Validation of the 2019 Expert Consensus Algorithm for the Management of Conduction Disturbances After TAVR

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ABSTRACT

OBJECTIVES The aim of this study was to validate the 2019 consensus algorithm in a large cohort of contemporary transcatheter aortic valve replacement (TAVR) patients.

BACKGROUND The optimal management of patients with atrioventricular conduction disturbances after TAVR is unknown. Guidance was consolidated in an expert consensus algorithm in 2019.

METHODS In a retrospective analysis of a prospective registry, patients were classified according to the 2019 consensus algorithm as eligible for early discharge (day 1 or 2 after TAVR), higher risk for high-degree atrioventricular block (HAVB) or complete heart block (CHB) or in need for a permanent pacemaker (PPM). The primary endpoint was the incidence of PPM implantation for HAVB or CHB within 30 days after TAVR. Patients with prior PPM or implantable cardioverter-defibrillator implantation, valve-in-valve procedures, or incomplete electrocardiographic data were excluded.

RESULTS Among 1,439 patients undergoing TAVR between January 2014 and December 2019, the 2019 consensus algorithm classified 73% as eligible for early discharge, 21% as at higher risk for HAVB or CHB, and 6% as in need of PPM. PPM implantation for HAVB or CHB occurred in 234 patients (16%) within 30 days after TAVR. The incidence of PPM implantation was 2.7% in the early discharge group, 41% in the group with higher risk for HAVB or CHB, and 100% in the PPM group.

CONCLUSIONS The 2019 consensus algorithm safely identifies patients with no need for PPM implantation. This strategy allows more uniform management of TAVR patients and facilitates early discharge of low-risk patients without prolonged monitoring in 3 of 4 patients. However, the algorithm is less precise in the identification of high-risk patients.

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The introduction of transcatheter aortic valve replacement (TAVR) has profoundly changed the treatment of patients with severe, symptomatic aortic stenosis. Aggregate evidence from randomized clinical trials comparing TAVR and surgical aortic valve replacement in high-, intermediate-, and low-risk patients shows similar or superior clinical outcomes irrespective of baseline surgical risk and valve type (1). As the TAVR procedure continues to expand to lower risk patients, the focus has shifted to the determinants of long-term effectiveness, such as prosthetic valve durability, para-valvular regurgitation, and atrioventricular (AV) conduction disturbances.
The prevalence of paravalvular regurgitation has decreased with time (2) because of design iterations of transcatheter heart valves and improvements in multimodality imaging that in turn optimize device selection, valve sizing, and positioning (2).

In contrast, AV conduction disturbances, particularly those that require the implantation of a permanent pacemaker (PPM), remain substantial and are in the range of 5% to 30% with contemporary transcatheter heart valves (3-5). Although the long-term prognostic implications of PPM implantation post-TAVR remain controversial (3), the unpredictability of such rhythm disturbances can complicate the clinical pathway after TAVR and have impacts on associated costs. An increasing number of patients are being discharged within 24 to 48 h after TAVR (6), and in select cases, they are discharged on the same day (7). As such, validated strategies that reliably and expeditiously triage patients as being safe for early discharge as compared to those who are at increased risk of requiring PPM implantation will be an important next step in streamlining post-procedural care pathways. At the same time, the occurrence of complete heart block (CHB) as an outpatient event potentially leading to sudden cardiac death needs to be avoided.

Pre-procedural factors (such as male sex and pre-existing right bundle branch block [RBBB]) as well as procedural factors (such as self-expanding valves [SEVs] and implantation depth) have been consistently identified as major predictors of subsequent high-degree AV block (HAVB) (3,8). There is significant variability in management strategies, and this translates to substantial differences in PPM implantation rates following TAVR, even with the use of the same valve types (3,9). Although some guidelines still recommend observation periods as long as 7 days (10), procedural electrocardiographic (ECG) changes as well as those in the subsequent 24 h have emerged as important indicators (11). Recently, the available evidence has been consolidated into an interdisciplinary expert consensus guideline with the aim of standardizing the management of conduction disturbances associated with TAVR (12).

The safety and efficacy of this algorithm have not been clinically validated to date. Therefore, the aim of the present investigation was to retrospectively validate this algorithm in a large, prospective cohort of contemporary patients undergoing TAVR.

**METHODS**

**STUDY POPULATION.** Consecutive patients undergoing TAVR for severe, symptomatic aortic stenosis at Bern University Hospital were prospectively enrolled in an institutional registry, which is a part of the Swiss TAVI registry (NCT01568250) (13). The registry was approved by the Bern cantonal ethics committee, and patients provided informed written consent for participation.

For the purpose of the present analysis, the following patients were excluded: those declining participation, those in whom no transcatheter heart valve or a device lacking Conformité Européenne mark approval was implanted, those with alternative, nontransfemoral access, those requiring emergent conversion to open heart surgery, valve-in-valve procedures, pre-existing PPMs or implantable cardioverter-defibrillators, and those with incomplete ECG data pre- or post-TAVR.

**COLLECTION OF CLINICAL, PROCEDURAL, AND FOLLOW-UP DATA.** All baseline clinical, procedural, and follow-up data were prospectively entered into a dedicated web-based database held and maintained at the Clinical Trials Unit of the University of Bern. Clinical follow-up data were obtained by standardized interviews, documentation from referring physicians, and hospital discharge summaries at 30 days and 1 year. All adverse events were systematically collected and adjudicated by a dedicated clinical event committee according to Valve Academic Research Consortium-2 criteria (14).

**CLASSIFICATION OF PATIENTS ACCORDING TO THE 2019 EXPERT CONSENSUS DOCUMENT.** Twelve-lead electrocardiograms were recorded and analyzed at baseline, immediately post-procedure, and daily thereafter during the in-hospital period. In addition, patients were monitored by continuous telemetry both during and after their procedures until discharge. The information obtained from telemetry and the relevant ECG recordings from the hospital stay were used to retrospectively categorize patients into 1 of 5 groups, as described in the 2019 expert consensus document (12) (group 1, no new changes without RBBB pre-procedure; group 2, no new changes with RBBB pre-procedure; group 3, new ECG changes with pre-existing ECG abnormalities; group 4, new-onset left bundle branch block [LBBB]; group 5, HAVB or CHB during the procedure). Patients were also classified into 1 of the following 3 algorithm management groups as described in the expert consensus document (12): eligible for early discharge,
higher risk for HAVB or CHB, or need for PPM implantation.

**INDICATIONS FOR PPM IMPLANTATION.** A PPM was implanted at the discretion of the attending electrophysiologist for CHB, advanced HAVB, LBBB with progressive QRS widening after TAVR, or in the presence of sinus node dysfunction and documented symptomatic bradycardia. For the purpose of this study, all indications leading to PPM implantation were reviewed and classified as either AV node dysfunction (HAVB or CHB) or sinus node dysfunction. Patients with HAVB or CHB indications were further subclassified into: 1) CHB; 2) 2:1 AV block (AVB); 3) alternating bundle branch block; 4) atrial fibrillation with symptomatic pauses; or 5) LBBB with increasing QRS and/or PR interval. Patients at risk for advanced conduction disturbances who did not undergo PPM implantation were followed up with ECG monitoring. No electrophysiological studies were performed in this registry.

**PRIMARY AND SECONDARY ENDPOINTS.** The pre-specified primary endpoint of the present analysis was the incidence of PPM implantation for HAVB or CHB within 30 days after TAVR as a function of the 3 algorithm management recommendations: eligible for early discharge, higher risk for HAVB or CHB, or need for PPM implantation. Secondary endpoints included the aforementioned incidence according to: 1) the 5 proposed groups as described in the consensus document; 2) type of transcatheter heart valve; and 3) the timing of the occurrence of HAVB or CHB. The pre-specified primary prognostic endpoint was all-cause mortality at 1 year after TAVR.

**STATISTICAL ANALYSIS.** Categorical data are represented as frequencies and percentages, and differences between groups were evaluated using the chi-square test. Continuous variables are expressed as median (interquartile range) and were compared between groups using the Mann-Whitney U test or the Kruskal-Wallis test. Event-free survival curves were constructed using the Kaplan-Meier method, and the log-rank test was used to assess differences between groups. Throughout the present study, a p value of <0.05 was considered to indicate statistical significance. Statistical analyses were performed using IBM SPSS Statistics for Windows version 25.0 (IBM, Armonk, New York).

**RESULTS**

**STUDY POPULATION.** Among 1,851 consecutive patients undergoing TAVR between January 2014 and December 2019, 1,439 met the inclusion criteria (see Supplemental Figure 1 for details). Baseline clinical, ECG, and procedural characteristics of the study population are summarized in Table 1. The median age was 83 years (interquartile range: 79 to 86 years), and 737 patients (51%) were women. Balloon-expandable valves (BEV) were used in 738 patients (51%), SEVs in 597 patients (42%), and mechanically expandable valves (MEV) in 104 patients (7%). Details on the valve types used in the study are presented in Supplemental Table 1. The median length of hospital stay was 7 days (interquartile range: 6 to 8 days).

**INCIDENCE OF PPM IMPLANTATION FOR HAVB OR CHB WITHIN 30 DAYS AFTER TAVR.** Two hundred thirty-four patients (16.2%) underwent PPM implantation for HAVB or CHB within the first 30 days after the TAVR procedure. The rate of PPM implantation for HAVB or CHB was 12.6% for BEVs, 17.3% for SEVs, and 36.5% for MEVs.

Baseline characteristics of patients with and without PPM implantation for HAVB or CHB within the first 30 days after TAVR are presented in Table 1. PPM recipients were more often male, had evidence of pre-existing conduction system disease (first-degree AVB, RBBB, left anterior hemiblock), and more often underwent implantation with SEVs or MEVs. The timing of PPM implantation after TAVR is shown in Figure 1. Of all PPMs, 32% were implanted on days 0 and 1; up to day 4, 66% were implanted, reaching 95% on day 9. Of the 234 PPM implantations, 225 (96%) occurred during the inpatient stay and 9 (4%) following hospital discharge. Details regarding the types of AV conduction abnormalities leading to PPM implantation are shown in Supplemental Table 2.

An additional 15 patients (1.0%) underwent PPM implantation for isolated symptomatic sinus node dysfunction within 30 days of the TAVR procedure.

**GROUP ASSIGNMENTS AND MANAGEMENT RECOMMENDATIONS ACCORDING TO THE EXPERT CONSENSUS ALGORITHM.** Group assignments immediately following the TAVR procedure based on the presence or absence of pre-existing and new ECG changes according to the expert consensus algorithm were as follows: 642 patients (45%) were classified in group 1, 68 patients (5%) in group 2, 298 patients (21%) in group 3, 312 patients (22%) in group 4, and 119 patients (8%) in group 5.

The resulting management recommendation of the consensus algorithm was early discharge in 1,054 patients (73%), while 303 patients (21%) were assigned to the group with higher risk for HAVB or CHB. PPM implantation was recommended in 82 patients (6%). The baseline characteristics of the patients according to the 3 management recommendation groups are shown
in Table 2. The association of the post-procedural algorithm groups within the management recommendation groups is shown in Table 3.

**INCIDENCE OF PPM IMPLANTATION ACCORDING TO THE POST-PROCEDURAL ALGORITHM GROUPS.**

The PPM implantation rate for HAVB or CHB within 30 days as a function of algorithm group assignment immediately after the TAVR procedure is shown in Figure 2. PPM rates were highest in group 5 (intraprocedural HAVB or CHB), followed by group 2 (pre-existing RBBB without new ECG changes immediately after the procedure). A sensitivity analysis focusing exclusively on patients with second- or third-degree AVB indications for PPM implantation yielded similar results (Supplemental Table 3A).

**INCIDENCE OF PPM IMPLANTATION ACCORDING TO THE ALGORITHM’S MANAGEMENT RECOMMENDATION.**

The overall PPM implantation rate for HAVB or CHB within 30 days after TAVR according to the algorithm’s management recommendation is shown in Figure 3A and Central Illustration. Among patients
who were classified as eligible for early discharge, 28 (2.7%) underwent PPM implantation for HAVB or CHB within 30 days of the TAVR procedure, which corresponds to a negative predictive value of 97.3%. Patients classified by the algorithm as being at higher risk for HAVB or CHB had a 30-day PPM implantation rate of 40.9%.

Thirty-day PPM implantation rates according to device type are shown in Figure 3B. In patients classified as eligible for early discharge, rates were 2.6%, 2.1%, and 8.3% in patients with BEVs, SEVs, and MEVs, respectively. In patients classified as at higher risk for HAVB or CHB, PPM implantation rates within 30 days were 35.1%, 42.5%, and 51.1% in those with BEVs, SEVs, and MEVs, respectively.

A sensitivity analysis focusing exclusively on patients with second- or third-degree AVB indications for PPM implantation yielded similar results (Supplemental Table 3B).

**TABLE 2 Baseline and Procedural Characteristics According to Algorithm Assignment**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Eligible for Early Discharge (n = 1,054)</th>
<th>Higher Risk for HAVB/CHB (n = 303)</th>
<th>Recommendation for PPM (n = 82)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>83 (79-86)</td>
<td>82 (78-86)</td>
<td>84 (80-88)</td>
<td>0.08</td>
</tr>
<tr>
<td>Female</td>
<td>569 (54)</td>
<td>127 (42)</td>
<td>41 (50)</td>
<td>0.001</td>
</tr>
<tr>
<td>STS PROM</td>
<td>3.70 (2.49-5.43)</td>
<td>3.72 (2.40-6.03)</td>
<td>3.91 (2.78-5.73)</td>
<td>0.28</td>
</tr>
<tr>
<td>Concomitant diseases/history</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>908 (86)</td>
<td>265 (88)</td>
<td>74 (90)</td>
<td>0.52</td>
</tr>
<tr>
<td>Diabetes</td>
<td>267 (25)</td>
<td>87 (29)</td>
<td>19 (23)</td>
<td>0.42</td>
</tr>
<tr>
<td>CKD (eGFR &lt; 60 ml/ min/1.73 m²)</td>
<td>702 (67)</td>
<td>192 (63)</td>
<td>62 (76)</td>
<td>0.24</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>610 (58)</td>
<td>194 (64)</td>
<td>49 (60)</td>
<td>0.16</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>107 (10)</td>
<td>37 (12)</td>
<td>6 (7)</td>
<td>0.37</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>334 (32)</td>
<td>88 (29)</td>
<td>37 (45)</td>
<td>0.02</td>
</tr>
<tr>
<td>Echocardiographic data</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LVEF</td>
<td>60 (50-65)</td>
<td>60 (40-65)</td>
<td>60 (45-65)</td>
<td>0.006</td>
</tr>
<tr>
<td>Aortic valve area, cm²</td>
<td>0.62 (0.50-0.80)</td>
<td>0.70 (0.50-0.85)</td>
<td>0.65 (0.48-0.82)</td>
<td>0.03</td>
</tr>
<tr>
<td>Electrocardiographic data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-degree AVB</td>
<td>163 (15)</td>
<td>115 (38)</td>
<td>17 (21)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RBBB</td>
<td>59 (6)</td>
<td>44 (15)</td>
<td>35 (43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LBBB</td>
<td>111 (11)</td>
<td>44 (15)</td>
<td>9 (11)</td>
<td>0.16</td>
</tr>
<tr>
<td>LAHF</td>
<td>72 (7)</td>
<td>24 (8)</td>
<td>12 (15)</td>
<td>0.04</td>
</tr>
<tr>
<td>Valve type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balloon-expandable valve</td>
<td>573 (54)</td>
<td>134 (44)</td>
<td>31 (38)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self-expandable valve</td>
<td>433 (41)</td>
<td>124 (41)</td>
<td>40 (49)</td>
<td></td>
</tr>
<tr>
<td>Mechanically expandable valve</td>
<td>48 (5)</td>
<td>45 (15)</td>
<td>11 (13)</td>
<td></td>
</tr>
</tbody>
</table>

Values are median (interquartile range) or n (%). Abbreviations as in Table 1.

**TABLE 3 Association of Post-Procedural Group Assignment and Final Management Recommendation Provided by the Algorithm**

<table>
<thead>
<tr>
<th>Group Assignment</th>
<th>All Patients (N = 1,439)</th>
<th>Eligible for Early Discharge (n = 1,054)</th>
<th>Higher Risk for HAVB/CHB (n = 303)</th>
<th>Recommendation for PPM (n = 82)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: no new changes without RBBB pre-procedure</td>
<td>642 (45)</td>
<td>618 (59)</td>
<td>19 (6)</td>
<td>5 (6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Group 2: no new changes with RBBB pre-procedure</td>
<td>68 (5)</td>
<td>44 (4)</td>
<td>13 (4)</td>
<td>11 (13)</td>
<td>0.001</td>
</tr>
<tr>
<td>Group 3: new ECG changes with pre-existing changes</td>
<td>298 (21)</td>
<td>148 (14)</td>
<td>135 (45)</td>
<td>15 (18)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Group 4: new-onset LBBB</td>
<td>312 (22)</td>
<td>200 (19)</td>
<td>106 (35)</td>
<td>6 (7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Group 5: HAVB/CHB during the procedure</td>
<td>119 (8)</td>
<td>44 (4)</td>
<td>30 (10)</td>
<td>45 (55)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are n (%). ECG = electrocardiographic; other abbreviations as in Table 1.
Detailed clinical characteristics of patients eligible for early discharge with subsequent PPM implantation are presented in Supplemental Table 4.

ASSOCIATION OF PPM IMPLANTATION AND ALGORITHM CLASSIFICATION ON CLINICAL OUTCOMES. In the first 30 days following TAVR, 21 patients died (1.5%). In 2 of the 25 (0.14% overall), asystole due to AVB was the suspected cause of death (both patients were assigned to early discharge by the algorithm and died on days 8 and 16 after TAVR). An additional 3 patients died unexpectedly on days 4, 6, and 22, but no additional information was available regarding the circumstances and causes of death.

After 1 year, no significant differences in all-cause mortality were observed when TAVR patients without PPM implantation (8.7%) were compared with those requiring PPM implantation within 30 days (12.1%; p = 0.11) (Figure 4A).

When stratified according to the 5 post-procedural algorithm groups, all-cause mortality was 8.7% in group 1, 5.0% in group 2, 11.0% in group 3, 9.6% in group 4, and 9.5% in group 5 (p = 0.63) (Figure 4B).

When stratified according to the 3 management recommendations of the algorithm, all-cause mortality was 8.4% in patients classified as safe for early discharge, 11.1% in those classified as at higher risk for HAVB or CHB, and 12.7% in those with immediate recommendations for PPM implantation (p = 0.21) (Figure 4C). For the subgroup of patients classified as at higher risk for HAVB or CHB, no difference in 1-year mortality was observed in patients undergoing and those not undergoing PPM implantation (9.7% vs. 12.2%; p = 0.48).

Similar results were observed for cardiovascular mortality (Supplemental Figure 2).
DISCUSSION

The optimal management of conduction disturbances after TAVR remains a key challenge. After consolidation of the available evidence into an expert consensus algorithm in 2019 (12), this is the first comprehensive clinical validation of the proposed algorithm in a large cohort of consecutive TAVR patients. Our principal findings can be summarized as follows.

First, the algorithm classified 73% of patients as eligible for early discharge, 21% were categorized as at higher risk for HAVB or CHB, and direct PPM implantation was recommended in 6% of the patients. Second, only 2.7% of patients deemed eligible for early discharge subsequently underwent PPM implantation for HAVB or CHB within 30 days of the TAVR procedure. The PPM implantation rates were similarly low for patients in the early discharge group with BEVs (2.6%) and SEVs (2.1%) but significantly higher for patients with MEVs (8.3%). Third, patients categorized as at higher risk for HAVB or CHB subsequently required PPM implantation for HAVB or CHB in 41% of cases within 30 days.

The expert consensus algorithm proposed in 2019 by a multidisciplinary group of interventional cardiologists, electrophysiologists, and cardiac surgeons attempted to provide a guide for the management of AV conduction disturbances after TAVR on the basis of the available evidence (12). Patients are assigned to 1 of 5 groups on the basis of the presence and type of conduction disturbances on the 12-lead electrocardiogram pre- and post-TAVR. This group
Validation of the 2019 Expert Consensus Algorithm for the Management of Conduction Disturbances Associated With Transcatheter Aortic Valve Replacement

**Central Illustration**

**Expert Consensus Algorithm for Management of Cardiac Conduction Disturbances Associated With TAVR**

- **Group 1**: No electrocardiographic changes in patients without right bundle branch block pre-procedure
  - N = 642 (45%)
- **Group 2**: No electrocardiographic changes in patients with pre-existing right bundle branch block
  - N = 68 (5%)
- **Group 3**: Electrocardiographic changes in patients with pre-existing right bundle branch block, left bundle branch block, intraventricular conduction disturbance with QRS ≥120 ms or 1st degree AVB
  - N = 298 (21%)
- **Group 4**: New-onset left bundle branch block
  - N = 312 (22%)
- **Group 5**: High-degree atrioventricular block/complete heart block during the procedure
  - N = 119 (8%)

**Permanent Pacemaker Implantation Rate After TAVR**

- Overall: 16.3%
- Early Discharge: 2.7%
- Higher Risk for high-degree atrioventricular block/complete heart block: 40.9%
- PPM: 100.0%

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TAVR — transcatheter aortic valve replacement.
assignment in combination with the occurrence of episodes of HAVB or CHB on telemetry and the evolution of the conduction disturbances on the 12-lead electrocardiography in the subsequent 24 to 72 h results in 1 of 3 management recommendations (eligible for early discharge, higher risk for HAVB or CHB, and direct PPM implantation).

The present validation of the algorithm has 2 clinical implications. First, with a classification of nearly 3 of 4 TAVR patients as eligible for early discharge and with a negative predictive value of 97.3% for subsequent need for PPM implantation, the algorithm appears both safe and effective. This might indeed allow more uniform identification of low-risk patients. It is an important step forward, will obviate unnecessary prolonged telemetry monitoring, and could help further shorten hospital stays after TAVR without compromising safety (6,7). Second, the performance is less precise with regard to the identification of high-risk patients. Of the 21% of patients assigned as at higher risk for HAVB or CHB, 41% ultimately required PPM implantation for HAVB or CHB within 30 days. The consensus document generally suggests 3 options for the further assessment of these patients: 1) continuous ECG monitoring after hospital discharge; 2) invasive electrophysiological study after guide the decision regarding PPM implantation; and 3) PPM implantation. Our data show that HAVB or CHB can occur with significant delay after the TAVR procedure. Cumulative frequency of PPM implantation reached 66% on day 4 and 95% on day 9. Accordingly, continuous ECG monitoring in-hospital or after hospital discharge would be needed for at least 7 days. A potential disadvantage of this strategy, however, is the uncertainty regarding the clinical presentation during the delayed occurrence of HAVB or CHB as an outpatient with the worst-case scenario being sudden cardiac death. It is nevertheless reassuring in that 2 recent studies using 30-day ambulatory rhythm monitors in an overall TAVR population (15) or implantable loop recorders in high-risk groups with new-onset LBBB (16) did not demonstrate sudden death episodes within the first weeks following TAVR, with the majority of initial episodes of advanced conduction disturbances following hospital discharge being either asymptomatic or associated with mild symptoms. The second option is an electrophysiological study. The potential of electrophysiological study for the identification of patients who need or do not need PPMs following TAVR, however, is unclear. The His-ventricular (HV) interval as a static marker for disease in the conduction system has been studied pre- and post-procedure (17,18). More recently, the value of a functional assessment of the conduction system by means of dynamic atrial pacing was assessed (19). To date, neither of the 2 strategies has been implemented in routine clinical practice. Several studies assessing the value of electrophysiological testing after TAVR are currently ongoing, and they certainly have the potential to improve discrimination in patients assigned to higher risk for HAVB or CHB. Because of the limitations of both prolonged continuous ECG monitoring and electrophysiological study,
the third option, namely, direct PPM implantation, should be strongly considered at this time especially given the comparatively high overall PPM implantation rate of 41%. Accordingly, clinical judgment remains important when evaluating patients classified as at higher risk for HAVB or CHB for pacemaker implantation post-TAVR. Additional strategies for refining the risk assessment in this group of patients are needed.

**STUDY LIMITATIONS.** First, this was a retrospective analysis of a prospective study. It is important to note that the patients were not treated as recommended by the algorithm, which was implemented only after the study period. Furthermore, 6% of the patients were excluded because of incomplete ECG data. Even though our study represents the first comprehensive clinical validation of the algorithm, the ongoing prospective validation study (PROMOTE [Prospective Validation of a Pre-Specified Algorithm for the Management of Conduction Disturbances Following Transcatheter Aortic Valve Replacement]; NCT04139616) will provide further clarification regarding the value of the expert algorithm.

Second, indications for PPM implantation after TAVR in patients with HAVB or CHB are not always clear cut, which is one of the reasons for the large variation in PPM implantation rates across studies (3–5). The decision to proceed to PPM implantation particularly in patients with LBBB and increasing QRS and/or PR intervals (15% of the PPM indications in our study) is often based on clinical judgment. This subjectivity, however, affects the performance of any criteria or algorithm attempting to identify patients in need of pacemaker placement and has the potential to introduce incorporation bias. Given that the expert consensus algorithm was only published in 2019, this should not have affected the assessment of its performance over the time period of 2014 to 2019 in our study.

Third, in line with previous studies, MEVs had by far the highest rate of PPM implantations (36.5%). The rate of 8.3% PPM implantation even in the early discharge group (compared with 2.6% and 2.1% in patients with BAVs and SEVs) indicates that further validation is needed before the use of the algorithm can be recommended in these patients.

**CONCLUSIONS**

The 2019 consensus algorithm effectively identifies patients not requiring PPM implantation with a negative predictive value of 97.3%. This strategy allows for a more uniform management of TAVR patients and identifies 3 of 4 TAVR patients who are eligible for safe and early discharge without prolonged monitoring. However, the algorithm is less precise in the identification of high-risk patients.

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WHAT IS KNOWN? Conduction abnormalities post-TAVR are frequent, and optimal patient selection for PPM implantations remains an unmet clinical need.

WHAT IS NEW? A consensus algorithm for management of conduction abnormalities published in 2019 safely identifies post-TAVR patients with no need for a PPM. This strategy allows a more uniform management of TAVR patients and early discharge of low-risk patients without prolonged monitoring in 3 out of 4 patients. The algorithm however is less precise in the identification of high-risk patients.

WHAT IS NEXT? Additional external validation of the algorithm is needed. In particular, the ongoing prospective validation study (PROMOTE [Prospective Validation of a Pre-Specified Algorithm for the Management of Conduction Disturbances Following Transcatheter Aortic Valve Replacement]; NCT04139616) will be important to further clarify on the value of the algorithm.

REFERENCES

KEY WORDS conduction disturbances, ECG algorithm, pacemaker implantation, transcatheter aortic valve replacement

APPENDIX For supplemental tables and figures, please see the online version of this paper.