Impact of COVID-19 Surge Periods on Clinical Outcomes of Transcatheter Aortic Valve Implantation

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Healthcare systems adopted various strategies to minimize the impact of the COVID-19 pandemic on clinical outcomes of patients with symptomatic severe aortic stenosis referred for transcatheter aortic valve implantation (TAVI). We aimed to compare baseline characteristics and procedural and clinical outcomes of patients who underwent TAVI during COVID-19 surge periods with those of patients who underwent TAVI during the nonsurge and prepandemic periods. In the prospective Bern TAVI registry, the pandemic period was divided into surge and nonsurge periods on the basis of the mean number of occupied beds in the intensive care unit in each month and matched with 11 months immediately preceding the pandemic. A total of 1,069 patients underwent TAVI between April 1, 2019 and December 31, 2021. Patients who underwent TAVI during surge periods had a higher surgical risk (Society of Thoracic Surgeons predicted risk of mortality) than that of patients who underwent TAVI during nonsurge and prepandemic periods. Diagnosis-to-procedure time (in days) was longer for patients who underwent TAVI during the surge period than during the nonsurge and prepandemic periods (95.20 ± 121.07 vs 70.99 ± 72.25 and 60.46 ± 75.43, both p <0.001). At 30 days, all-cause mortality was higher in the surge than in the nonsurge group (4.9 vs 1.1%, hazard ratio 4.68, 95% confidence interval 1.55 to 14.10, p = 0.006), and in the surge than in the prepandemic group (4.9 vs 1.3%, hazard ratio 3.67, 95% confidence interval 1.34 to 10.11, p = 0.012). In conclusion, TAVI during COVID-19 surge periods was associated with higher Society of Thoracic Surgeons predicted risk of mortality score, delayed procedure scheduling, and increased 30-day mortality than that of TAVI during nonsurge and prepandemic periods. **© 2023 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)** **(Am J Cardiol 2023;204:32−39)**

The COVID-19 pandemic resulted in an unprecedented challenge to healthcare systems around the globe, and health services had to be reorganized to ensure safe and efficient distribution and delivery of care.[1] Symptomatic severe aortic valve stenosis is associated with a high risk of mortality, approaching 50% at 1 year and 70% at 2 years if untreated, raising serious concerns related to treatment deferral during the pandemic.[2,3] Indeed, up to 1 of 3 patients awaiting aortic valve replacement experienced a cardiac event within 3 months in 2 studies reported during the COVID-19 pandemic.[4,5] To minimize the impact of the COVID-19 pandemic on the clinical outcomes of patients with symptomatic severe aortic valve disease, healthcare systems adopted various strategies based on risk stratification of patients while accounting for service capacity.[6,7] Transcatheter aortic valve implantation (TAVI) emerged as a safe and effective treatment for symptomatic severe aortic valve disease.[8] However, reports on the clinical impact of the pandemic and the adopted strategies on the clinical outcome of TAVI are scarce. In this analysis, we report our TAVI experience at Bern University Hospital during different stages of the pandemic and discuss potential clinical impact.

Methods

Consecutive patients who underwent TAVI at Bern University Hospital, Switzerland during the study period were prospectively enrolled in the Bern TAVI registry, which is a part of the nationwide Swiss TAVI registry (NCT01368250). The registry is approved by the cantonal ethics committee Bern and complies with the Declaration of Helsinki. All participants provided written informed consent before inclusion.

The pandemic period between March 1, 2020 and December 31, 2021 was divided into surge and nonsurge periods (11 months each) on the basis of the mean number of occupied beds in the intensive care unit (ICU) in each month, and matched with 11 months immediately preceding the pandemic (April 1, 2019 to February 28, 2020) for the prepandemic period (Figure 1). The rationale for this stratification was capped numbers of TAVI procedures per week and restricted access to ICU during surge conditions.

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Pharmaceutical and medical device companies provide direct funding to some of these studies.

See page 38 for Declaration of Competing Interest.

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https://doi.org/10.1016/j.amjcard.2023.07.072

A web-based database with standardized case report forms was used for prospective data collection. An independent clinical trials unit was responsible for central data monitoring to verify completeness and accuracy of data and to perform independent statistical analysis. Baseline echocardiographic and computed tomographic imaging data were independently re-evaluated by dedicated imaging specialists and integrated into the database. Clinical follow-up data at 30 days were obtained using standardized interviews, documentation from referring physicians, and hospital discharge summaries. All reported serious adverse events were reviewed by a dedicated clinical event committee and adjudicated according to the standardized end point definitions proposed by the Valve Academic Research Consortium (VARC).[9]

Technical success of the TAVI procedure was defined according to the VARC-3 and included (1) freedom from death; (2) successful access, delivery of the device, and retrieval of the delivery system; (3) correct positioning of a single prosthetic heart valve into the proper anatomic location; and (4) freedom from surgery or intervention related to the device or a major vascular or access-related or cardiac structural complication.[9]

Categorical variables are reported as frequencies and percentages and compared using the chi-square test or 2-tailed Fisher's exact test. Continuous variables are presented as mean values ± SD and compared between groups using 2-sample *t* test, Omnibus analysis of variance, and Bonferroni correction. Cumulative time-to-event curves were depicted using the Kaplan-Meier method. Cox proportional hazards model was used to calculate hazard ratios (HRs) and 95% confidence intervals (CIs) for clinical outcomes. Mantel-Haenszel risk ratios for the primary outcomes were calculated. All statistical tests were 2-sided, and $p < 0.05$ was considered significant. Statistical analyses were performed using Stata 15.1 (StataCorp, College Station, Texas).

Results

A total of 1,069 patients underwent TAVI between April 1, 2019 and December 31, 2021 and were grouped into prepandemic (n = 372), pandemic nonsurge (n = 383), and pandemic surge periods (n = 314) (Figure 1).

Patient-related baseline characteristics are depicted in Table 1. Baseline clinical characteristics were similar

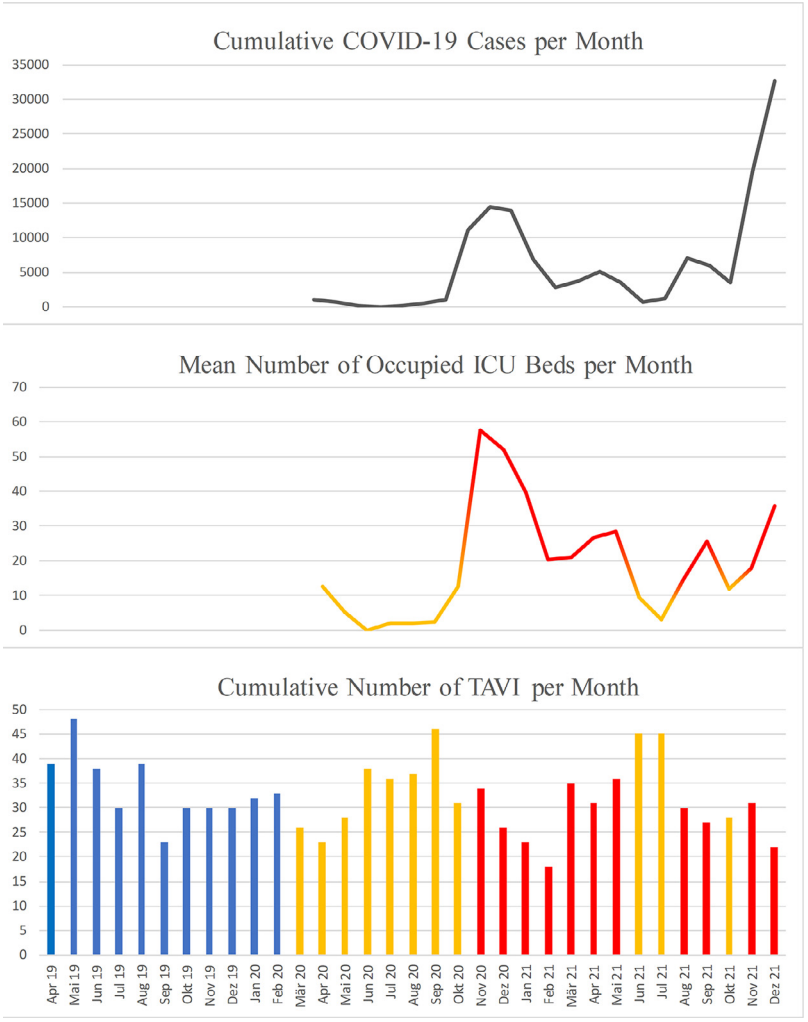

Figure 1. COVID-19 cases, occupied ICU beds, and number of TAVI per month. Cumulative COVID-19 cases, mean number of occupied ICU beds, and cumulative numbers of TAVI per month between April 1, 2019 and December 31, 2021. Blue, prepandemic; orange, nonsurge; and red, surge period.

across all groups for cardiovascular, cerebrovascular, and renal risk factors as summarized in Table 1. Society of Thoracic Surgeons predicted risk of mortality (STS-PROM) was higher in patients who underwent TAVI during surge than during nonsurge (5.05 ± 3.98 vs 4.18 ± 3.60, p = 0.003) and prepandemic periods (5.05 ± 3.98 vs 3.69 ± 3.61, p <0.001) but was similar between prepandemic and nonsurge periods (p = 0.062).

Diagnosis-to-procedure time (in days) was longer for patients who underwent TAVI during the surge period than during the nonsurge and prepandemic periods (95.20 ± 121.07 vs 70.99 ± 72.25, for surge vs nonsurge, p = 0.001) and (95.20 ± 121.07 vs 60.46 ± 75.43, for surge vs prepandemic, p <0.001). This difference was driven mainly by longer diagnosis to referral time (41.80 ± 104.48 vs 24.74 ± 62.65, for surge vs nonsurge, p = 0.009; and 41.80 ± 104.48 vs 15.87 ± 68.34, for surge vs prepandemic, p <0.001).

All echocardiography-derived parameters related to the direct assessment of the severity of aortic valve disease, valvular and left ventricular outflow tract total calcium score, left ventricular systolic function, concomitant mitral and tricuspid valve disease, and pulmonary hypertension, were similar across all 3 groups.

Procedure-related characteristics are presented in Table 2. Similar proportions of balloon- and self-expandable prostheses were used during the 3 periods. The rate of technical success as defined by VARC-3 was similar across groups. The rates of commonly recognized immediate procedural complications including valve dislocation, valve embolization, cardiac tamponade, annular rupture, aortic dissection, coronary artery occlusion, and major vascular complications were similar across groups, except for a trend for an increased risk of second valve implantation at the time of the index procedure in the surge compared with nonsurge and prepandemic groups (1.9 vs 0.3%, p = 0.05, and 1.9 vs 0.3%, p = 0.052, respectively).

Echocardiography-derived characteristics of the implanted valves (postprocedure/predischarge) showed smaller valve area of valves implanted during the pandemic than during the prepandemic period (valve area cm^2 1.70 ± 0.46 vs 1.81 ± 0.58, for surge vs prepandemic, p = 0.013; and 1.67 ± 0.49 vs 1.81 ± 0.58, for nonsurge vs prepandemic, p = 0.001). Prosthetic valve flow gradients remained similar across the groups.

Total length of hospital stay after procedure was similar across the groups: 6.9, 6.1, and 6.9 days, for surge, nonsurge, and prepandemic groups, respectively, although patients during the surge and nonsurge period stayed longer in the ICU than during the prepandemic period (length of stay (days) 2.07 ± 1.69, 1.83 ± 1.10 and 1.61 ± 1.17, respectively, p <0.01 for both pandemic periods vs prepandemic).

At 30 days, there was no significant difference in the rate of the composite end point of death, stroke, myocardial infarction, and major or life-threatening bleeding among all 3 groups (Figure 2, Table 3, Supplementary Table 1).

Rates of cardiovascular and all-cause mortality were similar in the prepandemic and the pandemic nonsurge groups. Conversely, the rate of cardiovascular death was higher among patients who underwent TAVI during the surge than during the nonsurge period (3.6 vs 1.1%, HR 3.43, 95% CI 1.09 to 10.77, p = 0.035), and there was a trend toward higher rates of cardiovascular mortality in the surge than in the prepandemic group (3.6 vs 1.3%, HR 2.69, 95% CI 0.94 to 7.75, p = 0.066). Similarly, all-cause mortality was higher in the surge than in the nonsurge group (4.9 vs 1.1%, HR 4.68, 95% CI 1.55 to 14.10, p = 0.006) and in the surge than in the prepandemic group (4.9 vs 1.3%, HR 3.67, 95% CI 1.34 to 10.11, p = 0.012) (Figure 3, Supplementary Table 1).

Discussion

In this retrospective analysis of a single-center prospective registry cohort, we showed higher 30-day all-cause and cardiovascular mortality in patients who underwent TAVI during the surge period of the COVID-19 pandemic than in those who underwent the intervention during the nonsurge period or before the pandemic (Figure 4).

The increased 30-day all-cause and cardiovascular mortality in patients who underwent TAVI during the surge period did not translate into a significant difference in composite end point of death, stroke, myocardial infarction, and major or life-threatening bleeding among the 3 groups.

The increased rates of all-cause and cardiovascular mortality after TAVI intervention during the surge period of the pandemic in our cohort require careful interpretation. Supplementary Table 2 presents the immediate causes of death during the 3 periods; 75% of them occurred during the periprocedural index hospitalization (80%, 75%, and 73% for the prepandemic, pandemic nonsurge, and surge periods, respectively), and none of the deaths was considered directly attributable to COVID-19.

Patients who underwent intervention during the surge period had higher STS-PROM scores. An increased STS-PROM score points to greater patient complexity and associated adverse outcome.[10–13] Moreover, patients who underwent TAVI in the surge group had to wait for longer periods to be referred and to undergo the intervention than did patients in the other groups. It is also possible that there was some delay in making the diagnosis owing to organizational changes during the pandemic, which was not examined in this study. Despite the longer delay to receive the intervention, there was no detected echocardiographic deterioration in the parameters related to the direct assessment of the stage of the aortic valve disease, such as left ventricular systolic function, concomitant mitral and tricuspid valve disease, and pulmonary hypertension. However, the difference in the waiting time in our report, although statistically significant, is not expected to be sufficient for the development of significant echocardiographic changes.

The association between diagnosis-to- and referral-to-procedure time for TAVI and adverse clinical outcome after intervention is well established in the literature.[14,15] Some studies reported a lack of association between referral-to-procedure time and early mortality in patients with elective TAVI but a significant relation between wait times and 1-year mortality after successful elective TAVI with a relative increase of 2% per week after referral.[14] Moreover, a Canadian cohort study reported a significant increase in wait times for TAVI year over year from 80 days in 2012 to

Table 1
Baseline characteristics

		COVID-19 pandemic						
	All patients	Pre-pandemic	Non-surge period	Surge period	p-value Non-surge vs pre	p-value Surge vs pre	p-value Surge vs non-surge	p-value Polynomial contrast
	N = 1069	N = 372	N = 383	N = 314				
Age (years)	81.02 ± 6.76	80.93 ± 6.69	80.44 ± 7.00	81.83 ± 6.48	0.329	0.075	*0.007*	0.025
Gender (female)	483 (45.2%)	175 (47.0%)	155 (40.5%)	153 (48.7%)	0.078	0.701	0.032	0.063
Body mass index (kg/cm^2)	26.97 ± 5.42	27.40 ± 5.38	26.76 ± 5.37	26.71 ± 5.53	0.101	0.097	0.901	0.159
STS-PROM, %	4.27 ± 3.76	3.69 ± 3.61	4.18 ± 3.60	5.05 ± 3.98	0.063	*<0.001*	*0.003*	<0.001
NYHA III or IV	600 (56.1%)	230 (61.8%)	207 (54.0%)	163 (51.9%)	0.033	*0.011*	0.594	0.020
ESC categories								
Elective	300 (28.1%)	84 (22.6%)	121 (31.6%)	95 (30.3%)	0.005	0.024	0.742	
Lower priority	756 (70.7%)	285 (76.6%)	256 (66.8%)	215 (68.5%)	0.004	0.020	0.685	
Urgent	7 (0.7%)	1 (0.3%)	3 (0.8%)	3 (1.0%)	0.624	0.337	1.000	
Emergency	6 (0.6%)	2 (0.5%)	3 (0.8%)	1 (0.3%)	1.000	1.000	0.631	
Concomitant diseases								
Arterial hypertension	974 (91.1%)	339 (91.1%)	354 (92.4%)	281 (89.5%)	0.596	0.517	0.183	0.401
Diabetes mellitus	313 (29.3%)	112 (30.1%)	113 (29.5%)	88 (28.0%)	0.874	0.556	0.675	0.831
Dyslipidaemia	755 (70.6%)	261 (70.2%)	266 (69.5%)	228 (72.6%)	0.874	0.499	0.402	0.641
Renal failure (GFR<60)	631 (59.0%)	216 (58.1%)	229 (59.8%)	186 (59.2%)	0.657	0.815	0.938	0.887
COPD	89 (8.3%)	31 (8.3%)	30 (7.8%)	28 (8.9%)	0.894	0.787	0.680	0.876
Atrial fibrillation	356 (33.4%)	129 (34.7%)	130 (33.9%)	97 (31.1%)	0.878	0.329	0.464	0.585
Previous history								
Coronary artery disease	531 (49.7%)	197 (53.0%)	186 (48.6%)	148 (47.1%)	0.244	0.145	0.761	0.273
History of PCI	271 (25.4%)	94 (25.3%)	95 (24.8%)	82 (26.1%)	0.933	0.861	0.727	0.924
History of CABG	105 (9.8%)	31 (8.3%)	41 (10.7%)	33 (10.5%)	0.322	0.358	1.000	0.489
History of MI	129 (12.1%)	39 (10.5%)	51 (13.3%)	39 (12.4%)	0.262	0.470	0.735	0.479
History of stroke	124 (11.6%)	31 (8.3%)	55 (14.4%)	38 (12.1%)	*0.011*	0.126	0.434	0.036
Peripheral artery disease	122 (11.4%)	40 (10.8%)	40 (10.4%)	42 (13.4%)	0.906	0.345	0.240	0.426
Previous pacemaker	79 (7.4%)	32 (8.6%)	22 (5.7%)	25 (8.0%)	0.157	0.783	0.288	0.296
Medications at baseline								
Aspirin	504 (47.2%)	190 (51.1%)	168 (43.9%)	146 (46.6%)	0.049	0.251	0.491	0.136
P_2Y12 antagonist	162 (15.2%)	54 (14.5%)	61 (15.9%)	47 (15.0%)	0.614	0.914	0.754	0.861
VKA	68 (6.4%)	27 (7.3%)	22 (5.7%)	19 (6.1%)	0.461	0.646	0.873	0.674
NOAC	293 (27.4%)	103 (27.7%)	110 (28.7%)	80 (25.6%)	0.808	0.545	0.393	0.643
Imaging data								
Aortic Valve Area (cm^2)	0.75 ± 0.33	0.74 ± 0.34	0.75 ± 0.31	0.74 ± 0.35	0.543	0.825	0.734	0.836
Mean Gradient (mmHg)	36.58 ± 16.56	37.06 ± 16.49	36.39 ± 16.37	36.23 ± 16.92	0.577	0.521	0.903	0.781
LVEF (%)	55.90 ± 13.71	55.97 ± 13.96	55.43 ± 13.82	56.43 ± 13.27	0.605	0.669	0.355	0.653
Moderate or severe AR	120 (16.1%)	37 (13.1%)	42 (16.4%)	41 (19.6%)	0.329	0.061	0.395	0.153
Moderate or severe MR	184 (21.8%)	72 (22.7%)	57 (19.8%)	55 (22.9%)	0.427	1.000	0.394	0.603
Moderate or severe TR	106 (13.6%)	42 (14.4%)	34 (12.6%)	30 (13.6%)	0.622	0.898	0.789	0.834
PASP	45.84 ± 19.40	44.09 ± 16.41	47.48 ± 22.55	46.09 ± 18.71	0.037	0.187	0.447	0.102
LVOT calcium (total) (mm^3)	9.13 ± 24.08	8.45 ± 20.71	8.56 ± 23.94	11.31 ± 29.53	0.951	0.210	0.280	0.400
Wait times (days)								
Diagnosis to referral	26.64 ± 79.67	15.87 ± 68.34	24.74 ± 62.65	41.80 ± 104.48	0.066	*<0.001*	*0.009*	<0.001
Referral to procedure	47.77 ± 45.08	44.59 ± 39.62	46.25 ± 33.65	53.39 ± 60.23	0.538	0.023	0.052	0.028
Diagnosis to procedure	74.41 ± 91.40	60.46 ± 75.43	70.99 ± 72.25	95.20 ± 121.07	0.053	*<0.001*	*0.001*	<0.001
SARS-CoV-19								
COVID-19 tests before TAVI	133 (12.7%)		70 (18.9%)	63 (20.3%)			0.698	
COVID-19 infection confirmed	3 (2.3%)		2 (2.9%)	1 (1.6%)			1.000	

Depicted are means with standard deviations (± SD), or counts with percentages (%). Pairwise p-values and omnibus p-value using polynomial contrasts; italic p-values remain significant after Bonferroni correction. Correction executed in case the omnibus test was also significant.

AR = aortic regurgitation; BMI = body mass index; CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease; CKD = chronic kidney disease; eGFR = estimated glomerular filtration rate; LVEF = left ventricular ejection fraction; MI = myocardial infarction; MR = mitral valve regurgitation; MS = mitral stenosis; NOAC = non vitamin K antagonist oral anticoagulant agent; NYHA = New York Heart Association; OAC = oral anticoagulant agent; PASP = pulmonary artery systolic pressure; PCI = percutaneous coronary intervention; STS-PROM = Society of Thoracic Surgeons Predicted Risk of Mortality; VKA = vitamin K antagonist.

110 days in 2018, which was associated with increased mortality.[16] However, the mean diagnosis-to-procedure and referral-to-procedure times during the surge period in our center are still considerably shorter than the waiting times reported in many European and North American centers before the pandemic.[14–16]

In addition, there was no increase in the proportion of urgent and emergency TAVI during both phases of the

Table 2
Procedural characteristics and complications

	COVID-19 pandemic							
	All patients N = 1069	Pre-pandemic N = 372	Non-surge period N = 383	Surge period N = 314	p-value Non-surge vs pre	p-value Surge vs pre	p-value Surge vs non-surge	p-value Polynomial contrast
Femoral main access site	1038 (97.1%)	368 (98.9%)	360 (94.0%)	310 (98.7%)	*<0.001*	1.000	*0.001*	<0.001
Type of valve								
Balloon-expandable	675 (63.2%)	229 (61.6%)	249 (65.2%)	197 (62.7%)	0.326	0.813	0.526	
Self-expandable	380 (35.6%)	132 (35.5%)	131 (34.3%)	117 (37.3%)	0.760	0.634	0.427	
Mechanical-expandable	13 (1.2%)	11 (3.0%)	2 (0.5%)	0 (0.0%)	0.011	0.001	0.504	
Pre dilation	417 (39.0%)	172 (46.2%)	140 (36.6%)	105 (33.4%)	*0.008*	*0.001*	0.425	0.001
Post dilation	223 (20.9%)	57 (15.3%)	92 (24.0%)	74 (23.6%)	*0.003*	*0.008*	0.929	0.005
Procedural Complications								
Valve in series	8 (0.7%)	1 (0.3%)	1 (0.3%)	6 (1.9%)	1.000	0.052	0.050	0.052
Valve dislocation/embolization	9 (0.8%)	1 (0.3%)	2 (0.5%)	6 (1.9%)	1.000	0.052	0.149	0.084
Conversion to SAVR	5 (0.5%)	0 (0.0%)	2 (0.5%)	3 (1.0%)	0.499	0.095	0.662	0.507
Annulus rupture/aortic dissection	15 (1.4%)	2 (0.5%)	9 (2.3%)	4 (1.3%)	0.064	0.420	0.402	0.138
Cardiac tamponade/rupture	4 (0.4%)	1 (0.3%)	2 (0.5%)	1 (0.3%)	1.000	1.000	1.000	0.839
Coronary artery occlusion	3 (0.3%)	1 (0.3%)	0 (0.0%)	2 (0.6%)	0.493	0.596	0.203	0.480
Major vascular complication	78 (7.3%)	31 (8.3%)	26 (6.8%)	21 (6.7%)	0.491	0.470	1.000	0.636
Discharge or Post-Procedure								
Aortic valve area (mm)	1.73 ± 0.52	1.81 ± 0.58	1.67 ± 0.49	1.70 ± 0.46	*0.001*	*0.013*	0.458	0.002
Prosthetic valve mean gradient (mmHg)*	10.25 ± 4.79	10.25 ± 5.12	10.31 ± 4.67	10.18 ± 4.53	0.864	0.857	0.716	0.941
Aortic regurgitation grade*								
none	668 (62.5%)	220 (59.1%)	237 (61.9%)	211 (67.2%)	0.457	0.032	0.153	
mild	384 (35.9%)	143 (38.4%)	140 (36.6%)	101 (32.2%)	0.599	0.093	0.231	
moderate or severe	17 (1.6%)	9 (2.4%)	6 (1.6%)	2 (0.6%)	0.444	0.074	0.306	
Technical success (VARC-3)	799 (94.9%)	339 (93.9%)	284 (95.6%)	176 (95.7%)	0.385	0.435	1.000	0.533
Length of stay								
Total days	6.79 ± 3.48	6.90 ± 3.41	6.61 ± 3.32	6.89 ± 3.74	0.246	0.973	0.304	0.450
ICU days	0.12 ± 0.85	0.13 ± 1.11	0.10 ± 0.50	0.14 ± 0.85	0.631	0.852	0.393	0.780
Intermediate care days	1.82 ± 1.33	1.61 ± 1.17	1.83 ± 1.10	2.07 ± 1.69	*0.009*	*<0.001*	0.026	<0.001

Depicted are means with standard deviations (±SD), or counts with percentages (%). Pairwise p-values and omnibus p-value using polynomial contrasts. Italic p-values remain significant after Bonferroni correction. Correction executed in case the omnibus test was also significant.

ICU = intensive care unit; SAVR = surgical aortic valve replacement.

* If missing at discharge, post-procedure imaging used.

pandemic compared with the prepandemic period.[7] Both categories accounted for small percentages of the TAVI procedures delivered in all 3 phases, which is perhaps a reflection of relatively short waiting times for TAVI in our center.

Only 19% and 20% of patients were tested for COVID-19 during the nonsurge and surge period, respectively; in addition, only 14% of patients in the nonsurge and surge groups received COVID-19 tests within 30 days of the

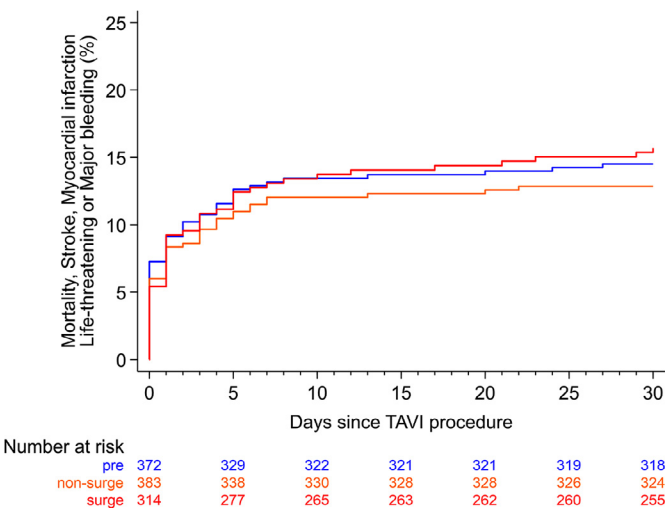

Figure 2. Cumulative event curves for the composite end point of all-cause-mortality, stroke, myocardial infarction, and life-threatening or major bleeding.

Table 3
Clinical outcomes at 30 days

	COVID-19 pandemic			Non-surge vs pre		Surge vs pre		Surge vs non-surge	
	Pre-pandemic N = 372	Non-surge period N = 383	Surge period N = 314	HR or RR (95% CI)	p-value	HR or RR (95% CI)	p-value	HR or RR (95% CI)	p-value
Composite endpoint of death, stroke, MI, and major or life-threatening bleeding	54 (14.5%)	49 (12.8%)	49 (15.7%)	0.88 (0.60-1.29)	0.512	1.08 (0.73-1.58)	0.711	1.22 (0.82-1.82)	0.316
VARC-2 early safety	54 (14.5%)	47 (12.3%)	46 (14.7%)	0.84 (0.57-1.25)	0.394	1.01 (0.68-1.50)	0.954	1.20 (0.80-1.80)	0.381
All-cause mortality	5 (1.3%)	4 (1.1%)	15 (4.9%)	0.79 (0.21-2.92)	0.718	3.67 (1.34-10.11)	0.012	4.68 (1.55-14.10)	0.006
Cardiovascular mortality	5 (1.3%)	4 (1.1%)	11 (3.6%)	0.78 (0.21-2.92)	0.718	2.69 (0.94-7.75)	0.066	3.43 (1.09-10.77)	0.035
SARS-CoV-19 mortality	0 (0.0%)	0 (0.0%)	0 (0.0%)						
Any stroke (disabling and non-disabling)	14 (3.8%)	10 (2.6%)	15 (4.8%)	0.70 (0.31-1.57)	0.384	1.29 (0.62-2.67)	0.493	1.85 (0.83-4.12)	0.132
Disabling stroke	6 (1.6%)	5 (1.3%)	5 (1.6%)	0.81 (0.25-2.66)	0.730	1.00 (0.30-3.26)	0.994	1.23 (0.35-4.24)	0.747
Myocardial infarction	1 (0.3%)	0 (0.0%)	1 (0.3%)			1.18 (0.07-18.94)	0.905		
Major or life-threatening bleeding	40 (10.8%)	39 (10.2%)	30 (9.7%)	0.94 (0.61-1.47)	0.796	0.88 (0.55-1.42)	0.612	0.94 (0.58-1.51)	0.792
New permanent pacemaker implantation	50 (13.5%)	69 (18.2%)	54 (17.5%)	1.38 (0.96-1.99)	0.080	1.32 (0.90-1.95)	0.153	0.96 (0.67-1.37)	0.805
NYHA III or IV*	35 (9.7%)	31 (8.6%)	9 (3.2%)	0.89 (0.56-1.40)	0.606	0.33 (0.16-0.67)	0.002	0.37 (0.18-0.77)	0.008
Covid-19 infection / number tested*	-/0	1/54 (1.9%)	2/45 (4.4%)					2.40 (0.22-25.92)	0.471

Depicted are number of events (counting first event per patient only), with Kaplan-Meier cumulative incidences in percentages in brackets and hazard ratios HR with 95% CI in brackets from Cox's regression.

CI = confidence intervals; HR = hazard ratio; MI = myocardial infarction; RR = rate ratio; VARC-2 = Valve Academic Research Consortium-2

* Rate ratio with 95% confidence interval from robustified Poisson regression.

intervention, of whom 1.9% (n = 1) and 4.4% (n = 2) received positive test results for COVID-19. At Bern University Hospital, COVID-19 testing of patients without symptoms before TAVI has never been mandatory, which explains the relatively small proportion of patients who were tested for COVID-19 in our cohort. However, the low testing rate should not have affected the increased rate of all-cause mortality after TAVI during the surge period because none of the deaths in our study was considered to be directly attributable to COVID-19 (Supplementary Table 2). A potentially increased risk related to intervening during the surge period must be balanced against the risk posed by deferring the procedure. Evidence suggests prolonging waiting time for interventions is associated with an increased risk of mortality and hospitalization with heart failure.[16] Moreover, evidence derived from our own experience suggests that deferral of TAVI by 1 month in patients with symptomatic severe aortic stenosis was associated with a significant increase in the risk of hospitalization for valve-related symptoms or worsening heart failure, in addition to adverse clinical outcomes.[5,17]

Our study has several limitations, including the inherent deficiencies of registries. First, the registry reflects only patients who underwent TAVR. Patients with aortic stenosis who were not referred for intervention or TAVR candidates who died while waiting for intervention are not reflected in the present analysis. Second, differentiation of individual periods was based on ICU-bed occupation, which was a surrogate for healthcare capacity. The latter may have had a delayed effect on elective procedures. In turn, we did not report cumulative COVID-19 cases in the community, which may have affected outcomes in patients with severe aortic stenosis. However, none of the death cases in our study was believed to be directly caused by COVID-19. Third, a significant number of patients had an undocumented COVID-19 status before and after the procedure. Finally, this is a monocentric study, and its findings may not apply to other institutions with different policies and waiting times during the pandemic. Nevertheless, the study is a depiction of real-life experience of short-term TAVI outcomes during the pandemic, which is poorly reported in the literature.

In conclusion, TAVI during COVID-19 surge periods was associated with higher STS-PROM score, longer wait times, and increased 30-day all-cause and cardiovascular mortality compared with nonsurge and prepandemic periods.

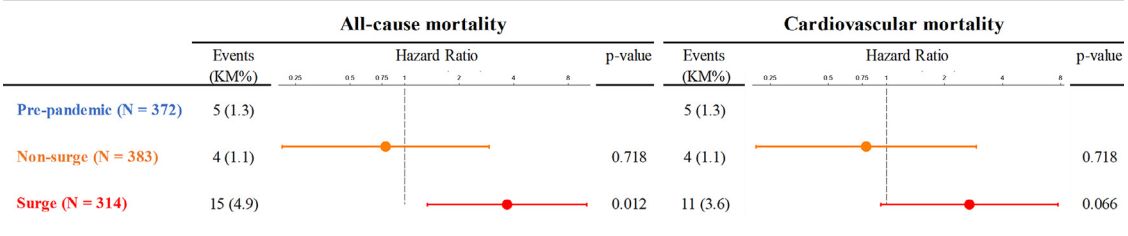

Figure 3. Forest plot for all-cause and cardiovascular mortality with prepandemic period as reference. HR with 95% confidence interval from Cox's regression. p value testing versus prepandemic period. KM% = Kaplan-Meier failure estimate.

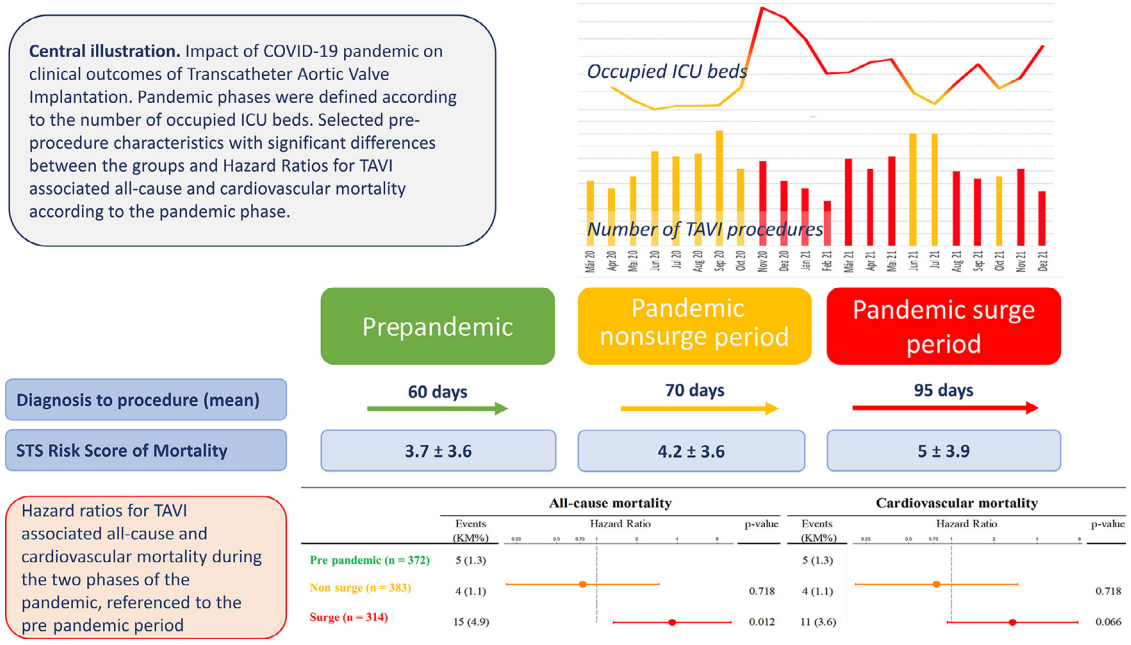

Figure 4. Central illustration. Pandemic phases were defined according to the number of occupied ICU beds. Selected preprocedure characteristics with significant differences among the groups and forest plot for all-cause and cardiovascular mortality with prepandemic period as reference. KM% = Kaplan-Meier failure estimate.

Declaration of Competing Interest

Dr. Windecker reports research, travel, or educational grants to the institution from Abbott, Abiomed, Amgen, AstraZeneca, Bayer, Biotronik, Boehringer Ingelheim (Ingelheim, Germany), Boston Scientific, Bristol Myers Squibb, Cardinal Health, CardioValve, Corflow Therapeutics, CSL Behring, Daiichi Sankyo, Edwards Lifesciences, Guerbet, InfraRedx, Janssen-Cilag, Johnson & Johnson, Medicure, Medtronic, Merck Sharp & Dohm, Miracor Medical, Novartis, Novo Nordisk, Organon, OrPha Suisse, Pfizer, Polares, Regeneron, Sanofi-Aventis (Bridgewater, New Jersey), Servier, Sinomed, Terumo, Vifor, and V-Wave. Dr. Windecker serves as advisory board member and/or member of the steering/executive group of trials funded by Abbott, Abiomed, Amgen, Astra Zeneca, Bayer, Boston Scientific, Biotronik, Bristol Myers Squibb, Edwards Lifesciences, Janssen, Med Alliance, Medtronic, Novartis, Polares, Recardio, Sinomed, Terumo, V-Wave, and Xeltis with payments to the institution but no personal payments. He is also member of the steering/executive committee group of several investigator-initiated trials that receive funding by industry without impact on his personal remuneration. Dr. Pilgrim reports research, travel or educational grants to the institution without personal remuneration from Biotronik, Boston Scientific, Edwards Lifesciences, and ATSens; speaker fees and consultancy fees to the institution from Biotronik, Boston Scientific, Edwards Lifesciences, Abbott, Medtronic, Biosensors, and Highlife. Dr. Stortecky has received research grants to the institution from Edwards Lifesciences and Medtronic; and has received personal fees from Boston Scientific, Teleflex, and BTG. Dr Praz has received travel expenses from Abbott, Edwards Lifesciences, and Polares Medical. Dr. Okuno has received speaker fees from Abbott. Dr. Heg has no conflicts of interest to declare; his employer, CTU Bern, University of Bern, has a staff policy of not accepting honoraria or consultancy fees. However, CTU Bern is involved in design, conduct, or analysis of clinical studies funded by not-for-profit and for-profit organizations. This resource provides an up-to-date list of CTU Bern's conflicts of interest: http://www.ctu.unibe.ch/research/declaration_of_interest/index_eng.html. The remaining authors have no competing interests to declare.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2023.07.072.

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