in comparison to cardiac surgery, significantly reduces the risk of major bleeding, especially life-threatening bleeding, acute kidney injury, and new-onset atrial fibrillation (NOAF) in the short postoperative period (30 days) as well as in the long-term follow-up (1 year) [6]. TAVI via the iliofemoral access sitemay also be supported by improvement in quality of life in the short-term postoperative period (1 month) compared to surgery, as expressed in self-assessment forms [7]. Thus, the TAVI procedure allows a faster discharge after the procedure and a faster improvement in the health status based on standardized questionnaires in the population of people > 75 years old and with frailty syndrome. The TAVI procedure, compared to a surgical operation, is much less invasive but has limitations. Contraindications for TAVI arise from factors limiting the procedural success and/or giving a high risk of complications, such as lack of vascular access, suboptimal or calcified iliac vessels or their tortuous course making the insertion of a vascular guide impossible or too risky, severe coexisting abnormalities of other heart valves, thrombus in the left ventricle, or active infective endocarditis [8][9]. Anatomical features such as a low coronary artery outflow (<12 mm) or small sinus of Valsalva (<30 mm in diameter) are also contraindications to TAVI [10]. Relative contraindications include untreated coronary artery disease requiring revascularization and hemodynamic instability [11][12]. In the case of relative contraindications, an important factor for evaluation is the individual clinical condition of the patient to determine the risk of abandonment and performing the procedure.

The aforementioned aspects are stated in the 2021 ESC guidelines regarding the treatment of valvular heart diseases, where the choice of TAVI is supported by a patient profile with higher surgical risk, older age (≥75 years), previous heart surgery (especially previous coronary artery bypass grafting and being at risk for the injury of intact grafts during sternotomy), severe frailty (defined as at least 2 factors in the Katz index), adequate transfemoral access, history of chest irradiation, porcelain aorta, high risk of patient-valve prosthesis mismatch (AVA < 0.65 cm^2/m^2 BSA), and severe thoracic deformity or scoliosis [1].

Therefore, when deciding on the treatment of AS, a comprehensive clinical assessment of the patient is crucial, considering the individual surgical risk and the existence of the associated factors. The above mentioned factors should be assessed by a qualified heart team and discussed in light of the center's experience in treatment with both methods. The TAVI procedure is used successfully in patients at high surgical risk but may be also performed in patients younger than 75 years and with intermediate or low surgical risk [13][14][15][16]. Studies have shown no worse (non-inferiority) outcomes for patients with high and intermediate surgical risk undergoing TAVI compared to SAVR in a follow-up of up to 5 years [6][17][18][19][20][21][22][23][24][25][26][27]. A 5-year follow-up in intermediate-risk-for-SAVR patients undergoing TAVI showed that mortality or occurrence of a disabling stroke did not differ from the surgically treated group [25]. There are also data for no worse outcomes of TAVI in the low-surgical risk group of patients in a 2-year follow-up [28][29][30][31]. However, data on the benefits of TAVI in the low-risk-for-SAVR group are limited. The characteristics of these patients are different in comparison to patients who usually qualify for TAVI. One of the major problems is the durability of percutaneously implanted valves in younger patients [25].

2. Types of Cardiac Conduction Abnormalities after TAVI and Their Management

From the electrocardiological point of view, the most common complication after TAVI is the left bundle branch block (LBBB), occurring in 13.3–39% [32][33] of patients, but the most serious complication is an atrioventricular block (AVB) requiring implantation of a cardiac pacemaker (PM). These complications are related to the anatomical proximity of the atrioventricular (AV) junction and the aortic valve structures (the left bundle branch runs within the membranous septum directly under the tissue separating the non-coronary and right coronary leaflets [34]). Mechanical pressure on the AV node and the bundle of His structures by the expanding valve may cause conduction disturbances due to edema, local hematoma or ischemia of the conduction system structures [11][35].

The incidence of the need for PM implantation after TAVI is higher than for SAVR, ranging from 3.4% to 25.9% [36] or even 2% to 51% [37][38], depending on the study, while for SAVR it is 5.5% (relative risk [RR]: 2.43; 95% confidence interval [CI]: 1.62–3.63) [39]. Differences between reported rates of PM placement after TAVI are related to the most commonly used valve systems, with higher rates using the Medtronic CoreValve Revalving System compared to the Edwards Sapien Valve [38]. Time criteria for the onset of conduction disturbances allow a distinction to be made between early disturbances requiring PM occurring up to 48 h after the procedure and delayed disturbances defined as occurring over 48 h after the procedure (about 18% of conduction disturbances requiring PM after TAVI) [40]. The above percentages of need for PM regarding early and late disorders include all conduction disturbances requiring PM implantation. Regarding the incidence of LBBB, most manifest perioperatively or within 24 h of surgery; in the analysis by Auffret et al. [34], 85–94% of LBBB manifested perioperatively, whereas 6.6–17.8% occurred >24 h after surgery. In 55% of cases, the disturbance persisted for at least 30 days. Occurrences of LBBB after discharge to a 1-year follow-up are sporadic, with a frequency of 0–2.9% [34]. Thus, it seems that conduction disturbances that may suggest PM implantation stabilize 3 days after the procedure [41]. It has also been suggested that patients after TAVI can be discharged home within the first 48 h after the procedure if a balloon-expandable valve without predilatation was used or if they do not have factors for the development of delayed conduction disturbances, such as non-specific conduction disturbances with a QRS duration > 110 ms, a previous right bundle branch block (RBBB), the implantation of a self-expandable valve, and predilatation during the procedure because of the low risk of conduction disturbances after 48 initial hours [40]. However, if the patient has dynamic electrocardiographic (ECG) changes after the procedure, such as a new bundle branch block accompanied by prolongated PR or QRS intervals, then extended hospital monitoring of up to 5 days using ECG should be considered [36]. The nature of conduction abnormalities is an interesting issue. In the Placement of AoRtic TraNscathetER Valves (PARTNER) registry analysis by Nazif et al. at 1-year follow-up, 50% of patients with PM had pacing present on ECG evaluation, so the authors, in the absence of more detailed registry data on cardiac pacing dependence, suggested that pacing dependence in these patients is less than 50% [42]. In other analyzes [43], the observed cardiac pacing dependence was 16.1% after 30 days and 12.9% after 1 year. In another study by Costa et al. [44], pacing dependence was found in 35.7%, 35.8%, and 33.3% of patients at follow-ups of 1, 6, and 12 months, respectively. In the smallest of these studies, the assessed dependence at the 6- to 8-week follow-up after the procedure was 37% [45]. Analyses of the above data with decreasing pacing dependence over time may indicate the dynamic and, at least in some cases, the transient nature of the conduction

disturbances due to the temporality of contributing factors, such as transient inflammation, edema, ischemia, and transient mechanical compression, which may resolve over time [44].

Less frequent potential indication for PM in patients after TAVI may be sinus sick syndrome (SSS) [46]. It is worth noticing that patients referred for TAVI are at an older age, frequently with comorbidities and structural heart diseases, which may predispose them to myocardial fibrosis, which is associated with both SSS and AV conduction abnormalities [47]. It was shown that SSS and AV conduction disturbances may coexist in up to 67% of patients and annually 0.6–1.9% of patients with SSS develop AVB, which suggests dual-chamber PM implantation when SSS is diagnosed [48][49].

Evaluation of related data shows that the occurrence of conduction disturbances after TAVI remains the most frequent complication of the procedure [6]. This consideration goes against the potential pressure toward a minimalist approach, including early discharge of TAVI recipients, and the possible risks associated with too-precipitous clinical decisions. Rodés-Cabau et al. [50] in the consensus regarding the management of conduction disturbances associated with TAVI formulated a multidisciplinary initial attempt to provide a guide based on the best available data and group expertise (interventional cardiologists, electrophysiologists, and cardiac surgeons) [50]. They proposed an interesting example for the evaluation of the patients, creating algorithm proposals for the management of patients related to the specific risk categories. According to this approach, patients with pre-existing RBBB, new-onset LBBB, high-degree AVB, complete AVB, or prior conduction disturbances and with new conduction changes reflected by PR or QRS interval prolongation (>20 ms) after the implantation procedure should be secured with temporary PM for 24 h. Patients with a persistent high-degree or complete AVB should be qualified for permanent PM. Careful re-evaluation is suggested in patients with a persistent increase of PR or QRS of at least 20 ms and pre-existing first-degree AVB or QRS duration ≥ 120 ms [50]. Electrophysiology study (EPS) or continuous ECG monitoring should be considered, according to the scientific expert panel, in cases of a further PR or QRS duration increase of at least 20 ms and in patients with a PR interval > 240 ms or a QRS duration > 150 ms in qualifying for permanent PM (rather not in the case of a PR interval > 240 ms, but a QRS duration < 120 ms) [50]. Highlighting the potentially transient nature of conduction disturbances after TAVI, some authors suggest performing EPS post-TAVI in order to decide about PM implantation in patients with equivocal indications. Rogers et al., in their study, showed that this strategy with positive EPS (intra/infrahisian block, His-Ventricle interval > 100 ms at baseline or after intravenous administration of 1 g of procainamide) as an indication for PM avoided implantation in 70% of dubious cases [51]. Postprocedural PR interval prolongation or cardiac axis change, after TAVI, may be caused by mechanical compression of the conduction system by a calcified aortic ring and/or by an implanted valve [52]. The 2021 ESC guidelines on cardiac pacing and cardiac resynchronization therapy [36] suggest several management pathways depending on preprocedural conduction abnormalities and post-procedural ECG findings. Their comparison with the American College of Cardiology (ACC)/American Heart Association Guidelines is shown in **Table 1** [36][53].

Table 1. Overview of the European Society of Cardiology and American College of Cardiology/American Heart Association Guidelines regarding cardiac conduction abnormalities after TAVI management.

Management	ESC 2021 Guidelines	ACC/AHA 2018 Guidelines
PM implantation	PM implantation: high- or third-degree AVB persisting for 24–48 h or new alternating BBB after TAVI procedure (class I recommendation, levels of evidence B or C, respectively), PM implantation within 24 h or immediately after TAVI: previous RBBB with new conduction abnormalities (change in QRS axis, increase in PR interval, transient high-degree AVB) (class IIa recommendation, level of evidence B).	PM implantation before discharge: new AVB with symptoms/hemodynamic instability (class I recommendation, level of evidence B) PM implantation: new persistent LBBB (class IIb recommendation, level of evidence B)
Additional examination/observation	Continuous ambulatory ECG monitoring for 7–30 days or EPS ≥ 3 days after TAVI: • New LBBB and QRS duration > 150 ms or PR > 240 ms without change in duration at >48 h after the procedure (class IIa recommendation, level of evidence C) * • QRS or PR increase > 20 ms with previous conduction abnormalities without further prolongation during 48-h observation (class IIb recommendation, level of evidence C)	Careful observation: new persistent BBB (class II b recommendation, level of evidence B)

ACC/AHA: American College of Cardiology/American Heart Association, AVB: atrioventricular block, BBB: bundle branch block, ESC: European Society of Cardiology, LBBB: left bundle branch block, RBBB: right bundle branch block, PM: pacemaker. * High-risk features for high-degree AVB development in patients with new LBBB consist of: LVEF < 40%, atrial fibrillation and prolonged PR interval.

What is also worth mentioning is that ESC guidelines state that PM should not be implanted as a prophylactic measure in patients with previous RBBB, who have no indications for cardiac pacing.

The perspective of possible conduction disturbances and lifetime pacing device presence should be considered. The necessity of PM replacement due to battery depletion and possible pacing-induced cardiomyopathy (PICM), along with pacing device-related complications, puts patients at risk of additional hospitalizations. Although studies show that PM after TAVI increases the risk of hospitalization and mortality in high-risk patients [54], data on younger individuals are still limited and results from trials on low-risk patients are needed [55].

Appropriate CIED selection for patients after TAVI is another issue in patients with coexisting heart failure with reduced ejection fraction (HFrEF). Generally, according to ESC 2021 guidelines, cardiac resynchronization therapy

(CRT) is recommended in patients requiring ventricular pacing with high-degree AVB and HFrEF (LVEF < 40%) (class I recommendation, level of evidence A) or especially in symptomatic heart failure (HF) patients with sinus rhythm and LBBB QRS morphology (QRS duration ≥ 150 ms) [36][56]. Currently published data on CRT de novo implantation after TAVI and outcomes are limited; however, results are promising. Meguro et al. presented a case of a patient with new LBBB after TAVI and concomitant ischemic HFrEF during optimal medical treatment [57]. After TAVI, the patient was qualified for CRT-defibrillator (CRT-D) placement, which significantly decreased the patients' N-terminal pro–B-type natriuretic peptide levels and improved LVEF along with the left ventricular end-diastolic diameter [57]. Osmancik et al. described a case of primary dual-chamber PM implantation after TAVI with progressing HF symptoms and LVEF impairment due to right ventricular (RV) pacing despite optimal medical treatment. The patient was referred for an ‘upgrade’ to CRT afterward, which led to improvement in patient-reported symptoms and LVEF (increase from 25 to 45%) [58]. Decision-making on implanting PM or de novo CRT or introduction of conduction system pacing (CSP) with or without implantable cardioverter-defibrillator (ICD) capabilities after TAVI and choosing the right time for these procedures is challenging. Studies specifically addressing this issue would be valuable.

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