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# The impact of frailty on adverse outcomes after transcatheter aortic valve replacement in older adults: A retrospective cohort study

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## Abstract

**Background:** Transcatheter aortic valve replacement (TAVR) is an effective alternative to surgical aortic valve replacement for patients who are at increased surgical risk. Consequently, frailty is common in patients undergoing TAVR.

**Objectives:** This study aims to investigate the impact of frailty on outcomes following TAVR.

**Methods:** A retrospective cohort study was conducted, including all TAVR candidates who visited the geriatric outpatient clinic for preoperative screening. Frailty status was assessed according to the Groningen Frailty Indicator. The primary outcome of the study was defined as the occurrence of postoperative complications, and this was evaluated according to the Clavien–Dindo classification. An additional analysis was performed to assess the impact of frailty on 1-year all-cause mortality and complications within 30 days of TAVR according to the Valve Academic Research Consortium (VARC-2) criteria. The VARC-2 criteria provide harmonized endpoint definitions for TAVR studies.

**Results:** In total, 431 patients with a mean age of 80.8 ± 6.2 years were included, of whom 56% were female. Frailty was present in 36% of the participants. Frailty was associated with a higher risk of the composite outcome of complications [adjusted odds ratio (OR): 1.55 (95% confidence interval, CI: 1.03–2.34)], 30-day mortality [adjusted OR: 4.84 (95% CI: 1.62–14.49)], 3-month mortality [adjusted OR: 2.52 (95% CI: 1.00–6.28)] and 1-year mortality [adjusted OR: 2.96 (95% CI: 1.46–6.00)].

**Conclusions:** Frailty is common in TAVR patients and is associated with an increased overall risk of postoperative complications, particularly mortality. Increased optimization of screening and treatment of frailty in the guidelines for valvular heart diseases is recommended.

KEYWORDS

complications, frailty, mortality, older adult, transcatheter aortic valve replacement, vulnerable

## 1 | INTRODUCTION

Aortic valve stenosis is the most prevalent form of valvular heart disease in western countries. The prevalence of aortic stenosis increases with age, and its incidence is expected to increase further due to the aging of the population.[1,2] Symptomatic aortic valve stenosis is associated with high mortality and morbidity rates, including heart failure and pulmonary hypertension.[2,3] In the past, the standard treatment for aortic valve stenosis was surgical aortic valve replacement (SAVR). Transcatheter aortic valve replacement (TAVR) has been established as an alternative to SAVR for patients who are at a high risk of complications.[4] In comparison to SAVR, TAVR is a less invasive treatment strategy. In current European Society of Cardiology (ESC) and European Association for Cardio-Thoracic Surgery (EACTS) guidelines for the management of valvular heart disease, the use of TAVR is recommended over surgical procedures in older patients with an increased surgical risk.[4] Nevertheless, adverse events such as peripheral vascular complications, stroke, residual aortic regurgitation, and the need for pacemaker implantation are associated with TAVR.[5,6] Therefore, it is important to identify risk factors that predict adverse outcomes of TAVR. Prior research has indicated that preoperative frailty is a strong predictor of 30-day mortality and late mortality among patients undergoing TAVR.[7,8] Frailty is commonly defined as a "biologic syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiologic systems, and causing vulnerability to adverse outcomes."[9] Postoperative delirium is frequently observed following TAVR and often leads to a prolonged hospital stay and increased mortality.[10,11] A recent Dutch single-center study has confirmed the association between frailty and postoperative delirium among 213 TAVR patients,[12] although a self-developed and not formally validated frailty score was used to assess frailty and the study population was relatively small. Previous studies have examined the impact of frailty on both separate TAVR outcomes and composite outcomes formulated by the Valve Academic Research Consortium (VARC).[7,8,13–15] However, no study has examined the overall risk of a variety of relevant geriatric complications (including reinterventions, intensive care unit admission, falls, infections, delirium, admission to a rehabilitation center, hospital readmission, and mortality). The aim of our study is to investigate, using a validated frailty instrument, the association between frailty and the total risk of different complications in a large sample of patients undergoing TAVR.

## 2 | MATERIALS AND METHODS

### 2.1 | Study design and patient selection

This retrospective single-center cohort study was performed at the University Medical Center Utrecht, a tertiary hospital in the Netherlands. Between January 2014 and December 2019, all TAVR candidates referred to the geriatric outpatient clinic for a geriatric preoperative screening (POS) were included in this study, regardless of age. Patients referred for a POS before operations other than TAVR, patients in whom frailty was not determined, patients with canceled operations, and patients with follow-up appointments after December 31, 2019, were excluded. Ethical approval was waived by the Medical Ethics Committee of the University Medical Center Utrecht due to the retrospective nature of the study and the fact that all the procedures were part of routine care. The study has been conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. According to Dutch national regulations, in the case of file research, there is no obligation to obtain informed consent where the subject himself/herself is not physically involved in the research.

### 2.2 | TAVR procedure

The decision for TAVR intervention was determined by a multidisciplinary heart valve team consisting of at least one interventional cardiologist and one cardiac surgeon. The femoral artery was the preferred access site. Procedures were performed under general or local anesthesia according to the decision of the anesthesiologist.

### 2.3 | Geriatric POS

The POS assessment was performed by geriatric nurse practitioners under the supervision of a geriatrician. A comprehensive anamnesis was performed, including the patient medical history and current physical complaints. Patients were screened for cognitive impairment using the Mini-Mental State Examination (MMSE)[16] or Montreal Cognitive Assessment (MOCA)[17] (<5% of cases), for depression using the Geriatric Depression Scale (GDS),[18] for risk of malnutrition using the Malnutrition Universal Screening Tool (MUST)[19] and for dependence in (instrumental) activities of daily living ((i)ADL) using the KATZ-15 index.[20] Patients underwent a physical examination that included measurement of handgrip strength and gait speed. The Charlson Comorbidity Index (CCI) was assessed to quantify somatic comorbidity.[21] There is general consensus that a comprehensive geriatric assessment (CGA) is the best approach for the identification of frailty.[22] During the CGA, the health of the elderly population is assessed in a systematic manner, focusing on the medical, mental, functional, and social domains. Due to the time-consuming nature of the CGA, several screening tools have been developed to detect frailty. In this study, frailty was assessed with the Groningen Frailty Indicator (GFI, Supporting Information: Table 1).[23,24] The GFI is a validated 15-item instrument that determines the loss of function and resources in the four domains of the CGA.[25] After discussing the questions of the GFI with the patient, the geriatric nurse practitioner completed the GFI during the POS assessment. The GFI is widely used in clinical practice and research.[24,26] During the study period, local guidelines for assessing frailty changed and frailty was also

determined in some patients ($n$ = 155) using the Edmonton Frail Scale (EFS).[27] The EFS determines 9 domains of frailty (cognition, general health status, functional independence, social support, medication use, nutritional status, mood, continence, functional performance) using 10 questions and 1 physical "timed up and go" assessment. The EFS has been shown to correlate well with various geriatric conditions such as independence, drug use, mood, mental, functional, and nutritional status.[28] Additional analyses were performed using frailty data determined with the EFS. It is not known which screening tool is most suitable for determining frailty in patients with cardiovascular disease. Previously, the Clinical Frailty Scale (CFS) has been used for patients with TAVR surgery.[29] Although this screening instrument is easy to use because it does not require stopwatches, dynamometers, or other specialized equipment or personnel, it is also semiquantitative and subjective in nature, and therefore, prone to interobserver variability.[30] Moreover, this instrument is primarily focused on the functional domain, with little or no attention paid to the cognitive, social, and medical domains. The GFI and EFS were used in the current study, because of their multidimensional character. Furthermore, data were collected on living situation, alcohol use, and smoking status. The American Society of Anesthesiologists (ASA) score was determined for each patient by the anesthesiologist involved.[31] After the geriatric assessment was completed, advice was given on the prevention of delirium, such as perioperative haloperidol prescription or involving family during the period of bed rest. In addition, advice was given on fall prevention, reduction of smoking and alcohol use, and improvement of medication use, mobility, and nutritional status. When necessary, (e.g., in case of serious comorbidity or severe cognitive or functional impairment) advice was given to postpone or cancel the operation.

## 2.4 | Geriatric postoperative involvement

After the TAVR procedure, patients were visited by a geriatric nurse practitioner to assist in the prevention or treatment of geriatric complications, such as postoperative delirium, falls, or stroke. Patients were observed by nurses from the cardiologic department during admission and an additional assessment using the Delirium Observation Screening Scale (DOSS) was performed three times a day. The DOSS screens for typical behavioral patterns related to delirium.[32] The geriatric consulting team confirmed the diagnosis of postoperative delirium and gave treatment advice. Delirium was diagnosed using the criteria of the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders*[33]: an acute and fluctuating attention and awareness deficit complemented by a disturbance in cognition, which is the direct consequence of another medical condition, substance intoxication, or withdrawal or exposure to a toxin. The disturbances in attention, awareness, and cognition are not better explained by a pre-existing, established, or evolving neurocognitive disorder and do not occur in the context of a severely reduced level of arousal, such as a coma.

## 2.5 | Follow-up

A follow-up appointment with a geriatric nurse practitioner under the supervision of a geriatrician was scheduled for 3 months after TAVR. Data were collected on the occurrence of postoperative complications.

## 2.6 | Data collection and processing

All data were collected from electronic medical records and imported into a database using the Statistical Package for the Social Sciences, version 25 (SPSS Inc.).

Demographic variables obtained were age, sex, alcohol status (current use, regardless of amount), smoking status (current use), body mass index (BMI), and living situation. The living situation was considered independent when patients lived in their own house, with or without home care. The living situation was considered dependent when patients lived in an assisted nursing facility or skilled nursing facility.

The somatic variables obtained were the CCI, ASA class, and medication use. An adjusted CCI score without considering points for age category was used because it was assumed that there would be little variation in the age of the patients. This way, only the number of comorbidities was assessed. All types of medication were included, except for eye drops, dermal creams, food supplements without prescription, and medication only taken when necessary. Polypharmacy was identified when the patient was using ≥5 medications during the POS visit.[34]

Cognitive variables obtained were MMSE (or MOCA in <5% of the cases) and GDS. Functional variables obtained were KATZ-15, MUST, gait speed, and handgrip strength. For the purpose of the analyses, all values except BMI were dichotomized at standard cutoff points, as explained in Table 1. A cutoff value of ≥6 for the EFS and ≥4 for the GFI indicated frailty.[25,26]

## 2.7 | Primary and secondary outcomes

The primary outcome of the study was the occurrence of major postoperative complications categorized by the Clavien–Dindo classification.[35] A recent study demonstrated that the Clavien–Dindo classification offers an accurate reflection of the complexity of postoperative evolution in cardiac adult surgery.[36] Under the Clavien–Dindo classification, complications are graded in five categories according to the required treatment, ranging from any deviation from the normal postoperative course to intensive care admission and death (Supporting Information: Table 2). Grade ≥II was considered a major postoperative complication. All postoperative complications that occurred during admission were categorized into the five Clavien–Dindo categories. When multiple complications in different categories occurred, the highest grade was taken into the analysis.

Secondary outcomes are as follows: first, during admission, the presence of postoperative delirium confirmed by the geriatric consulting team, postoperative infections treated with antibiotics, the occurrence of reintervention, unplanned intensive care unit admission or admission to a rehabilitation center; and second, within 3 months of TAVR, the occurrence of falls, all-cause mortality, or one or more hospital readmissions. A composite outcome of postoperative complications was created to determine the risk of patients developing one or more of the secondary outcomes. Additionally, complication data were also reported according to the VARC-2 criteria, to determine the relationship between frailty and adverse outcomes after TAVR in a complementary manner.[15] Finally, the association between frailty and all-cause mortality 30 days and 1 year after TAVR surgery was assessed.

### 2.8 | Statistical methodology

Dichotomized baseline variables were expressed as numbers and corresponding percentages. Differences in baseline characteristics between frail and nonfrail patients were determined by the $\chi^2$ test or Fisher's exact test as appropriate. Continuous baseline variables were expressed as means ± standard deviation (SD) and differences between frail and nonfrail patients were determined by Student's *t*-test. All outcome variables were entered into a univariate logistic regression analysis and subsequently into a multivariate logistic regression analysis to determine the relationship between frailty and the outcomes. Odds ratios (ORs) and 95% confidence intervals (95% CI) were calculated. The ORs were adjusted for age and sex. In addition, the presence of effect modification by age was examined.

The number of missing values did not exceed 10%. Therefore, imputation methods were not used. A $p \leq 0.05$ was considered statistically significant. The data were analyzed using the Statistical Package for the Social Sciences version 25 (SPSS Inc.).

## 3 | RESULTS

### 3.1 | Patient inclusion and baseline characteristics

From January 2014 to December 2019, 484 patients were referred for a geriatric POS, and 431 of these patients were included in this study. Exclusions were due to operations other than TAVR ($n = 24$), incomplete follow-up ($n = 17$), incomplete POS assessments ($n = 7$), and cancelled operations ($n = 5$). A flowchart of the patient inclusion process is presented in Figure 1. In most cases, the reason for operation cancelation was severe comorbidities.

Baseline characteristics are summarized in Table 1. The mean age of the study population was 80.8 (SD ± 6.2) years and 56% ($n = 240$) were female. Frailty (GFI ≥ 4) was present in 36% ($n = 155$) of the study population. Female patients were significantly more often frail. Patients with dependence in (i)ADL, at risk of malnutrition, or with reduced mobility were significantly more often frail, as were patients with an increased CCI score and patients with polypharmacy. Furthermore, a lower MMSE score and a higher GDS score were significantly more often present in frail patients.

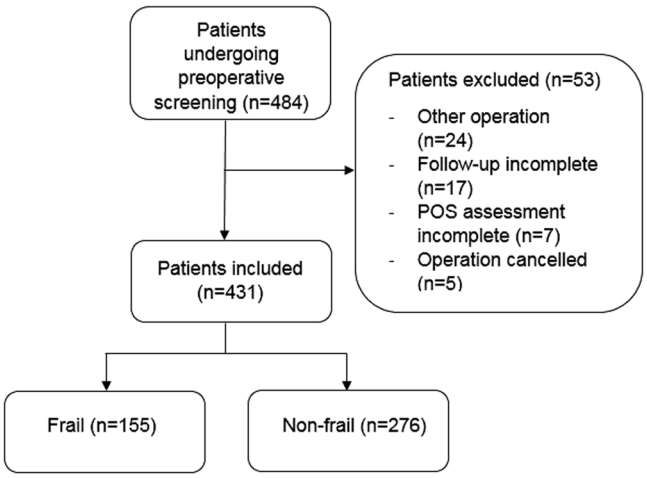


**FIGURE 1** Flowchart of patient inclusion

### 3.2 | Postoperative complications

In 28% of the patients, the maximum observed Clavien–Dindo classification grade was I. Prevalence of ascending grades was 16%, 17%, 3%, and 3% (Supporting Information: Table 3). A Clavien–Dindo classification grade ≥II occurred in 43% ($n = 67$) of the frail patients and in 37% ($n = 103$) of the nonfrail patients (Figure 2). The occurrence of the composite outcome of postoperative complications was 45% in frail patients and 34% in nonfrail patients (Figure 3). Mortality within 3 months of TAVR occurred in 5% ($n = 20$) of all patients. Eleven patients were frail (7%) and 9 patients were nonfrail (3%). Postoperative delirium was diagnosed in 20 patients (5%); it occurred in 10 frail patients (7%) and 10 nonfrail patients (4%). Reintervention occurred in 13% of frail patients and 17% of nonfrail patients. Readmission rates within 3 months of TAVR were similar for the frail group (10%) and the nonfrail group (11%).

### 3.3 | Association between frailty and postoperative complications

All postoperative complications are presented in Figure 3. Frailty was not significantly associated with a higher risk of major postoperative complications, defined as Clavien–Dindo grade ≥II [OR: 1.20 (95% CI: 0.80–1.80) $p = 0.39$] (Table 2). Frailty was associated with a significantly higher risk of the composite outcome of postoperative complications [OR: 1.55 (95% CI: 1.03–2.34) $p = 0.04$]. The risk of 3-month mortality was significantly higher in frail patients compared to the nonfrail group [OR: 2.52 (95% CI: 1.00–6.28) $p = 0.05$]. The risk of other postoperative complications was not significantly higher for the frail group compared to the nonfrail group (all $p \geq 0.18$).

**TABLE 1** Baseline characteristics of study participants

| | All ($n$ = 431) | Frail ($n$ = 155) | Nonfrail ($n$ = 276) | $p$ Value |
|---|---|---|---|---|
| *Demographics* | | | | |
| Age (years) | | | | |
| Mean ± SD | 80.8 ± 6.2 | 81.7 ± 6.3 | 80.3 ± 6.1 | 0.03 |
| ≥80 years | 284 (66%) | 108 (70%) | 176 (64%) | 0.21 |
| Female sex | 240 (56%) | 99 (64%) | 141 (51%) | 0.01 |
| Smoking | 28 (7%) | 11 (7%) | 17 (6%) | 0.71 |
| Alcohol | 206 (48%) | 53 (34%) | 153 (56%) | <0.001 |
| BMI (kg/m$^2$ ), mean ± SD | 26.4 ± 4.7 | 26.3 ± 5.6 | 26.5 ± 4.2 | 0.71 |
| Living dependent | 20 (5%) | 15 (10%) | 5 (2%) | <0.001 |
| *Functional status* | | | | |
| (i)ADL[a] (≥1) | 268 (64%) | 134 (89%) | 134 (50%) | <0.001 |
| MUST[b] (≥1) | 67 (16%) | 46 (30%) | 21 (8%) | <0.001 |
| Gait speed (<0.8 m/s) | 91 (24%) | 55 (40%) | 36 (14%) | <0.001 |
| Handgrip strength (≤20 kg [women]/≤30 kg [men]) | 169 (42%) | 76 (53%) | 93 (36%) | <0.001 |
| *Somatic status* | | | | |
| Charlson comorbidity index[c] (≥3) | 224 (52%) | 97 (63%) | 127 (46%) | <0.001 |
| ASA-score[d] (≥3) | 378 (92%) | 145 (95%) | 233 (90%) | 0.04 |
| Polypharmacy (≥5 medications) | 340 (79%) | 139 (90%) | 201 (73%) | <0.001 |
| *Cognitive and psychological status* | | | | |
| MMSE[e] (≤24) | 44 (11%) | 30 (20%) | 14 (5%) | <0.001 |
| GDS[a] (≥6) | 10 (3%) | 8 (6%) | 2 (1%) | <0.001 |

*Note*: Possible range: [a]0–15, [b]0–6, [c]0–33 (points for age not included), [d]1–5, [e]0–30.

Abbreviations: (i)ADL, (instrumental) activities of daily living; ASA, American Society of Anesthesiologists; BMI, body mass index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental State Examination; MUST, Malnutrition Universal Screening Tool; SD, standard deviation.

An additional analysis was performed to assess whether the effect of frailty was modified by age. In patients younger than 80 years, frailty was associated with a higher risk of the composite outcome of postoperative complications [OR: 2.38 (95% CI: 1.14–4.97)], while in patients of 80 years and older, frailty was not significantly associated with a higher risk of this outcome [OR: 1.25 (95% CI: 0.77–2.05)]. The interaction term for age-frailty was not statistically significant when entered into the multivariate model ($p$ = 0.28).

### 3.4 | Association between frailty, 1-year mortality, and complications according to VARC-2 criteria

An additional analysis was performed to determine the association between frailty, 1-year mortality, and complications according to the VARC-2 criteria 30 days after TAVR surgery (Figure 4). Frailty was determined by the EFS or, if absent, the GFI. Frailty was significantly associated with an increased mortality risk 30 days after TAVR surgery [OR: 4.84 (95% CI: 1.62–14.49)] and 1 year after TAVR surgery [OR: 2.96 (95% CI: 1.46–6.00)] when corrected for age and sex (Table 2). Frailty was not significantly associated with an increased complication risk. A subgroup analysis that included only patients in whom frailty was identified by the GFI ($n$ = 431) showed that in both the unadjusted analysis [OR: 3.45 (95% CI: 1.20–9.91)] and the age- and sex-adjusted analysis [OR: 3.89 (95% CI: 1.32–11.47)], frailty was significantly associated with an increased risk of mortality. A subgroup analysis including only patients in whom frailty was assessed by the EFS ($n$ = 155) showed similar but not statistically significant results, probably due to a power issue [unadjusted OR: 2.06 (95% CI: 0.21–20.78)] and [adjusted OR: 1.81 (95% CI: 0.17–19.75)].

## 4 | DISCUSSION

### 4.1 | Main findings

The aim of this study was to determine whether frailty is associated with a higher risk of adverse outcomes after TAVR. In 36% of the

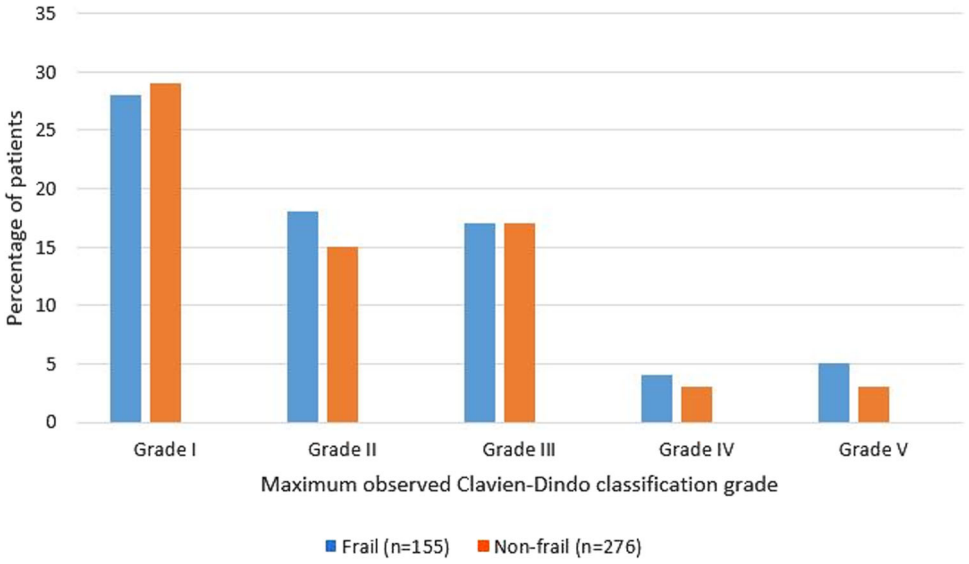


**FIGURE 2** The percentage of patients in whom the maximum observed Clavien–Dindo classification degree was I, II, III, IV, or V, respectively. [Color figure can be viewed at wileyonlinelibrary.com]

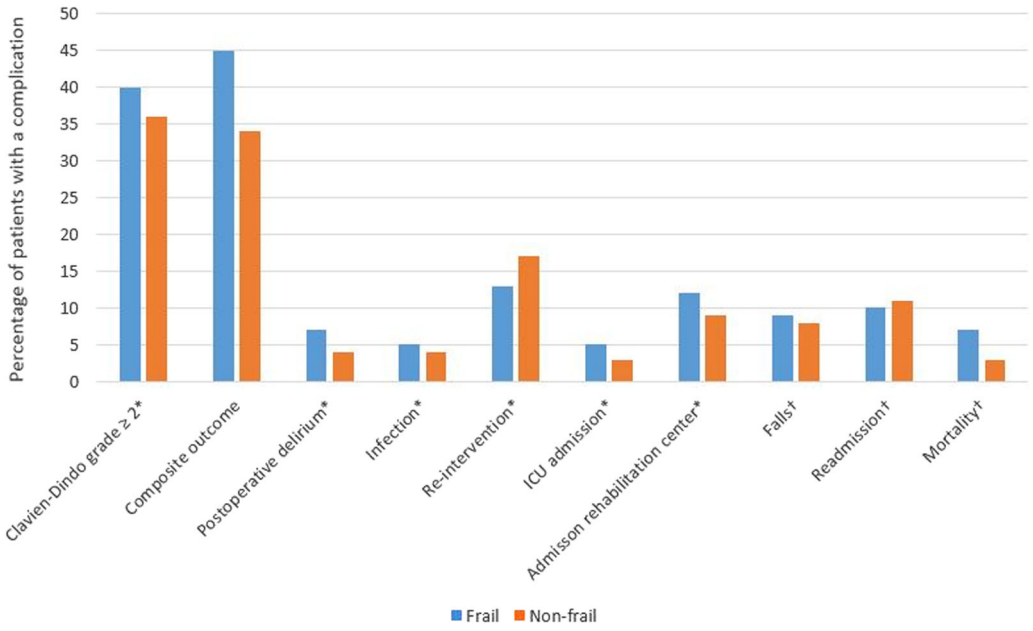


**FIGURE 3** The occurrence of (geriatric) postoperative complications, during admission (indicated by *) and within 3 months of surgery (indicated by †), stratified by frailty status. [Color figure can be viewed at wileyonlinelibrary.com]

participants, frailty was present. Frailty was significantly associated with an increased risk of the composite outcome of postoperative complications. In particular, frailty was associated with a higher risk of mortality within 30 days, 3 months, and 1 year of TAVR.

## 4.2 | Comparison with other studies

The prevalence of frailty in this study was in accordance with other studies investigating frailty in the TAVR population, ranging from 29% to 63%.[8] To the best of our knowledge, no previous study has investigated the association between frailty and adverse outcomes using the Clavien–Dindo classification. A recent systematic review found some evidence for the association between frailty and the following complications according to VARC criteria: major bleeding complications, blood transfusions, delirium, acute kidney injury, and infections. Frailty was not associated with vascular complications, stroke, or other major complications.[8] The finding of an increased 3-month (7% in frail patients, 3% in nonfrail patients, OR 2.52) and 1-year (15% in frail patients, 7% in nonfrail patients, OR 2.96)

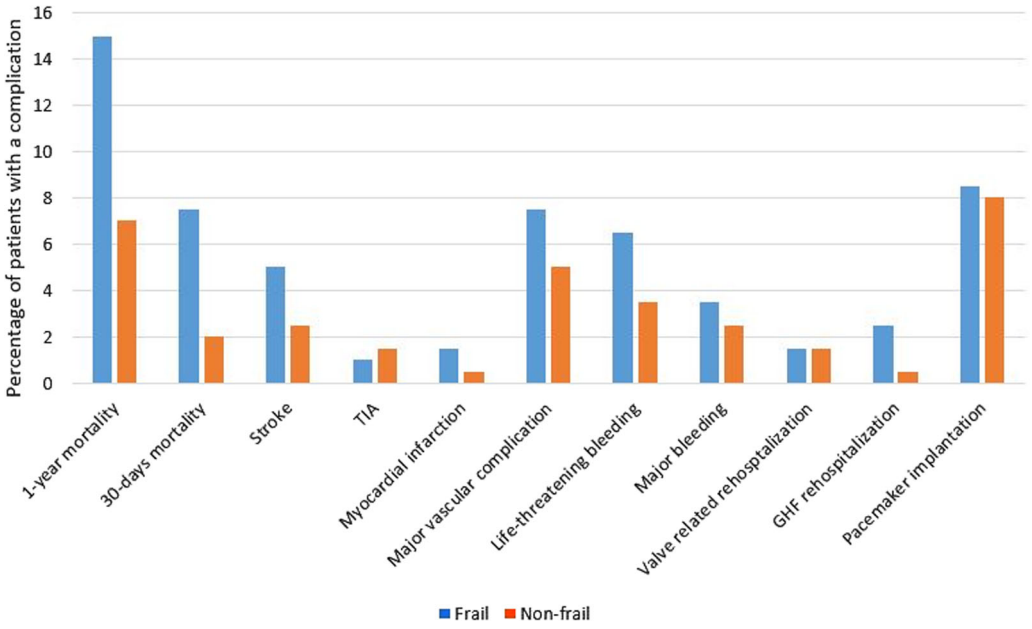


**FIGURE 4** The occurrence of 1-year mortality and postoperative complications according to the Valve Academic Research Consortium criteria 30-days after TAVR, stratified by frailty status. [Color figure can be viewed at wileyonlinelibrary.com]

mortality risk in frail patients was in accordance with previous studies.[7,8,37] A systematic review described a relative risk for 6-month mortality ranging from 1.11 to 13.77 and a 30-day mortality risk of 4%–17% in frail patients and 1%–6% in nonfrail patients, which is consistent with the risk found in this study (7.4% in frail patients and 1.9% in nonfrail patients).[8] In this study, the incidence of delirium after TAVR was 5%, while a recent systematic review found a pooled incidence of postoperative delirium of 8% (95% CI: 7%–9%).[10] This small difference may be a result of the geriatric consultation team's involvement.

## 4.3 | Strengths and limitations

The strengths of this study are the comprehensiveness of the geriatric assessment and the involvement of the geriatric team in TAVR care, the relatively large study population, the use of a validated multidomain frailty instrument, and the assessment of the composite outcome. In this study, a wide variety of complications were analyzed using the Clavien–Dindo classification, and there was a focus on secondary outcomes of importance to the geriatric population: delirium, infection, reintervention, unplanned intensive care unit admission, admission to a rehabilitation center, falls, and hospital readmissions. To carefully compare our results with other studies, we performed an additional analysis in which association was determined for frailty and 30-day complications according to the VARC-2 criteria. A recent article on frailty in heart failure patients indicates that decline in physical function (decreased walking speed and grip strength) is not the only phenotype of frailty.[38] The concept of frailty is a multidomain problem, featuring problems in physical, psychological, and social domains. This is also evident in Table 1 of our study, which shows a significant association between frailty and reduced walking speed, reduced grip strength, and increased risk of malnutrition (the physical domain) as well as cognitive impairment and depression (the psychological domain) and living dependent (the social domain). Although the GFI aligns with this perspective on frailty, we performed a subgroup analysis including patients in whom frailty had been determined using the EFS, since the more objective "timed up and go" variable is part of the EFS.

This study has some limitations. First, selection bias may exist, since the frailest patients have already been rejected for a TAVR by the cardiologist. However, the prevalence of frailty was similar to other studies. Second, due to a change in local guidelines regarding frailty instruments, different frailty instruments were used between January 2014 and December 2019. For this reason, the GFI for some patients was not registered by the geriatric nurse practitioner. For those patients, the GFI was calculated by using information from the POS to determine the frailty status by GFI in each patient. Most information was obtained reliably from medical records, for example, by means of other validated scales like the GDS or KATZ-15, which were performed during POS. Third, during the index admission and follow-up period, we may have missed complications. Delirium is not always well recognized, especially hypoactive delirium. Regarding the occurrence of falls at home, a recall bias may exist. Data on complications during hospital admission was not available for patients transferred to another hospital after the intervention. Fourth, the limited number of cases led to a potential power problem when classifying adverse events into specific complications or mortality. Finally, in this study, several screening tools were applied, all of which have been validated in older adults of whom some had cardiovascular

**TABLE 2** The association between frailty and adverse outcomes following TAVR

| | Odds ratio (95% CI) | | |
|---|---|---|---|
| | Unadjusted | Adjusted[a] | |
| Clavien–Dindo classification grade ≥II[b] | 1.21 (0.81–1.81) | 1.20 (0.80–1.80) | During admission |
| Composite outcome of postoperative complications[c] | 1.55 (1.04–2.32) | 1.55 (1.03–2.34) | |
| Postoperative delirium | 1.86 (0.76–4.57) | 1.80 (0.72–4.86) | During admission |
| Infection | 1.05 (0.41–2.74) | 1.11 (0.42–2.91) | During admission |
| Reintervention | 0.75 (0.43–1.32) | 0.73 (0.41–1.30) | During admission |
| Intensive care unit admission | 1.82 (0.67–4.96) | 1.99 (0.72–5.46) | During admission |
| Admission to rehabilitation center | 1.45 (0.76–2.77) | 1.45 (0.75–2.80) | During admission |
| Falls | 1.21 (0.57–2.55) | 1.16 (0.54–2.51) | <3 months |
| Hospital readmission | 0.94 (0.48–1.85) | 1.00 (0.50–1.99) | <3 months |
| All-cause mortality | 2.27 (0.92–5.60) | 2.52 (1.00–6.28) | <3 months |
| All-cause mortality[d] | 2.41 (1.23–4.69) | 2.96 (1.46–6.00) | <1 year |
| All-cause mortality[d] | 4.07 (1.42–11.7) | 4.84 (1.62–14.49) | <30 days |
| Stroke[d] | 2.28 (0.75–6.92) | 2.2 (0.7–6.91) | <30 days |
| TIA[d] | 0.64 (0.07–5.81) | 0.76 (0.08–7.2) | <30 days |
| Myocardial infarction[d] | 5.24 (0.47–58.3) | 7.57 (0.61–94.12) | <30 days |
| Major vascular complication[d] | 1.60 (0.68–3.75) | 1.48 (0.62–3.57) | <30 days |
| Life-threatening bleeding[d] | 1.94 (0.76–4.95) | 1.92 (0.73–5.06) | <30 days |
| Major bleeding[d] | 1.49 (0.43–5.19) | 1.77 (0.48–6.51) | <30 days |
| Valve-related rehospitalization[d] | 1.03 (0.20–5.40) | 1.08 (0.20–5.91) | <30 days |
| Congestive heart failure-related rehospitalization[d] | 7.92 (0.82–76.93) | 5.25 (0.53–51.98) | <30 days |
| Pacemaker implantation[d] | 1.04 (0.48–2.23) | 1.00 (0.46–2.19) | <30 days |

Abbreviations: TAVR, transcatheter aortic valve replacement; VARC-2, Valve Academic Research Consortium.

[a]Adjusted for sex and age.

[b]Possible range I–V.

[c]Composite outcome consisting of the following variables: postoperative delirium, infection, reintervention, intensive care unit admission, admission to rehabilitation center, falls, hospital readmission and all-cause mortality within 3 months.

[d]Complications according to the VARC-2 criteria.

disease. However, most of these tools have not been validated specifically in the TAVR population.

## 4.4 | Clinical implications and recommendations

This study demonstrates that frailty is not associated with a higher risk of postoperative complications according to the Clavien–Dindo classification or the VARC-2 criteria. The Clavien–Dindo classification grades complications based on the actual treatment of those complications. A cardiologist or cardiac surgeon may have a cautious attitude, particularly in frail patients, regarding the performance of a reintervention or admission to the intensive care unit. Therefore, the Clavien–Dindo classification is most likely not an appropriate tool for measuring differences in outcomes between frail and nonfrail patients. However, it is recommended that the total risk of complications after TAVR is investigated by means of a composite outcome, as this study showed that frail patients had a significantly higher risk of this outcome. Mortality appears to be the most important factor for this higher risk in frail patients, but there is likely also a cumulative contribution of multiple complications to this risk.

The current ESC guidelines for the management of valvular heart disease recommend TAVR instead of SAVR in frail patients.[4] However, the TAVR guidelines contain very few recommendations

regarding screening and treatment of frailty.[4,39] We recommend that frailty is included in conventional risk models for predicting mortality in cardiac surgery, such as The European System for Cardiac Operative Risk Evaluation (EuroSCORE) and the Society of Thoracic Surgeons (STS) risk score.[40] We advise POS by the geriatrician to assess frailty status. This screening provides balanced information on the risks and benefits of TAVR and enables shared decision-making.[41] Interventions such as family involvement, cotreatment with geriatrics, or a postoperative cardiac rehabilitation program can be useful in the prevention and postoperative treatment of geriatric complications like delirium or functional decline.[40,42,43] Through assessment of frailty, patients can be selected for prerehabilitation, as preoperative interventions to reduce frailty can be useful. A recent systematic review and network meta-analysis on interventions to prevent or reduce the level of frailty found physical activity and nutritional supplementation to be most effective.[44] Effective interventions to improve frailty, quality of life, cognition and mood were physical activity, nutritional supplementation, medication management, psychosocial and cognitive training, and pharmacotherapy. These interventions can be performed or prescribed by geriatricians. Currently, a randomized controlled trial is being conducted in which half of the frail older TAVR candidates receive an intervention consisting of a home-based exercise program and a protein-rich oral nutritional supplement. The effect on several outcomes will be evaluated (the PERFORM-TAVR Trial). We suggest further research on the efficacy and feasibility of the aforementioned interventions to improve frailty in TAVR candidates to improve clinical outcomes.

## 5 | CONCLUSION

This study shows that frailty is associated with an increased overall risk of postoperative complications and particularly 30-day, 3-month, and 1-year mortality in older patients undergoing TAVR. Therefore, recommendations should be made in the TAVR guidelines with respect to the geriatric POS and treatment of frail patients.

### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

Data available on reasonable request.

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